NAVISTAR, INC.

Material, Parts, and Process Specifications (MPAPS)	NUMBER: MPAPS F-31, Part I	
	Former Designation: *CEMS A-31, Part 1*	
TITLE: **Steel Bolts and Studs**	CURRENT REV No.: **1402**	DATE: **Feb. 2014**
WRITTEN/EDITED BY: **Materials Engineering**	APPROVED BY: **Materials Engineering**	SUPERSEDES: **CEMS A-31, Part 1 – Oct. 2012**

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This specification may involve hazardous materials, equipment, and procedures. This specification does not purport to address all of the safety issues associated with its use. The user is responsible to consult appropriate safety and health practices and to determine the applicability of regulatory limits prior to use.

Change Notice: **New MPAPS format; editorial changes.**

1.0 APPLICATION

This specification provides guidance to the selection and use of steel bolts and studs in Navistar design. Bolted joints are used extensively in the assembly of our products and provide for adjustment, replacement and ease of repair. Material properties of both inch and metric fasteners are covered in this specification.

2.0 SCOPE

This specification covers the Corporation's requirements for the material and properties of steel bolts and studs. Dimensional requirements and general specifications for standard bolts are covered in the Engineering Standard Parts (ESP) standards, Section B and BM. Nonstandard bolts and studs will be covered by engineering drawings which should refer to this specification for material and property requirements. For purposes of this specification, the term "bolts" also includes cap screws and SEMS (i.e., term used to describe screw and washer assemblies); the term “studs” also includes quenched and tempered U-bolts.

2.1 Restricted Chemical Substances

Effective January 1, 2007, all product supplied to the requirements of this specification must comply with the requirements of the MPAPS B-50 specification.

3.0 CONTENTS

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4.0 REFERENCE DOCUMENTS

Unless otherwise specified, the latest issue of all referenced standards shall apply. The following Specifications, Standards, and Regulations are referenced in this specification.

Quality System Standard ISO 9001 or TS-16949
CFR Title 29, Part 1910
NAVISTAR Manufacturing Std. MS-D-13
NAVISTAR CEMS AT-2
NAVISTAR Engineering Design Std A-16
NAVISTAR Eng. Procedural Std ESP-61
NAVISTAR MPAPS B-50
ASTM E 3
ASTM A 490
ASME B1.1
ISO 965-1
ISO 898-1
ASTM A 307
ASTM A 325
ASTM A 354
ASTM A 354
ASTM A 370
ASTM A 449
ASTM E8
ASTM E18
ASTM E112
ASTM F606/F606M
ASTM F2328
SAE J429
SAE J121
SAE J123
SAE J417
SAE J1061

5.0 CLASSIFICATION AND IDENTIFICATION

5.1 Classification

Steel bolts and studs are classified, or graded, on the basis of their mechanical properties. Increasing Class or Type numbers correspond to increasing tensile strength requirements. Suffix letters or numbers are used to denote physical, chemical or other property variations of fasteners within the same strength classification.

5.2 Identification

Identification requirements for each Navistar Type or Class are shown in Tables I, Ia, and Ib. All standard and/or special bolts, except Type I, will have permanent, legible, head markings (raised or depressed) to indicate bolt Type or Class as shown in Tables I, Ia, and Ib. A manufacturer's identification symbol, which uniquely identifies the manufacturer, will be included and should preferably be in the center of the head. For Types 8R and 9R, the manufacturer's identification symbol must be in the center of the head. The symbol must not exceed 0.4 mm (0.016 inch) in height, nor be of length greater than 33% of the dimension across flats.

5.3 Manufacturer’s Identification

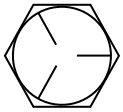
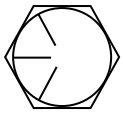
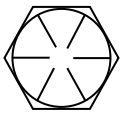
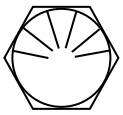
Specific requirements for the registry of manufacturer’s identification symbols may be established by regulatory controls. Manufacturer's identification symbols used on Navistar fasteners must comply with all established regulatory controls.

