encore metals

Product Manual

2016

Table of Contents

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In the case that any shipment of product proves unsatisfactory, it is understood and agreed that the purchaser will immediately discontinue its use of such product so that the possible loss or damage to either party shall be prevented or minimized.

The purchaser shall give immediate notification to Encore Metals upon discovery of any alleged defect in the product and make the product available for inspection and testing by Encore Metals. On receipt of notification Encore Metals shall determine whether the product supplied was defective, whether the alleged defect was caused by the purchaser's improper installation, processing, or maintenance, or for any other reason. If Encore Metals determines that a defect existed in the product as supplied, the purchaser's sole and exclusive remedy for defective product or service shall be, at Encore Metal's sole and absolute discretion, repair or replacement of the product, or refund of the purchase price. Provided however, no product shall be deemed defective if the alleged defect is discoverable only by inspections means more stringent than those requested by the purchaser in connection with the placing of its order. No action arising out of the transaction under this agreement may be brought by the purchaser more than one year after the cause of action has occurred.

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MISSION STATEMENT

Encore Metals will provide superior service and the highest quality products to our customers while maintaining a safe work environment for all employees, contractors, and visitors. Our goal is to ensure long term sustainable growth and provide a meaningful return on the business for our stakeholders.

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PREFACE

We are specialist suppliers of high grade steel and metal products including carbon and alloy machinery steels; and extensive range of stainless steels including duplex grades and nickel-based corrosion resistant alloys: iron bar products; forgings; castings; aluminum extrusions; tool steels and bronze products.

Processing services provided include bar sawing, trepanning, stainless plate profiling, and plate sawing.

Our suppliers are all mills of high repute with facilities which include VIM, ESR, and VAR equipment and employ the latest steelmaking technology. As a result, our products are backed by the most advanced metallurgical and research facilities available.

Mill Test Certificates are available upon request as well as a copy of our Quality Assurance Manual which conforms to the requirements of ISO 9001.

PRODUCTS AND SERVICES

SECTION 1. PRODUCTS

Products Overview

Alloy	Alloy Steel bars (Hot Rolled) are stocked from 3/8" to 26 ½" diameter.	– 3312 Annealed Round – 4130 Heat Treated Rounds, API 6A – 4140 Annealed Rounds – 4140 Annealed Hexagons, Squares, Flats – 4140 HTSR Rounds – 4140 Plate – 4140 Rc 22 max Rounds – 4140 Cold Finished Steel Chrome Plated Shafting & HTSR Precision Ground & Cold Drawn – 4145H Mod HTSR – 4150 Calcium Treated HTSR Rounds – 4330+V Modified, HTSR – 4340 Annealed Rounds, CQ and AQ, squares & flats – 4340 HTSR Rounds, CQ and AQ – EN30B Quench & Tempered Rounds, Annealed Rounds – 8620 Hot Rolled Rounds, and cold finished – 52100
Aluminum		– 6061 T6 Rounds
Bronze Cast		– SAE 660 Bearing Bronze (C93200, ASTM B505) – Alloy 954 Aluminum Bronze (C95400, ASTM B505)
Carbon	Carbon Steel Bars (Hot Rolled) are stocked from 1" to 24" diameter. Cold Finished Steel Bars are stocked from 1/8" to 8" diameter.	– 1018 Rounds – 1040/ 1045 Rounds – A105/A350-LF2 – 1018 Cold Finished Steel Rounds, Squares, Flats – 12L14 Cold Finished Steel Rounds, Hexagons – 1045 Cold Finished Steel Precision Ground Shafting – 1045 Cold Finished Steel Chrome Plated Shafting (Imperial & Metric) – 1045 Cold Finished Steel Induction Hardened, Chrome Plated Shafting (Imperial & Metric – 1144 Cold Finished Steel CD Hi-Strength
Cast Iron		– Continuous Cast Iron Bar – Ductile 65-45-12 – Continuous Cast Iron Bar – Pearlitic Gray Iron - G2 – Continuous Cast Iron Bar – 80-55-06

		– Continuous Cast Iron Bar – 100-70-02
Specialty	– Ornamental Stainless Steel Tubing are stocked from 1/2" OD x 0.049" wall to 3" OD x 0.065" wall and 3/4" square x 0.065" wall to 4" square x 0.025" wall.	– 4140 CD and Hot Finished Seamless Mechanical Tubing, L80 & P100 – Stainless Steel Ornamental Tubing – Non-Magnetic Drilling Components, Staballoy AG 17TM – Enhanced Corrosion Resistance Non-Magnetic Steel, Datalloy 2TM – Nickel/ Cobalt Alloys 400, 500 – Nickel/ Cobalt Corrosion Resistant Alloys, C-276, C-22 – Tool Steels Drilling/Mining
Stainless Steel	– Bars are stocked from 1/8" diameter to 12" diameter. – Sheets are stocked from 26 GA to 10 GA. Maximum width 60". – Plates are stocked from 3/16" to 3".	– T303 CD Rounds, Hexagons – T304/304L Rounds – T304 HRAP Flats, Slit Edge and Mill Edge – T304 CD/HRAP Hexagons – T304 HRAP Angles – T304/304L 2B and #4 Finish Sheet/Coil – T304/304L HRAP Sheet/Coil – T304/304L HRAP Plate – 309S Plate – T310/T310S Plate – T316/316L Rounds – T316L CG Rounds – T316L HRAP Angles – T316/316L PSQ Rounds – T316 HRAP Flats, Slit Edge and Mill Edge – T316 CD/HRAP Hexagons, Squares – T316/316L 2B Finish Sheet/Coil – T316/316L Plate, HRAP – T317L Plate, HRAP – T410 HT CG/RT Rounds & NACE MR-01-75 – T410 CG Rounds – T416 PSQ Rounds – T630/17-4PH Condition “A” Rounds – T630/17-4PH H1150 (NACE) Rounds – 15-5PH – Duplex 2205 (UNS S31803) Rounds – XM-19 – 13% Chrome – 9Cr-1Mo – Alloy 20Cb3 – Duplex 2304 Plate (UNS S32304) – Duplex 2205 Plate (UNS S31803/S32205) – 904L – 1925 HMo Plate (6% Molybdenum)

Alloy Steels

Alloy

3312

Alloy AISI/SAE 3312	*- a 3 ½% Nickel-Chromium Case Hardening Alloy Steel*
Typical Analysis	C .11 · Mn .47 · P .010 · S .002 · Si .27 · Ni 3.33 · Cr 1.47
Characteristics	– High alloy carburizing grade for those heavy-duty applications requiring high core strength, toughness and fatigue resistance over and above the widely used AISI 8620. Core strengths in the order of 170,000 psi (1172 N/mm2) are attainable. It is the preferred grade for carburized parts in severe operating conditions with excellent low-temperature properties. 3312 may also be used in the heat treated, non-carburized condition for many applications requiring extra strength and toughness. It is normally supplied in the annealed condition and hardness HB 212 would be typical.
Typical Applications	– Heavy-duty gears, pinions, spline shafts, piston pins, transmission components, rock drilling bit bodies, plastic molds, etc.

Typical Heat Treatment	– Forging
	  – Commence 1215˚C max.
	  – Finish 925˚C Bury in Mica.
	– Annealing
	  – 840˚C Furnace cool
	– Normalizing
	  – 900˚C Air cool
	– Hardened & Tempered (Uncarburized) - Heat to 815˚ / 840˚C and oil quench or Heat to 840˚ / 870˚C and air quench, then temper at 200˚ / 650˚C according to properties required.
	– Case Hardening - single refining treatment. After carburizing at 900˚ / 925˚C, cool to RT. Reheat to 775˚ / 800˚C, oil quench and temper at 200˚C.

Mechanical Properties	– Typical as supplied, Annealed.
	– Tensile Strength - 102,000 psi
	  – $_2$Tensile Strength - 704 N/mm
	– Yield Strength - 80,000 psi
	  – $_2$Yield Strength - 552 N/mm
	– Elongation - 24%
	– Reduction of Area - 65%
	– Hardness - HB 212
	– Machinability - 40

Alloy AISI/SAE 3312	Mechanical Properties - UNCARBURIZED (Hardened & Tempered)	
Size - inches	1" Dia	4" Dia
Tensile Strength, psi	136,000	131,500
Tensile Strength, N/mm²	938	907
Yield Strength, psi	117,500	108,000
Yield Strength, N/mm²	810	745
Elongation (%)	19	17
Reduction of Area (%)	63	57
Izod Ft./Lbs.	83	68
Izod Joules	113	92
HB of Core	293	285

Alloy AISI/SAE 3312	Mechanical Properties - CARBURIZED - Single refining (Hardened & Tempered)	
Size - inches	1" Dia	4" Dia
Tensile Strength, psi	173,000	152,000
Tensile Strength, N/mm²	1,193	1,048
Yield Strength, psi	132,000	109,000
Yield Strength, N/mm²	910	752
Elongation (%)	20	23
Reduction of Area (%)	60	63
Izod Ft./Lbs.	60	63
Izod Joules	81	89
HB of Core	341	311
Hardness of Case HRC	62	60

Alloy
4130

Alloy AISI/SAE 4130 (UNS G 41300)	*- a "30" Carbon Chromium-Molybdenum Alloy Steel*
Typical Analysis	C .30 · Mn .50 · P .015 · S .010 · Si .25 · Cr .90 · Mo .20
Characteristics	– We stock this quality of E-4130 to meet the regulations of API Spec.6A. – Bars are heat treated to Designation 75K and are Charpy V-notch impact- tested to Classification K. – Stocks also conform to NACE Standard MROI- 75 with a maximum hardness of HRC22/HB235. E-4130 is readily machineable and weldable.
Typical Applications	– Flanges, wellhead components, tool joints, etc.

Typical Heat Treatment	– Forging
	  – Commence 1200˚C max.
	  – Finish 950˚C
	– Annealing
	  – 830˚C/ 855˚C Cool slowly in furnace
	– Normalizing
	  – 870˚C/ 930˚C Cool in air
	– Hardened & Tempered: 840˚C/ 870˚C Water quench, 855˚C/ 885˚C Oil quench; 430˚C/ 700˚C According to properties required.

Mechanical Properties	– Annealed Typical – Tensile Strength - 80,000 psi – Yield Strength - 80,000 psi – Elongation - 28% – Reduction of Area - 57% – Hardness - 22 Rc Max, surface

Alloy AISI/SAE 4130 (UNS G 41300)	Mechanical Properties - Normalized, Hardened & Tempered at 1150°F min - Typical, API-6A Designation 75K, Classification K			
Size - inches	4" Dia	7" Dia.	9 1/2" Dia	15 1/4" Dia
Size - mm	101.6	177.8	241.3	387.4
Tensile Strength, psi	105,500	107,000	104,000	103,000
Tensile Strength, N/mm²	727	737	717	710
Yield Strength, psi	78,480	80,000	77,400	78,000
Yield Strength, N/mm²	541	551	534	538
Elongation (%)	26.8	25.1	28.2	24
Reduction of Area (%)	66.5	64.0	68.3	71.0
HB	223	228	225	220
CVN @-75°F	45/50/47	35/39/42	36/40/43	40/38/42

Alloy

4140 Plate

Alloy AISI 4140 PLATE	
Typical Analysis	C .40 · Mn .85 · P .020 · S .025 · Sl .25 · Cr .90 · Mo .20
Characteristics	– The combined effect of the chromium and molybdenum contents ensures excellent hardenability with uniform properties. In the heat treated condition, plate exhibits strong abrasion and wear resistance as well as good impact and fatigue properties
Typical Applications	– Recommended for use in high stress, abrasion/wear resistant applications such as gears, oil tools and machine tool components
Condition	– As rolled surface finish, annealed alloy steel plate
Plate Dimensions	– Available in gauge/width combinations from 1/4" x 96" to 4 1/4" x 72"

Alloy Cold Finished

4140 TG&P

Alloy Cold Finished AISI 4140 PRECISION GROUND SHAFTING (UNS G 41400)	*- Turned, ground and polished shafting* *- Straightness tolerance of 1 1/16" max in any five feet (5')*

Typical Analysis

	C	Mn	P	S	Si	Cr	Mo
4140	.40	.85	.020	.025	.25	.90	.20
	C	Mn	P	S	Si	Cr	Mo
E-4140	.42	.83	.006	.005	.28	1.02	.22

Characteristics

– This high strength precision ground shafting is produced to exacting OD tolerances. The product offers the highest degree of overall accuracy and concentricity with a seam free surface finish of RMS 25 max. Precision ground shafting 4140 is available in both imperial and metric sizes

Typical Applications

– All forms of close tolerance shafting: camshafts, drive shafts, mill shafts, motor shafts, pump shafts, bolts, pins, studs, etc

Mechanical Properties

– For 215/16" or 74.9 mm diameter bar and smaller,
– ASTM A193, Grade B7 applies.
– For 3" or 76.2 mm diameter and greater, ASTM A434,
– Class BD or BC applies.

Alloy Cold Finished AISI 4140 PRECISION GROUND SHAFTING (UNS G 41400)	**Size Tolerances** *- all tolerances are MINUS*
11/2" dia. (38.1 mm) and under	Minus 0.001" (0.03 mm)
Over 1 1/2" dia. to 2 1/2" dia (63.5 mm)	Minus 0.0015" (0.04 mm)
2 1/2" dia. to 3" dia. (76.2 mm)	Minus 0.002" (0.05 mm)
Over 3" dia. to 4" dia (101.6 mm)	Minus 0.003" (0.08 mm)
Over 4" dia. to 6" dia (152.4" mm)	Minus 0.004" (0.10 mm)
Over 6" dia	Minus 0.005" (0.13 mm)

Alloy

4140/ 4142

Alloy AISI/SAE 4140/ 4142 (UNS G 41400/G 41442)	*- Chromium-Molybdenum Alloy Machinery Steel*

Typical Analysis

	C	Mn	P	S	Si	Cr	Mo
4140	.40	.85	.020	.025	.25	.90	.20

	C	Mn	P	S	Si	Cr	Mo
4142	.42	.83	.006	.005	.28	1.02	.22

Characteristics

- These chromium-molybdenum alloys are among the most widely used and versatile machinery steels. The chromium content provides good hardness penetration and the molybdenum imparts uniformity of hardness and strength. They respond readily to heat treatment and tensile strengths in order of 170,000 psi (1172 N/mm^2) for small sections and 140,000 psi (965 N/mm^2) for larger sections are attainable, all combined with good ductility and resistance to shock. They may be used in both high and low temperature applications and also in sour gas environments with appropriate heat treatments.
- In the hardened and tempered condition these steels possess good wear resistance which may be considerably increased by flame or induction hardening. Alternatively, they may be nitrided. In the annealed condition, bars are supplied to a hardness of HB 207 approximately. Some sizes may be calcium treated. The 4140 Product is also available in a precision ground surface finish (25RMS Max).

Typical Applications

- Shafts, gears, bolts, studs, connecting rods, spindles, tool holders. A wide variety of "oil patch" applications, drill collars, Kelly bars, tool joints, subs, couplings etc.

