SECTION 12

REFERENCE SECTION

ASTM SPECIFICATIONS

Copies of these specifications are available on request.

A 6-87d	Specification for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use.
A 7	Discontinued-Replaced by A 36 (for rolled shapes), A 283, A 663, A 675.
A 20-87a	Specification for General Requirements for Steel Plates for Pressure Vessels.
A 29-87b	Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for.
A 36-87	Specification for Structural Steel.
A 53-87b	Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless.
A 105-87a	Specification for Forgings, Carbon Steel, for Piping Components.
A 106-87a	Specification for Seamless Carbon Steel Pipe for High-Temperature Service.
A 108-81	Specification for Steel Bars, Carbon, Cold-Finished, Standard Quality.
A 109-85	Specification for Steel, Carbon, Cold-Rolled Strip.
A 120-84	Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated (Galvanized) Welded and Seamless, for Ordinary Uses (Discontinued).
A 135-86	Specification for Electric-Resistance-Welded Steel Pipe.
A 242-87	Specification for High-Strength Low-Alloy Structural Steel.
A283-87	Specification for Low and Intermediate Tensile Strength Carbon Steel Plates, Shapes, and Bars,
A 285-82	Specification for Pressure Vessel Plates, Carbon Steel, Low - and Intermediate- Tensile Strength.
A 304-79	Specification for Alloy Steel Bars Subject to End-Quench Hardenability Requirements.
A 320-85a	Specification for Alloys- Steel Bolting Materials for Low-Temperature Service.
A 322-87	Specification for Steel Bars, Alloy, Standard Grades.
A 366-85	Specification for Steel, Carbon, Cold-Rolled Sheet, Commercial Quality.
A 370-87c	Test Methods and Definitions for Mechanical Testing of Steel Products.
A 387	Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum.
A 414-83	Specification for Carbon Steel Sheet for Pressure Vessels.
A 434-81	Specification for Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered.
A 441-85	Specification for High-Strength Low-Alloy Structural Manganese Vanadium Steel.
A 446-87	Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Structural (Physical Quality).
A 455	Pressure Vessel Plates, Carbon Steel, High-Strength Manganese.
A 463-85	Specification for Steel Sheet, Cold-Rolled, Aluminum-Coated Type I and Type II.
A 500-84	Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
A 501-84	Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.
A 513-85	Specification for Electric-Resistance-Welded Carbon And Alloy Steel Mechanical Tubing.
A 514-87a	Specification for High-Yield Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding.
A 515-82	Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher - Temperature Service.

ASTM SPECIFICATIONS (Continued)

A 516-86	Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service.
A 517-87a	Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered.
A 519-86b	Specification for Seamless Carbon and Alloy Steel Mechanical Tubing.
A 537-86	Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel.
A 568-83	Specification for General Requirements for Steel, Carbon and High-Strength Low-Alloy Hot-Rolled Sheet and Cold-Rolled Sheet.
A 569-85	Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip, Commercial Quality.
A 570-85	Specification for Hot-Rolled Carbon Steel Sheet and Strip, Structural Quality.
A 572-84	Specification for High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality.
A 576-87	Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality.
A 588-87	Specification for High-Strength Low-Alloy Structural Steel With 50 ksi (345 MPa) Minimum Yield Point to 4” Thick.
A 591-77	Specification for Steel Sheet, Cold-Rolled, Electrolytic Zinc-Coated.
A 607-85	Specification for Steel Sheet and Strip, Hot-Rolled and Cold-Rolled, High-Strength, Low-Alloy Columbium and/or Vanadium.
A 612	Pressure vessel plates, carbon steel, high strength, for moderate and lower temperature service.
A 616-87	Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement.
A 620-84	Specification for Steel, Sheet, Carbon, Drawing Quality, Special Killed, Cold-Rolled.
A 621-82	Specification for Steel Sheet and Strip, Carbon, Hot-Rolled, Drawing Quality.
A 622-82	Specification for Steel, Sheet and Strip, Carbon, Drawing Quality, Special Killed, Hot-Rolled.
A 633	Normalized high strength, low alloy structural steel.
A 635	Steel, sheet and strip, heavy thickness coils, carbon, hot rolled.
A 653CQ	Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Commercial Quality.
A 653LCQ	Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Lock-Forming Quality.
A 656-87a	Specification for Hot-Rolled Structural Steel, High-Strength, Low-Alloy Plate with Improved Formability.
A 663-85	Specification for Steel Bars, Carbon, Merchant Quality, Mechanical Properties.
A 700-81	Practices for packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment.
A 706	Low Alloy steel deformed bars for concrete reinforcement.
A 709	Structural steel for bridges.
A 715-87	Specification for Steel Sheet and Strip, High-Strength, Hot-Rolled, and Steel Sheet, Cold-Rolled, High-Strength, Low-Alloy, with Improved Formability.
A 792-95	Specification for 55% Aluminum-Zinc Alloy-Coated steel sheet in coils and cut lengths.
A 924	Specification for General Requirements for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process.

FEDERAL SPECIFICATIONS

Federal Specifications are identified with a QQ prefix followed by the letter S designating steel and the specifications number. Copies of these specifications are available upon request. Cancelled specifications are also listed since these specifications are still in use.

Specification Number	Specification Title
QQ-S-626	Steel Plate, Alloy (Structural Quality)
QQ-S-630	Steel, Bar, Carbon, Hot Rolled (Merchant Quality) CANCELLED Replaced by ASTM A575 and A663
QQ-S-631	Steel, Bar, Carbon, Hot Rolled (Special Quality) CANCELLED Replaced by ASTM A576 and A675
QQ-S-632	Steel Bar, Reinforcing (for Concrete)
QQ-S-633	Steel Bars, Carbon, Cold Finished and Hot Rolled (General Purpose) Replaced by ASTM A 108, A575, A663 and A675
QQ-S-634	Steel Bar, Carbon, Cold-Finished (Standard Quality) CANCELLED Replaced by ASTM A108
QQ-S-635	Steel Plate, Carbon
QQ-S-637	Steel Bar, Carbon, Cold Finished (Standard Quality, Free Machining) CANCELLED Replaced by ASTM A108
QQ-S-693	Steel, Sheet, Carbon - Hot Rolled CANCELLED this specification is for low carbon, medium carbon and untempered spring steel sheet and strip. Applicable specifications for low carbon sheet and strip are ASTM Nos. A109, 366, 569, 570, 611, 619, 620 and 621. For medium and high carbon--QQ-S-700. Refer to QQ-S-777 for untempered spring steel.
QQ-S-698	Steel Sheet and Strip, Low Carbon, Refer to ASTM Nos. A569, A570 and A621 for Hot Rolled Sheet Steel; and ASTM A109 for Cold Rolled Strip.
QQ-S-700	Steel Sheet and Strip, Medium and High Carbon.
QQ-S-741	Steel, Carbon, Structural Shapes, Plates, and Bars
QQ-S-775	Steel Sheets, Carbon, Zinc-Coated (Galvanized) by the Hot Dip Process
QQ-S-781	Strapping, Steel, and Seals
QQ-F-461	Floor Plate, Steel, Rolled

MILITARY SPECIFICATIONS

Military Specifications for steel are identified as Mil-S numbers. Some of these Specifications have been cancelled, but are still listed for reference. Other military specifications for inspection requirements, and quality control are listed under Miscellaneous Specifications. Copies of military specifications are available upon request.

Specification Number	Specification Title
Mil-S-872	Steel Bars, Billets and Forgings-Carbon-Molybdenum Alloy
Mil-S-890	Steel Forgings and Bars for Hulls, Engines, and Ordnance (heat treated)
Mil-S-5000	Steel: Chrome-Nickel-Molybdenum (E4340) Bars and Reforging Stock
Mil-S-5626	Steel: Chrome-Molybdenum (4140) Bars, Rods and Forging Stock (for aircraft applications)
Mil-S-6758	Steel: Chrome-Molybdenum (4130) Bars and Reforging Stock (aircraft quality)
Mil-S-7952	Steel: Sheet and Strip, Uncoated, Carbon (1020 and 1025) (aircraft quality)
Mil-S-8699	Steel Bars and Forging Stock (4330) Vanadium Modified, Aircraft Quality
Mil-S-13326	Steel, Alloy; Plate, Heat Treated, High Strength for Welded Structures
Mil-S-13281	Steel, Carbon, Alloy, and High Strength Low Alloy for Welded Structures (Stress Relieved)
Mil-S-16113	Steel Plate, High Tensile (HT), Hull and Structural CANCELLED Replaced by Mil-S-22698
Mil-S-16216	Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100)
Mil-S-16974	Steel Bars, Billets Blooms and Slabs; Carbon and Alloy (For Reforging or Other Operations before Heat Treatment)
Mil-S-18729	Steel Plate, Sheet, and Strip, Alloy 4130, Aircraft Quality
Mil-S-20166	Steel Structural Shapes, Weldable Medium Carbon and High Tensile; Hull and Structural
Mil-S-22698	Steel Plate and Shapes, Weldable Ordinary Strength and Higher Strength; Hull Structural
Mil-S-23284	Steel Forgings, Carbon and Alloy, for Shafts, Sleeves, Couplings, and Stocks (Rudders and Diving Planes)
Mil-S-24093	Steel Forgings, Carbon and Alloy Heat Treated
Mil-S-24113	Steel Plates, Carbon Manganese-Heat Treated by Normalizing or Quenching and Tempering
Mil-S-24238	Steel Plate Carbon and Low Alloy

MILITARY SPECIFICATIONS (Continued)

MISCELLANEOUS

Specification Number	Specification Title
Mil-A-12560	Armor Plate, Steel, Wrought, Homogenous
Mil-I-8950	Inspection, Ultrasonic, Wrought Metals, process For
Mil-45208	Inspection System Requirements
Mil-M-17194	Metal, Expanded, Steel
Mil-Q-9858	Quality Program Requirements
Mil-Std-295	Bills of Materials, Preparation of
Mil-Std-1520	Corrective Action and Disposition System for Nonconforming Material

CANADIAN STRUCTURAL STEEL SPECIFICATIONS

Comparison of ASTM Specifications with CSA G40.21/M Grades

ASTM Specifications	G40.21 Grade	G40.21/M Grade	Chemical Compositions Comparison	Mechanical Property Comparison G40.21	Mechanical Property Comparison G40.21/M"
A-36	33G	230G	Approximately the same.	Minimum yield strength and minimum tensile strength 3 ksi lower Grade 33G.	Minimum yield point and tensile strength 20MPa lower in Grade 230G.
	38W	260W	Lower carbon content in Grade 38W/260W.	Up to 1 1/2" thick, minimum yield point and minimum tensile strength is 2 ksi higher in Grade 38W.	Up to 40 mm thick, minimum yield point and tensile strength is 10 MPa higher in Grade 260W.
	44W	300W	Carbon content is lower and maximum manganese higher in Grade 44W/300W and may have grain refining elements present.	Up to 1 1/2" thick, minimum yield and tensile strength is 8 ksi higher in Grade 44W.	Up to 40 mm thick, minimum yield and tensile strength is 50 MPa higher in Grade 300W.
A-36 Killed Fine Grain	38T	260T	Lower carbon content in Grade 38T/260T.	Up to 2 1/2" thick, minimum yield point and tensile strength is 2 ksi higher in Grade 38T.	Up to 65 mm thick, minimum yield point and tensile strength is 10 MPa higher in Grade 260T.

CANADIAN STRUCTURAL STEEL SPECIFICATIONS (Continued)

Comparison of ASTM Specifications with CSA G40.21/M Grades

ASTM Specifications	G40.21 Grade	G40.21/M Grade	Chemical Compositions Comparison	Mechanical Property Comparison G40.21	Mechanical Property Comparison G40.21/M
A-36 Killed Fine Grain	44T	300T	Carbon content is lower and maximum manganese higher in Grade 44T/300T and may have grain refining elements present.	Minimum tensile strength is 8 ksi higher in Grade 44T. Minimum yield is 8 ksi higher up to 1 1/2" thick decreasing to 6 ksi higher up to 2 1/2" thick and to 4 ksi higher over 2 1/2" to 4" thick.	Minimum tensile strength is 50MPa higher in Grade 300T. Minimum yield is 50 MPa higher up to 40 mm thick, decreasing to 40 MPa higher up to 65 mm thick and to 30 MPa higher over 65 mm to 100 mm thick.
ASTM A-283 Grade D	33G	230G	Grade 33G/230G has limits on maximum carbon and manganese contents.	Same except tensile strength on 33G is 55-72 ksi instead of 60-72 ksi.	Same except tensile strength of 230G is 380-500 MPa instead of 415-495 MPa.
A-572 Grade 42	44W	300W	Slightly higher carbon and manganese contents permitted in Grade 44/W 300W.	Tensile strength is 65-85 ksi for Grade 44W instead of 60ksi minimum Yield point is 44 ksi up to 1 1/2 thickness instead of 42 ksi.	Tensile strength is 450-620 Mpa for Grade 300W instead of 415 Mpa min. Yield point is 300 Mpa up to 40 mm instead of 290 MPa.
A-572 Grade 50	50W	350W	Higher manganese permitted in Grade 50W/350W	Tensile strength is 65-90 ksi for Grade 50W instead of 65 ksi minimum.	Tensile strength is 450-620 Mpa for Grade 350W instead if 450 Mpa min Yield point is 350 Mpa up to 40 mm instead of 345 Mpa.
ASTM-A 572 Grade 50 Killed Fine Grain	50T	350T	Higher Manganese permitted in Grade 50T/350T.	Tensile strength is 65-90 ksi for Grade 50T instead of 65 ksi minimum. Yield strength is 50 ksi up to 1 1/2", decreasing to 48 ksi 1 1/2 - 2 1/2" and decreasing to 46 ksi over 2 1/2".	Tensile strength is 450-650 MPa for Grade 350T instead of 450 MPa min. Yield strength is 350 MPa up to 40 mm, decreasing to 330 MPa 40-65 mm and decreasing to 320 MPa over 65 mm thick.

CANADIAN STRUCTURALS STEEL SPECIFICATIONS
(Continued)

Comparison of ASTM Specifications with CSA G40.21/3 Grades

ASTM Specifi-cations	G40.21 Grade	G40.21/M Grade	Chemical Compositions Comparison	Mechanical Property Comparison G40.21	Mechanical Property Comparison G40.21/M
A-572 Grade 60	60W	400W	Lower carbon content and higher manganese content in Grade 60W/ 400W.	Tensile strength is 65-85 ksi for Grade 44W instead of 60 ksi minimum. Yield Point is 44 ksi instead of 45 ksi.	Tensile strength is 520-690- MPa in Grade 400W instead of 520 MPa min. Yield strength is 400 MPa up to 14 mm instead of 415 MPa.
A-588	50A	350A	Majority of grades in A-588 are covered in Grade 50A-350A Composition.	Identical.	Yield strength is 350 MPa in Grade 350A instead of 345 MPa. Tensile strength is 480-650 MPa instead of 485 MPa min.
A-514	100Q	700Q	Identical without specific proprietary grades in A-514.	Identical	Identical

CHEMICAL ELEMENTS IN STEEL

The following list of elements form the chemical composition of steel which is an alloy of iron consisting of carbon manganese phosphorous, sulfur and silicon. The many different grades and types of steel are manufactured by controlling the carbon content and/or alloying with one or a combination of elements to produce specific properties.The desired properties are then developed by controlled rolling or heat treatment after parts are machined or fabricated. Some of the steel categories or types of steel for special requirements would be carbon and alloy steels, free machining steels, tool and die, cutting tools, high temperature, stainless and electrical steels.

