SURFACE VEHICLE STANDARD

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Mechanical and Material Requirements for Externally Threaded Fasteners

RATIONALE

Allow higher S and P percentages in alloy steel than allowed in Table 2 for manufacturing Grade 8 screws and bolts by hot forging or machining from bar. As an example, this enables producers of Grade 8 bolts and screws to use SAE 4140 steel that might not otherwise be acceptable for hot forging and machining from bar. The S and P values in Table 2 must be adhered to for all cold formed fasteners.

1. SCOPE

This SAE Standard covers the mechanical and material requirements for inch-series steel bolts, screws, studs, screws for sems[1], and U-bolts[2] 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.

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 shall be borne by the end user.

[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. (The “U” configuration might 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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2. REFERENCES

2.1 Applicable Documents

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 International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J403 Chemical Compositions of SAE Carbon Steels

SAE J404 Chemical Compositions 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 J1268 Hardenability Bands for Carbon and Alloy H Steels

2.1.2 ASME Publications

Available from American Society of Mechanical Engineers, 22 Law Drive, P.O. Box 2900, Fairfield, NJ 07007-2900, Tel: 973-882-1170, www.asme.org.

ASME B18.2.1 Square, Hex, Heavy Hex, and Askew Head Bolts and Hex, Heavy Hex, Hex Flange, Lobed Head, and Lag Screws (Inch Series)

ASME B18.18 Inspection and Quality Assurance for Fasteners

2.1.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

ASTM F606 Test Methods for Determining the Mechanical Properties of Externally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets

ASTM F788/F788M Standard Specification for Surface Discontinuities of Bolts, Screws, and Studs Inch and Metric Series

ASTM F1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

ASTM F2328 Test Method for Determining Decarburization and Carburization in Hardened and Tempered Threaded Steel Bolts, Screws, and Studs

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Standard.

2.2.1 SAE Publication

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J995 Mechanical and Material Requirements for Steel Nuts

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

3.2.1 Bolts and screws are normally available in Grades 1, 2, 5, 5.2, 8, and 8.2 (see Appendix A).

3.2.2 Studs are normally available in Grades 1, 2, 4, 5, 8, and 8.1.

3.2.3 Grade 5.1 is applicable to sems which can 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

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

4.1.2 Refer to SAE J403, J404, or J1268 for the chemical composition limits of standard steel grades. Other standard and non-standard steels not defined by the above standard are acceptable if the resultant fasteners comply with all of the requirements in this standard. For Grades 5, 5.1, 5.2, 8, 8.1, and 8.2 the maximum content of bismuth selenium, tellurium, or lead each shall be 0.02%.

4.1.3 Alloy and medium carbon steels with additive boron for manufacturing 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, 8]

Grade Designation	Products	Nominal Size Dia, In	Full Size[7] Bolts, Screws, Studs Sems, Stress under Proof Load, psi	Full Size[7] Bolts, Screws Studs, Sems, Tensile Strength Min, psi	Machine Test Specimens of Bolts, Screws, and Studs Yield[2] Strength Min, psi	Machine Test Specimens of Bolts, Screws, and Studs Tensile Strength Min, psi	Machine Test Specimens of Bolts, Screws, and Studs Elongation Min, %	Machine Test Specimens of Bolts, Screws, and Studs Reduction of Area Min, %	Surface Hardness Rockwell 30N Max	Core Hardness Rockwell Min	Core Hardness Rockwell Max	Grade Identification Marking[3]
1	Bolts, Screws, Studs	1/4 thru 1-1/2	33 000[4]	60 000	36 000	60 000	18	35	—	B70	B100	None
2	Bolts, Screws, Studs	1/4 thru 3/4[5]	55 000[4]	74 000	57 000	74 000	18	35	—	B80	B100	None
		Over 3/4 thru 1-1/2	33 000	60 000	36 000	60 000	18	35	—	B70	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 (3)	1/4 thru 1	85 000	120 000	92 000	120 000	14	35	54	C25	C34	
		Over 1 thru 1-1/2	74 000	105 000	81 000	105 000	14	35	50	C19	C30	
5.1[6]	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 (3)	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 the scope.
2. Yield strength is stress at which a permanent set of 0.2% of gage length occurs.
3. Not applicable to studs or slotted and cross recess head products.
4. Proof load test. Requirements in these grades only apply to stress relieved products.
5. 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.
6. Grade 5 material heat treated before assembly with a hardened washer is an acceptable substitute.
7. “Full Size” means a tension test specimen consisting of a completed fastener for testing in the ready to use condition without alteration.
8. To convert pounds per square inch to Mega-Pascals (MPa) multiply the values above by .00689.