Typical Heat Treatment

- Forging
  - Commence 1200˚C max.
  - Finish 950˚C
- Annealing
  - 815˚C/ 850˚C Cool slowly in furnace
- Normalizing
  - 870˚C/ 900˚C Cool in air
- Hardened & Tempered: 820˚C/ 870˚C Oil quench; Tempering- Not usually below 430˚C and up to 700˚C according to the properties required.

Alloy AISI/SAE 4140/ 4142 (UNS G 41400/G 41442)	*- Chromium-Molybdenum Alloy Machinery Steel*
Mechanical Properties	– **Annealed:** – **Tensile Strength (min) - 100,000 psi** – **Elongation (min) - 18%** – **Reduction of Area (min) - 50%** – **Hardness: 22RC max** – **Charpy V-Notch at -50˚F - 20 FT LBS average- Minimum15 FT LB** – **Reduction Ratio - Minimum 4:1**

Alloy AISI/SAE 4140/ 4142 (UNS G 41400-G 41442)	**Mechanical Properties** - Heat treated to HRC 22 maximum for sour gas service. Minimum tempering temp 1150˚ F. Conforms to NACE Standard MR01-75. Also meets the tensile requirements of L80 as below - Heat Treated and Stress Relieved to requirements of ASTMA434CLBC/ BD ≥3" To 9 1/2" Dia, minimum values					
Size - inches	3 3/4" Dia		5 3/4" dia		9.5" dia	
Spec	BC	BD	BC	BD	BC	BD
Tensile Strength, psi	115K	140K	110K	135K	105K	130K
Yield Strength, psi	95K	110K	85K	105K	80K	100K
Elongation (%)	16	14	16	14	15	14
Reduction of Area (%)	45	35	45	35	40	35

Alloy AISI/SAE 4140/ 4142 (UNS G 41400/G 41442)	Mechanical Properties - Annealed - Typical			
Size - inches	1" dia.	2" dia.	4" dia.	8" dia.
Tensile Strength, psi	98,000	102,000	101,000	100,000
Yield Strength, psi	61,000	62,000	57,000	58,500
Elongation (%)	23	26	25	21
Reduction of Area (%)	54	55	56	59
HB	197	212	202	197
Machinability	66	66	66	66

Alloy AISI/SAE 4140/ 4142 (UNS G 41400/G 41442)	Mechanical Properties - Heat treated to requirements of ASTM A.193 Grade B7 – Up to 2.5" Diameter, Minimum Values	
Size - inches	Up to 2 1/2” dia	> 2 1/2” to 4”
Tensile Strength, psi	125,000	115,000
Yield Strength, psi	105,000	95,000
Elongation (%)	16	16
Reduction of Area (%)	50	50
HB (Max)	321	115,000

Alloy

4140, 4145

Alloy AISI/SAE 4140-4145 (UNS G 41400-G 41450)	*- Chromium-Molybdenum Alloy Machinery Steel*

Typical Analysis

4140

C	Mn	P	S	Si	Cr	Mo
.40	.85	.020	.025	.25	.90	.20

E-4140

C	Mn	P	S	Si	Cr	Mo
.42	.83	.006	.005	.28	1.02	.22

4145

C	Mn	P	S	Si	Cr	Mo
.45	.85	.020	.025	.25	.90	.20

Characteristics

- These chromium-molybdenum alloys are among the most widely used and versatile machinery steels. The chromium content provides good hardness penetration and the molybdenum imparts uniformity of hardness and strength. They respond readily to heat treatment and tensile strengths in order of 170,000 psi (1172 N/mm2) for small sections and 140,000 psi (965 N/mm2) for larger sections are attainable, all combined with good ductility and resistance to shock. They may be used in both high and low temperature applications and also in sour gas environments with appropriate heat treatments.
- In the hardened and tempered condition these steels possess good wear resistance which may be considerably increased by flame or induction hardening. Alternatively, they may be nitrided. In the annealed condition, bars are supplied to a hardness of HB 207 approximately. Some sizes may be calcium treated. The 4140 Product is also available in a precision ground surface finish (25RMS Max).

Typical Applications

- Shafts, gears, bolts, studs, connecting rods, spindles, tool holders. A wide variety of "oil patch" applications, drill collars, Kelly bars, tool joints, subs, couplings etc.

Typical Heat Treatment

- Forging
  - Commence 1200˚C max.
  - Finish 950˚C
- Annealing
  - 815˚C/ 850˚C Cool slowly in furnace
- Normalizing
  - 870˚C/ 900˚C Cool in air
- Hardened & Tempered: 820˚C/ 870˚C Oil quench; Tempering Not usually below 430˚C and up to 700˚C according to the properties required.

Alloy AISI/SAE 4140-4145 (UNS G 41400-G 41450)	Mechanical Properties - Heat treated to HRC 22 max for sour gas service. E-4140 Aircraft quality vacuum degassed to AMS 2301. Magnetic particle tested. Minimum tempering temp 1150˚ F. Conforms to NACE Standard MR01-75 Also meets the tensile requirements of C75 and L80			
Size - inches	2 1/4" Dia	3 3/4" Dia	6" Dia	10" Dia
Tensile Strength, psi	106,600	108,177	108,118	105,102
Yield Strength, psi	92,060	88,834	86,424	82,405
Elongation (%)	25.0	28.7	26.7	31.0
Reduction of Area (%)	69.0	66.7	67.0	66.4
Hardness RC	21	18	18	18
Charpy V-Notch at -50˚F	113-105-94	56-56-41	56-56-60	16-21-16
Reduction Ratio	70:1	37:1	13:1	10:1

Alloy AISI/SAE 4140-4145 (UNS G 41400-G 41450)	Mechanical Properties - Heat Treated and Stress Relieved to requirements of ASTMA434CLBD/ BC ≥3" To 9 1/2" Dia, Typical			
Size - inches	3 1/2" dia	5 3/4" dia	7 1/2" dia	10 1/2" dia
Tensile Strength, psi	156,572	149,714	140,571	147,616
Tensile Strength, N/mm²	1080	1032	969	1018
Yield Strength, psi	123,999	114,857	110,286	113,792
Yield Strength, N/mm²	855	792	760	785
Elongation (%)	17	15	18	16
Reduction of Area (%)	53.6	53.7	53.6	42.4
HB	321	311	293	302
Machinability	55	55	55	55

Alloy AISI/SAE 4140-4145 (UNS G 41400-G 41450)	Mechanical Properties - Heat treated to requirements of ASTM A.193 Grade B7 - ≤3" Dia, Typical			
Size - inches	3/8" dia.	1 1/8" dia	2" dia	3" dia
Tensile Strength, psi	154,000	131,000	140,000	135,000
Tensile Strength, N/mm²	1063	903	965	931
Yield Strength, psi	142,000	119,000	126,000	108,000
Yield Strength, N/mm²	979	820	869	745
Elongation (%)	20	18	18	19
Reduction of Area (%)	57	55	56	55
HB	311	269	286	277
Machinability	35	35	35	35

Alloy AISI/SAE 4140-4145 (UNS G 41400-G 41450)	Mechanical Properties - Annealed - Typical			
Size - inches	1" dia.	2" dia.	4" dia.	8" dia.
Tensile Strength, psi	98,000	102,000	101,000	100,000
Yield Strength, psi	61,000	62,000	57,000	58,500
Elongation (%)	23	26	25	21
Reduction of Area (%)	54	55	56	59
HB	197	212	202	197
Machinability	66	66	66	66

Alloy

4145 Drill Collar Bars

Alloy AISI 4145 H MODIFIED HTSR	*- Solid Drill Collars to API Spec 7*					
Typical Analysis						
4" - 6 1/4" dia	C	Mn	P+ S	Si	Cr	Mo
	.42/.49	.80/1.10	.025Max	.15/.35	.75/1.20	.15/.25
6 3/8" - 7" dia	C	Mn	P+ S	Si	Cr	Mo
	.42/.49	.85/1.15	.025Max	.15/.35	.85/1.15	.25/.35
7 1/8" - 10" dia	C	Mn	P+ S	Si	Cr	Mo
	.42/.49	.85/1.20	.025Max	.15/.35	.85/1.15	.25/.35
10 1/8" - 11" dia	C	Mn	P+ S	Si	Cr	Mo
	.42/.49	1.00/1.30	.025Max	.15/.35	1.00/1.30	.25/.35
Characteristics	– Drill collar bars are usually supplied in lengths of 31'0"/31'6" with a straightness tolerance of 125" in 5 ft. The heat treatment is by water quenching, tempering and stress relieving to the mechanical properties detailed below. Tensile and impact specimens are taken within 3 ft. of the end of the bar and at 1" below the surface. Tensile and impact testing is determined on the basis of one test per 10 bars per heat, per heat treatment lot. Bars are surface hardness tested at both ends, 9 ft. from each end. All bars are individually identified.					

Alloy AISI 4145 H MODIFIED HTSR	Mechanical Properties - Typical	
Size - inches	4 3/4" Dia	6 1/2" Dia
Tensile Strength, psi	156,509	148,884
Yield Strength, psi	137,452	126,020
Elongation (%)	19.6	18.6
Charpy V-Notch Ft/lb/J	52-52-51 ft/lbs	50-51-52 ft/lbs
Hardness HB	311	302

Alloy AISI 4145 H MODIFIED HTSR	Mechanical Properties - Specified	
Size - inches	Through 6 7/8" Dia	Over 6 7/8" Dia
Tensile Strength, psi	140,00	135,000
Tensile Strength, N/mm²	965	930
Yield Strength, psi	110,000	100,000
Yield Strength, N/mm²	759	689
Elongation (%)	13	13
Impact values at R.T.		
Izod ft/lbs/Joules		
Charpy V-Notch Ft/lb/J	40/54 Min	40/54 Min
Hardness HB	40/54 Min	40/54 Min
1/8" below surface	285/ 341	285/ 341
1" below surface	285 min	285 min

Alloy

4150 Calcium Treated

Alloy AISI 4150 CALCIUM TREATED HTSR	*- a '50' Carbon Chromium-Molybdenum Alloy Steel with Improved Machinability*
Typical Analysis	C: .50 · Mn: .85 · P: .020 · S: .06/.1 · Si: .30 · Ni: .95 · Cr: .20
Characteristics	– A general purpose alloy machinery steel with improved machinability as a result of an aim sulfur content. The product may or may not include the injection of a minute quantity of calcium. The calcium treatment modifies the sulfide inclusions in the steel to a much more globular form. Calcium also combines with the aluminates to form softer inclusions. The net effect (sulfur and calcium) is improved machinability and longer tool life. – Bars are supplied in the heat treated and stress relieved condition to a hardness level of approximately HB300 and are suitable for many service applications where strength and toughness are required
Typical Applications	– Shafts, gears, pinions, spindles, axles, bolting, etc
Typical Heat Treatment	– Hardening - 860˚C/1580˚F. Water Quench – Tempering - 550˚C/1022˚F. Air Cool – Stress Relieving - 450˚C/842˚F
Mechanical Properties	– HTSR - Typical – Tensile Strength – 50,000 psi – Yield Strength – 23,000 psi – Elongation – 20% – Reduction of Area – 52% – Hardness – HB302/Rockwell 'C' 32

Alloy

4330+V

Alloy Grade 4330+V	*- a Nickel-Chromium-Molybdenum-Vanadium Alloy Steel*
Typical Analysis	C .30 · Mn .85 · P .010 · S .005 · Si .25 · Ni 1.95 · Cr .90 · Mo .45 · V .08
Characteristics	– This steel is a modified Grade 4330 product with enhanced nickel, chromium, molybdenum and vanadium additions. The combination of chemistry and controlled heat treatment conditions result in an optimized combination of strength and toughness. This product is bested selected for highly stressed and demanding fatigue applications. Grande 4330 + V was developed for enhanced room temperature as well as low temperature Charpy-V-Notch performance. This product is available only in heat treated condition.
Typical Applications	– Highly stressed parts requiring enhanced toughness and fatigue properties
Mechanical Properties	– Grade 4330+V is available in two strength combinations: – Yield Strength, Minimum – 150/160 (10" Diameter Maximum) – Tensile Strength, Minimum –150,000 psi – % Elongation, Minimum – 160,000 psi – % Reduction of Area, Minimum – 14 – C-V-N, Room Temperature – 50 – Longitudinal ft-lbs, minimum – 45

Alloy

4340

Alloy AISI/SAE 4340 (UNS G 43400) & E04340 (UNS G43406)	*- a Nickel-Chromium-Molybdenum Alloy Machinery Steel*

Typical Analysis

C	Mn	P	S	Si	Ni	Cr	Mo
.40	.70	.020	.020	.25	1.80	.80	.25

Characteristics

- Richly alloyed heavy-duty steel, this nickel-chromium-molybdenum alloy possesses much deeper hardenability than the 4100 series, with increased ductility and toughness. These advantages are realized principally where high strength is required in heavy sections.
- Also the high fatigue strength of 4340 makes it ideal for all highly stressed parts in the most severe conditions. It may be used in both elevated and low temperature environments; and has good wear resistance.
- For special service conditions or where material may be subject to magnetic particle inspection we stock Aircraft Quality E-4340 to MIL-S- 5000 and AMS 2301 in condition E.I (Hot rolled Normalized and Tempered) to HB 235 max. AISI 4340 is stocked in the heat treated and stress-relieved condition at approximately 150,000 psi (1034 N/mm2) and in the annealed condition at HB 235 max.

Typical Applications

- High strength machine parts, heavy-duty shafting, high tensile bolts and studs, gears, axle shafts, crankshafts, boring bars and down-hole drilling components

Typical Heat Treatment

- Forging
  - Commence 1200˚C max.
  - Finish 950˚C
- Normalizing
  - 870˚C/ 900˚C
- Hardened & Tempered: (Owing to the air-hardening properties of AISI 4340, normalizing is not recommended except when followed by tempering.) 810˚C/860˚C. Oil quench.

Mechanical Properties

- Annealed Typical
- Tensile Strength - 80,000 psi
- Yield Strength - 80,000 psi
- Elongation - 28%
- Reduction of Area - 57%
- Hardness - 22 Rc Max, surface

Alloy AISI/SAE 4340 (UNS G 43400) & E04340 (UNS G43406)	Mechanical Properties - Annealed - Typical			
Size - inches	1" dia	2" dia	4" dia	8" dia
Size - mm	25.4 mm	50.8 mm	101.6 mm	203.2 mm
Tensile Strength, psi	114,000	110,000	106,000	104,000
Tensile Strength, N/mm²	786	758	731	717
Yield Strength, psi	91,000	86,000	85,500	81,500
Yield Strength, N/mm²	627	593	590	562
Elongation (%)	20	23	21	22
Reduction of Area (%)	46	49	50	48
HB	229	223	217	217
Machinability	55	55	55	55

Alloy AISI/SAE 4340 (UNS G 43400) & E04340 (UNS G43406)	Mechanical Properties - Heat Treated and Stress Relieved to ASTM A 434 - Typical.			
Size - inches	2” dia	3 3/4" dia	7" dia	10" dia
Size - mm	50.8 mm	95.25 mm	177.8 mm	254 mm
Tensile Strength, psi	162,000	155,904	145,152	144,256
Tensile Strength, N/mm²	1117	1075	1000	995
Yield Strength, psi	145,000	141,568	111,104	124,544
Yield Strength, N/mm²	1000	976	766	858
Elongation (%)	16	19	17	18
Reduction of Area (%)	50	55	47	45
HB	331	321	302	302

Alloy AISI/SAE 4340 (UNS G 43400) & E04340 (UNS G43406)	Mechanical Properties - Normalized and Tempered - Typical. E-4340 AQ MIL-S-5000	
Size - inches	2" dia	4" dia
Tensile Strength, psi	116,000	112,000
Yield Strength, psi	94,000	87,500
Elongation (%)	20	21
Reduction of Area (%)	53	52
HB	235	229

Alloy
8620

Alloy AISI/SAE 8620	*- a Nickel-Chromium-Molybdenum Case Hardening Alloy Steel*
Typical Analysis	C .20 · Mn .80 · P .020 · S .0025 · Si .25 · Ni .55 · Cr .50 · Mo .20
Characteristics	– The most widely used alloy case-hardening steel, which may be carburized and hardened to produce a hard wear resistant case combined with core strength of the order of 125,000 psi (862 N/mm2). Uniform case depth, hardness and wear properties with minimum distortion are characteristics of this grade. The steel may also be used, not carburized, in a variety of general applications where a '20' carbon alloy is desirable.
Typical Applications	– Heavy-duty gears, pinions, spline shafts, piston pins, transmission components, rock drilling bit bodies, plastic molds, etc.