ELEMENTS IN CARBON STEELS

Carbon Steel	Steel is considered to be carbon steel when no minimum content is specified or required for chromium, cobalt, columbium, molybdenum, nickel, titanium, vanadium or zirconium, or any other element added to obtain a desired alloying effect; when the specified minimum for copper does not exceed 0.40 percent; or when the maximum content specified for any of the following elements does not exceed the percentage noted: manganese
Carbon **C**	Carbon is the most important element in steel and as the percentage of carbon is increased it greatly affects the hardness and tensile strength. In percentages below .10% the steel product will have good ductility and malleability. The carbon content for structural steels is in the .12 to .25% range A carbon content of at least .30% is required for consistent heat treating results.
Manganese **Mn**	Manganese strengthens steel by increasing the strength of the iron grains, which increases impact strength and hardenability. It is usually present in quantities of .40 to 1.6% in most steels. Hadfield Manganese Steel which is a rapid work hardening steel will have a manganese content of 11 -13%.
Phosphorous **P**	Increasing phosphorous increases strength and hardness and decreases ductility and notch-impact toughness in the as-rolled condition, Higher phosphorous contents in the .04-.12% range improves machinability.
Sulfur **S**	With the exception of free-machining steels sulfur is considered an impurity in steel and forms with iron and manganese to form inclusions. Free machining steels will have sulfur contents of .08 to .33%
Silicon **Si**	This element is one of the principal deoxidizers used in steelmaking and when used in levels of .15% and above helps to produce a rolled steel product void of porosity. Electrical steels will have silicon levels of 2-6%.

ADDITIONAL ELEMENTS IN ALLOY STEELS

Chromium **Cr**	Chromium is a strong carbide former. It is added to steel to increase strength, hardness and hardenability. At higher percentage levels it improves corrosion resistance, high temperature strength and oxidation resistance at high temperatures. Chromium percentages will vary from .40 to 1.10% in commercial alloys and from 2 to 11H% in tool and die steels.

CHEMICAL ELEMENTS IN STEEL (Continued)

Nickel **Ni**	Nickel is a ferrite strengthener like manganese and increases strength and toughness In combination with chromium, nickel produces alloy steels with greater hardenability, high impact strength, and greater fatigue resistance than are possible with carbon steels. Nickel percentages will vary from .40 to 2.00% in structural alloys and up to 3.75% In some carburizing grades.
Molybdenum **Mo**	Molybdenum is added to constructional steels in the normal amounts of .10-.60%. Alloy steels which contain .15-.30% molybdenum show a minimized susceptibility to temper embrittlement.
Vanadium **V**	Vanadium is one of the strong carbide forming elements. Vanadium treated steels show a much finer structure than steels of a similar composition without vanadium. Vanadium is used as a strengthener in some types of A572 high strength-low alloy steel. Percentages In this case would be .01-.15%.
Tungsten **W**	This alloy combines with carbon in steel forming very hard abrasion resistant tungsten carbides. Steel alloys with tungsten are used in combination with other alloys for high speed cutting tools where abrasion resistance and high red hardness are important. Other uses for the alloy are high temperature super alloys and tungsten carbide welding rod to protect steel surfaces from abrasive wear.
Cobalt **Co**	This alloy is generally used in high speed cutting tools in combination with other alloys to increase hot hardness or red hardness. Also used for hard facing and abrasion resistant alloys, permanent and soft magnets and superalloys.

OTHER ELEMENTS USED IN STEEL

Boron **B**	Boron is added to fully killed steel to improve hardenability. Boron treated steels are produced to a range of .0005-.003%. Boron is very effective in lower carbon steels.
Columbium **Cb**	Columbium or niobium has the same application as vanadium to form carbides and Increase the strength of steel. Used in high strength-low alloy steels In percentages of .005-.05%.
Copper **Cu**	When added in amounts above .20%, copper increases the corrosion resistance of carbon steels by two times. Corrosion resistance of carbon steels can be increased four to six times by Increasing the copper content up to .50% and adding small percentages of chromium and nickel
Lead **Pb**	An element added to free machining steels, which could be carbon or alloy steels, to Increase the machinability of the steel by lubricating the cutting tool. Lead Is generally added in percentages of .15-.35%.
Nitrogen **N**	This element in small percentages of .004 to .020% greatly affects the hardness, tensile and yield strength of steel. Nitrogen is used in many high strength low alloy sheet and plate steels.

AISI/SAE CHEMICAL ANALYSIS

PLAIN CARBON GRADES-TABLE 1

Steel Designation AISI or SAE	Chemical Composition, Percent				
	UNS Number	C	Mn	P Max	S Max
1005	G10050	0.06 Max.	0.35 Max.	0.040	0.050
1006	G10060	0.08 Max.	0.25 Max.	0.040	0.050
1008	G10080	0.10 Max	0.30/0.50	0.040	0.050
1010	G10100	0.08/0.13	0.30/0.60	0.040	0.050
1012	G10120	0.10/0.15	0.30/0.60	0.040	0 050
1015	G10150	0.13/0.18	0.30/0.60	0.040	0.050
1016	G10160	0.13/0.18	0.60/0.90	0.040	0.050
1017	G10170	0.15/0.20	0.30/0.60	0.040	0.050
1018	G10180	0.15/0.20	0.60/0.90	0.040	0.050
1019	G10190	0.15/0.20	0.70/1.00	0.040	0.050
1020	G10200	0.18/0.23	0.30/0.60	0.040	0 050
1021	G10210	0 18/0.23	0 60/0.90	0.040	0.050
1022	G10220	0.18/0.23	0.70/1.00	0.040	0.050
1023	G10230	0.20/0.25	0.30/0.60	0.040	0 050
1025	G10250	0.22/0.28	0.30/0.60	0.040	0.050
1026	G10260	0.22/0.28	0.60/0.90	0.040	0.050
1029	G10290	0 2570.31	0 60/0.90	0.040	0.050
1030	G10300	0 28/0.34	0.60/0.90	0.040	0.050
1035	G10350	0.32/0.38	0.60/0.90	0.040	0 050
1037	G10370	0.32/0.38	0.70/1.00	0.040	0.050
1038	G10380	0.35/0.42	0.60/0.90	0.040	0.050
1039	G10390	0.37/0.44	0.70/1.00	0.040	0.050
1040	G10400	0 37/0.44	0 60/0.90	0.040	0.050
1042	G10420	0.40/0.47	0.60/0.90	0.040	0.050
1043	G10430	0.40/0.47	0.70/1.00	0.040	0.050
1044	G10440	0.43/0.50	0.30/0.60	0.040	0.050
1045	G10450	0.43/0.50	0.60/0.90	0.040	0.050
1046	G10460	0.43/0.50	0.70/1.00	0.040	0.050
1049	G10490	0 46/0.53	0.60/0.90	0.040	0 050
1050	G10500	0.48/0.55	0.60/0.90	0.040	0.050
1053	G10530	0.48/0.55	0.70/1.00	0.040	0.050
1055	G10550	0.50/0.60	0.60/0.90	0.040	0.050
1059	G10590	0.55/0.65	0.50/0.80	0.040	0.050
1060	G10600	0.55/0.65	0.60/0.90	0.040	0.050
1070	G10700	0.65/0.75	0.60/0.90	0.040	0.050
1078	G10780	0.72/0.85	0.30/0.60	0.040	0.050
1080	G10800	0.75/0.88	0.60/0.90	0.040	0.050
1084	G10840	0.80/0.93	0.60/0.90	0.040	0.050
1086	G10860	0.80/0.93	0.30/0.50	0.040	0.050
1090	G10900	0.85/0.98	0.60/0.90	0.040	0.050
1095	G10950	0.90/1.03	0.30/0.50	0.040	0.050

Note. In the case of certain qualities, the foregoing standard steels are ordinarily furnished lo lower phosphorous and lower sulfur maxima as hereinafter Indicated.

Silicon. Where silicon is required, the following limits and ranges are commonly used: for steel designations up to but excluding 1015, 0.10% max, for 1015 to 1025,0 10% max or ranges of 0.10-0.20%, 0.15-0.30%, 0.20-0.40%, or 0.30-0.60%; for over 1025, ranges of 0.10-0.20%, 0.15-0 .30%, 0.20-0.40%, or 0.30-0.60%.

Copper. When copper is required, 0.20 percent minimum is generally specified.

Lead. Standard carbon steels can be produced with a lead range of 0 15 to 0 35 percent, to improve machinability. Such steels are identified by inserting the letter "L" between the second and third numerals of the AISI number, e.g. 10L45. Lead is generally reported as a range of to 0.35 percent.

Boron. Standard killed carbon steels, which are generally fine grain, may be produced with a boron treatment addition to improve hardenability. Such steels can be expected to contain 0.005 to 0.003 percent boron. These steels are identified by inserting the letter "B" between the second and third numerals of the AISI number, e.g. 10B46.

AISI/SAE CHEMICAL ANALYSIS
(Continued)

PLAIN CARBON-HIGH MANGANESE GRADES-TABLE 2

Steel Designation AISI or SAE	Chemical Composition, Percent				
	UNS Number	C	Mn	P Max	S Max
1513	G15130	0 10/0.16	1.10/1.40	0.040	0.050
1522	G15220	0 18/0.24	1.10/1.40	0.040	0.050
1524	G15240	0.19/0.25	1.35/1.65	0.040	0.050
1526	G15260	0.22/0.29	1.10/1.40	0.040	0.050
1527	G15270	0.22/0.29	1.20/1.50	0.040	0.050
1541	G15410	0 36/0 44	1.35/1.65	0.040	0.050
1548	G15480	0 44/0.52	1.10/1.40	0.040	0.050
1551	G15510	0.45/0.56	0.85/1.15	0.040	0.050
1552	G15520	0.47/0.55	1.20/1.50	0.040	0.050
1561	G15610	0.55/0.65	0.75/1.05	0.040	0.050
1566	G15660	0.6O/0 71	0.85/1.15	0.040	0.050

Note. In the case of certain qualities, the foregoing standard steels are ordinarily furnished to lower phosphorous and lower sulfur maxima as hereinafter indicated.

Silicon. Where silicon ranges or limits are required, the values shown in Table I apply.

Copper. When copper is required, 0.20 percent minimum is generally specified.

Lead. See footnote for lead under Table I.

Boron. See footnote for boron under Table I.

RESULPHURIZED CARBON GRADES-TABLE 3

Steel Designation AISI or SAE	Chemical Composition, Percent				
	UNS Number	C	Mn	P Max	S Max
1110	G11100	0.08/0.13	0 30/0.60	0.040	0.08/0.13
1117	G11170	0.14/0.20	1.00/1.30	0.040	0.08/0.13
1118	G11180	0.14/0.20	1.30/1.60	0.040	0.08/0.13
1137	G11370	0.32/0.39	1.35/1.65	0.040	0.08/0.13
1139	G11390	0.35/0.43	1.35/1.65	0.040	0.13/0.20
1140	G11400	0.37/0.44	0.70/1.00	0.040	0.08/0.13
1141	G11410	0.37/0.45	1.35/1.65	0.040	0.08/0.13
1144	G11440	0.40/0.48	1 35/1.65	0.040	0 24/0.33
1146	G11460	0.42/0.49	0 70/1 00	0.040	0.08/0.13
1151	G11510	0.48/0.55	0.70/1.00	0.040	0.08/0.13

Silicon. Where silicon ranges or limits are required, the values shown in Table I apply.
Lead. See footnote for lead under Table I.
Note. Resulphurized steel is not subject to check analysis for sulphur.
u Standard grade generally more readily available.
*Former AISI grades identified as 1000 series, Example: 1524 was 1024.

REPHOSPHORIZED-RESULPHURIZED CARBON GRADES-TABLE 4

Steel Designation AISI or SAE	Chemical Composition, Percent				
	UNS Number	C	Mn	P Max	S Max
1211	G12110	0.13 Max.	0.60/0.90	0.07/0.12	0.10/0.15
1212	G12120	0.13 Max.	0.70/1.00	0.07/0.12	0.16/0.23
1213	G12130	0.13 Max.	0.70/1.00	0.07/0.12	0.24/0.33
1215	G12150	0.09 Max.	0.75/1.05	0.04/0.09	0.26/0.35
12L14*	G12144	0.15 Max.	0.85/1.15	0.04/0.09	0.26/0.35

*Pb-0.15/0.35

Silicon. It is not common practice to produce the 12XX series of steels to specified limits for silicon because of its adverse effect on machinability.

Lead. Standard carbon steels can be produced with a lead range of 0.15 to 0.35 percent to improve machinability. Such steel is identified by inserting the letter “L" between the second and third numerals of the AISI steel designation, e.g. "12L15." Lead is generally reported as a range of 0.15 to 0.35%.