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) Carbon Min	Product Chemical Analysis[1], (% by Weight) Carbon Max	Product Chemical Analysis[1], (% by Weight) P Max	Product Chemical Analysis[1], (% by Weight) S Max	Product Chemical Analysis[1], (% by Weight) Boron Min	Product Chemical Analysis[1], (% by Weight) Boron Max	Tempering Temperature °F (Min)
1	Bolts, Screws, Studs	1/4 thru 1-1/2	Low or Medium Carbon Steel	See 4.4		0.55	0.025	0.025			See 4.4
2	Bolts, Screws, Studs	1/4 thru 1-1/2	Low or Medium Carbon Steel	See 4.4	0.15	0.55	0.025	0.025[2]			See 4.4
4	Studs	1/4 thru 1-1/2	Medium Carbon Steel	Cold Drawn	0.28	0.55	0.025	0.13			See 4.4
5	Bolts, Screws, Studs	1/4 thru 1-1/2	Medium Carbon Steel(3) Or	Quenched & Tempered	0.25	0.55	0.025	0.025[4]			425 °C (800 °F)
			Carbon Steel with additives (e.g. Boron (6, 9) or Cr, or Mn) Or	Quenched & Tempered	0.15	0.40	0.025	0.025[4]	0.0005	0.003	425 °C (800 °F)
5.1(5)	SEMS	No 4 thru 5/8	Low or Medium Carbon Steel(3, 6 9)	Quenched & Tempered	0.15	0.30	0.025	0.025		0.003	340 °C (650 °F)
5.2	Bolts, Screws	1/4 thru 1	Low Carbon Boron Steel (6)	Quenched & Tempered	0.15	0.25	0.025	0.025	0.0005	0.003	425 °C (800 °F)
8	Bolts, Screws, Studs	1/4 thru 1-1/2	Carbon (8) Steel with additives (e.g., Boron(9) or Cr, or Mn) Or	Quenched & Tempered	0.25	0.55	0.025	0.025[4]		0.003	425 °C (800 °F)
			Medium Carbon Steel Or	Quenched & Tempered	0.25	0.55	0.025	0.025[4]			425 °C (800 °F)
			Alloy Steel (7,8)	Quenched & Tempered	0.25	0.55	0.025 (10)	0.025 (10)			425 °C (800 °F)
8.1	Studs	1/4 thru 1-1/2	Medium Carbon Alloy (7, 8) or SAE 1541 Steel	Elevated Temperature Drawn	0.28	0.55	0.025	0.040			425 °C (800 °F)

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) Carbon Min	Product Chemical Analysis(1), (% by Weight) Carbon Max	Product Chemical Analysis(1), (% by Weight) P Max	Product Chemical Analysis(1), (% by Weight) S Max	Product Chemical Analysis(1), (% by Weight) Boron Min	Product Chemical Analysis(1), (% by Weight) Boron Max	Tempering Temperature °F (Min)
8.2	Bolts, Screws	1/4 thru 1	Low Carbon Boron Steel (6, 9)	Quenched & Tempered	0.15	0.25	0.025	0.025	0.0005	0.003	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, alloy 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 the carbon content in boron steel is less than 0.25% the minimum manganese shall be 0.60%for Grades 5, 5.1, and 5.2 and 0.70% for Grades 8.2.
7. Alloy steel shall contain at least one of the following elements in the minimum quantity given: chromium 0.30 %, nickel 0.30 %, molybdenum 0.20 %, vanadium 0.10 %, manganese 1.65%. Where elements are specified in combinations of two, three, four, or five and have alloy contents less than those given above, the limit value to be applied for steel class determination is 70 % of the sum of the individual limit values shown above for the two, three, four or five elements concerned.
8. For steels of these types there shall be sufficient hardenability to ensure a microsructure consisting of approximately 90% martensite (refer Table 3) in the core of threaded sections of the fasteners after hardening and quenching and before tempering.
9. When boron is added the limits shall be 0.0005 % to 0.003 %.
10. Alloy steel used to make fasteners by hot forging or machining may have a maximum content by weight of 0.030% P (phosphorus) and 0.040% S (sulfur).

