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Submitted for recognition as an American National Standard

Mechanical and Material Requirements for Externally Threaded Fasteners

1. **Scope**—This SAE Standard covers the mechanical and material requirements for inch-series steel bolts, screws, studs, sems¹, and U-bolts² used in automotive and related industries in sizes to 1-1/2 in inclusive.

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.

- 1.1 The mechanical properties included in Table 1 were compiled at an ambient temperature of approximately 20 °C (68 °F). These properties are valid within a temperature range which depends upon the material grade used and thermal and mechanical processing. Other properties such as fatigue behavior, corrosion resistance, impact properties, etc., are beyond the scope of this document and responsibility for ensuring the acceptability of the product for applications where conditions warrant consideration of these other properties must be borne by the end user.

2. **References**

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

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

SAE J121—Decarburization in Hardened and Tempered Unified Threaded Fasteners

SAE J123—Surface Discontinuities on Bolts, Screws, and Studs

SAE J403—Chemical Compositions of SAE Carbon Steels

SAE J404—Chemical Composition of SAE Alloy Steels

SAE J409—Product Analysis—Permissible Variations from Specified Chemical Analysis of a Heat or Cast of Steel

1. Sems—Screw and washer assemblies

2. U-bolts covered by this SAE Standard are those used primarily in the suspension and related areas of vehicles. For specification purposes, this standard treats U-bolts as studs. Thus, wherever the word "studs" appears, "U-bolts" is also implied. (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.)

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SAE J411—Carbon and Alloy Steels
SAE J417—Hardness Tests and Hardness Number Conversions
SAE J1061—Surface Discontinuities on General Application Bolts, Screws, and Studs
SAE J1086—Numbering Metals and Alloys
SAE J1268—Hardenability Bands for Carbon and Alloy H Steels

2.1.2 ASME PUBLICATION—Available from ASME, 22 Law Drive, Box 2300 Fairfield, NJ 07007-2300.

ASME B18.2.1—
ASME B18.18.1M—Inspection and Quality Assurance for General Purpose Fasteners

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

ASTM E 18—Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J995—Mechanical and Material Requirements for Steel Nuts

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

ASTM F 1470—Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

3. Designations

3.1 Designation System—Grades are designated by numbers where increasing numbers represent increasing tensile strength, and by decimals of whole numbers where decimals represent variations at the same strength level. The grade designations are given in Table 1.

3.2 Grades—Bolts and screws are normally available only in Grades 1, 2, 5, 5.2, 8, and 8.2 (see Appendix A). Studs are normally available only in Grades 1, 2, 4, 5, 8, and 8.1. Grade 5.1 is applicable to sems which may be heat treated following assembly of the washer on the screw, and to products without assembled washer.

4. Materials and Processes

4.1 Steel Characteristics—All fasteners shall be made of steel conforming to the chemical composition requirements in Table 2 for each grade.

For the definition of carbon and alloy steels, see SAE J411. Refer to SAE J403, J404, J1086, or J1268 for the chemical composition limits of standard steel grades. Standard H grade steels are acceptable substitutes as are nonstandard steels which fit the definition of carbon and alloy steels in SAE J411. For Grades 5, 5.1, 5.2, 8, 8.1, and 8.2 the maximum content of bismuth selenium, tellurium, or lead shall be 0.02%.

Steel for Grades 8 and 8.2 fasteners shall be fine grained steel with sufficient hardenability to provide hardness equivalent to 90% minimum martensite at the center of a transverse section one diameter from the threaded end of the fastener after quenching. Minimum as-quenched hardness required for steels in the carbon range 0.15 to 0.55% is shown in Table 3.

TABLE 1—MECHANICAL REQUIREMENTS AND IDENTIFICATION MARKING FOR BOLTS, SCREWS, STUDS, SEMS, AND U-BOLTS⁽¹⁾

Grade Designation	Products	Nominal Size Dia. In	Full Size		Machine Test		Machine Test		Machine Test		Machine Test		Core Hardness		Grade Identification Marking ⁽⁴⁾
			Proof Load (Stress) Min, psi	Tensile Strength (Stress) Min, psi	Yield ⁽²⁾ Strength (Stress) Min, psi	Tensile Strength (Stress) Min, psi	of Bolts, Screws, and Studs	of Bolts, Screws, and Studs	of Bolts, Screws, and Studs	of Bolts, Screws, and Studs	Reduction of Area Min, %	Surface Hardness Rockwell 30N Max	Hardness Rockwell Min	Hardness Rockwell Max	
1	Bolts, Screws, Studs	1/4 thru 1-1/2	33 000 ⁽⁵⁾	60 000	36 000 ⁽⁶⁾	60 000	18	35	—	—	B70	B100	None		
2	Bolts, Screws, Studs	1/4 thru 3/4 ⁽⁷⁾ Over 3/4 thru 1-1/2	55 000 ⁽⁵⁾ 33 000	74 000 60 000	57 000 36 000 ⁽⁶⁾	74 000 60 000	18 18	35 35	—	—	B80	B100	None		
4	Studs	1/4 thru 1-1/2	65 000	115 000	100 000	115 000	10	35	—	—	C22	C32	None		
5	Bolts, Screws, Studs	1/4 thru 1 Over 1 thru 1-1/2	85 000 74 000	120 000 105 000	92 000 81 000	120 000 105 000	14 14	35 35	54 50	—	C25 C19	C34 C30	— —		
5.1 ⁽⁸⁾	Sems	No. 4 thru 5/8	85 000	120 000	—	—	—	—	59.5	—	C25	C40	— —		
5.2	Bolts, Screws	1/4 thru 1	85 000	120 000	92 000	120 000	14	35	56	—	C26	C36	— —		
8	Bolts, Screws, Studs	1/4 thru 1-1/2	120 000	150 000	130 000	150 000	12	35	58.6	—	C33	C39	— —		
8.1	Studs	1/4 thru 1-1/2	120 000	150 000	130 000	150 000	10	35	58.6	—	C33	C39	None		
8.2	Bolts, Screws	1/4 thru 1	120 000	150 000	130 000	150 000	10	35	58.6	—	C33	C39	— —		