AISI/SAE CHEMICAL ANALYSIS
(Continued)

STANDARD ALLOY GRADE TABLE 5

Steel Designation AISI or SAE	UNS Number	Chemical Composition, Percent							
		C	MN	P Max	S Max	SI	NI	CR	MO
1330	G13300	0.28/0.33	1.60/1.90	0.035	0.040	0.15/0.30	-	-	-
1335	G13350	0.33/0.38	1.60/1.90	0.035	0.040	0.15/0.30	-	-	-
1340	G13400	0.38/0.43	1.60/1.90	0.035	0.040	0.15/0.30	-	-	-
1345	G13450	0.43/0.48	1.60/1.90	0.035	0.040	0.15/0.30	-	-	-
4023	G40230	0.25/0.25	0.70/0.90	0.035	0.040	0.15/0.30	-	-	0.20/0.30
4024	G40240	0.25/0.25	0.70/0.90	0.035	0.035/0.050	0.15/0.30	-	-	0.20/0.30
4027	G40270	0.25/0.30	0.70/0.90	0.035	0.040	0.15/0.30	-	-	0.20/0.30
4028	G40280	0.25/0.30	0.70/0.90	0.035	0.035/0.050	0.15/0.30	-	-	0.20/0.30
4037	G40370	0.35/0.40	0.70/0.90	0.035	0.040	0.15/0.30	-	-	0.20/0.30
4047	G40470	0.45/0.50	0.70/0.90	0.035	0.040	0.15/0.30	-	-	0.20/0.30
4118	G41180	0.18/0.23	0.70/0.90	0.035	0.040	0.15/0.30	-	0.40/0.60	0.08/0.15
4130	G41300	0.28/0.33	0.40/0.60	0.035	0.040	0.15/0.30	-	0.80/1.10	0.15/0.25
4137	G41370	0.35/0.40	0.70/0.90	0.035	0.040	0.15/0.30	-	0.80/1.10	0.15/0.25
4140	G41400	0.38/0.43	0.75/1.00	0.035	0.040	0.15/0.30	-	0.80/1.10	0.15/0.25
4142	G41420	0.40/0.45	0.75/1.00	0.035	0.040	0.15/0.30	-	0.80/1.10	0.15/0.25
4145	G41450	0.43/0.48	0.75/1.00	0.035	0.040	0.15/0.30	-	0.80/1.10	0.15/0.25
4147	G41470	0.45/0.50	0.75/1.00	0.035	0.040	0.15/0.30	-	0.80/1.10	0.15/0.25
4150	G41500	0.48/0.53	0.75/1.00	0.035	0.040	0.15/0.30	-	0.80/1.10	0.15/0.25
4161	G41610	0.56/0.64	0.75/1.00	0.035	0.040	0.15/0.30	-	0.70/0.90	0.25/0.35
4320	G43200	0.17/0.22	0.45/0.65	0.035	0.040	0.15/0.30	1.65/2.00	0.40/0.60	0.20/0.30
4340	G43400	0.38/0.43	0.60/0.80	0.035	0.040	0.15/0.30	1.65/2.00	0.70/0.90	0.20/0.30
E4340	G43406	0.38/0.43	0.65/0.85	0.035	0.025	0.15/0.30	1.65/2.00	0.70/0.90	0.20/0.30
4615	G46150	0.13/0.18	0.45/0.65	0.035	0.040	0.15/0.30	1.65/2.00	-	0.20/0.30
4620	G46200	0.17/0.22	0.45/0.65	0.035	0.040	0.15/0.30	1.65/2.00	-	0.20/0.30
4626	G46260	0.24/0.29	0.45/0.65	0.035	0.040	0.15/0.30	0.70/1.00	-	0.15/0.25
4720	G47200	0.17/0.22	0.50/0.70	0.035	0.040	0.15/0.30	0.90/1.20	0.35/0.55	0.20/0.30
4815	G48150	0.13/1.18	0.40/0.60	0.035	0.040	0.15/0.30	3.25/3.75	-	0.20/0.30
4817	G48170	0.15/0.20	0.40/0.60	0.035	0.040	0.15/0.30	3.25/3.75	-	0.20/0.30
4820	G48200	0.50/0.70	0.18/0.23	0.035	0.040	0.15/0.30	3.25/3.75	-	0.20/0.30

AISI/SAE CHEMICAL ANALYSIS
(Continued)

STANDARD ALLOY GRADES-TABLE 5

Steel Designation AISI or SAE	UNS Number	Chemical Composition, Percent							
		C	Mn	P Max	S Max	Si	Ni	Cr	Mo
5117	G51770	0.15/0.20	0.70/0.90	0.035	0.04	0.15/0.30	----	0.70/0.90	----
5120	G51200	0.17/0.22	0.70/0.90	0.035	0.04	0.15/0.30	----	0.70/0.90	----
5130	G51300	0.28/0.33	0.70/0.90	0.035	0.04	0.15/0.30	----	0.80/1.10	----
5132	G51320	0.30/0.35	0.60/0.80	0.035	0.04	0.15/0.30	----	0.75/1.00	----
5135	G51350	0.33/0.38	0.60/0.80	0.035	0.04	0.15/0.30	----	0.80/1.05	----
5140	G51400	0.38/0.43	0.70/0.90	0.035	0.04	0.15/0.30	----	0.70/0.90	----
5150	G51500	0.48/0.53	0.70/0.90	0.035	0.04	0.15/0.30	----	0.70/0.90	----
5155	G51550	0.51/0.59	0.70/0.90	0.035	0.04	0.15/0.30	----	0.70/0.90	----
5160	G51600	0.56/0.64	0.75/1.00	0.035	0.04	0.15/0.30	----	0.70/0.90	----
E51100	G51986	0.98/1.10	0.25/0.45	0.025	0.025	0.15/0.30	----	0.90/1.15	----
E52100	G52986	0.98/1.10	0.25/0.45	0.025	0.025	0.15/0.30	----	1.30/1.60	----
6118	G61180	0.16/0.21	0.50/0.70	0.035	0.04	0.15/0.30	----	0.50/0.70	0.10/0.15V
6150	G61500	0.48/0.53	0.70/0.90	0.035	0.04	0.15/0.30	----	0.80/1.10	0.15 Min.V
8615	G86150	0.13/0.18	0.70/0.90	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8617	G86170	0.15/0.20	0.70/0.90	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8620	G86200	0.18/0.23	0.70/0.90	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8622	G86220	0.20/0.25	0.70/0.90	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8625	G86250	0.23/0.28	0.70/0.90	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8627	G86270	0.25/0.30	0.70/0.90	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8630	G86300	0.28/0.33	0.70/0.90	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8637	G86370	0.35/0.40	0.75/1.00	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8640	G86400	0.38/0.43	0.75/1.00	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8642	G86420	0.40/0.45	0.75/1.00	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8645	G86450	0.43/0.48	0.75/1.00	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8655	G86550	0.51/0.59	0.75/1.00	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.15/0.25
8720	G87200	0.18/0.23	0.70/0.90	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.20/0.30
8822	G88220	0.20/0.25	0.75/1.00	0.035	0.04	0.15/0.30	0.40/0.70	0.40/0.60	0.30/0.40
9260	G92600	0.56/0.64	0.75/1.00	0.035	0.04	1.80/2.20	---	---	---

AISI/SAE CHEMICAL ANALYSIS
(Continued)

STANDARD ALLOY GRADES-TABLE 5

NOTES

Note 1. Grades shown in the preceding list with prefix letter E are normally made by the basic electric furnace process. All others are normally manufactured by the basic open hearth or basic oxygen process but may be manufactured by the basic electric furnace process.

Note 2. If electric furnace practice is specified or required for grades other than those designated (i.e., E4340) the limits for phosphorous and sulfur are 0.025 percent respectively and the prefix E is added.

Note 3. For acid electric and acid open hearth steels, the limits for phosphorous and sulfur are 0.050 percent respectively.

Note 4. In the case of certain qualities the foregoing standard steels are ordinarily furnished to lower phosphorous and lower sulfur maxima as hereinafter indicated.

Note 5. Small quantities of certain elements are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts. Copper, 0.35%; Nickel, 0.25%; Chromium, 0.20%; and Molybdenum, 0.06%.

Note 6. The chemical ranges and limits shown in Table VI and in the notes below that Table are subject to the product analysis tolerances published by the AISI.

Note 7. Standard Steels can be produced with a lead range of 0.15/0.35 percent Such steels are identified by inserting the letter "L" between the second and third numerals of the AISI number, e.g. 41L40. Lead is generally reported as a range of 0.15/0.35 percent.

Note 8. Where minimum and maximum sulfur content is shown it is indicative of resulfurized steel.

Note 9. Standard Alloy Steels, which are generally fine grain, may be produced with a boron treatment addition to improve hardenability. Such steels can be expected to contain 0.0005 to 0.003 percent boron. These steels are identified by inserting the letter "B" between the second and third numerals of the AISI number, e.g. 50B46.

TENSILE METRIC (N/mm2)

The International System of Units (SI for short) is a modern version of the metric system used internationally to standardize engineering units. This chart is used for conversion of yield and tensile strengths.

Look up stress to be converted in the boldface column. If in Ksi (10^3 psi), read MP a in right hand column. If in Mpa, read ksi in left hand column. Conversion factors: 1 MPa = 1 MN/m^2 (meganewton per square metre) or 1 N/mm2 (newton per square milimetre); 1 Mpa = 0.1450377 ksi, and 1 ksi = 6.894759 MPa.

0 to 100

ksi		MPa	ksi		MPa
-	0	-	7.25	50	344.7
0.15	1	6.89	7.40	51	351.6
0.29	2	13.79	7.54	52	358.5
0.44	3	20.68	7.69	53	365.4
0.58	4	27.57	7.83	54	372.3
0.73	5	34.47	7.98	55	379.2
0.87	6	41.37	8.12	56	386.1
1.02	7	48.26	8.27	57	393.0
1.16	8	55.16	8.41	58	399.9
1.31	9	62.05	8.56	59	406.8
1.45	10	68.95	8.70	60	413.7
1.60	11	75.84	8.85	61	420.6
1.74	12	82.74	8.99	62	427.5
1.89	13	89.63	9.14	63	434.4
2.03	14	96.53	9.28	64	441.3
2.18	15	103.4	9.43	65	448.2
2.32	16	110.3	9.57	66	455.1
2.47	17	117.2	9.72	67	462.0
2.61	18	124.1	9.86	68	468.8
2.76	19	131.0	10.01	69	475.7
2.90	20	137.9	10.15	70	482.6
3.05	21	144.8	10.30	71	489.5
3.19	22	151.7	10.44	72	496.4
3.34	23	158.6	10.59	73	503.3
3.48	24	165.6	10.73	74	510.2
3.63	25	172.4	10.88	75	517.1
3.77	26	179.3	11.02	76	524.0
3.92	27	186.2	11.17	77	530.9
4.06	28	193.1	11.31	78	537.8
4.21	29	199.9	11.46	79	544.7
4.35	30	206.8	11.60	80	551.6
4.50	31	213.7	11.75	81	558.5
4.64	32	220.6	11.89	82	565.4
4.79	33	227.5	12.04	83	572.3
4.93	34	234.4	12.18	84	579.2
5.08	35	241.3	12.33	85	586.1
5.22	36	248.2	12.47	86	593.0
5.37	37	255.1	12.62	87	899.8
5.51	38	262.0	12.76	88	606.7
5.66	39	268.9	12.91	89	613.6
5.80	40	275.8	13.05	90	620.5
5.95	41	282.7	13.20	91	627.4
6.09	42	289.6	13.34	92	634.3
6.24	43	296.5	13.49	93	641.2
6.38	44	303.4	13.63	94	648.1
6.53	45	310.3	13.78	95	655.0
6.67	46	317.2	13.92	96	661.9
6.82	47	324.1	14.07	97	668.8
6.96	48	331.0	14.21	98	675.7
7.11	49	337.8	14.36	99	682.6
			14.50	100	689.5

TENSILE (N/mm2) (Continued)

100 to 200

ksi		MPa	ksi		MPa
14.50	100	689.5	21.76	150	1034
14.65	101	696.4	21.90	151	1041
14.79	102	703.3	22.05	152	1048
14.94	103	710.2	22.19	153	1054
15.08	104	717.1	22.34	154	1062
15.23	105	724.0	22.48	155	1069
15.37	106	730.8	22.63	156	1076
15.52	107	737.7	22.77	157	1082
15.66	108	744.6	22.92	158	1089
15.81	109	751.5	23.06	159	1096
15.95	110	758.4	23.21	160	1103
16.10	111	765.3	23.35	161	1110
16.24	112	772.2	23.50	162	1117
16.39	113	779.1	23.64	163	1124
16.53	114	786.0	23.79	164	1131
16.68	115	792.9	23.93	165	1138
16.82	116	799.8	24.08	166	1145
16.97	117	806.7	24.22	167	1151
17.11	118	813.8	24.37	168	1158
17.26	119	820.5	24.51	169	1165
17.40	120	827.4	24.66	170	1172
17.55	121	834.3	24.80	171	1179
17.69	122	841.2	24.95	172	1186
17.84	123	848.1	25.09	173	1193
17.98	124	855.0	25.24	174	1200
18.13	125	861.8	25.38	175	1207
18.27	126	868.7	25.53	176	1213
18.42	127	875.6	25.67	177	1220
18.56	128	882.5	25.82	178	1227
18.71	129	889.4	25.96	179	1234
18.85	130	896.3	26.11	180	1241
19.00	131	903.2	26.25	181	1248
19.14	132	910.1	26.40	182	1255
19.29	133	917.0	26.54	183	1262
19.44	134	923.9	26.69	184	1269
19.58	135	930.8	26.83	185	1276
19.73	136	937.7	26.98	186	1282
19.87	137	944.6	27.12	187	1289
20.02	138	951.5	27.27	188	1296
20.16	139	958.4	27.41	189	1303
20.31	140	965.3	27.56	190	1310
20.45	141	972.2	27.70	191	1317
20.60	142	979.1	27.85	192	1324
20.74	143	986.0	27.99	193	1331
20.89	144	992.9	28.14	194	1338
21.03	145	999.7	28.28	195	1344
21.18	146	1007	28.43	196	1351
21.32	147	1014	28.57	197	1358
21.47	148	1020	28.72	198	1365
21.61	149	1027	28.86	199	1372
			29.01	200	1379

TENSILE (N/mm2) (Continued)

200 to 300

ksi		MPa	ksi		MPa
29.01	200	1379	36.40	251	1731
29.15	201	1386	36.55	252	1737
29.30	202	1393	36.69	253	1744
29.44	203	1400	36.84	254	1751
29.59	204	1407	36.98	255	1758
29.73	205	1413	37.13	256	1765
29.88	206	1420	37.27	257	1772
30.02	207	1427	37.42	258	1779
30.17	208	1434	37.56	259	1786
30.31	209	1441	37.71	260	1793
30.46	210	1448	37.85	261	1800
30.60	211	1455	38.00	262	1806
30.75	212	1462	38.14	263	1813
30.89	213	1469	38.29	264	1820
31.04	214	1475	38.43	265	1827
31.18	215	1482	38.58	266	1834
31.33	216	1489	38.73	267	1841
31.47	217	1496	38.87	268	1848
31.62	218	1503	39.02	269	1855
31.76	219	1510	39.16	270	1862
31.91	220	1517	39.31	271	1868
32.05	221	1524	39.45	272	1875
32.20	222	1531	39.60	273	1882
32.34	223	1538	39.74	274	1889
32.49	224	1544	39.89	275	1896
32.63	225	1551	40.03	276	1903
32.78	226	1558	40.18	277	1910
32.92	227	1565	40.32	278	1917
33.07	228	1572	40.47	279	1924
33.21	229	1579	40.61	280	1931
33.36	230	1586	40.76	281	1937
33.50	231	1593	40.90	282	1944
33.65	232	1600	41.05	283	1951
33.79	233	1606	41.19	284	1958
33.94	234	1613	41.34	285	1965
34.08	235	1620	41.48	286	1972
34.23	236	1627	41.63	287	1979
34.37	237	1634	41.77	288	1986
34.52	238	1641	41.92	289	1963
34.66	239	1648	42.06	290	1999
34.81	240	1655	42.21	291	2006
34.95	241	1662	42.35	292	2013
35.10	242	1669	42.50	293	2020
35.24	243	1675	42.64	294	2027
35.39	244	1682	42.79	295	2034
35.53	245	1689	42.93	296	2041
35.68	246	1696	43.07	297	2048
35.82	247	1703	43.22	298	2055
35.97	248	1710	43.37	299	2062
36.11	249	1717	43.51	300	2068
36.26	250	1724			