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

Primary operations for bolt and screw manufacturing other than upsetting or extrusion are permitted only by special agreement between purchaser and supplier.

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

4.2.2 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.

4.2.3 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. 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

4.4.1 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 470 °C (875 °F) minimum. (Prior agreement with purchaser shall 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 470 °C (875 °F) minimum.

4.4.2 Grades 4 and 8.1 studs are manufactured from pretreated material and the studs, as manufactured, need no further heat treatment.

4.4.3 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 425 °C (800 °F).

4.4.4 Grade 5.1 Sems shall be heat treated (fully austenitized), quenched, and tempered at a minimum tempering temperature of 340 °C (650 °F); quenchants whose principal constituent is water shall not be used, unless specifically approved by the user.

4.4.5 Grade 8 bolts and screws and studs shall be heat treated (fully austenitized), oil quenched, and tempered at a minimum tempering temperature of 425 °C (800 °F).

4.4.6 Grade 8.2 bolts and screws shall be heat treated (fully austenitized), quenched in oil, water based quenchant 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, 5.1 and 5.2 bolts, screws, and studs shall conform to Class 1, and Grades 8, 8.1, and 8.2 bolts, screws, and studs shall conform to Class 2 as described in ASTM F2328.

4.6 Surface Discontinuities

All bolts, screws, and studs shall be in conformity with the requirements of ASTM F788/F788M.

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 conducted in accordance with ASTM F606.

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 ensure accurate reproducible readings in accordance with SAE J417. Proper correction factors shall be used when hardness tests are made on curved surfaces, per ASTM E18.

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, can 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 ASTM F2328 shall be used. Parts shall be accepted when ASTM F2328 testing does not substantiate carburization.

In applying the ASTM F2328 procedure, a difference between Knoop and Rockwell 30N readings by conversion can occur. This difference is disregarded because the primary purpose of the Knoop traverse in ASTM F2328 is to establish the existence of carburization.

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

Product	Grade	Specified Minimum Ultimate Tensile Load, lbf	Length of Product[1, 4]	Hardness[2] max	Hardness[1] Min	Tests Conducted Using Full Size Products[1] Proof Load	Tests Conducted Using Full Size Products[1] Wedge Tensile Strength	Tests Conducted Using Full Size Products[1] Axial Tensile Strength	Tests Conducted Using Machine Test Specimens[1] Yield Strength	Tests Conducted Using Machine Test Specimens[1] Axial Tensile Strength	Tests Conducted Using Machine Test Specimen[1] Elongation	Tests Conducted Using Machine Test Specimens[1] Reduction of Area	Surface Hardness max[3]	Decarburi-zation in Threaded Section[2]
Short Bolts and Screws	1, 2, 5, 5.2, 8, 8.2	All	Less than 2-1/2 D	*	*	—	—	—	—	—	—	—	*	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
			Over 12 in.	*	—	Option C	Option A	—	Option B	Option B	Option B	Option B		Option C
		Over 100 000	2-1/2D and longer	*	—	Option C	Option A	—	Option B	Option B	Option B	Option B	*	Option C
All Other Bolts and Screws	1, 2, 5, 5.2, 8, 8.2	100 000 and less	2-1/2 to 8D or 8 in., whichever is greater	*	—	Option C	—	*	—	—	—	—	*	Option C
			Over 8D or 8 in., whichever is greater	*	—	Option C	—	Option A	Option B	Option B	Option B	Option B	*	Option C
		Over 100 000	2-1/2D and longer	*	—	Option C	—	Option A	Option B	Option B	Option B	Option B	*	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	*	—	—	—	—	—	*	Option C
			Over 8D or 8 in., whichever is greater	*	—	Option C	Option A	—	Option B	Option B	Option B	Option B	*	Option C
		Over 100 000	3D and longer	*	—	Option C	Option A	—	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 (6)	All	2-1/2D and longer	*	—	Option C	*	—	—	—	—	—	*	Option C
Other Bolts, Screws, and Sems	5.1	All	2-1/2D and longer	*	—	Option C	—	*	—	—	—	—	*	Option C
Tests to be performed in accordance with paragraph				6.1	6.1	6.4	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. SEMS products below ¼ inch diameter shall be tested with a 6 degree wedge angle.