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TABLE I
CLASSIFICATION AND IDENTIFICATION—INCH FASTENERS

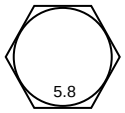
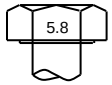
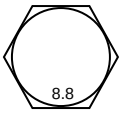
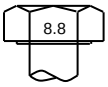
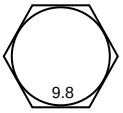
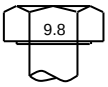
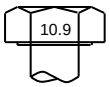
Designation					Material Type (2)	Thermal Treatment (2)	Head Marking
Navistar		Obsolete IH Type	Approx. SAE J429 Grade	Approx. ASTM (Bolts Only)			
Type *	Product						
1	Bolts Screws Studs	—	2 (1)	A 307	Low or Medium Carbon Steel	None	None
5	Bolts Screws Studs	2	5	A 325 Type 1, or A 449	Medium Carbon Steel (3)	Quenched and Tempered	
5.1	SEMS	---	5.1	---	Low or Medium Carbon Steel (3)		
5.2	Bolts Screws	5B	5.2	A 325, Type 2	Low Carbon Boron Steel		
8	Bolts Screws Studs	3, 4	8	A 354, Grade BD, or A 490	Medium Carbon or Medium Carbon Alloy Steel (4)	Quenched and Tempered	
8.2	Bolts Screws	8B	8.2	—	Low Carbon Boron Steel		
8.1**	Studs	4E or 8E	8.1	—	1541 Modified or Medium Carbon Alloy Steel	Elevated Temperature Drawn	None

* Bolts in sizes through ¾ inch with lengths through 6 inches will be roll threaded unless otherwise specified.
** Studs only (includes U-bolts)
(1) SAE Grade 2 is not applicable to Type 1 studs over ¾ inch diameter.
(2) For detailed chemical composition and heat treatment requirements, see Table II for Chemical Composition and Table VIII for Heat Treatment requirements.
(3) For Type 5 and 5.1 fasteners, medium carbon boron or medium carbon alloy steels used for Grade 8 may be used at the supplier's option.
(4) 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.

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TABLE Ia
CLASSIFICATION AND IDENTIFICATION—METRIC FASTENERS

Designation		Nom. Size	Material Type (1)	Thermal Treatment (1)	Head Marking (2)	
Navistar Class *	Approximate ISO 898-1				**Preferred**	**Optional**
5.8 (3)	5.8	M5 thru M24	Low or Medium Carbon Steel	None Required		
8.8	8.8	M1.5 thru M36	Medium Carbon or Medium Carbon Boron or Medium Carbon Alloy Steel or Low Carbon Boron Steel	Quenched and Tempered		
9.8 (4) (5)	9.8	M1.6 thru M16				
10.9	10.9	M6 thru M36				

* Bolts in sizes through 20 mm with lengths through 150 mm will be roll threaded unless otherwise specified.

(1) For detailed chemical composition and heat treatment requirements, see "see Table IIa for Chemical Composition and Table VIII for Heat Treatment requirements.

(2) When low carbon boron steels are used for fastener sizes thru M20 in classes 8.8 and 9.8, the symbol will be underlined (e.g., 8.8, 9.8).

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

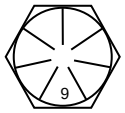
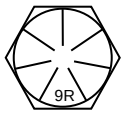
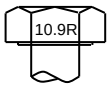
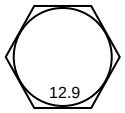
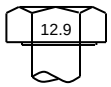
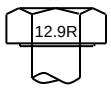
(4) Not to be specified for new designs. Class 9.8 is an acceptable alternate to Class 8.8 to assure maximum material availability in North America.

(5) For Class 9.8 SEMS base metal hardness may be 25-40 HRC and surface hardness shall not exceed 60 HR30N. This requirement is applicable to fasteners manufactured same as SEMS except without the washer, sizes M1.6 thru M12.

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TABLE Ib
CLASSIFICATION AND IDENTIFICATION--SPECIAL USE FASTENERS

Navistar Designation *	Type of Material **	Thermal Treatment **	Head Marking (1)	
			Preferred	Optional
Class	**INCH FASTENERS**			
8 R (2)	Medium Carbon or Medium Carbon Alloy Steel	Quenched and Tempered, Roll Threaded After Heat Treatment		—
9 (3)	Medium Carbon Alloy Steel	Quenched and Tempered		—
9R (2) (3)	Medium Carbon Alloy Steel	Quenched and Tempered, Roll Threaded After Heat Treatment		—
Class	**METRIC FASTENERS**			
10.9R (2)	Medium Carbon, Medium Carbon Alloy Steel	Quenched and Tempered, Roll Threaded After Heat Treatment		
12.9 (3)	Medium Carbon Alloy Steel	Quenched and Tempered		
12.9R (2) (3)		Quenched and Tempered, Roll Threaded After Heat Treatment		

* Bolts sizes thru M20 or ¾ inch with lengths thru 150 mm or 6 inches will be roll threaded unless otherwise specified.