TENSILE (N/mm2) (Continued)

300 to 400

ksi		MPa	ksi		MPa
43.51	300	2068	50.76	350	2413
43.66	301	2075	50.91	351	2420
43.80	302	2082	51.05	352	2427
43.95	303	2089	51.20	353	2434
44.09	304	2096	51.34	354	2441
44.24	305	2103	51.49	355	2448
44.38	306	2110	51.63	356	2455
44.53	307	2117	51.78	357	2461
44.67	308	2124	51.92	358	2468
44.82	309	2130	52.07	359	2475
44.96	310	2137	52.21	360	2482
45.11	311	2144	52.36	361	2489
45.25	312	2151	52.50	362	2496
45.40	313	2158	52.65	363	2503
45.54	314	2165	52.79	364	2510
45.69	315	2172	52.94	365	2517
45.83	316	2179	53.08	366	2523
45.98	317	2186	53.23	367	2530
46.12	318	2193	53.37	368	2537
46.27	319	2199	53.52	369	2544
46.41	320	2206	53.66	370	2551
46.56	321	2213	53.81	371	2558
46.70	322	2220	53.95	372	2565
46.85	323	2227	54.10	373	2572
46.99	324	2234	54.24	374	2579
47.14	325	2241	54.39	375	2585
47.28	326	2248	54.53	376	2592
47.43	327	2255	54.68	377	2599
47.57	328	2261	54.82	378	2606
47.72	329	2268	54.97	379	2613
47.86	330	2275	55.11	380	2620
48.01	331	2285	55.26	381	2627
48.15	332	2289	55.40	382	2634
48.30	333	2296	55.55	383	2641
48.44	334	2303	55.69	384	2648
48.59	335	2310	55.84	385	2654
48.73	336	2317	55.98	386	2661
48.88	337	2324	56.13	387	2668
49.02	338	2330	56.27	388	2675
49.17	339	2337	56.42	389	2682
49.31	340	2344	56.56	390	2689
49.46	341	2351	56.71	391	2696
49.60	342	2358	56.85	392	2703
49.75	343	2365	57.00	393	2710
49.89	344	2372	57.14	394	2717
50.04	345	2379	57.29	395	2723
50.18	346	2386	57.43	396	2730
50.33	347	2392	57.58	397	2737
50.47	348	2399	57.72	398	2744
50.62	349	2406	57.87	399	2751
			58.02	400	2758

TENSILE (N/mm²) (Continued)

500 TO 5000

ksi		MPa	ksi		MPa
72.52	**500**	3447	145.04	**1000**	6895
87.02	**600**	4137	290.08	**2000**	13.790
101.53	**700**	4826	435.11	**3000**	20.684
116.03	**800**	5516	580.15	**4000**	27.579
130.53	**800**	6205	725.19	**5000**	34.474

To convert ksi or Mpa values above 400, use the supplemental table. Example: Convert 1320 MPa to ksi. Solution: 1000 MPa = 145.04 ksi (from the small table), and 320 MPa = 46.41 ksi (from the large table). Then 145.04 + 46.41 = 191.45 ksi.

DECIMAL AND MILLIMETER EQUIVALENTS OF INCH FRACTIONS

Fraction	Decimal	Millimeter	Fraction	Decimal	Millimeter
1/64	.0156	0.397	33/64	.5156	13.095
1/32	.0312	0.794	17/32	.5312	13.494
3/64	.0468	1.191	35/64	.5468	13.891
1/16	.0625	1.588	9/16	.5625	14.288
5/64	.0781	1.984	37/64	.5781	14.684
3/32	.0937	2.381	19/32	.5937	15.081
7/64	.0193	2.778	39/64	.6093	15.478
1/8	.1250	3.175	5/8	.6250	15.875
9/64	.1406	3.572	41/64	.6406	16.272
5/32	.1562	3.969	21/32	.6562	16.669
11/64	.1718	4.366	43/64	.6718	17.066
3/16	.1875	4.763	11/16	.6875	17.463
13/64	.2031	5.159	45/64	.7031	17.859
7/32	.2187	5.556	23/32	.7187	18.256
15/64	.2343	5.953	47/64	.7343	18.653
1/4	.2500	6.350	3/4	.7500	19.050
17/64	.2656	6.747	49/64	.7656	19.447
9/32	.2812	7.144	25/32	.7812	19.844
19/64	.2968	7.541	51/64	.7968	20.241
5/16	.3125	7.938	13/16	.8125	20.638
21/64	.3281	8.334	53/64	.8281	21.034
11/32	.3437	8.731	27/32	.8437	21.431
23/64	.3593	9.128	55/64	.8593	21.828
3/8	.3750	9.525	7/8	.8750	22.225
25/64	.3906	9.922	57/64	.8906	22.622
13/32	.4062	10.319	29/32	.9062	23.019
27/64	.4218	10.716	59/64	.9218	23.416
7/16	.4375	11.113	15/16	.9375	23.813
29/64	.4531	11.509	61/64	.9531	24.209
15/32	.4687	11.906	31/32	.9687	24.606
31/64	.4843	12.303	63/64	.9843	25.003
1/2	.5000	12.700	1	1.0000	25.400

HARDNESS CONVERSION TABLE

BRINELL AND ROCKWELL HARDNESS

NUMBERS FOR STEEL AND THE APPROXIMATE TENSILE STRENGTH

Brinell Indentation Diameter mm	Brinell Hardness Number 300-Kg. 10mm Tungsten Carbide Ball	B-Scale 100Kg. Load 1/16 in Dia. Ball	C-Scale 150-Kg. Load Brale Penetrator	Tensile Strength (Approx-imate) in 1000 psi
2.25	745	-	65.3	-
2.35	682	-	61.7	-
2.40	653	-	60.0	-
2.45	627	-	58.7	-
2.50	601	-	57.3	-
2.55	578	-	56.0	-
2.60	555	-	54.7	298
2.65	534	-	53.5	288
2.70	514	-	52.1	274
2.75	495	-	51.0	264
2.80	477	-	49.6	252
2.85	461	-	48.5	242
2.90	444	-	47.1	230
2.95	429	-	45.7	219
3.00	415	-	44.5	212
3.05	401	-	43.1	202
3.10	388	-	41.8	193
3.15	375	-	40.4	184
3.20	363	-	39.1	177
3.25	352	-	37.9	171
3.30	341	-	36.6	164
3.35	331	-	35.5	159
3.40	321	-	34.3	154
3.45	311	-	33.1	149
3.50	302	-	32.1	146
3.55	293	-	30.9	141
3.60	285	-	29.9	138
3.65	277	-	28.8	134
3.70	269	-	27.6	130
3.75	262	-	26.6	127
3.80	255	-	25.4	123
3.85	248	-	24.2	120
3.90	241	100.0	22.8	116
3.95	235	99.0	21.7	114
4.00	229	98.2	20.5	111
4.05	223	97.3	(18.8)	108
4.10	217	96.4	(17.5)	105
4.15	212	95.5	(16.0)	102
4.20	207	94.6	(15.2)	100

HARDNESS CONVERSION TABLE
(Continued)

Brinell Indentation Diameter mm	Brinell Hardness Number 300-Kg. 10mm Tungsten Carbide Ball	B-Scale 100Kg. Load 1/16in Dia. Ball	C-Scale 150-Kg. Load Brate Penetrator	Tensile Strength (Approx-imate) in 1000 psi
4.25	201	93.8	(13.8)	98
4.30	197	92.8	(12.7)	95
4.35	192	91.9	(11.5)	93
4.40	187	90.7	(10.0)	90
4.45	183	90.0	(9.0)	89
4.50	179	89.0	(8.0)	87
4.55	174	87.8	(6.4)	85
4.60	170	86.8	(5.4)	83
4.65	167	86.0	(4.4)	81
4.70	163	85.0	(3.3)	79
4.80	156	82.9	(0.9)	76
4.90	149	80.8	-	73
5.00	143	78.7	-	71
5.10	137	76.4	-	67
5.20	131	74.0	-	65
5.30	126	72.0	-	63
5.40	121	69.8	-	60
5.50	116	67.6	-	58
5.60	111	65.7	-	56

TEMPERATURE CONVERSIONS

The general arrangement of this table was devised by Sauveur and Boylston more than 40 years ago. The middle column of figures (in bold-faced type) contains the reading (F or C) to be converted. If converting from degrees Fahrenheit to degrees Centigrade (Celsius), read the Centigrade equivalent in the column headed “C”. If converting from Centigrade to Fahrenheit, read the Fahrenheit equivalent in the column headed “F”.

F		C	F		C
-148.0	**-100**	-73.33	+32.0	**±0**	-17.78
-144.4	**-98**	-72.22	+35.6	**+2**	-16.67
-140.8	**-96**	-71.11	+39.2	**+4**	-15.56
-137.2	**-94**	-70.00	+42.8	**+6**	-14.44
-133.6	**-92**	-68.89	+46.4	**+8**	-13.33
-130.0	**-90**	-67.78	+50.00	**+10**	-12.22
-126.4	**-88**	-66.67	+53.6	**+12**	-11.11
-122.8	**-86**	-65.56	+57.2	**+14**	-10.00
-119.2	**-84**	-64.44	+60.8	**+16**	-8.89
-115.6	**-82**	-63.33	+64.4	**+18**	-7.78
-112.0	**-80**	-62.22	+68.0	**+20**	-6.67
-108.4	**-78**	-61.11	+71.6	**+22**	-5.56
-104.8	**-76**	-60.00	+75.2	**+24**	-4.44
-101.2	**-74**	-58.89	+78.8	**+26**	-3.33
-97.6	**-72**	-57.78	+82.4	**+28**	-2.22
-94.0	**-70**	-56.67	+86.0	**+30**	-1.11
-90.4	**-68**	-55.56	+89.6	**+32**	+0.00
-86.8	**-66**	-54.44	+93.2	**+34**	+1.11
-83.2	**-64**	-53.33	+96.8	**+36**	+2.22
-79.6	**-62**	-52.22	+100.4	**+38**	+3.33
-76.0	**-60**	-51.11	+104.0	**+40**	+4.44
-72.4	**-58**	-50.00	+107.6	**+42**	+5.56
-68.8	**-56**	-48.89	+111.2	**+44**	+6.67
-65.2	**-54**	-47.78	+114.8	**+46**	+7.78
-61.6	**-52**	-46.67	+118.4	**+48**	+8.89
-58.0	**-50**	45.56	+122.0	**+50**	+10.00
-54.4	**-48**	-44.44	+125.6	**+52**	+11.11
-50.8	**-46**	-43.33	+129.2	**+54**	+12.12
-47.2	**-44**	-42.22	+132.8	**+56**	+13.33
-43.6	**-42**	-41.11	+136.4	**+58**	+14.44
-40.0	**-40**	-40.00	+140.0	**+60**	+15.56
-36.4	**-38**	-38.89	+143.6	**+62**	+16.67
-32.8	**-36**	-37.78	+147.2	**+64**	+17.78
-29.2	**-34**	-36.67	+150.8	**+66**	+18.89
-25.6	**-32**	-35.56	+154.4	**+68**	+20.00
-22.0	**-30**	-34.44	+158.0	**+70**	+21.11
-18.4	**-28**	-33.33	+161.6	**+72**	+22.22
-14.8	**-26**	-32.22	+165.2	**+74**	+23.33
-11.2	**-24**	-31.11	+168.8	**+76**	+24.44
-7.6	**-22**	-30.00	+172.4	**+78**	+25.56
-4.0	**-20**	-28.89	+176.0	**+80**	+26.67
-0.4	**-18**	-27.78	+179.6	**+82**	+27.78
+3.2	**-16**	-26.67	+183.2	**+84**	+28.89
+6.8	**-14**	-25.56	+186.8	**+86**	+30.00
+10.4	**-12**	-24.44	+190.4	**+88**	+31.11
+14.0	**-10**	-23.33	+194.0	**+90**	+32.22
+17.6	**-8**	-22.22	+197.6	**+92**	+33.33
+21.2	**-6**	-21.11	+201.2	**+94**	+34.44
+24.8	**-4**	-20.00	+204.8	**+96**	+35.56
+28.4	**-2**	-18.89	+208.4	**+98**	+36.67
			+212.0	**+100**	+37.78

APPROXIMATE HARDNESS AND STRENGTH LEVEL OF VARIOUS STEEL PRODUCTS

Approx. Tensile Strength X1000psi	Brinell Hardness	Rockwell Hardness B	Rockwell Hardness C	Steel Grades	
			66	High Speed Tool Steel	
			62		
			61	Tool and Die Steels	
			54		
264	505		51		Carbon and Alloy Steel Machinery Parts
234	456		48	Spring Steel Hardness Range	
204	405		44		
195	388		42		
				AR 360	
180	360		39		
				AR 321	
161	322		34	4140 Heat Treated and 4150 mod	
131	265		27		
				A514	
124	252		25	AR Plate	
121	247		24	Stressproof	
119	242		23	4140 Annealed	
				1045 As-Rolled	
101	219		18		
		95	16		
88	190	92	11	A656 Gr.80	
84	171	87			A656 Gr. 70
				HSLA-A537	
				A572 A588	
				A607 GR50 Sheet	
75	152	82			
				A36 Plate and Structurals	
				A285 A516 A607 Sheet	
				Tubing and Pipe	
62	124	71			
		60		CRCQ Sheet	
				CRCQ Sheet	
		38		CRDQSK Sheet	

SHEAR STRENGTH CHART

Material Description	Hardness	Ultimate	
		Tensile P.S.I	Shear P.S.I
STEELS			
Low Carbon, H.R. Sheet ASTM A-415	Rb 70	60,000	50,000
Low Carbon, C.R. Sheet Special killed Drawing Quality	Rb 50	50,000	40,000
Low Carbon, C.R. Sheet			
(Soft)	Rb 45-60	53,000	42,000
(1/4 Hard)	Rb 60-75	60,000	45,000
(1/2 Hard)	Rb 70-85	72,000	50,000
(Hard)	Rb 80-95	92,000	61,000
40-50% Carbon Steel H.R. Sheet	BHN 200	100,000	80,000
SAE 1074 C.R. Annealed Spring Steel	Rb 90	95,000	75,000
SAE 1095 C.R. Annealed Spring Steel	Rb 95	100,000	80,000
SAE 1074 or 1095 Spring Steel Hardened to Spring Temper	Rc 45-50	260,000	200,000
Abrasion-Resisting H.R. Sheet Steel	BHN 200/245	120,000	100,000
Cor-Ten Steel	BHN 140	70,000	55,000
Tri-Ten Steel	BHN 120	60,000	50,000
T-1 Steel (Types A&B) 100,000 P.S.I. Y.S.	BHN 260	130,000	105,000
STAINLESS STEELS			
202- Annealed	Rb 95	110,000	90,000
302, 303, 304 - Annealed	Rb 85	95,000	75,000
310- Annealed	Rb 90	105,000	90,000
316, 321, 430 - Annealed	Rb 90	95,000	75,000
410- Annealed	Rb 85	85,000	75,000

To determine the punching load for press capacity the following formula can be used to calculate the tonnage requirements. The ultimate shear strength from the above table can be used in place of S in the table. To calculate tonnage divide through by 2000.