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; re-temper 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 re-tempering) shall be no greater than two points Rockwell C. This is a referee test and not a mandatory requirement.

6.4 Proof Load

The proof load test consists of stressing the bolt, screw, stud, or sems with a specified load that the product shall withstand without permanent set. Testing shall be conducted in accordance with ASTM F606, Proof Load testing, Method 1, unless otherwise agreed to between the supplier and purchaser.

6.5 Axial Tensile Strength

Following proof load testing, the same bolt, screw, stud, or sems shall be reassembled in the testing machine and axial loading shall be applied until failure. Testing shall be conducted in accordance with ASTM F606.

6.6 Wedge Tensile Strength

6.6.1 Bolts and Screws

Following proof load testing, the same bolt or screw shall be wedge tensile tested in accordance with ASTM F606.

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, with the exception of special head bolts and screws (See footnote 5 under Table 4.)

6.6.2 Studs

Following proof load testing, the stud shall be tested in accordance with ASTM F606.

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 in accordance with ASTM F606. Tensile testing of full size bolts is the referee method in cases of dispute.

NOTE: Bolts, screws, and studs cannot be tested in full size when for example a tensile test machine lacks the capacity to test full size bolts of a given size and strength. However, whenever possible, tensile testing of full size bolts is preferred. For example, with large diameter bolts it is not unusual for a machined specimen to exhibit lower strength than a full size bolt, unless very careful precautions are taken to ensure that the machined specimen is representative of the bolt cross section.

To meet the requirements of Section 5, the test specimens shall 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.

TABLE 5 - PROOF LOAD AND TENSILE STRENGTH REQUIREMENTS [1, 3]