1. See footnote 2 of text.
2. Yield strength is stress at which a permanent set of 0.2% of gage length occurs.
3. See Table 8 for gage length.
4. Not applicable to studs or slotted and cross recess head products.
5. Proof load test: Requirements in these grades only apply to stress relieved products.
6. Yield point shall apply instead of yield strength at 0.2% offset.
7. Grade 2 requirements for sizes 1/4 through 3/4 in apply only to bolts and screws 6 in and shorter in length, and to studs of all lengths. For bolts and screws longer than 6 in, Grade 1 requirements shall apply.
8. Grade 5 material heat treated before assembly with a hardened washer is an acceptable substitute.

TABLE 2—CHEMICAL COMPOSITION TEMPERING TEMPERATURE AND IDENTIFICATION FOR BOLTS, SCREWS, AND STUDS

Grade Designation	Products	Nominal Size Dia, In	Material	Treatment	Product Chemical Analysis ⁽¹⁾ (% by Weight)		Product Chemical Analysis ⁽¹⁾ (% by Weight)		Product Chemical Analysis ⁽¹⁾ (% by Weight)		Tempering Temperature °F (Min)	Grade Identification Marking
					Carbon	Manganese	P	S	Boron	Boron		
1	Bolts, Screws, Studs	1/4 thru 1-1/2	Low or Medium Carbon Steel	See 4.4	0.55	0.030	0.050				See 4.4	None
2	Bolts, Screws, Studs	1/4 thru 1-1/2	Low or Medium Carbon Steel	See 4.4	0.15	0.030	0.050 ⁽²⁾				See 4.4	None
4	Studs	1/4 thru 1-1/2	Medium Carbon Steel	Cold Drawn	0.28	0.030	0.13				See 4.4	None
5	Bolts, Screws, Studs	1/4 thru 1-1/2	Medium Carbon Steel ⁽³⁾	Quenched & Tempered	0.28	0.030	0.050 ⁽⁴⁾			427 °C (800 °F)		—
5.1 ⁽⁵⁾	Sems	No. 4 thru 5/8	Low or Medium Carbon Steel ⁽³⁾	Quenched & Tempered	0.15	0.030	0.050			340 °C (650 °F)		—
5.2	Bolts, Screws	1/4 thru 1	Low Carbon Boron Steel	Quenched & Tempered	0.15	0.25	0.030	0.050	0.0005	427 °C (800 °F)		—
8	Bolts, Screws, Studs	1/4 thru 1-1/2	Medium Carbon Alloy Steel ⁽⁶⁾	Quenched & Tempered	0.28	0.55	0.030	0.050		427 °C (800 °F)		—
8.1	Studs	1/4 thru 1-1/2	Medium Carbon Alloy or SAE1541 Steel	Elevated Temperature Drawn	0.28	0.55	0.030	0.040		427 °C (800 °F)		None
8.2	Bolts, Screws	1/4 thru 1	Low Carbon Boron Steel	Quenched & Tempered	0.15	0.25	0.030	0.050	0.0005	340 °C (650 °F)		—

1. All values are for product analysis (percent by weight). For cast or heat analysis, use standard permissible variations as shown in SAE J409.
 2. For studs only, sulfur content may be 0.33% maximum.
 3. For Grades 5 and 5.1, fasteners, medium carbon boron or medium carbon boron or medium carbon boron steels, as specified for Grades 8 fasteners, may also be used at the manufacturer's option.
 4. For studs only, sulfur content may be 0.13% maximum.
 5. Grade 5 material heat treated before assembly with a hardened washer is an acceptable substitute.
 6. When agreed to by manufacturer and purchaser, medium carbon steel may be used for products 7/16 inch in nominal diameter and smaller and medium carbon boron steel may be used for products 1 inch in nominal diameter and smaller.

**TABLE 3—CARBON CONTENT VERSUS MINIMUM AS-QUENCHED
HARDNESS FOR 90% MARTENSITE**

Carbon (%)	Hardness HRC
0.15 through 0.19	35
0.20 through 0.24	38
0.25 through 0.29	41
0.30 through 0.34	44
0.35 through 0.39	47
0.40 through 0.44	50
0.45 through 0.55	53

- 4.2 Heading Practice**—Methods other than upsetting and/or extrusion are permitted only by special agreement between purchaser and supplier.

Grade 1 bolts and screws shall be hot or cold headed, at option of the manufacturer.

Grades 2, 5, 5.2, 8, and 8.2 bolts and screws in sizes up to 3/4 in, inclusive, and in lengths up to 6 in, inclusive, shall be cold headed, except that by special agreement they may be hot headed. Larger sizes and longer lengths shall be hot or cold headed, at option of the manufacturer.

Grade 5.1 sems screws shall be cold headed.