Typical Heat Treatment	– Forging
	  – Commence 1200˚C max.
	  – Finish 950˚C
	– Annealing
	  – 840˚C Furnace cool
	– Normalizing
	  – 900˚C Air cool
	– Hardened & Tempered (Uncarburized) - Heat to 816˚/ 840˚C, , oil or water quench, temper at 200˚/650˚C according to properties required
	– Carburizing - Direct oil quench - Carburize at 900˚/925˚C for eight hours (for .060 case depth). Oil quench. Temper at 150˚/232˚C
	– 150˚C - Case hardness approx. RC 63
	– 232˚C - Case hardness approx. RC 58.

Availability	– Grade 8620 is typically available Hot Rolled, As Rolled. – Larger diameters are Hot Forged, As Forged.

Alloy

EN30B

Alloy EN30B - BS 970 GRADE 835M30 BAR	*- a 4 1/4% Nickel-Chromium-Molybdenum Alloy Steel*

Typical Analysis

C	Mn	P	S	Si	Ni	Cr	Mo
.28/.33	.40/.60	.025x	.015x	.10/.35	4.0/4.3	1.1/1.24	.02/.40

Characteristics

- This product is stocked in two heat treat conditions:
  - Quench and tempered
  - Annealed
- EN30B may be carburized if extra wear resistance is required.
- This steel may be calcium treated.
- * EN30B is produced to AQ, AMS 2301 cleanliness level.

Typical Applications

- Down-hole tools, heavy duty construction tools, rock drilling bit bodies, highly stressed gears and transmission components, heavy duty shafts and rolls.

Typical Heat Treatment

- Forging - Commence 1200˚C (2190˚F) Max.
- Double Annealing - Austenitize 850˚ to 865˚C (1560˚F to 1590˚F)
  - For best, air Cool to approximately 40˚C (100˚F)
- Machinability: Double Anneal at 635˚C to 650˚C (1175˚F to 1200˚F)
  - Do not exceed 660˚C (1220˚F)
  - A Hardness of 269 HB Max is achievable.
- Normalize, Temper & Stress Relieve - Austenitize 850˚C to 865˚C (1560˚F to 1590˚F).
  - Air cool to room temperature
  - Temper 530˚C (990˚F), air cool
  - Stress Relieve 500˚C (930˚F), air cool
- Hardened & Tempered Austenitize 850˚C to 865˚C (1560˚F to 1590˚F) Forced air cool or oil quench. Temper at 200˚C (400˚F), air cool.

Mechanical Properties

- Measured at 1" below the surface

Alloy EN30B - BS 970 GRADE 835M30 BAR	Mechanical Properties - Quench, Tempered & Stress Relieved - Typical - Annealed - Typical - HB 269 Maximum	
Size - inches	Up to and including 10" dia.	Greater than 10" Dia
Yield Strength, psi	135,000 psi	130,000 psi
Ultimate	160,000 psi	150,000 psi
Elongation (%)	13%	13%
Reduction of Area (%)	50%	45%
CVN at -50°F	15 ft-lbs	15 ft-lbs
CVN at Room Temperature	45 ft-lbs	45 ft-lbs
Hardness	HB321 to 363	HB321 to 363

* Note that the mechanical properties of EN30B bar exceeding 10" dia. are on an "aim to" basis.

Alloy

E52100

Alloy AISI/SAE 52100 (UNS G52986)	*- High-Carbon, Chromium Alloy*
Typical Analysis	C .98/1.10 · Mn .25/.45 · P .025 Max · S .025 Max · Si .15/.30 · Cr 1.3/1.6
Characteristics	– This high carbon, chromium alloy is stocked in the annealed condition. – This grade is manufactured by the electric furnace process. Typically the quenched hardness is 62 to 66 HRC depending mainly upon section thickness
Typical Applications	– Grade E52100 is used primarily for races and balls or rollers of rolling-element (anti-friction) bearings. The grade is also suitable for parts requiring high hardness and wear resistance
Typical Mechanical Properties (Annealed)	– Yield – 85,000 psi – Tensile – 105,000 psi – Elongation – 17% – Reduction Area – 50% – BHN at surface– 228

Aluminum Extrusions

Aluminum Squares and Rounds Only

6061

Aluminum 6061 - ASTM B221, AMS 4150	*- Alloy & Temper 6061-T-6 Solution heat-treated and artificially aged.*

Typical Analysis

Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
BAL	.4/.8	.7	.15/.4	.15	.8/1.2	.04/.35	.25	.15

Characteristics

- This is the least expensive and most versatile of the heat-treatable aluminum alloys and offers a good range of properties. It is generally selected where welding or brazing is required and for its high corrosion resistance.

Typical Applications

- General engineering and structural components. Trucks and trailers. Boats.
- Furniture. Pipe fittings. Miscellaneous parts requiring good corrosion resistance.

Mechanical Properties

- Minimum Properties:
  - UTS Yield – 38 ksi, 35 ksi
  - Elongation in 2” – 8%-10%
- Typical Properties:
  - UTS Yield – 45 ksi, 41 ksi
  - Elongation in 2” – 12%-17%
  - Shear Strength – 30 ksi

Aluminum

Bar Data Table

Aluminum Grade 6061 and 6063 Weight Table			
Diameter (inches)	Decimal (inches)	Section Area (sq. in.)	Weight (lbs/ ft.)
3/8	0.375	0.110	0.133
1/2	0.500	0.196	0.236
5/8	0.625	0.307	0.367
3/4	0.750	0.442	0.529
7/8	0.875	0.601	0.721
1	1.000	0.785	0.940
1 1/8	1.125	0.994	1.164
1 1/4	1.250	1.227	1.470
1 3/8	1.375	1.484	1.780
1 1/2	1.500	1.766	2.120
1 3/4	1.750	2.404	2.880
2	2.000	3.140	3.780
2 1/4	2.250	3.974	4.830
2 1/2	2.500	4.906	5.880
2 3/4	2.750	5.937	6.990
3	3.000	7.065	8.800
3 1/8	3.125	7.666	9.200
3 1/4	3.250	8.292	9.940
3 1/2	3.5 0	9.616	11.500
3 3/4	3.750	11.039	12.989
4	4.000	12.560	15.100
4 1/8	4.125	13.357	16.040
4 1/4	4.250	14.179	17.160
4 1/2	4.500	15. 896	19.100
4 3/4	4.750	17.712	21.010
5	5.000	19.625	23.091
5 1/8	5.125	20. 619	24.750
5 1/2	5.500	23.746	27.990
6	6.000	28.260	33.900
6 1/8	6.125	29. 450	35.360
6 1/4	6.250	30.664	36.820
6 1/2	6.500	33.166	38.980
7	7.000	38.465	45.170
7 1/2	7.500	44.156	52 .130
8	8.000	50.240	60.320
8 1/2	8.500	56.716	67.250
9	9.000	63.585	74.740
9 1/2	9.500	70.846	83.400
10	10.000	78.500	94.330
12	12.000	113.040	133.240

Bronze Cast

Bronze

SAE660 Bearing

SAE660 Bearing Bronze (UNS C93200)	
Typical Analysis	Cu: 83%; Sn: 6.9%; Pb: 7.0%; Zn: 2.5%
Characteristics	– Produced conforming to ASTM B505, SAE660 Bearing Bronze (Bars and Tubes). Produced oversized. to finish, machine to the nominal size ordered. – Density: 0.322 lb/in3 at 68°F; 8.91 g/cm3 at 20°C
Typical Applications	– Industrial Machinery & Equipment Market: In-plant Equipment, Industrial Valves & Fittings, Turbines, Off-highway Vehicles – Products: Bushings, Plumbing Valves, Air Brakes, Brass Anodes for Plating, Brass Plating of Steel Belts in Tires, Wear Plates in Cranes, Hydraulic Seals, Gears, Bearings, Valve Stems, Turbine seals, Flanges – Transportation Equipment Market: Automotive Non-electrical, Railroad, Marine, Aircraft – Products: Motors, General Hardware, Carburetor Assemblies, Fittings – Military Market: All Specified Military Applications – Water Handling Equipment: Alloys used in Marine service and products such as seawater piping, pumps, valves, etc – Special Market (Fastest Growing Market) Products: Food Processing Equipment, Hydraulic Seals, Plumbing Valves, Wear Plates and Guides.
Mechanical Properties	– Yield - 18,000 psi – Tensile Strength - 35,000 psi – Elongation - 20% – Hardness - 60-70 HBN

Bronze

Aluminum Bronze Alloy 954

ALUMINUM BEARING BRONZE, ALLOY 954 (UNS C95400)			
Typical Analysis	Cu	Fe	Al
	85%	4.0%	11.0%
Characteristics	– Produced conforming to ASTM B505, Alloy 954 Aluminum Bronze is produced oversized to finish, machine to the nominal size ordered. – Density: 0.340 lb/in3 at 68°F; 9.41 g/cm3 at 20°C		
Typical Applications	– adjusting nuts – agitators – ball socket seats collets – blanks and rolls – boring tools – cam followers and slides – chuck Jaws – chutes – collets – cylinder mold tie rods – die rings – draw dies – fasteners – fingers – fittings – farming rolls and sections	– gibs and ways – guide pins – hold down bars – hydraulic valve parts – inserts – keys – lathe beds – liners – machine tool parts – mandrels – pickling hooks – pilots – piston guides – plastic mold applications – plungers – pump rods	– runout table slides – scraper blades – screw down nuts – shoes – slides – steel mill slippers – strike plates – support rails – brine slurry equipment tie rods – unscrewing mold components – wear plates and strips – welding jaws – wipers – wiping blocks – work rest blades
Mechanical Properties	– Yield - 35,000 psi – Tensile Strength - 85,000 psi – Elongation - 18% – Hardness - 140-170 HBN		

Carbon Steels

Carbon

1018

Carbon AISI/SAE 1018 (UNS S10180)	*- a Special Quality Low-Carbon Machinery Steel*
Typical Analysis	C .18 · Mn .57 · P .020 · S .030 · Si .22
Characteristics	– Produced to the requirements of ASTM A576 , this special bar quality, low-carbon machinery steels, is extremely versatile. It machines well and is easily weldable. The steel grade can be carburized
Typical Applications	– Bearing in mind the tensile strength of approximately 60,000 psi (414 N/mm^2), the steel is suitable for a wide variety of general engineering parts, shafts, studs, bolts, tie-rods etc
Mechanical Properties	– Typical as supplied – Tensile Strength - 58,000 psi – $_2$Tensile Strength - 400 N/mm^2 – Yield Strength - 32,000 psi – $_2$Yield Strength - 220 N/mm^2 – Elongation - 25% – Reduction of Area - 50% – Hardness - HB 116
Comment	– This product may also conform to the requirements of ASTMA36 complete with the mechanical property requirements detailed below – Tensile Strength - 58,000 - 80,000 psi – Yield Strength - 36,000 psi minimum, 250 Mpa minimum – Elongation minimum - 20%

Carbon

1018 Cold Finished

Carbon AISI/SAE 1018 COLD FINISHED (UNS G10180)	*- Cold Drawn '20' Carbon Steel, available in all bar sections*
Typical Analysis	1018: C .18, Mn .70, P .022, S .024 1020: C .20, Mn .50, P .017, S .025
Characteristics	– Most cold finished bars are produced by cold drawing oversize hot rolled bars through a die. The cold reduction of the bar results in significantly improved mechanical properties, with a smooth surface finish to close tolerances. The cold working of the bar likewise improves machinability, usually rated at 76. Larger bars are often produced by turning and polishing only. In this case, the properties of the steel are not improved and remain the same as the original hot rolled, special quality bar. The product is easy to weld and readily responds to carburizing. Cold finished product is manufactured in conformance to ASTM A108
Typical Applications	– All forms of shafting and machinery parts. When carburized - gears, pinions, king pins

Carbon AISI/SAE 1018 COLD FINISHED (UNS G10180)	Size Tolerances -Rounds Tolerances *- all tolerances are MINUS*
11/2" dia. (38.1 mm) and under	Minus 0.002” (.050 mm)
Over 1 1/2" dia. to 2 1/2" dia (63.5 mm)	Minus 0.003” (.075 mm)
Over 2 1/2" dia. to 4" dia (101.6 mm)	Minus 0.004” (.100 mm)
Over 4" dia. to 6" dia (152.4" mm)	Minus 0.005” (.125 mm)
Over 6" dia. to 8" dia (203.2 mm)	Minus 0.006” (.150 mm)

Carbon AISI/SAE 1018 COLD FINISHED (UNS G10180)	Mechanical Properties - Expected minimum properties - Cold Drawn		
Size - inches	1" dia	2" dia	3" dia
Size - mm	25.4	50.4	76.2
Tensile Strength, psi	65,000	60,000	55,000
Tensile Strength, N/mm²	448	414	379
Yield Strength, psi	55,000	50,000	45,000
Yield Strength, N/mm²	379	345	310
Elongation (%)	16	15	15
Reduction of Area (%)	40	35	35
HB	131	121	111

Carbon AISI/SAE 1018 COLD FINISHED (UNS G10180)	Mechanical Properties - Typical properties of material supplied - Cold Drawn		
Size - inches	1" dia	2" dia	3" dia
Size - mm	25.4	50.4	76.2
Tensile Strength, psi	91,000	84,000	74,000
Tensile Strength, N/mm²	627	579	510
Yield Strength, psi	73,000	68,000	60,000
Yield Strength, N/mm²	503	469	414
Elongation (%)	14.4	16.2	20.7
Reduction of Area (%)	52.1	48.5	49.4
HB	187	183	163

Carbon

1040-1045

Carbon AISI/SAE 1040-1045 (UNS G10400-G10450)	*- a Special Bar Quality Medium-Carbon Machinery Steel*
Typical Analysis	C .40 Mn .75 P .020 S .030 Si .25
Characteristics	– General purpose, fine grain, machinery steel suitable for a wide range of applications in the condition as supplied - approximately 90,000 psi (620 N/mm2) depending on the size of section. This steel is primarily water- hardening, but may also be quenched in oil. Excellent wear resistance can be obtained by flame or induction hardening. Care required if welding, due to higher carbon content. Good machinability
Typical Applications	– Shafts, axles, spindles, bolts, lightly stressed gears, machined parts of all types.
Typical Heat Treatment	– Forging - Commence 1150˚C Max finish 925ºC. – Annealing - 800˚ to 830˚C Surface cool – 870/ 915˚C air Cool – Normaling - 830˚C to 850˚C water quench – Hardening - 850˚C to 870˚C oil quench. – Tempering - 425˚C to 870˚C according to properties
Mechanical Properties	– Typical - as supplied – Tensile Strength - 90,000 psi (620 N/mm^2) – Yield Strength - 23,000 psi (410 N/mm^2) – Elongation - 25% – Reduction of Area - 50% – Hardness - HB 201 – Machinability - 65

Carbon Cold Finished

1045 TG&P

Carbon AISI 1045 PRECISION GROUND SHAFTING (UNS G 10450)	*- Ground and polished shafting supplied in fibre tubes*
Typical Analysis	C .47 · Mn .75 · P .030 · S .035 · Si .25
Characteristics	– This high strength precision ground shafting is produced to exacting size and straightness tolerances. The product offers the highest degree of overall accuracy and concentricity with a seam free surface finish of RMS 25 max. Precision ground shafting C1045 is available from 1/2" - 615/16"dia. with tensile strength ranging from 90,000 to 115,000 psi (621/793 N/mm2). A first class product at an economical price. Cold finished product is manufactured in conformance to ASTM A108.
Typical Applications	– All forms of close tolerance shafting: camshafts, drive shafts, mill shafts, motor shafts, pump shafts, bolts, pins, studs etc.