PUNCHING LOAD (PER PUNCH)

P = LTS where:

P = Punching load (lb)
L = Length of cut (in)
T = Stock thickness (in)
S = Ultimate shear strength (lb/in2)

MACHINABILITY RATINGS

The factors involved in machinability and the machinability rating index are cutting speed, resultant surface produced and tool life. There are many variables involved in machinability such as steel hardness, inclusions, size and shape of the cutting tool and cutting fluids. The following table is a composite of many tables from steel mills and the Society of Automotive Engineers. Machinability ratings are based on 1212 which is rated at 100% or 168 surface feet per minute.

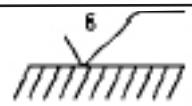
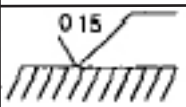
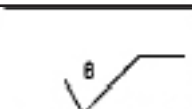
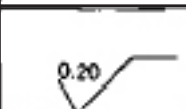
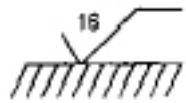
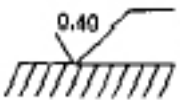
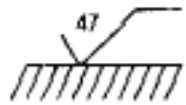
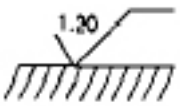
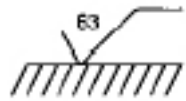
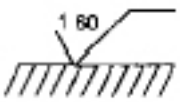
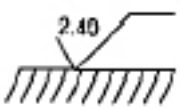
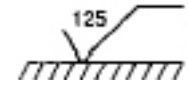
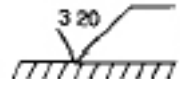
Steel Grade	Condition	Machinability Rating	Surface Feet Per Minute
CARBON STEELS			
A36	HR	53	88
1018	CD	66	111
1020	HR	58	98
1040	HR	62	104
1045	HR	55	92
FREE MACHINING			
1117	CD	89	150
1144	CD	83	140
STRESSPROOF	CD	83	140
1212	CD	100	168
12L14	CD	195	325
1215	CD	137	230
ALLOYS			
4130	HRN&T	65	110
4140	HRA	65	110
4140	HRHT	47	78
4150+	HRHT	57	85
4340	HRA	51	80
8620	HR	60	100
8630	HRA	60	100
8640	HRA	54	90
EDT 150		75	125

HR hot rolled
CD cold drawn
A annealed
N&T normalized and tempered
HT heat treated (262-321)
+ resulfurized and heat treated (262-321)

SURFACE ROUGHNESS DATA

This section is a guide to engineering, shop and inspection departments as to finishes which can be attained with automatic screw machines and various secondary operations.

The typical methods of producing the finishes listed here do not include all possible means of obtaining the desired results. There are other additional methods not listed which may be used to obtain the specified surface finish.

Surface Roughness µ In	Surface Roughness µ m	Ordinary Method of Producing	Relative Costs
		Superfinish buff. Produced by microphone lap, or very fine buff.	Very expensive.
		Ground, lapped, honed, fine honed fine buffed, etc	Expensive.
		Very fine grind, lapped, honed, fine buffed, etc.	Expensive except where a special machine can be used in mass production setups.
		Fine grind, broached burnished, buffed, cold pressed, smooth emery buff, etc.	Fairly inexpensive for hardened steel on a high production basis impracti-able on automatics except for burnishing operations.
		Finish grind, very fine machine finish, broached, reamed, shaved, buffed, hand finish with emery cloth, etc.	Very difficult and relatively expensive on automatics. Relatively inexpensive for cylindrical or surface grinding, especially on hardened steel.
		Smooth grind, broached, rolled, very light machine cut, shaved, turned, bored, milled, reamed, smooth disc grind, ball seat swaging, etc.	Possible but difficult even with best tool practice for automatic screw machine work . Easily attained in many secondary operations.
		Medium grind, light finish tool cut, reamed, shaved, turned, bored, milled, etc	Less difficult but requires care and proper tooling in machining operations.
		Commercial grind, finish tool cut, broached, rolled, reamed, shaved, turned, bored, milled, drilled, spotfaced, counter-bored, fine filed, etc.	This finish should be maintained in most automatic operations.

STEEL FASTENERS

MECHANICAL AND MATERIAL REQUIREMENTS FOR EXTERNALLY THREADED FASTENERS- SAE J429 JAN 80 SAE STANDARD

This SAE standard covers the mechanical and material requirements for steel bolts, screws, studs, sems[1], and U-bolts[2] used in automotive and related industries in sizes to 1 1/2 in., inclusive

[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, whenever 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.

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

Grades--Bolts and screws are normally available only in Grades 1,2,5, 5.2, 7, 8, and 8.2. Studs are normally available only in Grades 1, 2,4, 5,8, and 8.1. Grade 5.1 is applicable to sems which are heat treated following assembly of the washer on the screw, and to products without assembled washer.

Steel Characteristics--Bolts, screws, studs, and sems shall be made of steel conforming to the description and chemical composition requirements specified in Table 2.

MECHANICAL REQUIREMENTS AND IDENTIFICATION MARKING

FOR BOLTS, SCREWS, STUDS, SEMS AND U-BOLTS”

Grade Designation	Products	Nominal Diameter, Inch	Full Size Bolts Screws, Studs, Sems		Machine Test Specimens of Bolts, Screws, and Studs				Surface Hardness	Core Hardness		Grade Identification Marking
			Proof Load (Stress), psi	Tensile Strength (Stress) Min., psi	Yields Strength (Stress) Min., psi	Tensile Strength (Stress) Min., psi	Elongation Min., %	Reduction of area Min.%	Rockwell 30N Max.	Rockwell Min.	Rockwell Max.	
1	Bolts Screws, Studs	1/4 thru 1 1/2	33,000[i]	60,000	36,000[b]	60,000	18	35	-	B70	B100	None
2	Bolts Screws, Studs	1/4 thru 3/4[c]	55,000[i]	74,000	57,000	74,000	18	35	-	B80	B100	
		over 3/4 to 11/2	33,000	60,000	36,000[b]	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	1/4 thru 1	85,000	120,000	92,000	120,000	14	35	54	C25	C34	
		Over 1 to 1 1/2	74,000	105,000	81,000	105,000	14	35	50	C19	C30	
5.1[d]	Sems[g]	No. 6 thru 5/8	85,000	120,000	-	-	-	-	59.5[f]	C25	C40[i]	
	Bolts, Screws	No. 6 thru 1/2										
5.2	Bolts Screws	1/4 thru 1	85,000	120,000	92,000	120,000	14	35	56	C26	C36	
7[e]	Bolts	1/4 thru 1 1/2	105,000	133,000	115,000	133,000	12	35	54	C28	C34	

MECHANICAL REQUIREMENTS AND IDENTIFICATION MARKING (CONTINUED)

FOR BOLTS, SCREWS, STUDS, SEMS AND U-BOLTS[h]

Grade Designation	Products	Nominal Diameter, inch	Full Size Bolts Screws, Studs, Sems		Machine Test Specimens of Bolts, Screws, and Studs				Surface Hardness	Core Hardness		Grade Identification Marking
			Proof Load (Stress) psi	Tensile Strength (Stress) Min. psi	Yield Strength (Stress) Min. psi	Tensile Strength (Stress) Min. psi	Elongation Min., %	Reduction of Area Min., %	Rockwell 30N Max.	Rockwell Min.	Rockwell Max	
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	-	C32	C38	None
8.2	Bolts Screws	1/4 thru 1	120,000	150,000	130,000	150,000	10	35	61	C35	C42	

[a] Yield strength is stress at which a permanent set of 0.2% of gage length occurs.

[b] Yield point shall apply instead of yield strength at 0.2% offset.

[c] 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.

[d] Grade 5 material heat treated before assembly with a hardened washer is an acceptable substitute.

[e] Grade 7 bolts and screws are roll threaded after heat treatment.

[f] Hex washer head and hex flange products without assembled washers shall have a core hardness not exceeding Rockwell C38 and a surface hardness not exceeding Rockwell 30N 57.5.

[g] Sems and similar products without washers.

[h] Not applicable to studs or slotted and cross recess head products.

[i] Proof load tests: Requirements in these grades only apply to stress relieved products.

CHEMICAL COMPOSITION

REQUIREMENTS FOR STEEL FASTENERS

Grade	Material and Treatment	Element, %					
		C		MN Min.	P Max.	S Max.	B Min.
		Min.	Max.				
1	Low or medium carbon steel	-	0.55	-	0.048	0.058	-
2	Low or medium carbon steel	-	0.55	-	0.048	0.058[b]	-
4	Medium carbon cold drawn steel	-	0.55	-	0.048	0.058	-
5	Medium carbon steel, quenched and tempered	0.28	0.55	-	0.048	0.058[c]	-
5.1	Low or medium carbon steel, quenched and tempered[e]	0.15	0.30	-	0.048	0.058	-
5.2	Low carbon martensite steel, fully killed, fine grain quenched and tempered	0.15	0.25	0.74	0.048	0.058	0.005
7	Medium carbon alloy steel, quenched and tempered[d]	0.28	0.55	-	0.040	0.045	-
8	Medium carbon alloy steel, quenched and tempered[d]	0.28	0.55	-	0.040	0.045	-
8.1	Elevated temperature drawn steel-medium carbon alloy or SAE 1541 (or 1541H steel)	0.28	0.55	-	0.048	0.058	-
8.2	Low carbon martensite steel, fully killed, fine grain quenched and tempered[f]	0.15	0.25	0.74	0.048	0.058	0.0005

[a]All values are for product analysis use (percent by weight). For cast or heat analysis, use standard permissible variations as shown in SAE J409 (January, 1942).
[b]For studs only, sulfur content may be 0.33% max.
[c]For studs only, sulfur content may be 0.13% max.
[d]Steel shall be fine grain, with hardenability that will produce a minimum hardness of Rockwell C47 on the center of a transverse section one diameter from the threaded end of the bolt, screw, or stud after all quenching (see SAE J407 August, 947). Carbon steel may be used by agreement between producer and consumer for sizes 1/4-3/4in. diameter products.
ϕSAE 1541 (or 1541H) steel, oil quenched and tempered, may be used at the option of the producer for products 7/» in. nominal diameter and smaller.
[e]For sems only, sizes 7/ie-H in. diameter, low carbon martensite steel (as specified for Grade 5.2) may be used.
[f]Steel with hardenability that will produce a minimum hardness of Rockwell C38 at the center of a transverse section one diameter from the threaded end of the bolt or screw after quenching.

HEAT TREATMENT PRACTICE

Grade 1 bolts and screws and Grades 1 and 2 studs need not be heat treated. When specified by purchaser, Grade 2 cold headed bolts and screws shall be stress relieved at a minimum stress relief temperature of 875° F (468° C) 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, oil or water quenched, at option of manufacturer, and tempered at a minimum tempering temperature of 800° F (427° C). Grade 5.1 bolts, screws, and sems shall be heat treated, quenched, and tempered at a minimum tempering temperature of 650° F (343° C). For Grade 5.1 sems, quenchants whose principal constituent is water shall not be used, unless specifically approved by the user. Grades 7 and 8 bolts and screws and Grade 8 studs shall be heat treated, oil quenched, and tempered at a minimum tempering temperature of 800° F (427° C). Grade 8.2 bolts and screws shall be fully austenitized, quenched in oil or water, and tempered at a minimum temperature of 650° F (340° C).

ASTM GRADES FOR STEEL FASTENERS

Specification	Classification	Nominal Size Range 6 In.
A193	Alloy steel and stainless steel bolting materials for high temperature service.	
A307	Carbon steel externally threaded standard fasteners.	1/4 thru 4
A320	Alloy steel bolting materials for low temperature service	1/4 thru 2 1/2
A325	High strength bolts for structural steel joints.	1/2 thru 1 1/2
A449	Quench and tempered steel bolts and studs.	1/4 thru 3
A490	Quench and tempered alloy steel bolts for structural steel joints.	1/2 thru 1 1/2

RECOMMENDED ELECTRODES

FOR SHIELDED METAL ARC WELDING OF CARBON AND LOW ALLOY STEELS

ASTM Specification	Description	Grades	Recommended Electrodes
A36	structural 36,000 PSI YS min	-	(2)
A131	ship structural	A,B,C, CS, D	(2)
		AH, DH & EH	E7018
A148	steel castings for structural use	80-40 & 50	E8018-C3
		90-60	E9018-G
A242	high strength structurals	all	E7018 or E7028[4]
A283	structural plates	all	(2)
A285	pressure vessel plates	all	(2)
A366	commercial quality sheets	-	(2)
A414	pressure vessel sheets.	A,B,C&D	(2)
		E & F	E7018 or E7028
A441	high strength structurals	all	E7018 or E7028[4]
A514	quenched and tempered plates	all	E7018-M[7]
A515	pressure vessel plates	all	E7018 or E7028
A516	pressure vessel plates	55 & 60	E7018 or E7028
		65 & 70	E7018 or E8018-C3
A517	quenched and tempered plates	all	E11018-M[7]
A526	galvanized sheet, commercial	-	(2.5)
A537	pressure vessel plates	class 1	BOXXC1-C2-C3
A570	structural sheets and strip	all	(2)
A572	structural steel	42 & 45	(2)
		50 & 55	E7018 or E7028
		60 & 65	E8018-C3
A588	high strength structurals	all	E7018 or E70283[4]
A615	reinforcement bars	40	(2)
		60	E9018-G
		75	E11018-M
A656	high strength plate	70 & 80	E8018
A53	steel pipe	all	(2), (8)
A106	seamless carbon steel pipe	all	(2), (8)
A120	steel pipe	all	(2), (8)
A500	structural tubing	A, B & C	E7018[5]

Steel Grades		
1018/1020	low carbon steel	(2)
1045	medium carbon steel	E11018-M
4140	alloy steel	E12018-M

1. These recommendations are based on matching the tensile properties of the weld deposit and plate, and also the compositions of the weld deposit where chemistry is important. Since it is impossible to foresee all the conditions of every application, electrodes other than those recommended here may also be satisfactory and should be tested before the weldment is started.
2. Unless restricted by specifications, use any E60XX or E70XX electrode for steel grades with 60,000 psi or lower tensile strength; for steel grades with 60,000 to 70,000 psi tensile strength, use E70XX electrodes.

FOR SHIELDED METAL ARC WELDING OF CARBON AND LOW ALLOY STEELS

3. Do not use E1018-B2 for low temperature applications.
4. Use E-8018-C1 or E8010-B2 for best color match on unpainted steels with enhanced atmospheric corrosion resistance. Consult the steel supplier.
5. Usually E6010 is the most satisfactory electrode for galvanized sheet.
6. E7018 or E7028 for fillets, or E8018-C3 for general- purpose welding, can be used on these steels. If the weldment is to be precipitation hardened or high weld strength is required, use E8012-B2.
7. E7018 or E8018-C3 are frequently used for fillet welds.
8. Use E7010-G, an electrode designed for field welding of pipe.
9. Unless restricted by specifications, any E60XX or E70XX electrode may also be used for grades with 60,000 psi or lower tensile strength; any E70XX electrode may be used for grades with 60,000 to 70,000 psi tensile strength.
10. It is standard practice to preheat the following steel categories; over 80,000 psi tensile, over .30% carbon content and quench and tempered steels.