- 4.3 Threading Practice**—Grades 2, 5, 5.2, 8, and 8.2 bolts and screws in sizes up to 3/4 in, inclusive, and lengths up to 6 in, inclusive, shall be roll threaded, except by special agreement. Grade 5.1 sems shall be roll threaded. Threads of all sizes of Grade 1 bolts and screws, and Grades 2, 5, 5.2, 8, and 8.2 bolts and screws in sizes over 3/4 in and/or lengths longer than 6 in shall be rolled, cut, or ground, at option of the manufacturer. Threads of all grades and sizes of studs shall be rolled, cut, or ground, at option of the manufacturer.

- 4.4 Heat Treatment Practice**—Grades 1 and 2 bolts and studs need not be heat treated. Grades 1 and 2 cold headed carriage bolts and other bolts and screws with thin heads shall be stress relieved at 468 °C (875 °F) minimum. (Prior agreement with purchaser will be required if mechanical properties are affected). Additionally, when specified by purchaser, Grade 2 cold headed hex head bolts and screws shall be stress relieved at 468 °C (875 °F) minimum. Grades 4 and 8.1 studs are manufactured from pretreated material and the studs, as manufactured, need no further heat treatment. Grades 5 and 5.2 bolts, screws, and studs shall be heat treated (fully austenitized), oil or water quenched, at option of manufacturer, and tempered at a minimum tempering temperature of 427 °C (800 °F). Grade 5.1 Sems shall be heat treated (fully austenitized), quenched, and tempered at a minimum tempering temperature of 343 °C (650 °F); quenchant whose principal constituent is water shall not be used, unless specifically approved by the user. Grade 8 bolts and screws and studs shall be heat treated (fully austenitized), oil quenched, and tempered at a minimum tempering temperature of 427 °C (800 °F). Grade 8.2 bolts and screws shall be heat treated (fully austenitized), quenched in oil or water, and tempered at a minimum temperature of 340 °C (650 °F).

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

- 4.5 Decarburization**—Unless otherwise specified, Grades 5 and 5.2 bolts, screws, and studs shall conform to Class C, and Grades 8, 8.1, and 8.2 bolts, screws, and studs shall conform to Class B as described in SAE J121.
- 4.6 Surface Discontinuities**—Grades 5, 5.1, 5.2, 8, 8.1, and 8.2 bolts, screws, and studs in sizes up to 1 in inclusive, and lengths up to 6 in inclusive shall be in conformity with the requirements of SAE J1061.

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When the engineering requirements of the application necessitate that surface discontinuities of bolts, screws, and studs should 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.

5. **Mechanical Requirements**—Bolts, screws, studs, and sems shall be tested in accordance with the mechanical testing requirements for the applicable type, grade, size, and length of product as specified in Table 4 and shall meet the mechanical requirements specified for that product in Table 1.

In the case of U-bolts having thread length equal to 3D or longer, cut stud-like specimens from either leg of the "U" (utilizing the maximum available thread length) and test as shown for studs. Where thread length is less than 3D, test for hardness only as shown for "short studs." (Applicable mechanical tests are shown in Table 4 and shall meet requirements specified for that product in Table 1.)

6. **Methods of Test**

- 6.1 **Hardness**—The hardness of bolts, screws, studs, and sems shall be determined at mid-radius of a transverse section through the threaded portion of the product taken at a distance of one diameter from the end of the product. The reported hardness shall be the average of four hardness readings located at 90 degrees to one another. The preparation of test specimens and the performance of hardness tests shall be in conformity with the requirements of SAE J417.

To meet the requirements of Section 5, the hardness shall not exceed the maximum hardness specified in Table 1 for the applicable grade. In addition, as required in Section 5 and Table 4, the hardness shall not be less than the minimum hardness specified in Table 1 for the applicable grade.

- 6.2 **Surface Hardness**—Tests to determine surface hardness conditions shall be conducted on the ends, hexagon flats, or unthreaded shanks which have been prepared by lightly grinding or polishing to insure accurate reproducible readings in accordance with SAE J417. Proper correction factors shall be used when hardness tests are made on curved surfaces, per ASTM E 18.

Depending on the location and individual surface upon which the test is conducted, some increase in hardness above that specified in Table 1, when measured on the Rockwell 30N scale, may occur for reasons other than carburization. To ensure that lots of products not considered acceptable for this cause are in fact carburized, the metallographic and hardness checking technique described in SAE J121 shall be used. In cases where carburization is not substantiated by SAE J121 testing, the parts shall be accepted.

In applying the SAE J121 procedure, a difference between Knoop and Rockwell 30N readings by conversion may occur. This difference is disregarded since the primary purpose of the Knoop traverse in SAE J121 is to establish the existence of carburization.

- 6.3 **Referee Tempering Temperature Test**—In a dispute concerning the tempering temperature, the following procedure shall be used for referee purposes. Conduct hardness test (6.1) on one or more bolts, screws, or studs from the lot; retemper the products at a temperature 6.7 °C (20 °F) less than the specified minimum tempering temperature for a minimum of 30 min per 1.0 in nominal diameter but not less than 30 min; repeat product hardness test. The difference between the mean hardness (before and after retempering) shall be no greater than two points Rockwell C. This is a referee test and not a mandatory requirement.