** For detailed chemical composition and heat treatment requirements, see Table IIb for Chemical Composition, and Table VIII for Heat Treatment.

(1) Head marking for identification is mandatory as described in Section 5.3. Where an optional head marking is not indicated, the preferred head marking is required.

(2) When roll threading after heat treatment is required, roll threading will be accomplished in one pass; rerolling is not permitted. Normally, roll threaded after heat treatment bolts are specified for special applications requiring enhanced fatigue resistance. Typically, these bolts are designed and specified with special configurational refinements that increase fatigue life. The usage of bolts roll threaded after heat treatment (8R, 10.9R, 9R, or 12.9R) is allowed after consultation with Design Analysis and Materials Engineering. These fasteners are associated with cost penalties.

(3) Applications for Type 9 and Class 12.9 Hex Headed fasteners should be minimized. These fasteners require approval from Design Analysis and Materials Engineering. The capability of the bolt manufacturer and the anticipated in-use environment must be considered. These products require rigid production controls and may be susceptible to stress corrosion cracking in certain environments.

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6.0 GENERAL REQUIREMENTS

6.1 Chemical Composition

Bolts and studs purchased to this specification will conform to the limits and requirements shown in Tables II, IIa, and IIb (Chemical Composition, Inch Fasteners; Chemical Composition, Metric Fasteners, and Chemical Composition, Special Usage Fasteners). Fasteners in any one container will consist of only one nominal steel analysis.

TABLE II. CHEMICAL COMPOSITION *, INCH FASTENERS

Navistar Type	Approx SAE J429 Grade	Nominal Diameter, Inches	Elemental Composition, weight percent (Max, except where shown as min or range)				Deoxidation Practice
			Carbon	Phosphorus	Sulfur	Alloys **	
BOLTS							
1	2	¼ - 1½	0.15- 0.55	0.05 0.05	0.06 0.06	Optional	Optional
5†	5	¼ - 1½	0.25-0.55	0.05	0.06	Optional	Fully Killed
5.1†	5.1	No.4 thru 5/8"	0.15-0.55			Optional	Fully Killed, Fine Grain (1)
5.2	5. 2	¼ thru 1" dia	0.15-0.25			Boron: required. Other: optional	
8 (3) (4)	8	¼ - 1½	0.25-0.55	0.05	0.06	Optional	Fully Killed, Fine Grain (1)
8.2 (2)	8.2	¼ thru 1" dia	0.15-0.25	0.05	0.06	Boron: required. Other: optional	
STUDS							
1	2	All (5)	0.15- 0.55	0.12	0.35	Optional	Optional
5†	5	All	0.25-0.55	0.05	0.15	Optional	Fully Killed
8 (3) (4)	8	Under ¾ ¾ & Over	0.25-0.55	0.05	0.06	Optional	Fully Killed, Fine Grain (1)
8.1 (5)	8.1	All	0.28-0.55	0.05	0.06	Optional	Fully Killed

* Values are for product analysis; additional variations for check analysis do not apply. Use of steels to which bismuth, selenium, tellurium, or lead has been intentionally added is not permitted for Types 5 or 8 bolts or studs.

** Refers to alloying elements: Mn, Ni, Cu, Cr, Mo, and B. For boron steels, B = 0.0005 - 0.003%.

† For Type 5 and 5.1 fasteners, medium carbon boron or medium carbon alloy steels used for grade 8 may be used at the supplier's option.

(1) Austenitic grain size will be 5 or finer as determined by the McQuaid-Ehn, Test Method AT-2 or other suitable test (occasional grains as large as 3 are permissible). In the event of controversy, the McQuaid-Ehn test per ASTM E112, Appendix III will be the referee method with any modifications as may be noted.

(2) Use of Type 8.2 requires prior approval by Engineering. Tempering temperature is 650°F, instead of the regular 800°F

(3) Steel for Type 8 bolts and studs will have sufficient hardenability to produce 90% min. martensite at the center of the threaded section, one diameter from the end of the bolt or stud as specified in Section 6.4, "Heat Treatment".