GEOMETRIC FORMULAS

CIRCLES
Area = Square of Diameter x .7854
or Square of Radius x π (3.1416, etc.)
CIRCUMFERENCE = Diameter x π
DIAMETER = Circumference x .3183
Doubling diameter increases area four times; tripling diameter increases area nine times.

CONE
AREA OF CURVED SURFACE = Diameter of base x Slant Height x 1.5708
VOLUME = Diameter of Base Squared x Perpendicular Height
x.2618 or Area of Base x 1/3 Perpendicular Height

CUBE
AREA OF SURFACE = Square of Side x 6
VOLUME = Cube of Side
DIAGONAL = Side x 1.732

CYLINDER
AREA OF CURVED SURFACE = Diameter x Length x π
VOLUME = Square of Diameter x Length x .7854

HEXAGON
AREA = Square of Distance across Flats x.866
or Square of Side x 2.598
SIDE = 1/2 Of Diagonal
or Distance across Flats x .577
DIAGONAL = Distance across Flats x 1.155
or Side x 2

OCTAGON
AREA = Square of Distance across Flats x .828
or Square of Side x 4.828
SIDE = Diagonal x. 383
or Distance across Flats x .414
DIAGONAL = Distance across Flats x 1.082
or Side x 2.613

RECTANGLE
AREA = Length x Width
DIAGONAL = Square root of sum of squares of Width and Length

SPHERE
AREA OF SURFACE = Square of Diameter x π
VOLUME - Cube of Diameter x .5236
Holds the largest volume possible for the smallest surface.

SQUARE
AREA = Square of Side
DIAGONAL = Side x 1.4142
SIDE = Diagonal x .7071

SQUARE INSCRIBED IN CIRCLE
SIDE OF SQUARE = Diameter of Circle x .7071
or Circumference of Circle x .2251
DIAMETER OF CIRCLE = Side of Square x 1.4142
CIRCUMFERENCE OF CIRCLE - Side of Square x 4.4429

SQUARE AND CIRCLE OF EQUAL AREA
SIDE OF SQUARE - Diameter of Circle x .8862
DIAMETER OF CIRCLE - Side of Square x 1.128
CIRCUMFERENCE OF CIRCLE = Side of Square x 3.545

TRIANGLE
AREA - Base x 1/2 of Perpendicular Height
180° = Sum of all inside angles

CIRCUMFERENCES AND AREAS OF CIRCLES

Diam. In.	Circum. In.	Area Sq. In.
1/64	.04909	.00019
1/32	.09818	.00077
3/64	.14726	.00173
1/16	.19635	.00307
3/32	.29452	.00690
1/8	.39270	.01227
5/32	.49087	.01917
3/16	.58905	.02761
7/32	.68722	.03758
1/4	.78540	.04909
9/32	.88357	.06213
5/16	.98175	.07670
11/32	1.0799	.09281
3/8	1.1781	.11045
13/32	1.2763	.12962
7/16	1.3744	.15033
15/32	1.4726	.17257
1/2	1.5708	.19635
17/32	1.6690	.22166
9/16	1.7671	.24850
19/32	1.8653	.27688
5/8	1.9635	.30680
21/32	2.0617	.33824
11/15	2.1598	.37122
23/32	2.2580	.40574
3/4	2.3562	.44179
25/32	2.4544	.47937
13/16	2.5525	.51849
27/32	2.6507	.55914
7/8	2.7489	.60132
29/32	2.8471	.64504
15/16	2.9452	.69029
3 1/32	3.0434	.73708
1	3.1416	.7854
1 1/16	3.3379	.8866
1 1/8	3.5343	.9940
1 3/16	3.7306	1.1075
1 1/4	3.9270	1.2272
1 5/16	4.1233	1.3530
1 3/8	4.3197	1.4849
1 7/16	4.5160	1.6230
1 1/2	4.7124	1.7671
1 9/16	4.9087	1.9175
1 5/8	5.1051	2.0739
1 11/16	5.3014	2.2365
1 3/4	5.4978	2.4053
1 13/16	5.6941	2.5802
1 7/8	5.8905	2.7612
1 15/16	6.0868	2.9483

Diam. In.	Circum. In.	Area Sq. In.
2	6.2832	3.1416
2 1/16	6.4795	3.3410
2 1/8	6.6759	3.5466
2 3/16	6.8722	3.7583
2 1/4	7.0686	3.9761
2 5/16	7.2649	4.2000
2 3/8	7.4613	4.4301
2 7/16	7.6576	4.6664
2 1/2	7.8540	4.9087
2 9/16	8.0503	5.1572
2 5/8	8.2467	5.4119
2 11/16	8.4430	5.6727
2 3/4	8.6394	5.9396
2 13/16	8.8357	6.2126
2 7/8	9.0321	6.4918
2 15/16	9.2284	6.7771
3	9.4248	7.0686
3 1/16	9.6211	7.3662
3 1/8	9.8175	7.6699
3 3/16	10.014	7.9798
3 1/4	10.210	8.2958
3 5/16	10.407	8.6179
3 3/8	10.603	8.9462
3 7/16	10.799	9.2806
3 1/2	10.996	9.6211
3 9/16	11.192	9.9678
3 5/8	11.388	10.321
3 11/16	11.585	10.680
3 3/4	11.781	11.045
3 13/16	11.977	11.416
3 7/8	12.174	11.793
3 15/16	12.370	12.177
4	12.566	12.566
4 1/16	12.763	12.962
4 1/8	12.959	13.364
4 3/16	13.155	13.772
4 1/4	13.352	14.186
4 5/16	13.548	14.607
4 3/8	13.744	15.033
4 7/16	13.941	15.466
4 1/2	14.137	15.904
4 9/16	14.334	16.349
4 5/8	14.530	16.800
4 11/16	14.726	17.257
4 3/4	14.923	17.721
4 3/16	15.119	18.190
4 7/8	15.315	18.665
4 15/16	15.512	19.147
5	15.708	19.635
5 1/16	15.904	20.129
5 1/8	16.101	20.629

CIRCUMFERENCE AND AREAS OF CIRCLES
(CONTINUED)

Diam. In.	Circum In.	Area Sq. In.
5 3/16	16.297	21.135
5 1/4	16.493	21.648
5 5/16	16.690	22.166
5 3/8	16.886	22.691
5 7/16	17.082	23.221
5 1/2	17.279	23.758
5 9/16	17.475	24.301
5 5/8	17.671	24.850
5 11/16	17.686	25.406
5 3/4	18.064	25.967
5 13/16	18.261	26.535
5 7/8	18.457	27.109
5 15/16	18.653	27.688
6	18.850	28.274
6 1/8	19.242	29.465
6 1/4	19.635	30.680
6 3/8	20.028	31.919
6 1/2	20.420	33.183
6 5/8	20.813	34.472
6 3/4	21.206	35.785
6 7/8	21.598	37.122
7	21.991	38.485
7 1/8	22.384	39.871
7 1/4	22.776	41.282
7 3/8	23.169	42.718
7 1/2	23.562	44.179
7 5/8	23.955	45.664
7 3/4	23.347	47.173
7 7/8	24.740	48.707
8	25.133	50.265
8 1/8	25.525	51.849
8 1/4	25.918	53.456
8 3/8	26.311	55.088
8 1/2	26.704	56.745
8 5/8	27.096	58.426
8 3/4	27.489	60.132
8 7/8	27.882	61.862
9	28.274	63.617
9 1/8	28.667	65.397
9 1/4	29.060	67.201
9 3/8	29.452	69.029
9 1/2	29.845	70.882
9 5/8	30.238	72.760
9 3/4	30.631	74.662
9 7/8	31.023	76.589
10	31.416	78.540
10 1/8	31.809	80.516
10 1/4	32.201	82.516
10 3/8	32.594	84.541
10 1/2	32.987	86.590
10 5/8	33.379	88.664
10 3/4	33.772	90.763
10 7/8	34.165	92.886
11	34.558	95.033
11 1/8	34.950	97.205
11 1/4	35.343	99.402
11 3/8	35.736	101.62
11 1/2	36.128	103.87
11 5/8	36.521	106.14
11 3/4	36.914	108.43
11 7/8	37.306	110.75
12	37.699	113.10
12 1/8	38.092	115.47
12 1/4	38.485	117.86
12 3/8	38.877	120.28
12 1/2	39.270	122.72
12 5/8	39.663	125.19
12 3/4	40.055	127.68
12 7/8	40.448	130.19
13	40.841	132.73
13 1/8	41.233	135.30
13 1/4	41.626	137.89
13 3/8	42.019	140.50
13 1/2	42.412	143.14
13 5/8	42.804	145.80
13 3/4	43.197	148.49
13 7/8	43.590	151.20
14	43.982	153.94
14 1/8	44.375	156.70
4 1/4	44.768	159.48
14 3/8	45.160	162.30
14 1/2	45.553	165.13
14 5/8	45.946	167.99
14 3/4	46.338	170.87
14 7/8	46.731	173.78
15	47.124	176.71
15 1/8	47.517	179.67
15 1/4	47.909	182.65
15 3/8	48.302	185.66
15 1/2	48.695	188.69
15 5/8	49.087	191.75
15 3/4	49.480	194.83
15 7/8	49.873	197.93
16	50.265	201.06
16 1/8	50.658	204.22
16 1/4	51.051	207.39
16 3/8	51.444	210.60
16 1/2	51.836	213.82
16 5/8	52.229	217.08
16 3/4	52.622	220.35
16 7/8	53.014	223.65

CIRCUMFERENCES AND AREAS OF CIRCLES
(Continued)

Diam. In.	Circum In.	Area Sq. In.
17	53.407	226.98
17 1/8	53.800	230.33
17 1/4	54.192	233.71
17 3/8	54.585	237.10
17 1/2	54.978	240.53
17 5/8	55.371	243.98
17 3/4	55.763	247.45
17 7/8	56.156	250.95
18	56.549	254.47
18 1/8	56.941	258.02
18 1/4	57.334	261.59
18 3/8	57.727	265.18
18 1/2	58.119	268.80
18 5/8	58.512	272.45
18 3/4	58.905	276.12
18 7/8	59.298	279.81
19	56.690	283.53
19 1/8	60.083	287.27
19 1/4	60.476	291.04
19 3/8	60.868	294.83
19 1/2	61.261	298.65
19 5/8	61.654	302.49
19 3/4	62.046	306.35
19 7/8	62.439	310.24
20	62.832	314.16
20 1/8	63.225	318.10
20 1/4	63.617	322.06
20 3/8	64.010	326.05
20 1/2	64.403	330.06
20 5/8	64.795	334.10
20 3/4	65.188	338.16
20 7/8	65.581	342.25
21	65.973	346.36
21 1/8	66.366	350.50
21 1/4	66.759	354.66
21 3/8	67.152	358.84
21 1/2	67.544	363.05
21 5/8	67.937	367.28
21 3/4	68.330	371.54
21 7/8	68.722	375.83
22	69.115	380.13
22 1/8	69.508	384.46
22 1/4	69.900	388.82
22 3/8	70.293	393.20
22 1/2	70.686	397.61
22 5/8	71.079	402.04
22 3/4	71.471	406.49
22 7/8	71.864	410.97
23	72.257	415.48
23 1/8	72.649	420.00
23 1/4	73.042	424.56
23 3/8	73.435	429.13
23 1/2	73.827	433.74
23 5/8	74.220	438.36
23 3/4	74.613	443.01
23 7/8	75.006	447.69
24	75.398	452.39
24 1/8	75.791	547.11
24 1/4	76.184	461.86
24 3/8	76.576	466.64
24 1/2	76.969	471.44
24 5/8	77.362	476.26
24 3/4	77.754	481.11
24 7/8	78.147	485.98
25	78.540	490.87
25 1/8	78.933	495.79
25 1/4	79.325	500.74
25 3/8	79.718	505.71
25 1/2	80.111	510.71
25 5/8	80.503	515.72
25 3/4	80.896	520.77
25 7/8	81.289	525.84
26	81.681	530.93
26 1/8	82.074	536.05
26 1/4	82.467	541.19
26 3/8	82.860	546.35
26 1/2	83.252	551.55
26 5/8	83.645	556.76
26 3/4	84.038	562.00
26 7/8	84.430	567.27
27	84.823	572.56
27 1/8	85.216	577.87
27 1/4	85.608	583.21
27 3/8	86.001	588.57
27 1/2	86.394	593.96
27 5/8	86.786	599.37
27 3/4	87.179	604.81
27 7/8	87.572	610.27
28	87.965	615.75
28 1/8	88.357	621.26
28 1/4	88.750	626.80
28 3/8	89.143	632.36
28 1/2	89.535	637.94
28 5/8	89.928	643.55
28 3/4	90.321	649.18
28 7/8	90.713	654.84
29	91.109	660.52
29 1/8	91.499	666.23

CIRCUMFERENCES AND AREAS OF CIRCLES
(Continued)

Diam In.	Circum In.	Area Sq. In.
29 1/4	91.892	671.96
29 3/8	92.284	677.71
29 1/2	92.677	683.49
29 5/8	93.070	689.30
29 3/4	93.462	695.13
29 7/8	93.855	700.98
30	94.248	706.86
30 1/8	94.640	712.70
30 1/4	95.033	718.69
30 3/8	95.426	724.64
30 1/2	95.819	730.62
30 5/8	96.211	736.62
30 3/4	96.604	742.64
30 7/8	96.997	748.69
31	97.389	754.77
31 1/8	97.782	760.87
31 1/4	98.175	766.99
31 3/8	98.567	773.14
31 1/2	98.960	779.31
31 5/8	99.353	785.51
31 3/4	99.746	791.73
31 7/8	100.138	797.98
32	100.531	804.25
32 1/8	100.924	810.54
32 1/4	101.316	816.86
32 3/8	101.709	823.21
32 1/2	102.102	829.58
32 5/8	102.494	835.97
32 3/4	102.887	842.39
32 7/8	103.280	848.83
33	103.673	855.30
33 1/8	104.065	861.79
33 1/4	104.458	868.31
33 3/8	104.851	874.85
33 1/2	105.243	881.74
33 5/8	105.636	888.00
33 3/4	106.029	894.62
33 7/8	106.421	901.26
34	106.814	907.92
34 1/8	107.207	914.61
34 1/4	107.600	921.32
34 3/8	107.992	928.06
34 1/2	108.385	934.82
34 5/8	108.778	941.61
34 3/4	109.170	948.42
34 7/8	109.563	955.25
35	109.956	962.11
35 1/8	110.348	969.00
35 1/4	110.741	975.91
35 3/8	111.134	982.84
35 1/2	111.527	989.80
35 5/8	111.919	996.87
35 3/4	112.312	1003.8
35 7/8	112.705	1010.8
36	113.097	1017.9
36 1/3	113.490	1025.0
36 1/4	113.883	1032.1
36 3/8	114.275	1039.2
36 1/2	114.668	1046.3
36 5/8	115.061	1053.5
36 3/4	115.454	1060.7
36 7/8	115.846	1068.0
37	116.239	1075.2
37 1/8	116.632	1082.5
37 1/4	117.024	1089.8
37 3/8	117.417	1097.1
37 1/2	117.810	1104.5
37 5/8	118.202	1111.8
37 3/4	118.596	1119.2
37 7/8	118.988	1126.7
38	119.381	1134.1
38 1/8	119.773	1141.0
38 1/4	120.166	1149.1
38 3/8	120.559	1156.6
38 1/2	120.951	1164.2
38 5/8	121.344	1171.7
38 3/4	121.737	1179.3
38 7/8	122.129	1186.9
39	122.522	1194.6
39 1/8	122.915	1202.3
39 1/4	123.308	1210.0
39 3/8	123.700	1217.7
39 1/2	124.093	1225.4
39 5/8	124.486	1233.2
39 3/4	124.878	1241.0
39 7/8	125.271	1248.8
40	125.664	1256.6
40 1/8	126.056	1264.5
40 1/4	126.449	1272.4
40 3/8	126.842	1280.3
40 1/2	127.235	1288.2
40 5/8	127.627	1296.2
40 3/4	128.020	1304.2
40 7/8	128.413	1312.2
41	128.805	1320.3
41 1/8	129.198	1328.3
41 1/4	129.591	1336.3
41 3/8	129.983	1344.3