TABLE 4—MECHANICAL TESTING REQUIREMENTS FOR BOLTS, SCREWS, STUDS, AND SEMS

Product	Grade	Specified Minimum Ultimate Tensile Load "lb"	Length of Product ⁽¹⁾	Hardness ⁽²⁾ max	Hardness ⁽¹⁾ Min	Tests Conducted Using Full Size Products ⁽¹⁾		Tests Conducted Using Full Size Products ⁽¹⁾		Tests Conducted Using Machine Test Specimens ⁽¹⁾		Tests Conducted Using Machine Test Specimens ⁽¹⁾		Decarburization in Threaded Section ⁽²⁾
						Proof Load	Wedge Tensile Strength	Conducted Using Full Size Products ⁽¹⁾	Axial Tensile Strength	Yield Strength	Axial Tensile Strength	Machine Test Specimens ⁽¹⁾	Machine Test Specimens ⁽¹⁾	
Short Bolts and Screws	1, 2, 5, 5.2, 8, 8.2	All	Less than 2-1/2 D ⁽⁴⁾	*	—	—	—	—	—	—	—	—	Option C	
Special Head ⁽⁵⁾ Bolts and Screws	1, 2, 5, 5.2, 8, 8.2	All	All	*	—	—	—	—	—	—	—	—	Option C	
Square and Hex Bolts and Screws	1, 2, 5, 5.2, 8, 8.2	100 000 and less	2-1/2D to 8D or 8 in, whichever is greater	*	Option C	*	—	—	—	—	—	—	Option C	
			Over 8D or 8 in, whichever is greater, thru and including 12 in	*	Option C	*	—	Option B	Option B	Option B	Option B	—	Option C	
All Other Bolts and Screws	1, 2, 5, 5.2, 8, 8.2	Over 100 000	Over 12 in	*	Option C	Option A	—	Option B	Option B	Option B	Option B	Option B	Option C	
		100 000 and less	2-1/2 to 8D or 8 in, whichever is greater	*	Option C	Option A	—	Option B	Option B	Option B	Option B	Option B	Option C	
			Over 8D or 8 in, whichever is greater	*	Option C	—	*	—	—	—	—	—	Option C	
Short Studs	1, 2, 4, 5, 8, 8.1	All	Less than 3D	*	—	—	—	—	—	—	—	—	Option C	
All Other Studs	1, 2, 4, 5, 8, 8.1	100 000 and less	3D to 8D or 8 in, whichever is greater	*	—	—	—	—	—	—	—	—	Option C	
			Over 8D or 8 in, whichever is greater	*	Option C	Option A	—	Option B	Option B	Option B	Option B	Option B	Option C	
Short Bolts, Screws, and Sems	5.1	All	Less than 2-1/2D	*	—	—	—	—	—	—	—	—	Option C	
Hex Head Bolts, Screws, and Sems	5.1	All	2-1/2D and longer	*	—	—	—	—	—	—	—	—	Option C	
Other Bolts, Screws, and Sems	5.1	All	2-1/2D and longer	*	—	—	—	—	—	—	—	—	Option C	

Tests to be performed in accordance with paragraph 6.1 6.1 6.1 6.4 6.6 6.6 6.5 6.7 6.7 6.7 6.7 6.2 4.5

1. For purposes of Table 4 requirements, "length of product" is the nominal length including point chamfer as defined in ASME B18.2.1 and all special point products which shall be measured from the bearing surface to the crest of the last complete thread form.

2. Asterisks (*) denote mandatory tests. Where options are indicated, all Option A tests (which apply to full size products) or all Option B tests (which apply to machined specimens) shall be performed. Option C tests (which apply to full size products) are not mandatory unless specified in the original inquiry and purchase order. Option A and Option C tests shall be performed in case arbitration is necessary.

3. Surface hardness and decarburization requirements apply only to Grades 5, 5.1, 5.2, 8, 8.1, and 8.2.

4. D equals diameter of the product.

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

6.4 Proof Load—The proof load test consists of stressing the bolt, screw, stud, or sem with a specified load which the product must withstand without permanent set.

The overall length of the specimen shall be measured between conical or ball centers on the centerline of the specimen, using mating centers on the measuring anvils. The specimen shall be marked so that it can be placed in the measuring fixture in the same position for all measurements. The measurement instrument shall be capable of measurement to 0.0001 in. In the case of sems, the washer may be removed from the screw prior to assembly in the testing machine; however, for referee testing, the washer shall be removed. For bolts, screws, and sems, 3D or longer, the specimen shall be assembled in the fixture of the tensile machine so that six complete threads are exposed between the grips. This is obtained by freely running the nut or fixture to the thread runout of the specimen and then unscrewing the specimen six full turns. Short bolts, 2-1/2-3D in length, threaded to within 2-1/2 pitches of the bearing surface shall be assembled fingertight in the fixture and unscrewed two full turns. When proof load testing studs, one end of the stud shall be assembled in a threaded fixture to the thread runout. For studs having unlike threads, this shall be the end with the finer pitch thread. The other end of the stud shall likewise be assembled in a threaded fixture, as previously mentioned for bolts. The bolt, screw, stud, or sem shall then be axially loaded to the proof load specified for the applicable size, thread series, and grade in Table 5, the load retained for a period of 10 s, the load removed, and the overall length again measured. The speed of testing, as determined with a free running cross head, shall not exceed 0.12 in/min.

To meet the requirements of Section 5, the length of the bolt, screw, stud, or sem after loading shall be the same as before loading within a tolerance of ± 0.0005 in allowed for measurement error.

Variables, such as straightness and thread alignment (plus measurement error), may result in apparent elongation of the fasteners when the proof load is initially applied. In such cases, the fastener may be retested using a 3% greater load, and may be considered satisfactory if the length after this loading is the same as before this loading (within the 0.0005 in tolerance for measurement error).