(4) Medium carbon or medium carbon alloy steel required, unless deviation in steel composition is approved by the controlling design engineering department. 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.

(5) Maximum 0.38% lead permissible.

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TABLE IIa CHEMICAL COMPOSITION *, METRIC FASTENERS

Navistar Class	Nominal Diameter, mm	Elemental Composition, weight percent (Max, except where shown as min or range)				Deoxidation Practice
		Carbon	Phosphorus	Sulfur	Others	
BOLTS AND STUDS						
5.8	Thru M24	0.13- 0.55	0.05	0.06	Optional	Optional
8.8	All	0.25-0.55 (1)	0.05	0.06	Optional	Fully Killed
9.8	Thru M16	0.25-0.55 (1)	0.05	0.06	Optional	Fully Killed
10.9 **	All	0.25-0.55 (2)	0.05	0.06	Optional	Fully Killed, Fine Grain (3)

* All values are for product analysis; additional variation for check analysis does not apply.

** Steel for 10.9 bolts and studs will have sufficient hardenability to produce 90% min. martensite at the center of the threaded section, one diameter from the end of the bolt or stud as specified in Section 6.4, "Heat Treatment."

(1) Carbon range for low carbon boron steels is 0.15-0.25%, boron = 0.0005 - 0.003%.

(2) Low carbon boron steel may be used for sizes thru M20 only with engineering approval.

(3) Austenitic grain size will be 5 or finer as determined by the McQuaid-Ehn, Test Method CEMS AT-2 or other suitable test (occasional grains as large as 3 are permissible). In the event of controversy, the McQuaid-Ehn test per ASTM E 112, Appendix III (latest issue), will be the referee method with any modifications as may be noted.

TABLE IIb
CHEMICAL COMPOSITION *, SPECIAL USE FASTENERS

Navistar Designation	Nominal Diameter, mm	Elemental Composition, weight percent (Max, except where shown as min or range)				Deoxidation Practice
		Carbon	Phosphorus	Sulfur	Alloys **	
Type	**INCH FASTENERS**					
8R	Under ¾ ¾ & Over ***	0.26-0.55	0.05	0.06	Optional	Fully Killed, Fine Grain (1)
9, 9R	All	0.26-0.55	0.045	0.045	Optional	Fully Killed, Fine Grain (1)
Class	**METRIC FASTENERS**					
10.9R	All	0.26-0.55	0.05	0.06	Optional	Fully Killed, Fine Grain (1)
12.9, 12.9R	All	0.26-0.55	0.045	0.045	Optional	Fully Killed, Fine Grain (1)

* All values are for product analysis; additional variations for check analysis do not apply. Steels for bolts and studs will have sufficient hardenability to produce the required microstructure at the center of the threaded section, one diameter from the end of bolt or stud as specified in Section 6.4, "Heat Treatment".

** Refers to alloying elements: Mn, Ni, Cu, Cr, Mo, V, B. For boron steels B = 0.0005 – 0.003%.

*** Medium carbon alloy steel required, unless deviation in steel composition is approved by the controlling design engineering department. See Section 6.4, "Heat Treatment."

(1) Austenitic grain size will be 5 or finer as determined by the McQuaid-Ehn, Test Method CEMS AT-2 or other suitable test (occasional grains as large as 3 are permissible). In the event of controversy, the McQuaid-Ehn test per ASTM E 112, Appendix III (latest issue), will be the referee method with any modifications as may be noted.

6.2 Mechanical Properties

Bolts and studs purchased to this specification will meet the mechanical properties shown in Tables III, IIIa and IIIb. Required tests are summarized in Table IV. To determine proof stress and tensile strength, use the mean equivalent stress areas shown in Tables V or Va. For convenience, requirements converted to proof load and ultimate load for standard threads are also shown in Table V thru Table Vc.

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6.2.1 Thread Bend Test

This test is required only when specified on the drawing and is defined in Section 8.0, "Methods of Test". Currently this test is only applicable to Type 8 and Class 10.9 bolts (lengths 3D and greater), and Type 8 and 8.1 studs. When the thread bend test is required for other bolt classifications, the minimum allowable bend angle will be designated on the drawing.