Carbon AISI 1045 PRECISION GROUND SHAFTING (UNS G 10450)	Size Tolerances *- all tolerances are MINUS*
1 1/2" dia. (38.1 mm) and under	Minus 0.001” (.025 mm)
Over 1 1/2" dia. to 21/2" dia (63.5 mm)	Minus 0.0015” (.075 mm)
2 1/2" dia. to 3" dia (76.2 mm)	Minus 0.002” (.050 mm)
Over 3" dia. to 4" dia (101.6 mm)	Minus 0.003” (.75 mm)
Over 4" dia. to 6" dia (152.4" mm)	Minus 0.004” (.125 mm)
Over 6" dia. to 7" dia (177.8 mm)	Minus 0.005” (.150 mm)

Carbon AISI 1045 PRECISION GROUND SHAFTING (UNS G 10450)	Mechanical Properties - Typical as supplied		
Size - inches	1" dia	3" dia	7" dia
Size - mm	25.4	76.2	177.8
Tensile Strength, psi	115,000	102,500	90,000
Tensile Strength, N/mm^2	793	707	620
Yield Strength, psi	94,000	79,000	59,000
Yield Strength, N/mm^2	648	524	407
Elongation (%)	18	17	18
Reduction of Area (%)	34	42	35
HB	229	212	187
Machinability	64	64	64

Carbon Cold Finished

1045 Chrome Plated Shafting

Carbon AISI/SAE 1045 CHROME PLATED SHAFTING	*- This product is available in both imperial and metric sizes*
Typical Analysis	C .45 / Mn .75 / P .030 / S .040 / Si .20
Characteristics	– The basic product is cold drawn, precision ground and polished AISI 1045 shafting with a seam free surface finish of RMS 25 max. The bars are then hard chrome plated by electrolytically deposited layer of chromium metal on the surface. This hard chromed surface confers the important properties of corrosion resistance and wear resistance; it is also very smooth and therefore has a low coefficient of friction. Not least of all, it has an attractive and durable decorative appearance.
Typical Applications	– Hydraulic shafting, pneumatic piston rods, pump shafting, etc
Chrome Plating	– Finished thickness of – .0005" min per side (Winnipeg Branch: 0.001”min per side) – Hardness of chrome – Rockwell C 65/70 – Surface finish – RMS 12 max

Carbon AISI/SAE 1045 CHROME PLATED SHAFTING	Size Tolerances *- Despite the chrome plating, the same fine minus tolerances of AISI 1045 Precision Ground Shafting apply* *- all tolerances are MINUS*
1 1/2" dia. (38.1 mm) and under	Minus 0.001” (.025 mm)
Over 1 1/2" dia. to 21/2" dia (63.5 mm)	Minus 0.0015” (.037 mm)
2 1/2" dia. to 3" dia (76.2 mm)	Minus 0.002” (.060 mm)
Over 3" dia. to 4" dia (101.6 mm)	Minus 0.003” (.075 mm)

Carbon Cold Finished

1045 Induction Hardened

Carbon AISI/SAE 1045 INDUCTION HARDENED AND CHROME PLATED SHAFTING	*- Induction Hardened and Chrome Plated Precision Ground Shafting, supplied in fibre tubes* *- This product is available in both imperial and metric sizes*
Typical Analysis	C .45 Mn .75 P .030 S .040 Si .20
Characteristics	– As with chrome plated shafting, the basic material is cold drawn, precision ground and polished AISI 1045 shafting. It is first induction hardened which results in surface hardness of approx. Rockwell C 55. – This improves the properties of the bar and the extra hardness ensures superior wear resistance. The bars are then hard chrome plated in the same way as chrome plated shafting with the same advantages of corrosion and wear resistance. However, the induction hardened bar will give superior service
Typical Applications	– Hydraulic shafting, oil and water pump shafting, rotary pump shafts, and piston rods
Chrome Plating	– Finished thickness of – .0005" min per side (Winnipeg Branch: 0.001”min per side) – Hardness of chrome – Rockwell C 65/70 – Surface finish – RMS 12 max
Induction Hardening	– Case Depth – .050” min – Case Hardness – Rockwell C50 min
Tolerances	– Allowance is made for the chrome plating and standard minus tolerances – apply as ASTM A29, Table A1.12 – See AISI 1045 Chrome Plated Shafting
Mechanical Properties	– Typical 75,000 psi minimum yield strength

Carbon Cold Finished

1144

Carbon AISI/SAE 1144 COLD DRAWN (UNS G 11440)	*- A High-Strength Re-sulphurized Carbon/Manganese Steel (Available in round bar)*
Typical Analysis	C: .44 · Mn: 1.50 · P: .040 · S: .28 · Si: .22
Characteristics	– This product is severely cold worked to produce 100,000 psi minimum yield strengths. It can therefore compete for application and use in parts normally requiring heat treated alloy grades in the HB range 235/277. The bars are stress relieved to minimize warpage. The sulphur content enhances machinability. C1144 has excellent induction hardening properties. Welding is not recommended. Conforms to ASTM A311, Class B. Available in cold drawn and precision ground surface finishes
Typical Applications	– Arbors, keyed shafts, spindles, gears, pinions, pump shafts, machined parts in wide variety
Mechanical Properties	– Typical - as supplied, Not normally available over 4" dia. because of the cold working required – Tensile Strength - 125,000 psi (862 N/mm^2) – Yield Strength - 100,000 psi (690 N/mm^2) – Elongation - 12% – Reduction of Area - 20% – Hardness - HB 255 – Machinability - 82
Tolerances	– For cold finish tolerances See 1045 TG&P

Carbon

A105, A350 - LF2 DUAL

Carbon ASTM A105 & ASTM A350-LF2 DUAL CERTIFIED	*- a Special Quality Fine Grain Carbon-Manganese Steel for Piping Components*

Typical Analysis

A105 Spec.	C	Mn	P	S	Si
	.35 max	.60/1.05	.040 max	.05 max0	.35 max
A350-LF2 Spec.	**C**	**Mn**	**P**	**S**	**Si**
	.30 max	1.35 max	.035 max	.04 max0	.15/.30
A105/A350-LF2	**C**	**Mn**	**P**	**S**	**Si**
	.20	1.24	.009	.021	.18

Characteristics

- A105 and A350-LF2 are standard specifications for forged carbon steel piping components. A105 for ambient and higher-temperature service; A350-LF2 for low-temperature service with Charpy V-Notch impact energy testing. Components include flanges, various fittings and valves.
- Some components may be machined from hot rolled or forged bar, suitably heat treated, up to and including NPS 4. See details in the ASTM designations

Typical Applications

- A105 allows that for each .01% Carbon below .35, an increase of .06% Manganese is permitted over 1.05 to a maximum of 1.35. This explains the typical analysis above.

Typical Heat Treatment

- Forging - Commence 1150˚C Max finish 925ºC.
- Annealing - 800˚ to 830˚C Surface cool
  - 870/ 915˚C air Cool
- Normaling - 830˚C to 850˚C water quench
- Hardening - 850˚C to 870˚C oil quench.
- Tempering - 425˚C to 870˚C according to properties

Carbon ASTM A105 & ASTM A350-LF2 DUAL CERTIFIED	Mechanical Properties		
Spec	**A105**	**A350-LF2**	**A105/A350-LF2**
Tensile Strength Min, psi	70,000	70,000-95,000	70,000-95,000
Tensile Strength Min, N/mm²	485	485-655	485-655
Yield Strength, min psi	36,000	36,000	36,000
Yield Strength Min, N/mm²	250	250	250
Elongation (%)	22	22	22
Reduction of Area (%)	30	30	30
Hardness, maximum	187	15/12 ft-lbs	15/12 ft-lbs
CVN at -50°F		20/16 joules	20/16 joules

Carbon Cold Finished

C12L14

Carbon AISI/SAE C12L14 COLD FINISHED (UNS G 12144)	*- Low-Carbon Re-sulphurized and Leaded Free machining Steel (Screw Stock), available n rounds, hexagons and some squares*
Typical Analysis	C .09 Mn .95 P .07 S .30 Pb .25
Characteristics	– A leaded free-machining steel, essentially for manufacturing parts that require considerable machining/threading with close tolerances and a bright, smooth finish. It is especially suitable for automatic screw machines. Not recommended for forming or welding; or parts subject to severe fatigue stress. Cold finished product is manufactured in conformance to ASTM A108
Typical Applications	– Fasteners, bushings, inserts, couplings

Carbon AISI/SAE C12L14 COLD FINISHED (UNS G 12144)	Mechanical Properties - Expected minimum properties - Cold Drawn - No minimum values are specified.
Size	1" dia. (25.4 mm) Cold Drawn
Tensile Strength, psi	87,500
Tensile Strength, N/mm^2	603
Yield Strength, psi	75,000
Yield Strength, N/mm^2	517
Elongation (%)	15
Reduction of Area (%)	42
HB	179
Machinability	195

Cast Iron

Continuously Cast Iron

65-45-12 Ductile Iron

Continuously Cast Iron 65-45-12 Ductile Iron	
Typical Analysis	C: 3.6-3.9; Mn: 0.1-0.4; P: .10 max; S: .015 maxx; Si: 2.3-2.8; Percent
Characteristics	– Ferritic, as-cast, 65-45-12, ductile iron will be the softest of the regular grades of ductile iron. The matrix structure will contain some pearlite and less than 5% well dispersed carbides. In bars over 2 in. (51 mm) diameter the pearlite content will range up to 25%. This microstructure permits high speed machining with good surface finishes. .
Typical Applications	– Hydraulic-pump rotors, gear blanks, rams, machine-tool gibs, foundry patterns plates, ways, collets, valve bodies, manifolds, compressor valves, hydraulic cylinder bushings, rod bushings, etc..
Typical Heat Treatment	– Because of its ferritic structure, this material is not intended for hardening
Mechanical Properties	– As-cast 65-45-12, ductile iron has approximately the same tensile and yield strengths as hot rolled SAE 1035 steel in the as-rolled condition. Elongations in as-cast, 65-45-12 will be slightly lower than SAE 1035 steel in the as-rolled condition. This material is manufactured to produce material similar to ASTM specification A536. – Tensile tests are taken from the actual as-cast bar. – Tensile Strength (min)* - 65,000 psi – Yield Strength (min)* - 45,000psi – Elongation (min)* - 12% – * Determined as prescribed by ASTM standards.

Continuously Cast Iron 65-45-12 Ductile Iron	Hardness - Hardness properties listed are minimum, maximum across the bar. Hardness for shapes other than rounds will be supplied on request	
Bar Dia - inches	**Bar Dia - centimeters**	**BHN min to max**
1-2	2.5-5.1	152 to 212
2-3	5.1 - 7.6	152 to 201
3-6	7.6 - 15.2	143 to 201
6 - 10	15.2 - 25.4	131 to 201
10 - 19	25.4 - 48.2	131 to 201

Continuously Cast Iron

G2 - Highly Pearlitic Gray Iron

Continuously Cast Iron G2 - Highly Pearlitic Gray Iron	
Characteristics	– This specification covers a dense fine-grained gray iron produced by the continuous cast process. The "highly pearlitic" structure is developed by alloy additions to the electrically melted base iron. This material is suitable for applications where higher strength irons requiring good wear resistance and response to heat treatment are required.
Typical Applications	– Hydraulic-pump rotors, gear blanks, rams, machine-tool gibs, foundry patterns plates, ways, collets, etc.
Typical Heat Treatment	– This iron can be hardened by fast methods, such as flame and induction hardening, in addition to conventional quench and temper methods. Gray Iron can be oil quench hardened from 1575˚F (855˚C) to a Rockwell "C" 50 minimum on the outside diameter of the bar. The inside diameter hardness will be less than Rockwell "C" 50. Lower quench hardnesses on the inside diameters are a result of larger graphite flakes and not a loss of matrix hardness.
Mechanical Properties	– Machining characteristics of this alloy are excellent. Although the hardness of the material is generally higher than found in static castings, the close grain structure, its freedom from inclusions, hard spots and porosity permit superior machining speeds.

Continuously Cast Iron G2 - Highly Pearlitic Gray Iron	Mechanical Properties - Hardness - Hardness properties listed are minimum, maximum across the bar. Hardness for shapes other than rounds will be supplied on request.	
Bar Dia - inches	**Bar Dia - centimeters**	**BHN min to max**
3/4 - 1 1/2	1.9 -3.8	207 to 285
1 1⁄2 - 3	3.8 - 7.6	207 to 277
3-6	7.6 - 15.2	197 to 269
6 - 10	15.2 - 25.4	183 to 269
10 - 19	25.4 - 48.2	183 to 269

Continuously Cast Iron

80-55-06 Partially Pearlite Ductile Iron

Continuously Cast Iron 80-55-06 Partially Pearlite Ductile Iron		
Characteristics	– Grade 80-55-06 ductile iron will contain nodular graphite in a matrix of ferrite and pearlite. The pearlite/ferrite structure provides higher wear resistance and strength when compared to a ferritic grade of ductile iron. This material will be readily machinable with good surface finishes. Tensile and yield strengths will be similar to AISI 1040 steel in the as-rolled condition. This specification is similar to ASTM A536 grade 80-55-06.	
Typical Applications	Fluid Power:	Cylinder Blocks, Gerotors, Manifolds, Pistons, Glands, Rotors, Valve Bodies.
	Machinery:	Bushings, Chain Sheave Rollers, Chuck Bodies, Die Blocks, Gears, Gear Racks, Pulleys, Press Rams, Rotary Tables, Tie Road Nuts, Ways, Barrel Rollers (cement truck), Flywheels, Pile Drivers, Pulleys, Rams.
	Transportation:	Pulleys, Gears, Rail Spacers.
	Pump and Compressor:	Gears, Housings, Liners, Pistons, Rotary Screws.
	Steel Mill:	Guide Rolls, Pinch Rolls, Runout Table Rolls.
	Miscellaneous:	Disamatic Pouring Rails, Dies, Pattern Plates, Core Boxes, Grinding Rolls, Mill Liners.
Typical Heat Treatment	– Grade 80-55-06 can be oil quench hardened from 1600˚F (885˚C) to a Rockwell C 50 minimum on the outside of the bar. The inside diameter hardness will be less than Rockwell C50. Lower quench hardnesses on the inside diameters are a result of larger graphite nodules and not a loss of matrix hardness. Typical Jominy end quench test data are shown in the section on Heat Treating.	
Mechanical Properties	– The tensile strength is determined from a longitudinal test specimen taken from mid-radius of the as-cast bar. – Tensile strength (min) - 80,000psi – Yield strength (min) - 55,000psi – Elongation (min) – 6% – In bars under 1.5" diameter elongation will be 4-6%.	