CIRCUMFERENCES AND AREAS OF CIRCLES (Continued)

Diam In.	Circum In.	Area Sq. In.
41 1/2	130.376	1352.7
41 5/8	130.769	1360.8
41 3/4	131.161	1369.0
41 7/8	131.554	1377.2
42	131.947	1385.4
42 1/8	132.340	1393.7
42 1/4	132.732	1402.0
42 3/8	133.125	1410.3
42 1/2	133.518	1418.6
42 5/8	133.910	1427.0
42 3/4	134.303	1435.4
42 7/8	134.696	1443.8
43	135.088	1452.2
43 1/8	135.481	1460.7
43 1/4	135.874	1469.1
43 3/8	136.267	1477.6
43 1/2	136.659	1486.2
43 5/8	137.052	1494.7
43 3/4	137.445	1503.3
43 7/8	137.837	1511.9
44	138.230	1520.5
44 1/8	138.623	1529.2
44 1/4	139.015	1537.9
44 3/8	139.408	1546.6
44 1/2	139.801	1555.3
44 5/8	140.194	1564.0
44 3/4	140.586	1572.8
44 7/8	140.979	1581.6
45	141.372	1590.4
45 1/8	141.764	1599.3
45 1/4	142.157	1608.0
45 3/8	142.550	1617.0
45 1/2	142.942	1626.0
45 5/8	143.335	1634.9
45 3/4	143.728	1643.9
45 7/8	144.121	1652.9
46	144.513	1661.9
46 1/8	144.906	1670.9
46 1/4	145.299	1680.0
46 3/8	145.691	1689.1
46 1/2	146.084	1698.2
46 5/8	146.477	1707.4
46 3/4	146.869	1716.5
46 7/8	147.262	1725.7
47	147.655	1734.9
47 1/8	148.048	1744.2
47 1/4	148.440	1753.5
47 3/8	148.833	1762.7
47 1/2	149.226	1772.1
47 5/8	149.618	1781.4
47 3/4	150.011	1790.8
47 7/8	150.404	1800.1
48	150.796	1809.6
48 1/8	151.189	1819.0
48 1/4	151.582	1828.5
48 3/8	151.975	1837.9
48 1/2	152.367	1847.5
48 5/8	152.760	1857.0
48 3/4	153.153	1866.5
48 7/8	153.545	1876.1
49	153.938	1885.7
49 1/8	154.331	1895.4
49 1/4	154.723	1905.0
49 3/8	155.116	1914.7
49 1/2	155.509	1924.4
49 5/8	155.902	1934.2
49 3/4	156.294	1943.9
49 7/8	156.687	1953.7
50	157.080	1963.5
50 1/8	157.472	1973.3
50 1/4	157.865	1983.2
50 3/8	158.258	1993.1
50 1/2	158.650	2003.0
50 5/8	159.043	2012.9
50 3/4	159.436	2022.8
50 7/8	159.829	2032.8
51	160.221	2042.8
51 1/8	160.614	2052.8
51 1/4	161.007	2062.9
51 3/8	161.399	2073.0
51 1/2	161.792	2083.1
51 5/8	162.185	2093.2
51 3/4	162.577	2103.3
51 7/8	162.970	2113.5
52	163.363	2123.7
52 1/8	163.756	2133.9
52 1/4	164.148	2144.2
52 3/8	164.541	2154.5
52 1/2	164.934	2164.8
52 5/8	165.326	2175.1
52 3/4	165.719	2185.4
52 7/8	166.112	2195.8
53	166.504	2206.2
53 1/8	166.897	2216.6
53 1/4	167.290	2227.0
53 3/8	167.683	2237.5
53 1/2	168.075	2248.0
53 5/8	168.468	2258.5

CIRCUMFERENCES AND AREAS OF CIRCLES
(Continued)

Diam. In.	Circum. In.	Area Sq. In.
53 3/4	168.861	2269.1
53 7/8	169.253	2279.6
54	169.646	2290.2
54 1/8	170.039	2300.8
54 1/4	170.431	2311.5
54 3/8	170.824	2322.1
54 1/2	171.217	2332.8
54 5/8	171.609	2343.5
54 3/4	172.002	2354.3
54 7/8	172.395	2365.0
55	172.788	2375.8
55 1/8	173.180	2386.6
55 1/4	173.573	2397.5
55 3/8	173.966	2408.3
55 1/2	174.358	2419.2
55 5/8	174.751	2430.1
55 3/4	175.144	2441.1
55 7/8	175.536	2542.0
56	175.929	2463.0
56 1/8	176.322	2474.0
56 1/4	176.715	2485.0
56 3/8	177.107	2496.1
56 1/2	177.500	2507.2
56 5/8	177.893	2518.3
56 3/4	178.285	2529.4
56 7/8	178.678	2540.6
57	179.071	2551.8
57 1/8	179.463	2563.0
57 1/4	179.856	2574.2
57 3/8	180.249	2585.4
57 1/2	180.642	2596.7
57 5/8	181.034	2608.0
57 3/4	181.427	2619.4
57 7/8	181.820	2630.7
58	182.212	2642.1
58 1/8	182.605	2653.5
58 1/4	182.998	2664.9
58 3/8	183.390	2676.4
58 1/2	183.783	2687.8
58 5/8	184.176	2699.3
58 3/4	184.569	2710.9
58 7/8	184.961	2722.4
59	184.354	2734.0
59 1/8	185.747	2745.6
59 1/4	186.139	2757.2
59 3/8	186.532	2768.8
59 1/2	186.925	2780.5
59 5/8	187.317	2792.2
59 3/4	187.710	2803.9
59 7/8	188.103	2815.7
60	188.496	2827.4
60 1/8	188.888	2839.2
60 1/4	189.281	2851.0
60 3/8	189.674	2862.9
60 1/2	190.006	2874.8
60 5/8	190.459	2886.6
60 3/4	190.852	2898.6
60 7/8	191.244	2910.5
61	191.637	2922.5
61 1/8	192.030	2934.5
61 1/4	192.423	2946.5
61 3/8	192.815	2958.5
61 1/2	193.208	2970.6
61 5/8	193.601	2982.7
61 3/4	193.993	2994.8
61 7/8	194.386	3006.9
62	194.779	3019.1
62 1/8	195.171	3031.3
62 1/4	195.564	3043.5
62 3/8	195.957	3055.7
62 1/2	195.350	3068.0
62 5/8	196.742	3080.3
62 3/4	197.135	3092.6
62 7/8	197.528	3104.9
63	197.920	3117.2
63 1/8	198.313	3129.6
63 1/4	198.706	3142.0
63 3/8	199.098	3154.5
63 1/2	199.491	3166.9
63 5/8	199.884	3179.4
63 3/4	200.277	3191.9
63 7/8	200.669	3204.4
64	201.062	3217.0
64 1/8	201.455	3229.6
64 1/4	201.847	3242.2
64 3/8	202.240	3254.8
64 1/2	202.633	3267.5
64 5/8	203.025	3280.1
64 3/4	203.418	3292.8
64 7/8	203.811	3305.6
65	204.204	3318.3
65 1/8	204.596	3331.1
65 1/4	204.989	3343.9
65 3/8	205.382	3356.7
65 1/2	205.774	3369.6
65 5/8	206.167	3382.4
65 3/4	206.560	3395.3
65 7/8	206.952	3408.2

CIRCUMFERENCES AND AREAS OF CIRCLES
(Continued)

Diam. In.	Circum. In.	Area Sq. In.
66	207.345	3421.2
66 1/8	207.738	3434.2
66 1/4	208.131	3447.2
66 3/8	208.523	3460.2
66 1/2	208.916	3473.2
66 5/8	209.309	3486.3
66 3/4	209.701	3499.4
66 7/8	210.094	3512.5
67	210.487	3525.7
67 1/8	210.879	3538.8
67 1/4	211.272	3552.0
67 3/8	211.665	3565.2
67 1/2	212.058	3578.5
67 5/8	212.450	3591.7
67 3/4	212.843	3605.0
67 7/8	213.236	3618.3
68	213.628	3631.7
68 1/8	214.021	3645.0
68 1/4	214.414	3658.4
68 3/8	214.806	3671.8
68 1/2	215.199	3685.3
68 5/8	215.592	3698.7
68 3/4	215.984	3712.2
68 7/8	216.377	3725.7
69	216.770	3739.3
69 1/8	217.163	3752.8
69 1/4	217.555	3766.4
69 3/8	217.948	3780.0
69 1/2	218.341	3793.7
69 5/8	218.733	3807.3
69 3/4	219.126	3821.0
69 7/8	219.519	3834.7
70	219.911	3848.5
70 1/8	220.304	3862.2
70 1/4	220.697	3876.0
70 3/8	221.090	3889.8
70 1/2	221.482	3903.6
70 5/8	221.875	3917.5
70 3/4	222.268	3931.4
70 7/8	222.660	3945.3
71	223.053	3959.2
71 1/8	223.446	3973.1
71 1/4	223.838	3987.1
71 3/8	224.231	4001.1
71 1/2	224.624	4015.2
71 5/8	225.017	4029.2
71 3/4	225.409	4043.3
71 7/8	225.802	4057.4
72	226.195	4071.5
72 1/8	226.587	4085.7
72 1/4	226.980	4099.8
72 3/8	227.373	4114.0
72 1/2	227.765	4128.2
72 5/8	228.158	4142.5
72 3/4	228.551	4156.8
72 7/8	228.944	4171.1
73	229.336	4185.4
73 1/8	229.729	4199.7
73 1/4	230.122	4214.1
73 3/8	230.514	4228.5
73 1/2	230.907	4242.9
73 5/8	231.300	4257.4
73 3/4	231.692	4271.8
73 7/8	232.085	4286.3
74	232.478	4300.8
74 1/8	232.871	4315.4
74 1/4	233.263	4329.9
74 3/8	233.656	4344.5
74 1/2	234.049	4359.2
74 5/8	234.441	4373.8
74 3/4	234.834	4388.5
74 7/8	235.227	4403.1
75	235.619	4417.9
75 1/8	236.012	4432.6
75 1/4	236.405	4447.4
75 3/8	236.798	4462.2
75 1/2	237.190	4477.0
75 5/8	237.583	4491.8
75 3/4	237.976	4506.7
75 7/8	238.368	4521.5
76	238.761	4536.5
76 1/8	239.154	4551.4
76 1/4	239.546	4566.4
76 3/8	239.939	4581.3
76 1/2	240.332	4596.3
76 5/8	240.725	4611.4
76 3/4	241.117	4626.4
76 7/8	241.510	4641.5
77	241.903	4656.6
77 1/8	242.295	4671.8
77 1/4	242.688	4686.9
77 3/8	243.081	4702.1
77 1/2	243.473	4717.3
77 5/8	243.866	4732.5
77 3/4	244.259	4747.8
77 7/8	244.652	4763.1
78	245.044	4778.4
78 1/8	245.437	4793.7

CIRCUMFERENCES AND AREAS OF CIRCLES
(Continued)

Diam in.	Circum. In.	Area Sq. In.
78 1/4	245.830	4809.0
78 3/8	246.222	4824.4
78 1/2	246.615	4839.8
78 5/8	247.008	4855.2
78 3/4	247.400	4870.7
78 7/8	247.793	4886.2
79	248.186	4901.7
79 1/8	248.579	4917.2
79 1/4	248.971	4932.7
79 3/8	249.364	4948.3
79 1/2	249.757	4963.9
79 5/8	250.149	4979.5
79 3/4	250.542	4995.2
79 7/8	250.935	5010.9
80	251.327	5026.5
80 1/8	251.720	5042.3
80 1/4	252.113	5058.0
80 3/8	252.506	5073.8
80 1/2	252.898	5089.6
80 5/8	253.291	5105.4
80 3/4	253.684	5121.2
80 7/8	254.076	5137.1
81	254.469	5153.0
81 1/8	254.862	5168.9
81 1/4	255.254	5184.9
81 3/8	255.647	5200.8
81 1/2	256.040	5216.8
81 5/8	256.433	5232.8
81 3/4	256.825	5248.9
81 7/8	257.218	5264.9
82	257.611	5281.0
82 1/8	258.003	5297.1
82 1/4	258.396	5313.3
82 3/8	258.789	5329.4
82 1/2	259.181	5345.6
82 5/8	259.574	5361.8
82 3/4	259.967	5378.1
82 7/8	260.359	5394.3
83	260.752	5410.6
83 1/8	261.145	5426.9
83 1/4	261.538	5443.3
83 3/8	261.930	5459.6
83 1/2	262.323	5476.0
83 5/8	262.716	5492.4
83 3/4	263.108	5508.8
83 7/8	263.501	5525.3
84	263.894	5541.8
84 1/8	264.286	5558.3
84 1/4	264.679	5574.8
84 3/8	265.072	5591.4