6.5 Axial Tensile Strength—Following proof load testing, the same bolt, screw, stud, or sem shall be reassembled in the testing machine per 6.4 and axial loading applied until failure. Typical fixturing is illustrated in Figure 1. The speed of testing, as determined with a free running cross head, shall not exceed 1 in/min.

To meet the requirements of Section 5, the bolt, screw, stud, or sem shall not fracture before having withstood the minimum tensile load specified for the applicable size, thread series, and grade in Table 5. In addition for bolts, screws, and sems with regular style heads, the ultimate failure location shall occur in the body or threaded section and not at the junction of the head and shank. (See footnote 5 under Table 4.)

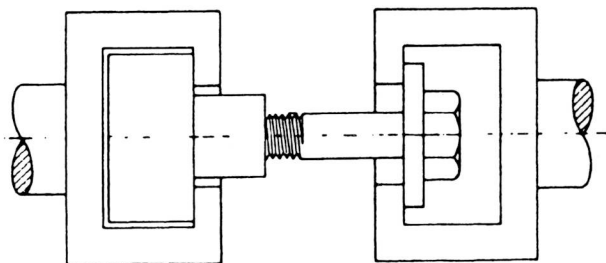


FIGURE 1—TENSILE TESTING OF FULL-SIZE BOLT OR SCREW

TABLE 5—PROOF LOAD AND TENSILE STRENGTH REQUIREMENTS⁽¹⁾

No.	Stress Area, in ²	Coarse Thread Series UNC											
		Grade 1 Proof Load, lb	Grade 1 Tensile Strength Min, lb	Grade 2 Proof Load, lb	Grade 2 Tensile Strength min, lb	Grade 2 Tensile Strength min, lb	Grade 4 Proof Load, lb	Grade 4 Tensile Strength Min, lb	Grade 5 and 5.2(1) Proof Load, lb	Grade 5 and 5.2(2) Tensile Strength Min, lb	Grade 5.1 Proof Load, lb	Grade 5.1 Tensile Strength Min, lb	Grade 8, 8.1, 8.2(1) Proof Load, lb
6-32	0.00909	—	—	—	—	—	—	—	—	750	1100	—	—
8-32	0.0140	—	—	—	—	—	—	—	—	1200	1700	—	—
10-24	0.0175	—	—	—	—	—	—	—	—	1500	2100	—	—
12-24	0.0242	—	—	—	—	—	—	—	—	2050	2900	—	—
1/4-20	0.0318	1050	1900	1750	2350	3650	2700	3800	3800	2700	3800	3800	4750
5/16-18	0.0524	1750	3150	2900	3900	6000	4450	6300	6300	4450	6300	6300	7850
3/8-16	0.0775	2550	4650	4250	5750	8400	6600	9300	9300	6600	9300	9300	11600
7/16-14	0.1063	3500	6400	5850	7850	12200	9050	12800	12800	9050	12800	12800	15900
1/2-13	0.1419	4700	8500	7800	10500	18300	12100	17000	17000	12100	17000	17000	21300
9/16-12	0.182	6000	10900	10000	13500	20900	15500	21800	21800	15500	21800	21800	27300
5/8-11	0.226	7450	13600	12400	16700	25400	19200	27100	27100	19200	27100	27100	33900
3/4-10	0.334	11000	20000	18400	24700	38400	28400	40100	40100	28400	40100	40100	50100
7/8-9	0.462	15200	27700	27000	36400	53100	39300	55400	55400	39300	55400	55400	69300
1-8	0.606	20000	36400	20000	36400	69700	51500	72700	72700	51500	72700	72700	90900
1-1/8-7	0.763	25200	45800	25200	45800	87700	56500	80100	80100	56500	80100	80100	114400
1-1/4-7	0.969	32000	58100	32000	58100	111400	71700	101700	101700	71700	101700	101700	145400
1-3/8-6	1.155	38100	69300	38100	69300	132800	85500	121300	121300	85500	121300	121300	173200
1-1/2-6	1.405	46400	84300	46400	84300	161600	104000	147500	147500	104000	147500	147500	210800
6-40	0.01015	—	—	—	—	—	—	—	—	850	1200	—	—
8-36	0.01474	—	—	—	—	—	—	—	—	1250	1750	—	—
10-32	0.0200	—	—	—	—	—	—	—	—	1700	2400	—	—
12-28	0.0258	—	—	—	—	—	—	—	—	2200	3100	—	—
1/4-28	0.0364	1200	2200	2000	2700	4200	3100	4350	4350	3100	4350	4350	5450
5/16-24	0.0580	1900	3500	3200	4300	6700	4900	6950	6950	4900	6950	6950	8700
3/8-24	0.0878	2900	5250	4800	6500	10100	7450	10500	10500	7450	10500	10500	13200
7/16-20	0.1187	3900	7100	6550	8800	13650	10100	14200	14200	10100	14200	14200	17800
1/2-20	0.1599	5300	9600	8800	11800	18400	13600	19200	19200	13600	19200	19200	24000
9/16-18	0.203	6700	12200	11200	15000	23300	17300	24400	24400	17300	24400	24400	30400
5/8-18	0.256	8450	15400	14100	18900	29400	21800	30700	30700	21800	30700	30700	38400
3/4-16	0.373	12300	22400	20500	27600	42900	31700	44900	44900	31700	44900	44900	56000
7/8-14	0.509	16800	30500	16800	30500	58500	43300	61100	61100	43300	61100	61100	76400
1-12	0.663	21900	39800	21900	39800	76200	56400	79600	79600	56400	79600	79600	99400
1-14 UNS	0.679	22400	40700	22400	40700	78100	57700	81500	81500	57700	81500	81500	101900
1-1/8-12	0.856	28200	51400	28200	51400	98400	63300	89900	89900	63300	89900	89900	128400
1-1/4-12	1.073	35400	64400	35400	64400	123400	79400	112700	112700	79400	112700	112700	161000
1-3/8-12	1.315	43400	78900	43400	78900	151200	97300	138100	138100	97300	138100	138100	197200
1-1/2-12	1.581	52200	94900	52200	94900	181800	117000	166000	166000	117000	166000	166000	237200