Continuously Cast Iron

100-70-02 Pearlitic Ductile Iron

Continuously Cast Iron 100-70-02 Pearlitic Ductile Iron	*- Grade 100-70-02 is a non-inventoried item. A wide variety of sizes and shapes is available by special order*	
Characteristics	– Grade 100-70-02 ductile iron contains nodular graphite in a matrix of pearlite with small amounts of ferrite. The pearlitic structure maximizes strength and wear characteristics in a non-alloyed as-cast ductile iron. This specification is similar to ASTM A536 grade 100-70-03.	
Typical Applications	Fluid Power:	Cylinder Blocks, Gerotors, Manifolds, Pistons, Glands, Rotors, Valve
	Machinery:	Bushings, Chain Sheave Rollers, Chuck Bodies, Die Blocks, Gears, Gear Racks, Pulleys, Press Rams, Rotary Tables, Tie Road Nuts, Ways, Barrel Rollers (cement truck), Flywheels, Pile Drivers, Pulleys, Rams.(also see fluid power)
	Transportation:	Pulleys, Gears, Rail Spacers, Hubs, Carriers, Camshafts
	Pump and Compressor:	Gears, Housings, Liners, Pistons
	Steel Mill:	Guide Rolls, Pinch Rolls, Runout Table Rolls.
	Miscellaneous:	Disamatic Pouring Rails, Dies,
Typical Heat Treatment	– Grade 80-55-06 can be oil quench hardened from 1600˚F (885˚C) to a minimum hardness of Rockwell C 50 on the outside of the bar. The inside diameter hardness will be less than Rockwell C 50. Lower quench hardnesses on the inside diameters are a result of larger graphite nodules and not a loss of matrix hardness. Typical Jominy end quench test data for 80-55-06 ductile iron are shown in the section on Heat Treating. Similar data applies to 100-70-02.	
Mechanical Properties	– The tensile strength is determined from a longitudinal test specimen taken from mid-radius of the as-cast bar. – Tensile strength (min) - 100,000psi – Yield strength (min) - 70,000psi – Elongation (min) – 2%	

Continuously Cast Iron 100-70-02 Pearlitic Ductile Iron	Mechanical Properties - Hardness - Hardness properties for various diameters are shown in the table below. Hardness properties listed are minimum, maximum across the bar. For rectangles, squares and shapes, the hardness properties will depend on minimum and maximum section thickness and will be supplied on request.	
Bar Dia - inches	**Bar Dia - millimeters**	**BHN min to max**
01.000 - 20.000	25 - 508	241 to 329

Specialty

Special Products

4140 Mechanical Tubing

Specialty - AISI 4140 MECHANICAL TUBING	*- Heavy wall, seamless alloy tubing is available upon enquiry.*						
Typical Analysis	C	Mn	P	S	Si	Cr	Mo
	.38/.43	.75/.0	.35 Max	.04 Max	.15/.35	.8/.1	.15/.25
Characteristics	– Two grades of seamless 4140 mechanical tubing are available, cold finished and hot rolled surface condition – This product is cold drawn or hot finished. Seamless alloy tubing with the mechanical properties created by a quench and temper.						
Typical Applications	– Blast Joint						

Specialty - AISI 4140 MECHANICAL TUBING	*- Heavy wall, seamless alloy tubing is available upon enquiry.*	
Spec	L80/NACE MR-01-75	**P110**
Tensile Strength min, psi	80,000	110,000/ 140,000
Yield Strength min, psi	95,000	125,000
Elongation (%)	18	-
Hardness	RC 16/22 HBN 235 max	RC 28/36
CVN (Ft-lbs min aim)	15	30
Test Temp (˚F)	50	50

Special Products

Stainless Steel Ornamental Tubing

Specialty - Stainless Steel Ornamental Tubing	*- Type 304 Stainless 180 grit finish* *- Also available in grades 301, 302, 304L, 316, 316L, 321, 409, 430, 434. Other grades available upon request.*

Typical Analysis

C	Mn	P	S	Si	Cr	Ni
.8 Max	2.0 Max	.04 Max	.03 Max	1.0 Max	18-20	8-11

Characteristics

- The advantages of this stainless steel tubular product include:
  - High strength to weight ratio
  - Cold working increases yield strength of the original metal
  - Ease of fabrication (bending, flattening, flanging, forming)
  - High corrosion resistance
  - Ease of maintenance
  - Available in a range of surface finishes

Typical Applications

- Marine Equipment
- Restaurant Equipment
- Food Processing/Meat Packing
- Medical
- Automotive
- Furniture
- Construction supports, frames and buildings
- Display cases
- Racks and carts

Special Products

Staballoy AG17

Specialty - Staballoy AG17	*- For Non-Magnetic Drilling Components*
Nominal Analysis	C .03 · Mn 20 · Cr 17 · N_2 .50 · Si .30 · Mo .05
Characteristics	– Staballoy AG17TM is an austenitic type stainless steel specifically developed for use under onerous drilling conditions. Control of critical elements results in excellent resistance to chloride induced stress corrosion cracking in the most aggressive drilling environments. – Staballoy AG17TM is a purpose designed composition offering excellent resistance to galling under high torque conditions. Mechanical / Magnetic properties in accordance with API 7 / Industry Standards. Properties are consistent throughout the length of every collar. – Staballoy AG17TM is available with optional "XL" warranty against stress corrosion cracking.
Physical Properties	– The very high structural stability of the alloy ensures that magnetic permeability remains below 1.005. Hot Spot Guarantee - Every Collar is tested over its full length using a Foerster 1.068 magnetoscope and 1.005-4502 differential probe and is certified free from magnetic hot spots (maximum deflection — ±0.5 µT/100mm).
Warranty	– Staballoy AG17TM XL treated drill collars are offered with a three year warranty against chloride induced stress corrosion cracking. Warranty conditions available on request.
Galling	– Staballoy AG17TM has excellent galling resistance with critical galling pressure approximately 7 times that of the conventional austeratic stainless steels. Using a laboratory 'button on block' test technique, in accordance with ASTM G98 procedures, and in make and break tests on machined connections, a critical galling pressure of 35 ksi has been determined. This compares with a value of 5 ksi for a standard nickel beating austenitic stainless steel.
Mechanical Properties	– The required high strength is achieved by a combination of composition, control and strain hardening during processing. The guaranteed properties apply to the full length of every component. The following are guaranteed minima..

Specialty - Staballoy AG17	Mechanical Properties - Test material taken from 1 inch below outer surface or mid-wall (whichever is the smaller value). Tensile test to BS EN 10002 Part 1 or ASTM A370. Impact Tests to BS EN 10045 Part 1 or ASTM E23.		
Drill Collar Outside Diameter	**< 6.7/ 8 inches**	**7 to 11 inches**	**> 11 inches**
0.2% Proof Stress (ksi)	110	100	90
Maximum Stress (ksi)	120	110	100
Elongation %	18	20	20
Impact Energy (CV)	J60	60	60
Brinell Hardness	277	277	255

Specialty - Staballoy AG17 — *- For Non-Magnetic Drilling Components*

Stress Corrosion Cracking

- a) Intergranular Resistance to Integranular Stress Corrosion Cracking is achieved by careful control of chemical composition. Freedom from susceptibility is demonstrated by testing to ASTM A262, Practice E.
- b) Transgranular Staballoy AG17TM has excellent resistance to chloride induced SCC and is suitable for use in most onerous drilling conditions, eg high temperature / high chloride drilling muds. The laboratory data below illustrate the material's excellent corrosion resistance in a variety of test environments.
- The possibility of cracking increases as stress approaches yield point and for the most arduous conditions, bore surface treatment by the "XL" procedure is recommended to farther resist initiation of stress corrosion cracking

Corrodent	Stress MPa (ksi)	Test Duration (Hours)
60% CaCl2 @ 130˚C	301 (43.8)	> 5000 (not cracked)
Magnesium Chloride mud (20%) @ 115˚C	300 (43.5)	> 2000 (not cracked)
Saturated NaCl @ 106˚C	400 (43.5)	> 2000 (not cracked)

- (Samples of the constant strain tensile type)

Datalloy 2

Specialty -Datalloy 2	*- an Enhanced Corrosion Resistance Non-Magnetic Steel*

Typical Analysis

C	Mn	Cr	N	Si	Mo	Ni
.03	15.1	15.3	0.4	.30	2.1	2.3

Characteristics

- Datalloy 2TM is a Cr-Mn-N non-magnetic stainless steel. It has been specially developed to exhibit enhanced resistance to both pitting and galvanic corrosion. It is suitable for use in critical non-magnetic drill string components including MWD tools, LWD tools, stabilisers and compressive service drill pipe.
- Datalloy 2TM has been designed to be used in place of standard Cr-Mn steels, in situations where increased corrosion resistance is required. Also the chemistry of Datalloy 2TM ensures that galvanic corrosion caused by coupling to dissimilar metals is resisted.
- The increased nickel content of Datalloy 2TM does not adversely affect its resistance to Stress Corrosion Cracking or its galling performance.
- Datalloy 2TM complies, as a minimum, to the mechanical property requirements of API 7.
- The material is also available in a "High Strength" condition with a guaranteed minimum of 140 ksi 0.2% proof strength.

Structure

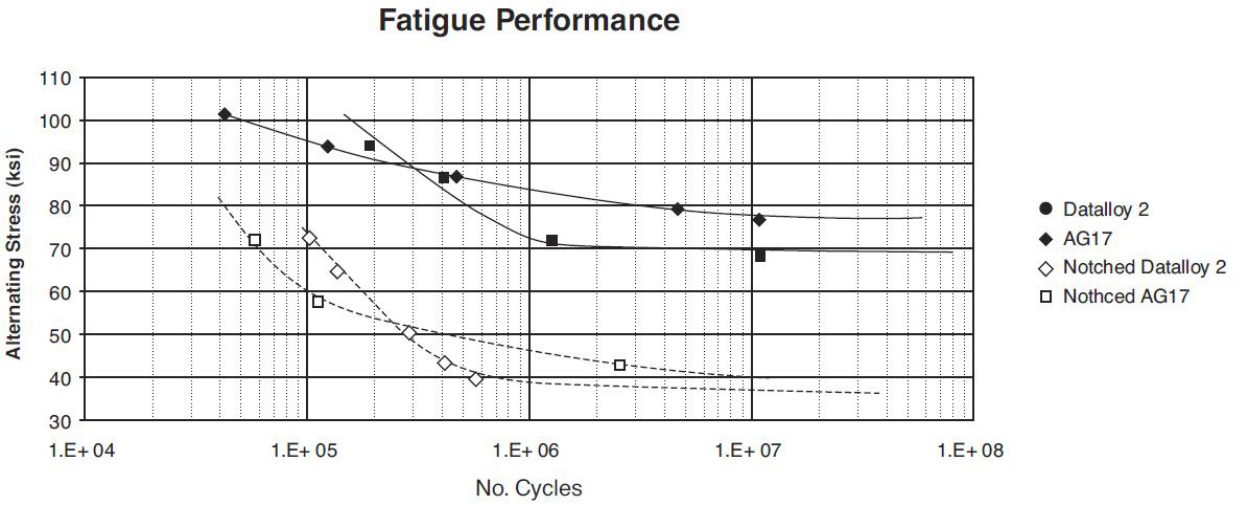
- Datalloy 2TM is a highly stable, austenitic stainless steel with a maximum magnetic permeability of 1.005.
- A combination of controlled hot forging and cold working generates the high proof strengths required in oilfield service. Datalloy 2TM cannot be hardened by heat treatment.
- Forging parameters are carefully designed to produce optimum pitting corrosion resistance through microstructural control.

Physical Properties

Modulus of Elasticity	200 GPa
Poisson's Ratio	0.4
Coefficient of Thermal Expansion	16 x 10-6 m/m/°K
Resistivity	680 µΩmm
Thermal Conductivity	0.035 W/m°K
Density	7.65 g/cm3
Relative Magnetic Permeability	1.005 max

Fatigue Performance

- Fatigue testing was performed using a Wöhler rotating bend test configuration, tested at 4000 cycles per minute. The Strength of the materials used are as below.
- In rotating bend Wöhler type fatigue tests, higher strength Datalloy 2TM with 0.2% proof strengths in excess of 140 ksi, has been shown to have a fatigue endurance limit in excess of ± 70 ksi.