TABLE III
MECHANICAL PROPERTIES, INCH FASTENERS

Designation		Appli-cable Fasteners	Nominal Diameter, inches	Full Size Bolts and Studs		Machined Tensile Specimens *			Surface Hardness	Base Metal Rockwell Hardness (1)
Navistar Type	Approx SAE J429 Grade			Proof Load Stress, min	Wedge or Axial Tensile Strength, min	Yield Strength 0.2% Offset, min	Axial Tensile Strength, min	Elong-ation, min		
				psi	psi	psi	psi	%		
1	2	Bolts, Studs	Thru ¾ **	55 000	74 000	57 000	74 000	18	—	100 B, max
		Bolts	Over ¾ Thru 1½	33 000	60 000	36 000 (2)	60 000			
	(3)	Studs	Over ¾ (3) Thru 1½	52 000	64 000	54 000	64 000			
5	5	Bolts, Screws and Studs	Thru 1	85 000	120 000	92 000	120 000	14	(6)	25-34 C
			Over 1 - 1½	74 000	105 000	81 000	105 000			19-30 C
5.1	5.1	SEMS	No.4 – 5/8	85,000	120,000	---	---	---	59.5 HR30N MAX	25-40C
5.2	5.2	Bolts, Studs	Optional: (5) Thru 1	85 000	120 000	92 000	120 000	14	(6)	26-36.C (4)
8	8	Bolts, Screw and Studs	Thru 1½	120 000	150 000	130 000	150 000	12	59 HR30N MAX	33-39 C
8.2	8.2	Bolts, Screws	Optional: (5) Thru 1	120 000	150 000	130 000	150 000	12		33-39 C
8.1	8.1	Studs	Thru 1½	120 000	150 000	130 000	150 000	10	—	32-38 C

* Required dimensions for standard and subsize test specimens are shown in Table XI.

** Applies only to bolts with lengths of 6 inches or less. Longer bolts will meet the requirements shown for bolts over ¾ inch diameter.

(1) Minimum hardness requirements will be waived provided that the chemical composition and all other mechanical properties are met. However, bolts or studs which cannot be tensile tested because of size or configuration will conform to the appropriate chemical composition and hardness requirements shown in Tables II and III, respectively. See Table IV for required mechanical tests.

(2) Yield point applies instead of yield strength.

(3) SAE Grade 2 is not applicable to Type 1 studs over 3/4 inch diameter.

(4) This hardness is for Type 5.2 bolts and studs made from low carbon boron martensitic steel (0.15-0.25% carbon) conforming to the optional chemical composition shown in Table II.

(5) Refers to low carbon boron steel bolts.

(6) Surface hardness will not exceed the base metal hardness by more than 2 points HRC equivalent.

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TABLE IIIa
MECHANICAL PROPERTIES, METRIC FASTENERS

Navistar Class	Nominal Diameter, mm	Full Size Bolts and Studs		Machined Tensile Specimens *			Surface Hardness	Base Metal Rockwell Hardness (1)
		Proof Load Stress, min	Wedge or Axial Tensile Strength, min	Yield Strength 0.2% Offset, min	Axial Tensile Strength, min	Elong-ation, min		
		MPa	MPa	MPa	MPa	%		
5.8 (2)	Thru M24	380	520	420**	520	10	—	82-95B
8.8	Thru M16	580	800	640	800	12	(3)	22-32C
8.8	M18 thru M39	600	830	660	830	12	(3)	23-34C
9.8	Thru M16	650	900	720	900	10	(3)	27-36C (4)
10.9	Thru M39	830	1040	940	1040	9	(3)	32-39C

* Required dimensions for test specimens are shown in Table XI.

** Yield point applies instead of yield strength.

(1) Minimum hardness requirements will be waived provided that the chemical composition and all other mechanical properties are met. However, bolts or studs, which cannot be tensile, tested because of size or configuration will conform to the appropriate chemical composition and hardness requirements shown in Tables IIa and IIIa, respectively. See Table IV for required mechanical tests.

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

(3) Surface hardness will not exceed the base metal hardness by more than 2 points HRC or equivalent) and, in the case of Class 10.9, will not exceed 59 HR30N.

(4) For Class 9.8, SEMS base metal hardness may be 25-40 HRC and surface hardness will not exceed 59 HR30N. This requirement is also applicable to products made same as SEMS except without the washer, sizes M1.6 to M12.