Diam. In.	Circum. In	Area Sq. In.
84 1/2	265.465	5607.9
84 5/8	266.857	5624.5
84 3/4	266.250	5641.2
84 7/8	266.643	5657.8
85	267.035	5674.5
85 1/8	267.428	5691.2
85 1/4	267.821	5707.9
85 3/8	268.213	5724.7
85 1/2	268.060	5741.5
85 5/8	268.999	5758.3
85 3/4	269.392	5775.1
85 7/8	269.784	5791.9
86	270.177	5808.8
86 1/8	270.570	5825.7
86 1/4	270.962	5842.6
86 3/8	271.355	5859.6
86 1/2	271.748	5876.5
86 5/8	272.140	5893.5
86 3/4	272.533	5910.6
86 7/8	272.926	5927.6
87	273.319	5944.7
87 1/8	273.711	5961.8
87 1/4	274.104	5978.9
87 3/8	274.497	5996.0
87 1/2	274.889	6013.2
87 5/8	275.282	6030.4
87 3/4	275.675	6047.6
87 7/8	276.067	6064.9
88	276.460	6082.1
88 1/8	276.853	6099.4
88 1/4	277.246	6116.7
88 3/8	277.638	6134.1
88 1/2	278.031	6151.4
88 5/8	278.424	6168.8
88 3/4	278.816	6186.2
88 7/8	279.209	6203.7
89	279.602	6221.1
89 1/8	279.994	6238.6
89 1/4	280.387	6256.1
89 3/8	280.780	6273.1
89 1/2	281.173	6291.2
89 5/8	281.565	6308.8
89 3/4	281.958	6326.4
89 7/8	282.351	6344.1
90	282.743	6361.7
90 1/8	283.136	6379.4
90 1/4	283.529	6397.1
90 3/8	283.921	6414.9
90 1/2	284.314	6432.6
90 5/8	284.707	6450.4

CIRCUMFERENCES AND AREAS OF CIRCLES
(Continued)

Diam In.	Circum In.	Area Sq. In.
90 3/4	285.100	6468.2
90 7/8	285.492	6486.0
91	285.885	6503.9
91 1/8	286.278	6521.8
91 1/4	286.670	6539.7
91 3/8	287.063	6555.6
91 1/2	287.456	6575.5
91 5/8	287.848	6593.5
91 3/4	288.241	6611.5
91 7/8	288.634	6629.6
92	289.027	6647.6
92 1/8	289.419	6665.7
92 1/4	289.812	6683.8
92 3/8	290.205	6701.9
92 1/2	290.597	6720.1
92 3/8	290.990	6738.2
92 3/4	291.383	6756.4
92 7/8	291.775	6774.7
93	292.168	6792.9
93 1/8	292.561	6811.2
93 1/4	292.954	6829.5
93 3/8	293.346	6847.8
93 1/2	293.739	6866.1
93 5/8	294.132	6884.5
93 3/4	294.524	6902.9
93 7/8	294.917	6921.3
94	295.310	6939.8
94 1/8	295.702	6958.2
94 1/4	296.095	6976.7
94 3/8	296.488	6995.3
94 1/2	296.881	7013.8
94 5/8	297.273	7032.4
94 3/4	297.666	7051.0
94 7/8	298.059	7069.6
95	298.451	7088.2
95 1/8	298.844	7106.9
95 1/4	299.237	7125.6

Diam. In.	Circum In.	Area Sq. In.
95 3/8	299.629	7144.3
95 1/2	300.022	7163.0
95 5/8	300.415	7181.8
95 3/4	300.807	7200.6
95 7/8	301.200	7219.4
96	301.593	7238.2
96 1/8	301.986	7257.1
96 1/4	302.378	7276.0
96 3/8	302.771	7294.9
96 1/2	303.164	7313.8
96 5/8	303.556	7332.8
96 3/4	303.949	7351.8
96 7/8	304.342	7370.8
97	304.734	7389.8
97 1/8	305.127	7408.9
97 1/4	305.520	7428.0
97 3/8	305.913	7447.1
97 1/2	306.305	7466.2
97 5/8	306.698	7485.3
97 3/4	307.091	7504.5
97 7/8	307.483	7523.7
98	307.876	7543.0
98 1/8	308.269	7562.2
98 1/4	308.661	7581.5
98 3/8	309.054	7600.8
98 1/2	309.447	7620.1
98 5/8	309.840	7639.5
98 3/4	310.232	7658.9
98 7/8	310.625	7678.3
99	311.018	7697.7
99 1/8	311.410	7717.1
99 1/4	311.803	7736.6
99 3/8	312.196	7756.1
99 1/2	312.588	7775.6
99 5/8	312.981	7795.2
99 3/4	313.374	7814.8
99 7/8	313.767	7834.4
100	314.159	7854.0

STEEL PROPRIETARY PRODUCTS COMPARISON CHART

A572 (PLATES, A607 (Sheets)

Ex-ten	(42, 45, 50, 60, 65)	U.S. Steel
INX	(42, 45, 50, 60, 65)	Inland Steel
"v"	(42, 45, 50, 60, 65)	Bethlehem Steel
Orelloy	(42, 45, 50, 60, 65)	Oregon Steel Mills
"c"	(42, 45, 50)	Armco Steel

A 514 (Plates) or A514 Alloy Type (Plates)

T-1	U.S. Steel
RQ 100	Bethlehem Steel
NA-XTRA 100	National Steel
Orelloy 100	Oregon Steel Mills
SSS 100	Armco Steel
INX 100	Inland Steel
Wel-ten 80C	Nippon Steel (A514 Alloy type) - Japanese
Sumi-ten 80S	Sumitomo Metals (A514 Alloy type) - Japanese
River Ace Ko	Kawasaki Steel

A588, A242

Corten	U.S. Steel
Mayari R	Bethlehem Steel
Orelloy 588/242	Oregon Steel Mills
Hi Strength A	Armco

AR Plates - Types - (235, 320, 360, 400, 500 Brinnell)

AR235	Bethlehem Steel
US AR	U.S. Steel
Wearalloy	Ford Steel
Firm-x	International Alloy

Other

"Z" Steel	Oregon Steel Mills
Orelloy 70FG	Oregon Steel Mills
Stressproof	LaSalle Steel - C1144
Fatigue-proof	LaSalle Steel
Century Series	Republic Engineered Products - C1144
Multi-cut	Republic Engineered Products
Strain Tempered	Bliss & Laughlin - C1144
"e.t.d."	LaSalle Steel

GLOSSARY OF STEEL TERMS

Abrasion - The process of rubbing, grinding or wearing away steel by friction.

Aging - In a metal or alloy a change in properties that generally occurs slowly at room temperature and more rapidly at higher temperatures.

Alloy -A mixture with metallic properties composed of two or more elements of which at least one is a metal.

Alloy Elements - Alloy elements in steel would be chromium, cobalt, nickel, molybdenum, tungsten and vanadium. These are added to steel to modify its properties. Other common elements added are copper, aluminium, titanium, columbium and boron. In each case established minimum percentages must be met to qualify the element as an alloy addition.

Annealing - The term annealing usually implies relatively slow cooling in a heat treating furnace. The more important purposes for which steel is annealed are as follows: to remove stresses, to induce softness, increase ductility and increase electrical and magnetic properties.

Anodizing - Forming of a conversion coating on a metal surface by anodic oxidation most frequently applied to aluminum.

As Rolled - A term used to describe steel bars or plate that are hot rolled only without any subsequent heat treating operation.

Bend Radius - The inside radius of a bent section.

Brinell Hardness - A test for determining the hardness of a metal by forcing a hard steel or carbide ball of specified diameter into the surface of the steel. The hardness number is a number in direct proportion to the diameter of the hole.

Carbon Equivalent - Various formulas used to determine the weldability of steel by adding the percentage of carbon plus the equivalent carbon of the other elements. It is assumed that if the carbon equivalent (CE) is not more that .45% the steel is considered weldable without preheating or postheating.

Carburizing - Increasing the surface carbon content of steel in a heat treating furnace. This process is used to increase wear resistance.

Case Hardening - A heat treatment method of surface treating steel for wear resistance. The most common methods would be carburizing and nitriding. Both of these elements are added to the surface of the steel to increase wear resistance. The other two methods are flame hardening and induction hardening with electrical current.

Charpy - An impact test to determine the toughness of steels conducted on a Charpy Impact Machine. The test is conducted on a small steel bar with a V-notch. The test is abbreviated CVN.

Coil Breaks - Creases or ridges across a metal sheet transverse to the direction of coiling occasionally occurring when the metal has been coiled hot and uncoiled cold.

Cold Drawing - Reducing the cross section of steel bars by pulling the steel through a die of reduced size, usually 1 /32". This process is done at ambient temperatures and is used to enhance the surface appearance, produce close tolerances and increase machinability.

Cold Rolling - Reducing the thickness of steel by rolling or ironing the steel below the recrystallization temperature. This method is used for sheet steel to produce lighter gauges and increase surface finish appearance.

GLOSSARY OF STEEL TERMS (Continued)

Cold Working - Any method used to plastically deform or reduce the thickness or cross sectional size of steel at ambient temperatures.

Corrosion - The deterioration of a metal by chemical or electrochemical reaction with its environment.

Crown - A contour on a sheet or roll where the thickness or diameter increases from edge to center.

Decarburlzatlon - A loss of carbon on the surface of steel which accelerates at temperatures above 1400 degrees F. All steels which are hot rolled, forged or heat treated in furnaces without controlled atmosphere will have a decarburized surface.

Deep Drawing - A process for stretching sheet steel in a die with a punch which is mounted in a stamping press.

Ductility - The ability of a material to deform plastically without fracturing. It is commonly evaluated by tensile testing.

Elastic Limit - The greatest unit stress to which a material may be subjected without permanent deformation remaining upon complete release of the stress.

Elongation - The percentage increase in the gauge length of a tensile specimen after it has been tension tested to failure.

Fatigue - The phenomenon leading to fracture under repeated or fluctuating stresses having a maximum value less than the tensile strength of the material.

Ferrite - Technical terms for the two types of iron occurring in steel.

Flame Hardening - Heating the surface of steel to its hardening temperature range and then immediately quenching the surface with water or a synthetic quenchant.

Forging - Plastically deforming metal, usually hot, into desired shapes with compressive force, with or without dies.

Free Machining - Pertains to the machining characteristics of steel to which an ingredient has been introduced to give small broken chips, lower power consumption, better surface finish and longer tool life.

Galvanizing - In steel terms to hot dip steel in a bath of molten zinc.

Hardenabillty - The property that determines the depth of hardness of steel after it has been heat treated by quenching and temperature.

Hardness - The ability of metal to resist penetration. The principal methods of hardness testing are the Rockwell and Brinell hardness testers.

Heat Affected Zone (HAZ) - That portion of the base metal which was not melted during brazing, cutting or welding but whose microstructure and physical properties were altered by the heat.

Honing - Removing stock generally on the internal cylindrical surface of a tube with an abrasive tool mounted in a holder

Hot Rolling - Rolling bars, plate, sheet, structurals through a series of rolls for size reduction or shape at temperatures of 1550 to 2100 degrees F.

Impact Test - A test used to determine the toughness of steel by impact with a falling pendulum. The common test used is the Charpy or Izod impact test which is conducted on specially designed equipment.

GLOSSARY OF STEEL TERMS (Continued)

Inclusions - Non-metallic impurities in steel in the form of oxides, sulfides, or silicates. These impurities are formed during the solidifacation of the steel in the ingot molds, or continuously cast blooms, billets or slabs.

Induction Hardening - This is a method of hardening the surface of a steel part electrically with high frequency current. The current is passed through a coil that is held very close to the surface to be hardened and the surface is immediately heated to approximately 1600º F. The surface is immediately quenched with water or a synthetic oil.

Killed Steel - Steel which is deoxidized or degassified in the melting operation to eliminate porosity and produce more sound steel products. Silicon and aluminum are two elements used to eliminate the gases in steel.

Laminations - The general term used for surface or internal defects parallel to the rolled surface of the steel product. Surface defects are slivers and laps: internal lamination is called piped steel and occurs in plate and sheet.

Longitudinal Direction - The principal direction of flow in a worked metal.

Mechanical Properties - Defined as tensile and yield strength, elongation, torsional strength and impact strength.

Modules of Elasticity - The ratio within the limit of elasticity of the stress to the corresponding strain The stress in pounds per square inch is divided by the elongation in fractions of an inch for each inch of original gauge length of the specimen.

Normalizing - Heating steels to approximately 100 degrees F above the critical temperature range followed by cooling to below that range in still air For instance, the normalizing temperature for A36 or A572 would be 1650° F.

Orange Peel - A pebble grained surface which develops in forming of metals having coarse grains.

Oxidation - A reaction with oxygen. In the case of steel, oxidation burns the carbon out of the surface of steel if the temperatures are above 1200° F. The resultant surface is termed decarburized.

Physical Properties - Are defined as electrical, magnetic, density coefficient of thermo expansion, etc

Pickling - A chemical treatment with acids to remove the scale or iron oxides on the surface of hot rolled steel products.

Pitting - Forming small sharp cavities in a metal surface by nonuniform electro-deposition or by corrosion.

Post Heating - Heating the weld and weld are to slow down the rate of cooling to eliminate weld cracking or cracking in the heat affected area.

Pre Heating - A welding term used to designate heating steel to a specific temperature prior to welding to prevent weld cracks.

Quenching - Rapid cooling of a metal during a heat treating operation. The quenching coolant could be water, oil or air. This is the method used to increase the hardness and strength of steel.

Reduction of Area - The percentage reduction of area is the difference between the original cross-sectional area and the least cross-sectional area of a tensile test specimen after rupture.

GLOSSARY OF STEEL TERMS (Continued)

Rimmed Steel -A method of producing very low carbon steels in an ingot mold by letting the steel form gases and solidify slowly. This results in a pure iron rim on the surface of the ingot which remains on the surface of the rolled product which is generally sheet steel.

Rockwell - Hardness testing device used to measure the resistance of metal to be indented. The numbers usually in Rockwell B or C hardness will designate the relative hardness and strength of the metal.

Scale - A complex iron oxide formed on the surface of steel when it is hot rolled or forged. Iron oxide will start to form at approximately 1100° in air.

Seams - A defect on the steel surface which is always in the rolling direction and appears as a thin crack.

Semi-Killed - Steel that is partially deoxidized where some of the gasses from the solidification in the ingot mold are still remaining. Semi-killed steels are intermediate between rimmed and killed.

Special Killed - Steel that has been completely deoxidized to prevent gases from forming during solidification in the ingot mold. Deoxidizing elements used to remove the gasses are aluminum and silicon. The term “killed” is used because such additions cause the steel to be quiet in the molds instead of boiling from the gasses.

Tensile Strength - The maximum load per unit of original cross-sectional area obtained before rupture of a tensile specimen

Trepanning - A type of boring where an annular cut is made into a solid material with the coincidental formation of a plug or solid cylinder.

Transverse - Across, usually signifying a direction or plain perpendicular to the direction of working such as cold drawing or rolling.

Toughness - Ability of a metal to absorb energy and deform plastically before fracturing. It is usually measured by the energy absorbed in a notch impact test. The most common test is the Charpy V-Notch Test.

Yield Point - This is the load per unit area at which the tensile specimen starts to deform or elongate without increase of load The yield point can also be defined as the stress at which a marked increase in strain occurs without an increase in stress.

Yield Strength - Stress corresponding to some fixed permanent deformation such as .1 or .2% offset from the modulus slope in the tensile test.