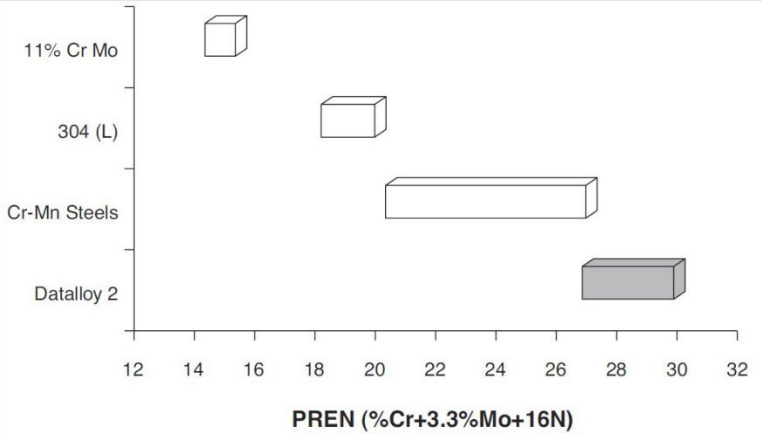


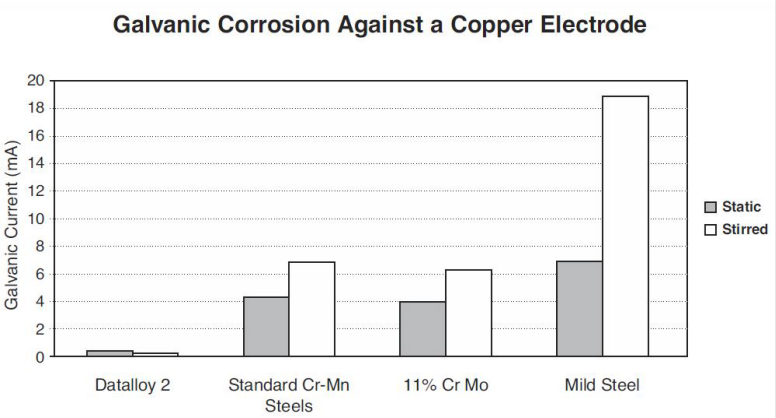
Specialty -Datalloy 2	Fatigue Performance
Material	**0.2% Proof Strength**
Datalloy 2TM	105 ksi
Staballoy AG17TM	116 ksi

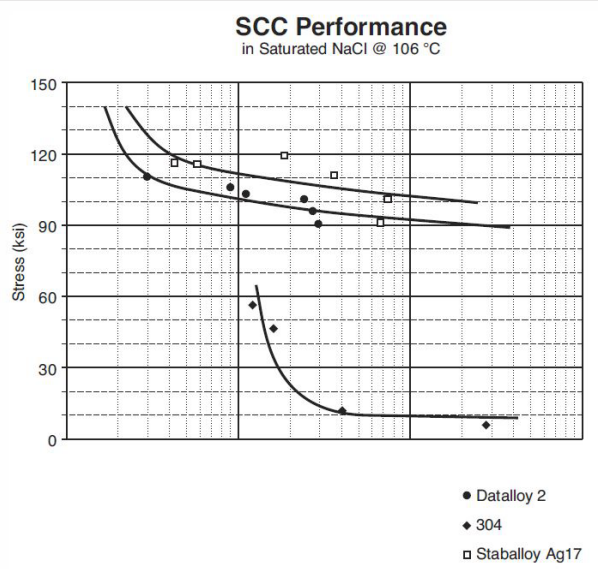
Specialty -Datalloy 2	Mechanical Properties Standard Strength.	
Size	**< 7 inches (Min-Typical)**	**> 7 inches (Min-Typical)**
0.2% Proof Stress (ksi)	110-125	100-115
UTS Stress (ksi)	120-148	110-135
Elongation %	18-33	20-35
Reduction of Area (%)	45-70	50-72
Longl. CVN at RT (J)	60-170	60-190
Hardness (HBN)	285-321	269-302

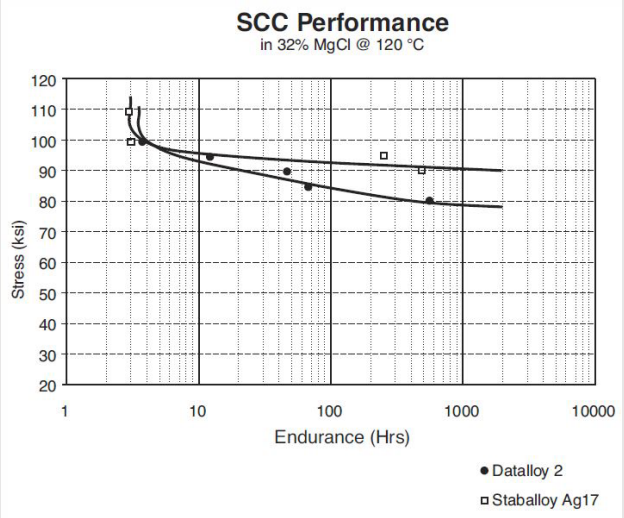
Specialty -Datalloy 2	Mechanical Properties High Strength.	
Size	**< 7 inches** (Min-Typical)	**> 7 inches** (Min-Typical)
0.2% Proof Stress (ksi)	140-148	135-145
UTS Stress (ksi)	150-162	145-160
Elongation %	18-28	20-30
Reduction of Area (%)	45-68	50-70
Longl. CVN at RT (J)	60-130	60-150
Hardness (HBN)	302-350	203-304

Specialty -Datalloy 2	Mechanical Properties Corrosion
Pitting Corrosion	– Pitting is caused by adverse localized conditions. Corrosion rate is dependent on the differential between oxidants in the pit and the supply of oxidants to the area around the pit. Thus highly oxidized muds, or stagnant muds which form deposits that deprive localized area of oxidant, generate more aggressive environments. One widely adopted indicator of pitting resistance is the PREN or pitting resistance equivalent number. This number is a calculation based on chemical analysis, and is commonly accepted as providing a good indication of pitting resistance. Higher values indicate increased resistance to pitting corrosion.



Specialty -Datalloy 2	Mechanical Properties Corrosion
Galvanic Corrosion	– When two dissimilar material come into contact it is possible that a galvanic cell will be set up, promoting corrosion in the least noble element of the couple. The resulting corrosion will usually be localized to the contact area and may be potentially catastrophic. Datalloy 2TM has been specifically designed to counteract this problem and, as the following graph shows, will resist attack even when coupled to pure copper. 
Stress Corrosion Cracking	– Stress corrosion cracking (SCC) is caused by the combined action of stress and a corrosive medium. The stress can be externally applied or can anise from residual stresses introduced during manufacture. It is also possible for loading and residual stresses to combine, giving a larger actual stress than is applied externally. There are two types of SCC: intergranular and transgranular. – **a) Intergranular** SCC is caused by microstructural, sensitisation of the steel. It has been largely eliminated in modem NMDC manufacture by strict analytical control during ste Material from all Allvac Ltd (Jessop Saville Oilfield Products) collars is tested to ASTM A262 practice E to ensure freedom from sensitisanion. – **b) Transgranular** SCC can occur in the presence of chloride ions when the steel surface is subjected to a tensile stress. Good engineering practice can help to reduce the occurrence of this type of SCC, as can surface treatments which introduce compressive stresses. Hammer peening is an optional treatment available at Allvac Ltd (Jessop Saville Oilfield, Products). It can introduce compressive stresses into the surface of our collars to a depth greater than 0.100". A 3 year warranty against stress corrosion cracking is offered on products treated in this way. The peening treatment also has the benefit of improving fatigue resistance.The possibility of cracking increases as stress approaches yield point and for the most arduous conditions, bore surface treatment by the "XL" procedure is recommended to farther resist initiation of stress corrosion cracking

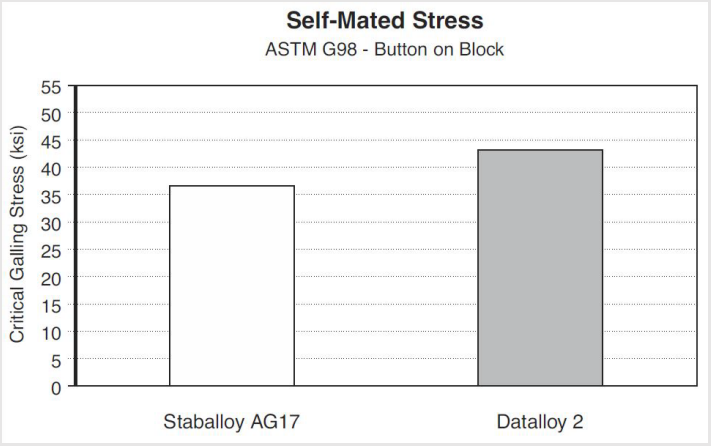




Specialty -Datalloy 2

Galling Resistance

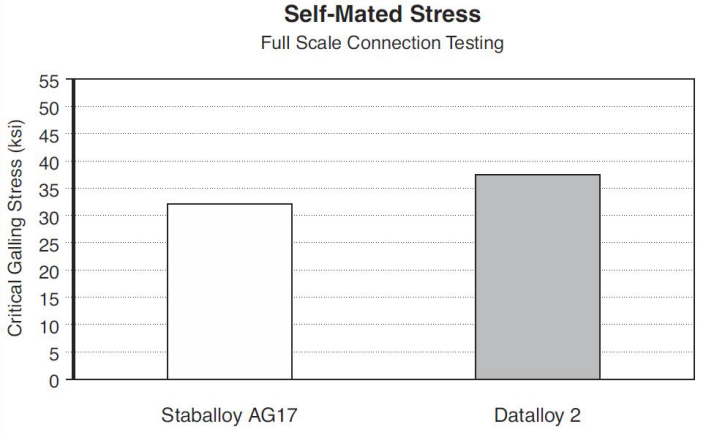
- Galling in the oil industry is defined as the seizure of, and damage to, threaded connections on tightening or untightening. Tests performed by Jessop Saville have shown that the intrinsic galling resistance of Datalloy 2TM is superior to that of other Cr-Mn steels.



- Standard A.S.T.M. G98 test conditions, contact area = 123mm2, no lubricant 4-1/2" IF connections. Torque applied without lubrication.

Specialty -Datalloy 2

Galling Resistance



- Furthermore, on full-scale make and break tests using a typical proprietary lubricant, galling was prevented at stresses over 50% greater than the recommended make up stress.

Quality Assurance

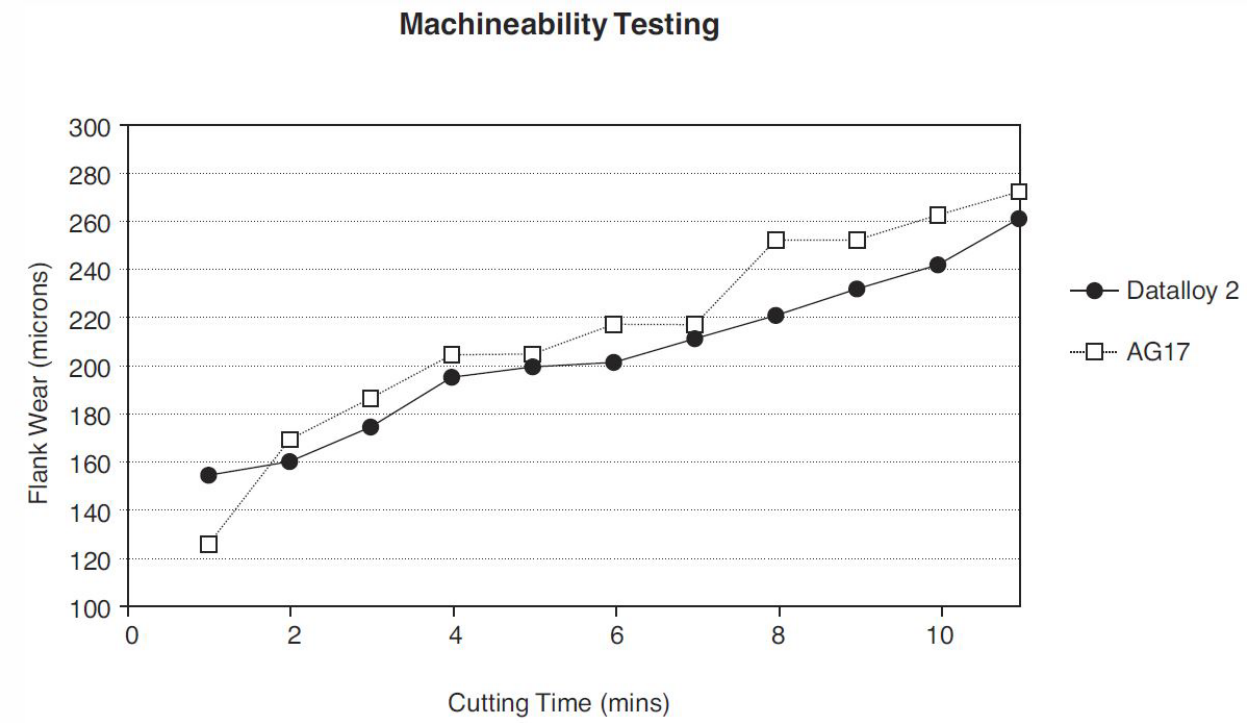
- All collars meet API 7 specified properties and conditions as a minimum standard
- Each collar is mechanically tested
- Each collar is tested for magnetic 'hotspots' using a Foerster EC Probe. Maximum deflection guaranteed less than ±0.5µT/100mm.
- Each collar is ultrasonically examined along its entire length
- Certification includes all relevant physical, chemical, mechanical, magnetic and ultrasonic results

Supply Forms

- Lengths of up to 35 feet and diameters from 4 to 9-1/2" inches are supplied as standard, although longer lengths and other diameters may be ordered by arrangement.
- Material can be supplied solid, bored, semi-finished or fully machined to drawing.
- Datalloy 2TM is usually supplied in the strain hardened condition.
- Arrangements can be made to supply an annealed product, but at reduced strength levels.
- Components up to 9-1/2" diameter can be supplied on request with guaranteed minimum 0.2% proof strengths of 140 ksi. Impact toughness levels remain high and corrosion properties are similar to that of standard strength material.

Machinability

- Datalloy 2 exhibits comparable machinability to Allvac Ltd (Jessop Saville Oilfield Products) grade Staballoy AG 17TM. The following graph relates measured tool wear to cutting time. Tests were performed at a cutting speed of 90m/min without lubrication, using a Sandvik CG235 insert.
- Austenitic steels are very ductile when compared to carbon and low alloy steels, so chip formation is far more difficult. Austenitic grades also work harden much more readily. These properties mean that cutting should be very positive and tools should not be allowed to dwell on the surface.



Specialty -Datalloy 2	Machinability - The following carbide tools are recommended, although high-speed steel tooling can be used at a lower cutting speed.			
Operation	**Tool Grade**	**Cutting Geometry**	**Cutting Speed**	**Feed Rate**
Rough Turning	GC415	QR	400 ft/min	0.018-0.024 in/rev
	GC435	QR	200 ft/min	0.018-0.024 in/rev
Self-Finish	GC415	QM	200 ft/min	0.008-0.018 in/rev
	GC435	QM	200 ft/min	0.008-0.018 in/rev
Milling & Drilling Using Inserts	GCA	145 and 190	300 ft/min	0.006-0.008 in/rev
	GC235	145 and 190	200 ft/min	0.006-0.008 in/rev

400

ALLOY 400 (UNS N04400)							
Typical Analysis	Ni + Co	C	Mn	Fe	S	Si	Cu
	63 min	.3 Max	2.0 Max	2.5 Max	.024	.5 Max	28-34
Characteristics	– Nickel-copper alloy 400 is a solid-solution alloy that can be hardened only by cold working. It has high strength and toughness over a wide temperature range and excellent resistance to many corrosive environments.						
Typical Applications	– Alloy 400 is widely used in many fields, especially marine and chemical processing. Typical applications are valves and pumps; pump and propeller shafts; marine fixtures and fasteners; electrical and electronic components; springs; chemical processing equipment; gasoline and fresh water tanks; crude petroleum stills; process vessels and piping; boiler feed water heaters and other heat exchangers; and deaerating heaters.						