		Stress Area, in^2	Grade 1 Proof Load, lbf	Grade 1 Tensile Load Min, lbf	Grade 2 Proof Load, lbf	Grade 2 Tensile Load Min, lbf	Grade 4 Proof Load, lbf	Grade 4 Tensile Load Min, lbf	Grades 5 and 5.2[2] Proof Load, lbf	Grades 5 and 5.2[2] Tensile Load Min, lbf	Grade 5.1 Proof Load, lbf	Grade 5.1 Tensile Load Min, lbf	Grades 8, 8.1, 8.2[2] Proof Load, lbf	Grades 8 8.1, 8.2[2] Tensile Load Min, lbf
						Coarse Thread Series UNC								
No.	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	2050	3650	2700	3800	2700	3800	3800	4750
	5/16-18	0.0524	1750	3150	2900	3900	3400	6000	4450	6300	4450	6300	6300	7850
	3/8-16	0.0775	2550	4650	4250	5750	5050	8400	6600	9300	6600	9300	9300	11 600
	7/16-14	0.1063	3500	6400	5850	7850	6900	12 200	9050	12 800	9050	12 800	12 800	15 900
	1/2-13	0.1419	4700	8500	7800	10 500	9200	18 300	12 100	17 000	12 100	17 000	17 000	21 300
	9/16-12	0.182	6000	10 900	10 000	13 500	11 800	20 900	15 500	21 800	15 500	21 800	21 800	27 300
	5/8-11	0.226	7450	13 600	12 400	16 700	14 700	25 400	19 200	27 100	19 200	27 100	27 100	33 900
	3/4-10	0.334	11 000	20 000	18 400	24 700	21 700	38 400	28 400	40 100	—	—	40 100	50 100
	7/8-9	0.462	15 200	27 700	15 200	27 700	30 000	53 100	39 300	55 400	—	—	55 400	69 300
	1 - 8	0.606	20 000	36 400	20 000	36 400	39 400	69 700	51 500	72 700	—	—	72 700	90 900
	1-1/8-7	0.763	25 200	45 800	25 200	45 800	49 600	87 700	56 500	80 100	—	—	91 600	114 400
	1-1/4-7	0.969	32 000	58 100	32 000	58 100	63 000	111 400	71 700	101 700	—	—	116 300	145 400
	1-3/8-6	1.155	38 100	69 300	38 100	69 300	75 100	132 800	85 500	121 300	—	—	138 600	173 200
	1-1/2-6	1.405	46 400	84 300	46 400	84 300	91 300	161 600	104 000	147 500	—	—	168 600	210 800
						Fine Thread Series UNF								
No.	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	2350	4200	3100	4350	3100	4350	4350	5450
	5/16-24	0.0580	1900	3500	3200	4300	3750	6700	4900	6950	4900	6950	6950	8700
	3/8-24	0.0878	2900	5250	4800	6500	5700	10 100	7450	10 500	7450	10 500	10 500	13 200
	7/16-20	0.1187	3900	7100	6550	8800	7700	13 650	10 100	14 200	10 100	14 200	14 200	17 800
	1/2-20	0.1599	5300	9600	8800	11 800	10 400	18 400	13 600	19 200	13 600	19 200	19 200	24 000
	9/16-18	0.203	6700	12 200	11 200	15 000	13 200	23 300	17 300	24 400	17 300	24 400	24 400	30 400
	5/8-18	0.256	8450	15 400	14 100	18 900	16 600	29 400	21 800	30 700	21 800	30 700	30 700	38 400
	3/4-16	0.373	12 300	22 400	20 500	27 600	24 200	42 900	31 700	44 800	—	—	44 800	56 000
	7/8-14	0.509	16 800	30 500	16 800	30 500	33 100	58 500	43 300	61 100	—	—	61 100	76 400
	1 - 12	0.663	21 900	39 800	21 900	39 800	43 100	76 200	56 400	79 600	—	—	79 600	99 400
	1- 14 UNS	0.679	22 400	40 700	22 400	40 700	44 100	78 100	57 700	81 500	—	—	81 500	101 900
	1-1/8-12	0.856	28 200	51 400	28 200	51 400	55 600	98 400	63 300	89 900	—	—	102 700	128 400
	1-1/4-12	1.073	35 400	64 400	35 400	64 400	69 700	123 400	79 400	112 700	—	—	128 800	161 000
	1-3/8-12	1.315	43 400	78 900	43 400	78 900	85 500	151 200	97 300	138 100	—	—	157 800	197 200
	1-1/2-12	1.581	52 200	94 900	52 200	94 900	102 800	181 800	117 000	166 000	—	—	189 700	237 200

1. Proof load and tensile load are computed by multiplying the stress at proof load and tensile strength values given in Table 1 by the stress area of the thread. The stress area (A_s) of sizes and thread series not included in Table 5 may be computed using the formula:

$$A_s = 0.7854 \left[D - \frac{0.9743}{n} \right]^2$$

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.
3. To convert the inch based pounds values above to metric based Newtons (N) multiple the values above by 4.448.

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 that 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, 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.

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 ASTM F1470 (chemical and physical testing) and ASME B18.18, Category 2, (dimensional inspection) as applicable unless otherwise specified by the purchaser.

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 purchasers consult with the manufacturer regarding material choice.

Although it is possible that purchase users have an awareness of product end use and environment, it is likely that purchasers of product for resale or distribution do not. For this reason, purchase resellers should 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

A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

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 425 °C (800 °F), minimum, specified for Grade 8, when considering bolts and screws that are 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). The same applies to Grade 8 fasteners.