Fine Thread Series UNF

1. Proof loads and tensile strengths are computed by multiplying the proof load stresses and tensile strength stresses given in Table 1 by the stress area of the thread. The stress area of sizes and thread series not included in Table 5 may be computed from the formula:

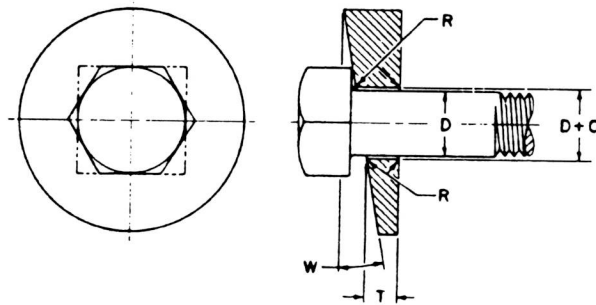
$$A_s = 0.7854 \left[D - \frac{n}{n} \right]^2$$

where D equals nominal diameter in inches and n equals threads per inch.

2. Grades 5.2 and 8.2 applicable to sizes 1/4 through 1 in.

6.6 Wedge Tensile Strength

6.6.1 **BOLTS AND SCREWS**—Following proof load testing, the same bolt or screw shall be assembled with a wedge inserted under the head, as illustrated in Figure 2, installed in the testing machine and tensile tested to failure, as described in 6.5. The angle of the wedge for the bolt or screw size and grade is specified in Table 6. The wedge shall be so placed that no corner of the square or hexagon bolt or screw head takes the bearing load; that is, a flat of the head shall be aligned with the direction of uniform thickness of the wedge. The wedge shall have a thickness of one-half the bolt or screw diameter measured at the thin side of the hole. The hole in the wedge shall have the following clearance over the nominal size of the bolt or screw, and its top and bottom edges shall be rounded or chamfered 45 degrees to the dimensions in Table 7.



C = CLEARANCE OF HOLE (SEE TABLE 7)
 D = DIAMETER OF BOLT OR SCREW
 R = RADIUS OR 45 DEGREE CHAMFER (SEE TABLE 7)
 T = MINIMUM THICKNESS OF WEDGE AT THIN SIDE OF HOLE
 EQUALS ONE HALF DIAMETER OF BOLT OR SCREW
 W = WEDGE ANGLE (SEE TABLE 6)

FIGURE 2—WEDGE TEST DETAILS—BOLTS AND SCREWS

TABLE 6—TENSILE TEST WEDGE ANGLES

Product	Grade	Nominal Size of Product, in	Wedge Angle deg
Bolts and Screws ⁽¹⁾	1,2	1/4 thru 1	10
		Over 1 to 1-1/2	6
	5, 5.2, 8, 8.2 ⁽²⁾	1/4 thru 1	10
		Over 1 to 1-1/2	6
Hex Head Sems	5.1	No. 6 thru 5/8	6
Studs	1, 2, 5, 8, 8.1	1/4 thru 3/4	6
		Over 3/4 to 1-1/2	4

1. For hex flange and hex washer head product, the wedge angle shall be 6 degrees.
2. For Grades 5, 5.2, 8, and 8.2 bolts and screws which are threaded 1 dia and closer to the underside of head, wedge angle shall be 6 degrees for sizes 1/4 through 3/4 in, and 4 degrees for sizes over 3/4 in.

TABLE 7—WEDGE, CLEARANCE, AND CHAMFER DIMENSIONS

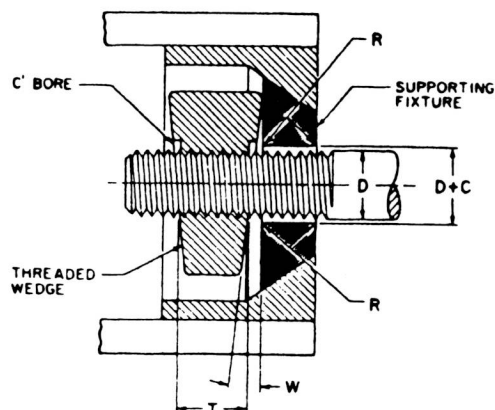
	Nominal Bolt or Screw Size, in	Clearance in Hole, in	Radius or Depth of Chamfer, in
No.	6 thru 12	0.020	0.020
	1/4 thru 1/2	0.030	0.030
	9/16 thru 3/4	0.050	0.060
	7/8 and 1	0.060	0.060
	1-1/8 and 1-1/4	0.060	0.125
	1-3/8 and 1-1/2	0.094	0.125

Wedge tensile testing shall be limited to product with hexagon, square, hex flange, or twelve point flange heads. Product with other head styles and shaped shoulders or those with shoulders substantially larger in diameter than the nominal bolt body diameter, should be axial tensile tested.