ALLOY 400 (UNS N04400)	Tensile Properties - *Form and Condition - Nominal Room Temperature*				
	Tensile Strength 1000 psi	*Yield Strength 1000 psi*	*Elongation %*	*Hardness Brinell (3000 kg)*	*Hardness Rockwell B*
Rod and Bar					
Annealed	75-90	25-50	60-35	110-149	60-80
Hot-Finished (except Hexagons over 2 1/8" & Angles)	80-110	40-100	60-30	140-241	75-100
Hot-Finished Hexagons over 2" and Angles)	75-100	30-55	50-30	130-184	72-90
Cold-Drawn, Stress-Relieved	84-120	55-100	40-22	160-255	85-20$_C$
Plate					
Hot-Rolled, As-Rolled	75-97	40-75	45-30	125-215	70-96
Hot-Rolled, Annealed	70-85	28-50	50-35	110-140	60-76
Sheet					
Annealed	70-85	30-45	45-35	-	65-80
Cold-Rolled, Hard	100-120	90-110	15-2	-	93 min$_a$
Strip Cold-Rolled					
Annealed	70-85	25-45	55-35	-	68 max$_a$
Spring Temper	100-140	90-130	15-2	-	98 min$_a$
Tube and Pipe, Seamless					
Cold-Drawn, Annealed	70-85	25-45	50-35	-	75 max$_a$
Cold-Drawn, Stress-Relieved	85-120	55-100	35-15	-	85-100$_a$
Heat-Exchanger, Annealed	70-85	28-45	50-35	-	75 max$_a$
Heat-Exchanger, Stress-Relieved	85-105	55-90	35-15	-	85-97$_a$
Hot-Extruded	-$_b$	-$_b$	-$_b$	-$_b$	-$_b$
No. 1 Temper (Annealed)	85 max	30-45	45-30	-	73 max$_a$
No. 2 Temper (Half Hard)	85-105	55-80	30-10	-	75-97$_a$
No. 3 Temper (Full-Hard)	110-130	90-110	10-3	-	95-27$_C$

ALLOY 400 (UNS N04400)	Tensile Properties - *Form and Condition - Nominal Room Temperature*				
	Tensile Strength 1000 psi	*Yield Strength 1000 psi*	*Elongation %*	*Hardness Brinell (3000 kg)*	*Hardness Rockwell B*
Wire-Cold-Drawn					
Annealed	70-95	30-55	45-25	-	-
No. 1 Temper	85-100	50-75	30-20	-	-
Quarter Hard	95-120	65-95	25-15	-	-
Half Hard	110-135	85-120	15-8	-	-
Three Quarter Hard	125-150	100-135	8-5	-	-
Full Hard – Spring Temper	145-180	125-170	5-2	-	-

a. The ranges shown are composites for various product sizes and therefore are not suitable for specification purposes. Hardness values are suitable. For specification purposes providing tensile properties are not also specified.
b. Properties on request.
c. Properties shown are for sizes from 0.032 to 0.250 in diameter. Properties for other sizes may vary from these.

ALLOY 400 (UNS N04400)	Impact Strength (Charpy V-Notch) (ft-lb)			
Temper	75˚F	-20˚F	-112˚F	-310˚F
Hot-Rolled	219	-	213	196
Cold Drawn, Annealed	216	212	219	212
Weld as Welded	78	-	-	73

Nickel Alloy

500

ALLOY 500 (UNS N05500)

Typical Analysis

Ni + Co	C	Mn	Fe	S	Si	Cu	Al	Ti
63 min	.25 Max	1.5 Max	2.0 Max	.01 Max	.5 Max	27-33	2.3-3.15	.35 -.85

Characteristics

- Nickel-copper alloy 500 combines the excellent corrosion resistance characteristic of alloy 400 with the added advantages of greater strength and hardness. The increased properties are obtained by adding aluminum and titanium to the nickel-copper base, and by heating under controlled conditions so that submicroscopic particles of Ni3 (Ti, Al) are precipitated throughout the matrix. The thermal processing used to effect precipitation is commonly called age hardening or aging.
- The corrosion resistance of alloy 500 is substantially equivalent to that of alloy 400 except that, when in the age-hardened condition, alloy 500 has a greater tendency toward stress-corrosion cracking in some environments.
- Alloy 500 has been found to be resistant to a sour-gas environment. After 6 days of continuous immersion in saturated (3500 ppm) hydrogen sulfide solutions at acidic and basic pH's (ranging from 1.0 to 11.0), U-bend specimens of age- hardened sheet showed no cracking. There was some tightly adherent black scale. Hardness of the specimens ranged from 28 to 40 Rc.
- The combination of very low corrosion rates in high-velocity sea water and high strength make alloy 500 particularly suitable for shafts of centrifugal pumps in marine service. In stagnant or slow-moving water, fouling may occur followed by pitting, but this pitting slows down after a fairly rapid initial attack.

Typical Applications

- Typical applications for alloy 500 are pump shafts and impellers; doctor blades and scrapers; oil well drill collars and instruments; electronic components; springs; and valve trim.

ALLOY 500 (UNS N05500)	Mechanical Properties - *Form and Condition - Nominal Ranges*				
	Tensile Strength 1000 psi	*Yield Strength 1000 psi*	*Elongation %*	*Hardness Brinell (3000 kg)*	*Hardness Rockwell*
Rod and Bar					
Hot-Finished	90-155	40-110	45-20	140-315	75B-35C
Hot-Finished, Aged[b]	140-190	100-150	30-20	265-346	27-38C
Hot-Finished, Annealed	90-110	40-60	45-25	140-185	75-90B
Hot-Finished, Annealed & Aged[b]	130-155	85-120	35-20	250-315	24-35C
Cold-Drawn, As- Drawn	100-140	70-125	35-13	175-260	88B-26C
Cold-Drawn, Aged[b]	135-185	95-160	30-15	255-370	25-41C
Cold-Drawn, Annealed	90-110	40-60	50-25	140-185	75-90B
Cold-Drawn, Annealed & Aged[b]	130-190	85-120	30-20	250-315	24-35C
Sheet, Cold-Rolled,					
Annealed	90-105	40-65	45-25	-	85B Max
Strip, Cold-Rolled					
Annealed	90-105	90-105	90-105	-	85B max
Annealed and Aged[b]	130-170	130-170	130-170	-	24C min
Spring Temper	145-165	145-165	145-165	-	25C min
Spring Temper and Aged[b]	170-220	170-220	170-220	-	34C min
Tube and Pipe Seamless					
Hot Finished	-c	-c	-c	-c	-c
Cold-Drawn, Annealed	90-110	90-110	90-110	90-110	90-110
Cold-Drawn, and Aged[b]	130-180	130-180	130-180	130-180	130-180
Cold-Drawn, As-Drawn	110-160	110-160	110-160	110-160	110-160
Cold-Drawn, As-Drawn and Aged[b]	140-220	140-220	140-220	140-220	140-220
Plate					
Hot Finished	90-135	90-135	90-135	90-135	90-135
Hot Finished and Aged[b]	140-180	140-180	140-180	140-180	140-180

ALLOY 500 (UNS N05500)	Tensile Properties - *Form and Condition - Nominal Room Temperature*				
	Tensile Strength 1000 psi	*Yield Strength 1000 psi*	*Elongation %*	*Hardness Brinell (3000 kg)*	*Hardness Rockwell B*
Wire-Cold-Drawn					
Annealed	80-110	80-110	80-110	80-110	80-110
Annealed and Aged[b]	120-150	120-150	120-150	120-150	120-150
Spring Temper	145-190	145-190	145-190	145-190	145-190
Spring Temper, Aged[b]	160-200	160-200	160-200	160-200	160-200

a. The ranges shown are composites for various product sizes and therefore are not suitable for specification purposes.
b. Nominal properties for material age-hardened to produce maximum properties.
c. Properties on request.
d. Properties shown are for sizes 0.0625-0.250-in. diameter. Properties for other sizes may vary from these.

Nickel Alloy

C-22 Corrosion Resistant - Hastelloy®

ALLOY C-22 (UNS NO6022)	*- HASTELLOY® and HAYNES® are registered trademarks of Haynes International, Inc.*

Nominal Analysis

Ni	Co	Cr	Mo	W	Fe	Si	Mn	C	V	P	S
Bal	2.5*	22	13	3	3	.08*	.5*	.01*	.35*	.02*	.01*

*Maximum

Characteristics

- Ni-22Cr-13Mo-3W-3Fe alloy with better overall corrosion resistance and versatility than any Ni-Cr-Mo alloy today. Outstanding resistance to localized corrosion, stress corrosion cracking and oxidizing and reducing chemicals.

Product Forms

- HASTELLOY® alloy C-22 is available in the form of plate, sheet, strip, billet, bar, wire, covered electrodes, pipe and tubing.
- Wrought forms of this alloy are furnished in the solution heat-treated condition unless otherwise specified.

Corrosion Resistance

- HASTELLOY® alloy C-22 is a versatile nickel-chromium-molybdenum alloy with better overall corrosion resistance than other Ni-Cr-Mo alloys available today, including HASTELLOY® alloys C-276 and C-4 and HAYNES alloy No. 625. C-22 alloy has outstanding resistance to pitting, crevice corrosion and stress-corrosion cracking. It has excellent resistance to oxidizing aqueous media including wet chlorine and mixtures containing nitric acid or oxidizing acids with chloride ions. Also, HASTELLOY® alloy C-22 has outstanding resistance to reducing aqueous media. Because of this versatility it can be used where "upset" conditions are likely to occur or in multipurpose plants.
- HASTELLOY® alloy C-22 has exceptional resistance to a wide variety of chemical process environments, including strong oxidizers such as ferric and cupric chlorides, hot contaminated solutions (organic and inorganic), chlorine, formic and acetic acids, acetic anhydride, and seawater and brine solutions.
- HASTELLOY® alloy C-22 resists the formation of grain-boundary precipitates in the weld heat-affected zone, thus making it suitable for most chemical process applications in the as-welded condition.

Fabrication

- **Heat Treatment:** Wrought forms of HASTELLOY® alloy C-22 are furnished in the solution heat treated condition unless otherwise specified. The standard solution, heat-treatment consists of heating at 2050˚F (1121˚C) followed by rapid air-cooling or water quenching. Parts which have been hot formed or severely cold formed should be solution heat-treated prior to final fabrication or installation.
- **Forming**: C-22™ alloy has excellent forming characteristics and cold forming is the preferred method of forming. Because of its good ductility, it can be easily cold-worked. The alloy is stiffer than the austenitic stainless steels. Therefore, more energy is

required during cold forming. More information, see H-2010 publication.

ALLOY C-22 (UNS NO6022)	*- HASTELLOY® and HAYNES® are registered trademarks of Haynes International, Inc.*
Applications	– Some of the areas of present or potential use for C-22 alloy are: – • Acetic Acid/Acetic Anhydride – • Cellophane Manufacturing – • Chlorine Spargers – • Chlorination Systems – • Circuit Board Etching Equipment – • Complex Acid Mixtures – • Fans and Blowers – • Galvanizing Line Equipment – • Gas Scrubber Systems – • Geothermal Wells – • HF Furnaces – • Incineration Systems – • Nuclear Fuel Reprocessing – • Pesticide Production – • Phosphoric Acid Applications – • Pickling System Components – • Plate Heat Exchangers – • Selective Leaching Systems – • SO2 Cooling Towers – • Sulfonation Systems – • Tubular Heat Exchangers
Field Test Program	– Samples of C-22 Alloy are readily available for laboratory or inplant corrosion testing. Analysis of corrosion resistance of the tested material can also be performed and the results provided to the customer as a free technical service. Try testing HASTELLOY® alloy C-22.
Specifications	– HASTELLOY® alloy C-22 is covered by ASME Section VIII, Division 1. Plate, sheet, strip, bar, tubing, and pipe are covered by ASME specifications SB-574, SB-575, SB-619, SB-622 and B-626 and by ASTM specifications B-574, B-575, B-619, B-622, and B-626. DIN specification is 17744 No. 2.4611 (all forms), TUV Werkstoffblatt 424 (all forms).

ALLOY C-22 (UNS NO6022)	**Tensile Properties** - *Form and Condition* - *Average tensile data, solution heat- treated*			
	Test Temp ˚F (˚C)	*Ultimate Tensile Strength Ksi*	*Yield Strength at 0.2% offset, Ksi*	*Elongation in 2 in. (50.8 mm), percent*
Sheet 0.028-.0125 in. (0.71-3.2mm) thick	Room	116	59	57
	200 (93)	110	54	58
	400 (204)	102	44	57
	600 (316)	98	42	62
	800 (427)	95	41	67
	1000 (538)	91	40	61
	1200 (649)	85	36	65
	1400 (760)	76	35	63
Plate 1/4"-3/4" in. (6.4-19.1mm) thick	Room	114	54	62
	200 (93)	107	49	65
	400 (204)	98	41	66
	600 (316)	95	36	68
	800 (427)	92	35	68
	1000 (538)	88	34	67
	1200 (649)	83	32	69
	1400 (760)	76	31	68

ALLOY C-22 (UNS NO6022)	Strength Properties *-Condition - PLATE - Average impact strength - V -Notch Impact Strength*			
	Room Temperature -320˚F (-196˚C)			
Condition	**ft.-lb**	**J**	**ft.-lb**	**J**
Heat-treated at 2050˚F (1121˚C) Rapid Quenched	260*	353*	54	351*
Aged 100 hrs. at: 500˚F (260˚C)	-	-	259*	351*
Aged 100 hrs. at: 1000˚F (538˚C)	-	-	259*	351*
Aged 1000 hrs. at: 1000˚F (538˚C)	-	-	87*	118*

*Specimens did not break

C-276 Corrosion Resistant - Hastelloy®

ALLOY C-276 (UNS N10276)

- HASTELLOY® and HAYNES® are registered trademarks of Haynes International, Inc.

Nominal Analysis

Ni	Co	Cr	Mo	W	Fe	Si	Mn	C	V	P	S
Bal	2.5*	14.5 16.5	15-17	3-4.5	4-7	.08*	1*	.01*	.35*	.025*	.01*

*Maximum

Characteristics

- Ni-1 6Cr-1 6Mo-6Fe-4W alloy, a highly versatile corrosion-resistant alloy. Excellent (N10276) resistance to oxidizing and reducing corrosives, acids, and chlorine-contaminated hydrocarbons.

Product Forms

- HASTELLOY® alloy-276 is available in the form of plate, sheet, strip, billet, bar, wire, covered electrodes, pipe and tubing.
- Available in Wrought Form

Corrosion Resistance

- Outstanding Corrosion Resistance in the as-Welded Condition
- HASTELLOY® alloy C-276 is a nickel-molybdenum-chromium wrought alloy that is generally considered the most versatile corrosion-resistant alloy available. Alloy C-276 is an improved wrought version of alloy C in that it usually doesn't need to be solution heat-treated after welding and has vastly improved fabricability. This alloy resists the formation of grain-boundary precipitates in the weld heat-affected zone, thus making it suitable for most chemical process applications in the as-welded condition.
- Alloy C-276 has outstanding resistance to localized corrosion and to both oxidizing and reducing media. Because of its versatility, alloy C-276 can be used where "upset" conditions are likely to occur or in multipurpose plants.
- HASTELLOY® alloy C-276 has exceptional resistance to a wide variety of chemical process environments, including strong oxidizers such as ferric and cupric chlorides, hot contaminated media (organic and inorganic), chlorine, formic and acetic acids, acetic anhydride, and seawater and brine solutions. It is used in flue gas desulfurization systems because of its excellent resistance to sulfur compounds and chloride ions encountered in most scrubbers. Alloy C-276 has excellent resistance to pitting, stress-corrosion cracking and to oxidizing atmospheres up to 1900°F (1038°C). It is also one of the few materials that with stands the corrosive effects of wet chlorine gas, hypochlorite and chlorine dioxide.