TABLE IIIb
MECHANICAL PROPERTIES, SPECIAL USE FASTENERS

Navistar Type or Class	Nominal Diameter	Full Size Bolts and Studs				Machined Tensile Specimens *				Elong-ation, %, min	Surface Hardness HR30N, max	Base Metal Rockwell Hardness
		Proof Load Stress, min		Wedge or Axial Tensile Strength, min		Yield Strength 0.2% Offset, min		Axial Tensile Strength, min				
		MPa	psi	MPa	psi	MPa	psi	MPa	psi			
8R	Thru 1½″	827	120 000	1034	150 000	896	130 000	1034	150 000	12	59	33-39 C
9 or 9R	Thru 1½″	970	141 000	1220	177 000	1100	160 000	1220	177 000	8	62	38-43 C
10.9R	Thru M39	830	120 400	1040	150 800	940	136 300	1040	150 800	9	59	33-39 C
12.9 or 12.9R	Thru M39	970	141 000	1220	177 000	1100	160 000	1220	177 000	8	62	39-44 C

* Required dimensions for test specimens are shown in Table XI.

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6.2.2 Required Mechanical Tests

Bolts and studs will be tested in accordance with requirements outlined in Table IV. Tests denoted by "●" are considered mandatory tests for the given product type, while those marked "○" indicate only those tests required when specifically requested on purchase order. For manufacturing control, alternate test methods may be approved (see Section 8.0, "Methods of Test").

TABLE IV
MECHANICAL TESTING REQUIREMENTS FOR BOLTS AND STUDS

Applicable Fasteners	Fastener Length (D = Nominal diam. factor)	Product Hardness **		Surface Hardness+	Full Size Bolts and Studs			Machined Test Specimens
		Max	Min	Max	Proof Load	Wedge Tensile Strength ***	Axial Tensile Strength ++	Yield Strength, Axial Tensile Strength, Elongation, Reduction in Area
Hexagon Head & Hex Flange Bolts	Less than 2 ½D	●	●	●	—	—	—	—
	2½ D – to 8 inches (200 mm) or 8D *	●	—	●	○	●	—	—
	Over 8 inches (200 mm) or 8D * – to 12 inches (300 mm)	●	—	●	○	●	—	—
	Over 12 inches (300 mm)	●	—	●	○	A	—	B
Special Head Bolts +++	All	●	●	●	—	—	—	—
All Other Bolts	Less than 2½D	●	●	●	—	—	—	—
	2½ D to 8D	●	—	●	○	—	●	—
	Over 8D	●	—	●	○	—	A	B
Studs	Less than 2½ D	●	●	●	—	—	—	—
	2½ D to 8 inches (200 mm) or 8D *	●	—	●	○	●	—	—
	Over 8 inches (200 mm) or 8D	●	—	●	○	A	—	B

* Whichever is greater.

** Minimum core hardness requirements will be waived provided that the chemical composition and all other mechanical properties are met. However, bolts or studs which cannot be tensile tested because of size or configuration will conform to the appropriate chemical composition and hardness requirements shown in Tables II, IIa, and IIb and in Tables III, IIIa, and IIIb, respectively.

*** Bolts and studs requiring a wedge tensile strength test not covered above will have this requirement, including wedge angle, specified on the drawing. Test details are subject to agreement between purchaser and supplier.

\+ Surface hardness requirements apply only to metric classes 8.8, 9.8, 10.9, and 12.9, and to inch classes 5, 5.1, 5.2, 8, 8.1, and 8.2.

++ For minimum product tensile strengths over 450 kN or 100,000 lbs, and lengths over 2-1/4 D, requirements will be the same as specified in the Tables for lengths over 8D, as applicable.

+++ Special head bolts are those with special configuration or drilled holes, which may be weaker than the threaded section. If tests other than hardness are required, they will be specified on the drawing. In these cases, minimum hardness is waived.

A Testing of machined test specimens may be performed as an option to testing full size bolts or studs. Referee tests will be on full size bolts and studs.

B Either all tests denoted "A" or all tests denoted "B" shall be performed.

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6.2.2.1 For convenience in testing, proof stress and tensile strength requirements shown in Tables III and IIIa are converted to load in pounds-force and kilonewtons by use of the mean equivalent stress areas of standard threads shown in Tables V, Va and Vb. The formula shown below the Tables may be used for nonstandard sizes.