To meet the requirement of Section 5, the bolt, screw, stud, or sems shall not fracture before having withstood the minimum tensile load specified for the applicable size, thread series, and grade in Table 5. In addition, the ultimate failure location shall occur in the body or threaded section and not at the junction of the head and shank. (See footnote 5 under Table 4.)

- 6.6.2 STUDS—Following proof load testing, the stud shall be assembled per 6.4 except with a threaded wedge, as illustrated in Figure 3. The angle of the wedge for the stud size and grade shall be as specified in Table 6. The stud shall be assembled in the testing machine and tensile tested to failure, as described in 6.5.

The length of the threaded section of the wedge shall be equal to the diameter of the stud. To facilitate removal of the broken stud, the wedge shall be counterbored. The thickness of the wedge at the thin side of the hole shall equal the diameter of the stud plus the depth of counterbore. The supporting fixture, as shown in Figure 3, shall have hole clearance over the nominal size of the stud, and shall have its top and bottom edges rounded or chamfered to the same limits specified for the hardened wedge in 6.6.1.



C = CLEARANCE OF HOLE (SEE TABLE 7)
 D = DIAMETER OF STUD
 R = RADIUS OR 45 DEGREE CHAMFER (SEE TABLE 7)
 T = D PLUS DEPTH OF COUNTERBORE
 W = WEDGE ANGLE (SEE TABLE 6)

FIGURE 3—WEDGE TEST DETAILS—STUDS

To meet the requirements of Section 5, the stud shall not fracture before having withstood the minimum tensile load specified for the applicable size, thread series, and grade in Table 5.

6.7 Testing of Machined Test Specimens—Where bolts, screws, and studs cannot be tested in full size for proof load and tensile strength requirements, tests shall be conducted using test specimens machined from the bolt, screw, or stud.

For 1-1/2 in diameter bolts, screws, and studs, a standard 0.500 in round 2 in gage length test specimen shall be turned from the bolt, screw, or stud with the axis of the specimen located midway between the center and outside surface of the bolt, screw, or stud shank, as shown in Figure 4. Bolts, screws, and studs 3/4 through 1-3/8 in diameter shall have their shanks machined to the dimensions of a standard 0.500 in round 2 in gage length test specimen concentric with the axis of the bolt, screw, or stud, leaving the bolt or screw head and threaded sections intact, as shown in Figure 5 and Table 8. Bolts, screws, and studs 1/4 through 5/8 in diameter shall have their shanks machined to subsized specimens having dimensions shown in Figure 5 and Table 8.

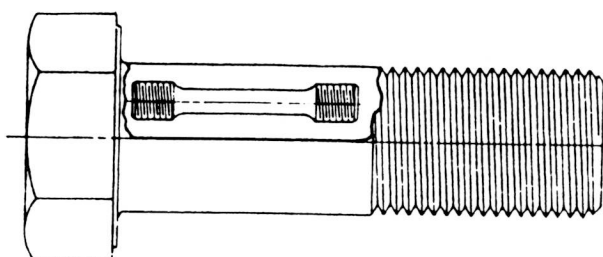


FIGURE 4—LOCATION OF STANDARD ROUNDS 2 IN GAGE LENGTH TENSILE TEST SPECIMEN WHEN TURNED FROM LARGE SIZE BOLTS OR SCREWS

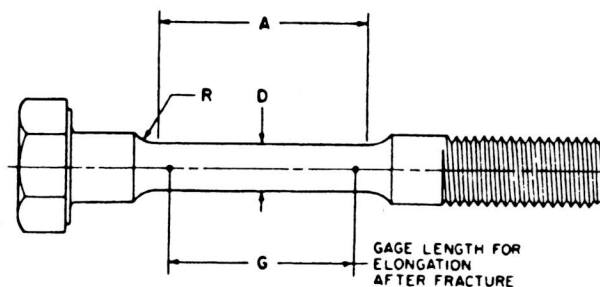


FIGURE 5—TENSILE TEST SPECIMEN FOR BOLTS OR SCREWS WITH TURNED DOWN SHANK

**TABLE 8—DIMENSIONS OF MACHINED TEST SPECIMENS
(SEE 6.7 AND FIGURE 5)**

Nominal Dia of Product	Gage Length G	Dia Parallel Section D	Length Parallel Section, Min A	Fillet Radius, Min R
3/4 thru 1-1/2	2.000 ± 0.005	0.500 ± 0.010	2.25	0.38 ⁽¹⁾
1/4 thru 5/8	1.400 ± 0.005	0.350 ± 0.007	1.75	0.25
	1.000 ± 0.005	0.250 ± 0.005	1.25	0.19

1. Minimum radius recommended 0.38 in; 0.12 minimum permitted.

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The test specimen shall be tensile tested as described in 6.5, and the yield strength, tensile strength, elongation, and reduction of area determined.

To meet the requirements of Section 5, the test specimens must have a yield strength, tensile strength, elongation, and reduction of area equal to or greater than the values for those properties specified for the applicable product size and grade in Table 1.

- 6.8 Common Test Fixture Details**—The grips of the tensile testing machine shall be self-aligning to avoid side thrust on the specimen.

The wedge shall have a minimum hardness of 45 HRC.

The hole in the fixture or washer used under the head of bolts and screws during proof load and tensile testing shall have the same clearance as that specified for wedges (6.6.1).

Wedges, nuts, and fixtures into which bolts, screws, and studs are threaded for proof load, tensile strength, and wedge tensile testing shall have threads which are of the same size, pitch, and tolerance class as the product being tested. (For standard products Class 3B tolerances are normally applicable.) For studs having interference fit threads, wedges shall be threaded to provide a finger-free fit.