TABLE V
PROOF LOAD AND ULTIMATE LOAD (POUNDS-FORCE) - INCH FASTENERS

Nominal Size (in.) and Threads Per Inch	Stress Area *, in^2	Type 1 Bolts				Type 1 Studs		Type 5 Bolts and Studs		Types 8 and 8R Bolts and Types 8 and 8E Studs	
		Under 6 Inches in Length		Over 6 Inches in Length							
		Proof Load	Ultimate Load	Proof Load	Ultimate Load	Proof Load	Ultimate Load	Proof Load	Ultimate Load	Proof Load	Ultimate Load
COARSE THREADED (UNC) BOLTS AND STUDS											
1/4–20	0.0318	1 750	2 350	1 050	1 900	1 750	2 350	2 700	3 800	3 800	4 750
5/16–18	0.0524	2 900	3 900	1 750	3 150	2 900	3 900	4 450	6 300	6 300	7 850
3/8–16	0.0775	4 250	5 750	2 550	4 650	4 250	5 750	6 600	9 300	9 300	11 650
7/16–14 (1)	0.1063	5 850	7 850	3 500	6 400	5 850	7 850	9 050	12 750	12 750	15 950
1/2–13	0.1419	7 800	10 500	4 700	8 500	7 800	10 500	12 050	17 050	17 050	21 300
9/16–12 **	0.1820	10 000	13 450	6 000	10 900	10 000	13 450	15 450	21 850	21 850	27 300
5/8–11	0.2260	12 450	16 750	7 450	13 600	12 450	16 750	19 200	27 100	27 100	33 900
3/4–10	0.3340	18 350	24 700	11 050	20 300	18 350	24 700	28 400	40 100	40 100	50 100
7/8–9 (1)	0.4620	15 250	27 700	15 250	27 700	24 000	29 550	39 300	55 450	55 450	69 300
1–8	0.6060	20 000	36 350	20 000	36 350	31 500	38 800	51 500	72 700	72 700	90 900
1 1/8–7 (1)	0.7630	25 200	45 800	25 200	45 800	39 700	48 850	56 450	80 100	91 550	114 450
1 1/4–7	0.9690	32 000	58 200	32 000	58 200	50 400	62 000	71 700	101 750	116 300	145 350
1 3/8–6 (1)	1.1550	38 100	69 300	38 100	69 300	60 050	73 900	85 450	121 300	138 600	173 250
1 1/2–6	1.4050	46 400	84 300	46 400	84 300	73 050	89 900	103 950	147 500	168 600	210 750
FINE THREADED (UNF) BOLTS AND STUDS (NONPREFERRED)											
1/4–28	0.0364	2 000	2 700	1 200	2 200	2 000	2 700	3 100	4 350	4 350	5 450
5/16–24	0.0580	3 200	4 300	1 900	3 500	3 200	4 300	4 950	6 950	6 950	8 700
3/8–24	0.0878	4 850	6 500	2 900	5 250	4 850	6 500	7 450	10 550	10 550	13 150
7/16–20	0.1187	6 550	8 800	3 900	7 100	6 550	8 800	10 100	14 250	14 250	17 800
1/2–20	0.1599	8 800	11 850	5 300	9 600	8 800	11 850	13 600	19 200	19 200	24 000
9/16–18 **	0.2030	11 150	15 000	6 700	12 200	11 150	15 000	17 250	24 350	24 350	30 450
5/8–18	0.2560	14 100	18 950	8 450	15 350	14 100	18 950	21 750	30 700	30 700	38 400
3/4–16	0.3730	20 500	27 600	12 300	22 400	20 500	27 600	31 700	44 750	44 750	55 950
7/8–14	0.5090	16 800	30 550	16 800	30 550	26 450	32 600	43 250	61 100	61 100	76 350
1–14 ***	0.6798	22 450	40 800	22 450	40 800	35 350	43 500	57 800	81 600	81 600	101 950
1–12	0.6630	21 900	39 800	21 900	39 800	34 500	42 450	56 400	79 550	79 550	99 450
1 1/8–12	0.8560	28 250	51 350	28 250	51 350	44 500	54 800	63 350	89 900	102 700	128 400
1 1/4–12	1.0730	35 400	64 400	35 400	64 400	55 800	68 650	79 400	112 650	128 750	160 950
1 3/8–12	1.3150	43 400	78 900	43 400	78 900	68 400	84 150	97 300	138 100	157 800	197 250
1 1/2–12	1.5810	52 150	94 850	52 150	94 850	82 200	101 200	117 000	166 000	189 700	237 150