- 7. Product Marking—Bolts and Screws**—Internal drive screws of all sizes and other screws and bolts of sizes smaller than 1/4 in need not be marked. All other screws and bolts of sizes 1/4 in and larger shall be marked permanently and clearly to identify the strength grade and the manufacturer. The grade identification symbols shall be as shown in Table 1. Markings shall be located on the top of the head and may be either raised or depressed. For hex head products, the markings may be indented on the side of the head. Studs need not be marked.

Marking product with special heads weaker than the threads and product manufactured with a collar shall be at the option of the manufacturer. The end user of product used for decorative purposes shall have the option of waiving the requirement for marking and its location.

8. Test Requirements

- 8.1 Manufacturer's Responsibility**—The requirements of this document are intended to be met by both special and standard fasteners which are generally produced in large volume for stock. During the manufacture of products to this specification, the manufacturer shall make periodic tests to ensure that the properties of the product are being maintained within the specified limits. Such tests shall be conducted in accordance with a planned program of control which shall include elements related to the selection of suitable material and to the product processing and testing practices. The test results shall be recorded.

- 8.2 Manufacturer's Test Reports**—When requested in writing by the purchaser, the supplier shall furnish a copy of the manufacturer's test report certified to be a report of the results of the tests for the specific type, size, length, and grade of product for each lot of fasteners.

Additional tests of products in individual shipments are not normally contemplated.

- 8.2.1 SMALL LOT PROVISIONS**—Where fasteners are produced to order in small quantities, 2000 pieces or less, having different lengths or cut to different lengths in subsequent operations, but made from the same mill heat of material of the same nominal diameter, head type or configuration, formed in a given machine and heat treated essentially together, they shall be considered a lot for test report purposes.

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- 8.3 Purchaser's Options**—If the purchaser requires that additional tests be performed by the manufacturer to determine that the properties of products in an individual shipment are within specified limits, or if the purchaser requires that a quality control program or particular sampling plan shall be used when determining the acceptability of a lot, or shipment of products, the purchaser shall specify the complete testing requirements, including sampling plan and basis of acceptance in the original inquiry and purchase order.
- 8.4 Quality Control**—Fasteners manufactured in conformance with this document shall be furnished to the purchaser in accordance with ASME B18.18.1M unless otherwise specified by the purchaser. If verifiable in-process inspection is used, inspection sample size and reporting shall be in accordance with the applicable ASME, ASTM, or SAE quality system consensus standard.
- 8.5 Purchaser's Responsibility**—When fasteners are to be used in conditions of an unusual nature and where corrosion, fatigue, or temperature is a consideration, it is desirable that a purchaser consult with the manufacturer regarding material choice.

While purchase users may have an awareness of product end use and environment, purchasers of product for resale or distribution may not. For this reason, it is suggested and recommended that purchase resellers give careful consideration when selecting alternative materials to be used in the manufacture of stocks for their inventories.

For the purpose of defining responsibility, this specification defines the responsible party to be the organization that supplies the fastener to the final purchaser. That organization should be able to certify that the fastener was manufactured, tested, and inspected in accordance with this specification, or some other related product specification and meets all of its requirements.

9. Notes

- 9.1 Marginal Indicia**—The change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE FASTENERS COMMITTEE

APPENDIX A

A.1 (Relative to 150 000 psi tensile strength bolts and screws produced from low carbon boron steels and designated as Grade 8.2.)

Users should recognize the difference in stress relaxation characteristics of various steels between the tempering temperature range of 340 °C (650 °F), minimum, specified for Grade 8.2 and 427 °C (800 °F), minimum, specified for Grade 8, when considering bolts and screws that may be exposed to such temperature range. The data available on elevated temperature properties of Grade 8.2 indicates that performance testing is desirable in applications where the operating temperature exceeds 260 °C (500 °F) (as may also be the case with Grade 8 fasteners).

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Rationale—Section 8.2.1, Small Lot Provisions was added to this document.

Relationship of SAE Standard to ISO Standard—Not applicable.

Application—This SAE Standard covers the mechanical and material requirements for inch-series steel bolts, screws, studs, sems¹, and U-bolts² used in automotive and related industries in sizes to 1-1/2 in inclusive.

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.

Reference Section

SAE J121—Decarburization in Hardened and Tempered Unified Threaded Fasteners

SAE J123—Surface Discontinuities on Bolts, Screws, and Studs

SAE J403—Chemical Compositions of SAE Carbon Steels

SAE J404—Chemical Composition of SAE Alloy Steels

SAE J409—Product Analysis—Permissible Variations from Specified Chemical Analysis of a Heat or Cast of Steel

SAE J411—Carbon and Alloy Steels

SAE J417—Hardness Tests and Hardness Number Conversions

SAE J995—Mechanical and Material Requirements for Steel Nuts

SAE J1061—Surface Discontinuities on General Application Bolts, Screws, and Studs

SAE J1086—Numbering Metals and Alloys

SAE J1268—Hardenability Bands for Carbon and Alloy H Steels

ASME B18.2.1—

ASME B18.18.1M—Inspection and Quality Assurance for General Purpose Fasteners

ASTM E 18—Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

ASTM F 1470—Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

Developed by the SAE Fasteners Committee

1. Sems—Screw and washer assemblies
2. U-bolts covered by this SAE Standard are those used primarily in the suspension and related areas of vehicles. For specification purposes, this standard treats U-bolts as studs. Thus, wherever the word “studs” appears, “U-bolts” is also implied. (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.)