* Stress areas are calculated from the following formula:

$$A_s = 0.7854 \left(D - \frac{0.9743}{N}\right)^2$$

Where: A_s = Mean equivalent stress area, square inches
D = Nominal Diameter, Inches
N = Number of Threads Per Inch

** Not recommended for new design.

*** 1 – 14 is the International standard thread (UNS – not UNF); refer to EPS- 61.

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TABLE Va
PROOF LOAD AND ULTIMATE LOAD (KILONEWTONS) — METRIC FASTENERS

Nominal Thread Diameter, mm	Pitch of Thread, mm	Stress Area,* mm^2	Class 5.8		Class 8.8		Class 9.8		Class 10.9, 10.9R	
			Proof Load	Ultimate Load	Proof Load	Ultimate Load	Proof Load	Ultimate Load	Proof Load	Ultimate Load
COARSE THREADED BOLTS AND STUDS										
M6	1	20.1	7.6	10.4	11.6	16.1	13.1	18.1	16.7	20.9
M7 (1)	1	28.9	11.0	15.0	16.8	23.1	18.8	26.0	24.0	30.1
M8	1.25	36.6	13.9	19.0	21.2	29.2	23.8	32.9	30.4	38.1
M10	1.5	58.0	22.0	30.2	33.7	46.4	37.7	52.2	48.1	60.3
M12	1.75	84.3	32.0	43.8	48.9	67.4	54.8	75.9	70.0	87.7
M14 (1)	2	115.0	43.7	59.8	66.7	92.0	74.8	104.0	95.5	120.0
M16	2	157.0	59.7	81.6	91.0	125.0	102.0	141.0	130.0	163.0
M18 (1)	2.5	192.0	73.0	99.8	115.0	159.0	—	—	159.0	200.0
M20	2.5	245.0	93.1	127.0	147.0	203.0	—	—	203.0	255.0
M22 (1)	2.5	303.0	115.0	158.0	182.0	252.0	—	—	252.0	315.0
M24	3	353.0	134.0	184.0	212.0	293.0	—	—	293.0	367.0
M27 (1)	3	459.0	—	—	275.0	381.0	—	—	381.0	477.0
M30	3.5	561.0	—	—	337.0	466.0	—	—	466.0	583.0
M33 (1)	3.5	694.0	—	—	416.0	576.0	—	—	570.0	722.0
M36	4	817.0	—	—	490.0	678.0	—	—	678.0	850.0
M39 (1)	4	976.0	—	—	586.0	810.0	—	—	810.0	1020.0
FINE THREADED BOLTS AND STUDS (NONPREFERRED)										
M8	1	39.2	14.9	20.4	22.7	31.4	25.5	35.3	32.5	40.8
M10	1.25	61.2	23.3	31.8	35.5	49.0	39.8	55.1	50.8	63.6
M12	1.25	92.1	35.0	47.9	53.4	73.7	59.9	82.9	76.4	95.8
M14	1.5	125.0	47.5	65.0	72.5	100.0	81.2	112.0	104.0	130.0
M16	1.5	167.0	63.5	86.8	96.9	134.00	109.0	150.0	139.0	174.0
M18	1.5	216.0	82.1	112.0	130.0	179.0	—	—	179.0	225.0
M20	1.5	272.0	103.0	141.0	163.0	226.0	—	—	226.0	283.0
M22	1.5	333.0	126.0	173.0	200.0	276.0	—	—	276.0	346.0
M24	2	384.0	146.0	200.0	230.0	319.0	—	—	319.0	399.0
M27	2	496.0	—	—	298.0	412.0	—	—	412.0	516.0
M30	2	621.0	—	—	373.0	515.0	—	—	515.0	646.0
M33	2	761.0	—	—	457.0	632.0	—	—	632.0	791.0
M36	3	865.0	—	—	519.0	718.0	—	—	718.0	900.0
M39	3	1030.0	—	—	618.0	855.0	—	—	855.0	1070.0

* Stress areas are calculated from the following formula:

$$A_s = 0.7854 \quad (D - 0.9382P)^2$$

Where: A_s = Mean equivalent stress area, mm^2
D = Nominal Diameter, mm
P = Thread Pitch, mm

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