ALLOY C-276 (UNS N10276)	*- HASTELLOY® and HAYNES® are registered trademarks of Haynes International, Inc.*
Fabrication	– HASTELLOY® alloy C-276 can be forged, hot-upset, and impact extruded. Although the alloy tends to work-harden, it can be successfully deep-drawn, spun, press formed or punched. All of the common methods of welding can be used to weld HASTELLOY® alloy C-276, although the oxy-acetylene and submerged arc processes are not recommended when the fabricated item is intended for use in corrosion service. Special precautions should be taken to avoid excessive heat input. Detailed fabricating information is available in the booklet, "Fabrication of CABOT™ Corrosion-Resistant Alloys". Ask for booklet H-2010.
Heat Treatment	– Wrought forms of HASTELLOY® alloy C-276 are furnished in the solution heat treated condition unless otherwise specified. Alloy C-276 is normally solution heat treated at 2050˚F (1121˚C) and rapid quenched. Parts which have been hot formed should be solution heat-treated prior to final fabrication or installation, if possible.
ASME Boiler and Pressure Vessel Code	– HASTELLOY® alloy C-276 plate, sheet, strip, bar, tubing and pipe are covered by ASME specifications SB-574, SB-575, SB-619, SB-622 and SB-626 under UNS number N10276.

ALLOY C-276 (UNS N10276)	**Strength Properties** *-Condition - PLATE - Average impact strength - U -Notch Impact Strength*		
	***Room Temperature* -320˚F (-196˚C)**		
Condition	ft.-lb	J	J
Heat-treated at 2050˚F (1121˚C) Rapid Quenched	263*	357	-
Aged 100 hrs. at:	500˚F (260˚C)	250	339
	1000˚F (538˚C)	96	130
Aged 1000 hrs. at:	1000˚F (538˚C)	64	87
As-Welded:	Weld (top)	88	119
	Weld (bottom)	86	117
	Heat-affected zone	160	217

*Five of six specimens did not break.

ALLOY C-276 (UNS N10276)		Tensile Properties - *Form and Condition - Average tensile data*			
Form	**Condition**	*Test Temp ˚F (˚C)*	*Ultimate Tensile Strength Ksi*	*Yield Strength at 0.2% offset, Ksi*	*Elongation in 2 in.(50.8 mm), percent*
Sheet, 0.078 in (02.0mm) thick	**Heat-treated at 2050˚F (1121˚C)Rapid Quenched**	Room	114.9 (792)	51.6 (356)	61
		400 (204)	100.6 (694)	42.0 (290)	59
		600 (316)	98.8 (681)	35.9 (248)	68
		800 (427)	94.3 (650)	32.7 (225)	67
Sheet, 0.094 in.(2.4mm) thick	**Heat-treated at 2050˚F (1121˚C) Rapid Quenched**	400 (204)	101.0 (696)	39.9 (275)	58
		600 (316)	97.6 (673)	33.5 (231)	64
		800 (427)	93.5 (645)	29.7 (205)	64
Sheet, 0.063 to0.187 in. (1.6 to 4.7mm) thick	**Heat-treated at 2050˚F (1121˚C) Rapid Quenched**	400 (204)[1]	100.8 (695)	42.1 (290)	56
		600 (316)[2]	97.0 (669)	37.7 (260)	64
		800 (427)[2]	95.0 (655)	34.8 (240)	65
		1000 (538)[2]	88.9 (613)	33.8 (233)	60
Plate, 3/16" to 1 in. (4.8 to 25.4mm) thick	**Heat-treated at 2050˚F (1121˚C) Rapid Quenched**	400 (204)[2]	98.9 (682)	38.2 (263)	61
		600 (316)[2]	94.3 (650)	34.1 (235)	66
		800 (427)[2]	91.5 (631)	32.7 (225)	60
		1000 (538)[2]	87.2 (601	32.8 (226)	59
Plate, 1 in. (25.4mm) thick	**Heat-treated at 2050˚F (1121˚C) Rapid Quenched**	Room	113.9 (785)	52.9 (365)	59
		600 (316)	96.3 (664)	36.2 (250)	63
		800 (427)	94.8 (654)	30.5 (210)	61
Sheet, 0.094 in (2.4mm) original (thickness	**Cold-Reduced**	Room	116.9 (806)	63.0 (434)	67
	0 percent	Room	129.7 (894)	92.2 (636)	48
	10 percent	Room	148.1 (1021)	129.1 (890)	26
	20 percent	Room	169.8 (1171)	157.1 (1083)	15
	30 percent	Room	193.8 (1336)	182.9 (1261)	9
	40 percent	Room	210.1 (1449)	195.4 (1347)	7
	50 percent	Room	116.9 (806)	63.0 (434)	67

Special Products

Tool Steels

Introduction

Encore Metals and its predecessors have been supplying steels to Western Canada since 1892. In the early days, stocks mainly consisted of mining and tool steels which were supplied directly to the mines and logging camps. Gradually the range of steels was extended to include alloy machinery and spring steels and shortly before World War II very small quantities of stainless steel. These were probably the first such inventories in Vancouver, British Columbia.

Tool Steels are a category of steels used to shape, cut and form an extremely wide variety of metals and other materials. The first known use of iron for tools dates back at least 6000 years. The fact that tools made from iron could be made harder by heating and quenching in water was known about 3000 years ago. Heating of iron in the solid state in contact with carbonaceous materials to produce hard tools was an art employed by blacksmiths and metal workers through the Dark and Middle-Ages. It was not until 1740 that Sheffield steelmakers used a crucible melting process to produce iron carbon alloys of more homogeneous nature; these were similar to the water hardening steel, type W1 grade, produced today. It was in the mid-19th century that the benefits of alloy elements such as manganese, vanadium and tungsten became apparent, although the alloying was often accidental due to the coincidental deposition of these other elements in an iron ore body. At the turn of the century an understanding of alloying benefits commenced which, as more alloying elements became available, led progressively to controlled steelmaking additions of manganese, vanadium, tungsten, cobalt, chromium, nickel and molybdenum. This led to the evolution of today's range of specialized tool steels for cold and hot working of metals, molding plastics, as well as many other special purposes.2011

AISI 01

Specialty - AISI 01 Cold Work Grades Tool Steels - *Rounds, Flats, Plates, Drill Rod, Precision Ground Flats*

Typical Analysis

C	Mn	Cr	V	W
.95	1.1	.6	.1	.6

Characteristics

- Good edge holding ability
- High hardenability, Low distortion in Heat-Treating.

Typical Applications

- Blanking and forming dies for short to medium production runs.
- Measuring Tools, gauges, jogs and fixtures, Shear Blades

Typical Heat Treatment

Soft annealing 740-770 ˚C	Cooling Furnace			Hardness HB max. 230	
Hardening from 780-820°C	Oil or hot bath 180-220°C			Hardness after quenching in HRC 64	
Tempering	˚C	100	200	300	400
	HRC	64	62	57	53

Property Tolerances

- Standard Tolerances - Length: 36 inches

AISI 01 Ground and Polished Drill Rod

Size Range	+/-
2.000 to .500	.001
.499 to .125	.0005
.124 and less	.0003

Precision Ground Flat Stock

Thickness	+/-.001
Width	Up to 6" + .005/-.000
	Over 6" to 8" + .008/-.000
Length	+ .250" - .000"

AISI A2, AISI D2

Specialty - AISI A2,

Typical Analysis

C	Cr	Mo	V
1.0	5.3	1.1	0.2

Characteristics

- Higher hardenability
- Very low distortion in heat treatment, high wear resistance and toughness

Typical Applications

- Blanking and forming dies
- Cold pilger mandrels, Cold coining dies, Punches, shear blades

Typical Heat Treatment

Soft annealing 800-840 °C		Cooling Furnace			Hardness HB max. 231		
Hardening from 930-970°C		Oil or hot bath 500-550°C			Hardness after quenching in HRC 63		
Tempering	°C	100	200	300	400	500	600
	HRC	63	62	59	57	59	52

Specialty - AISI D2,

Typical Analysis

C	Cr	Mo	V
1.55	12	.7	1.0

Characteristics

- Highest wear resistance combined with good toughness
- Best edge holding quality and dimensional stability after tempering

Typical Applications

- Thread Rolling dies, Cold extrusion tools
- Blanking and forming dies, precision blanking dies
- Circular Shear Blades, Deep drawing tools

Typical Heat Treatment

Soft annealing 830-860 °C		Cooling Furnace			Hardness HB max. 250		
Hardening from 1000-1050°C		Oil or hot bath 500-550°C			Hardness after quenching in HRC 63		
Tempering	°C	100	200	300	400	500	600
	HRC	63	61	58	58	58	50

AISI S7, AISI H13 and H13 ESR

Specialty - AISI S7

Typical Analysis

C	Cr	Mo
.5	3.25	1.4

Characteristics

- Most commonly used shock resisting tool steel
- Very good toughness with medium hardenability

Typical Applications

- Trimming Tools, Ejectors, Shear Blades, Chippers,
- Hammers, Swaging Dies

Typical Heat Treatment

Soft annealing 815-845 °C		Cooling Furnace			Hardness HB 187-223		
Hardening from 925-950°C		In air or oil			Hardness after quenching in HRC 61		
Tempering	°C	100	200	300	400	550	575
	HRC	59	57	56	56	52	45

Specialty - AISI H13 and H13 ESR - *Hot Work Grades*

Typical Analysis

C	Si	Cr	Mo	V
.40	1.0	5.3	1.4	1.0

Characteristics

- High hot tensile strength, hot wear resistance and toughness
- Good thermal conductivity and resistance to hot cracking
- Excellent machinability due to additional calcium treatment

Typical Applications

- Universal applicable Hot Work Tool Steel for pressure diecasting dies
- Metal extrusion tools for processing light metals
- Forging Dies, Moulds, Worms and Cylinders for processing plastics
- For highest demands H13 ESR is suggested

Typical Heat Treatment

Soft annealing 750-800 °C			Cooling Furnace				Hardness HB max. 230		
Hardening from 1020-1050°C			Oil or hot bath 500-500°C				Hardness or tensile Strength after quenching in HRC 54 N/mm² 1910		
Tempering									
°C	100	200	300	400	500	550	600	650	700
HRC	53	52	52	54	56	54	50	42	32
N/mm²	1850	1790	1790	1910	2050	1910	1670	1330	1020

AISI M2, AISI P20

Specialty – AISI M2 *- High Speed Steels*

Typical Analysis

C	Si	Cr	V	W
.90	4.1	5.	1.9	6.4

Characteristics

- Standard high speed steel grade with balanced alloy composition
- High toughness and good cutting power

Typical Applications

- For all Metal for Roughing, Finishing, Twist Drills, Milling Cutters Taps, Broaches, Reamers, Counter-sinks, Chasers Suitable for Cold Forming Tools, Cold Extrusion Rams and Dies

Typical Heat Treatment

Soft annealing 820-860 °C	1st preheating °C up to approx. 400 in an air circulating furnace
	2nd and 3rd Preheating °C a) 850 b) 850 and 1050
Cooling Furnace	Hardening in a) hot bath 550°C/air b) oil c) air from 1180-1220°C
	Tempering °C min. two times 530-560
Hardness HB 240-300	Hardness after quenching in HRC 61

Specialty – AISI P20 *- Plastic Mould Steels*

Typical Analysis

C	Mn	Cr	Mo
.40	1.5	1.9	.20

Characteristics

- Quenched and tempered, Hardness as Supplied 280 to 325 HB
- Excellent machinability due to additional calcium Treatment
- Good polishability, Suitable for Texturing

Typical Applications

- Plastic Injection Moulds, Mould Frames, Pressure Casting Dies, Pultrusion Dies

Typical Heat Treatment

Soft annealing 710-870 °C		Cooling Furnace			Hardness HB max. 235		
Hardening from 840-870°C		Oil or hot bath 180-220°C			Hardness or tensile Strength after quenching in HRC 54 N/mm² 1730		
Tempering							
°C	100	200	300	400	500	600	700
HRC	51	50	48	46	42	36	28
N/mm²	1730	1670	1570	1480	1330	1140	920

P20 + S, 420 and 420 ESR

Specialty – AISI P20 +S	*- Plastic Mould Grades*
Typical Analysis	C .40 · Mn 1.5 · Cr 1.9 · Mo .20 · S .05
Characteristics	– Hardness as supplied 280-325 BH – Improved machinability to P20 with good polishability
Typical Applications	– Plastic Moulds, Mould Frames and Pressure Casting Dies – Sleeves of Recipients
Typical Heat Treatment	– Refer to Information for P20

Specialty – AISI 420 and 420 ESR	*- Plastic Mould Grades*
Typical Analysis	C .42 · Cr 13
Characteristics	– Corrosion resistance plus good polishability – Good machinability due to the additional calcium treatment – For severe applications 420 ESR is suggested
Typical Applications	– Moulds for processing corrosive plastics
Typical Heat Treatment	Soft annealing 760-800 °C · Cooling Furnace · Hardness HB 230 Hardening From 1020-1050°C · In oil or hot bath 500- 550°C · Hardness after quenching HRC 56

Tempering	°C	100	200	300	400	500
	HRC	56	55	52	51	52

Machining Allowance

When purchasers order hot rolled, forged, cold drawn or thermally treated products that are to be machined, it is necessary to make adequate allowances to remove surface decarburization by specifying appropriate larger sizes when ordering. It is essential that the allowance be observed when removing surface metal:

Diameter Allowance Over Finished Size	
Up to 5/8" (16 mm) Incl.	.032" (0.80 mm)
Over 5/8" (16 mm) to 7/8" (22 mm) Incl.	.042" (1.07 mm)
Over 7/8" (22 mm) to 1" (25 mm) Incl.	.046" (1.17 mm)
Over 1" (25 mm) to 1 1/8" (29 mm) Incl.	.050" (1.27 mm)
Over 1-1/8" (29 mm) to 1-1/4" (32 mm) Incl.	056" (1.42 mm)
Over 1-1/4" (32 mm) to 1-3/8" (35 mm) Incl.	060" (1.52 mm)
Over 1-3/8" (35 mm) to 1-1/2" (38 mm) Incl.	066" (1.68 mm)
Over 1-1/2" (38 mm) to 2" (50 mm) Incl.	084" (2.13 mm)
Over 2" (50 mm) to 2-1/2" (64 mm) Incl.	104" (2.64 mm)
Over 2-1/2" (64 mm) to 3-1/2" (90 mm) Incl.	144" (3.66 mm)
Over 3-1/2" (90 mm) to 4-1/2" (115 mm) Incl	180" (4.57 mm)
Over 4-1/2" (115 mm) to 5-1/2" (140 mm) Incl.	220" (5.59 mm)
Over 5-1/2" (140 mm) to 6-1/2" (165 mm) Incl.	250" (6.35 mm)
Over 6-1/2" (165 mm) to 8" (200 mm) Incl.	310" (7.87 mm)
Over 8" (200 mm) to 9" (230 mm) Incl.	406" (10.31 mm)

NOTE: These allowances are in addition to normal manufacturing tolerances.

Stainless Steel

Stainless Steel

T-303

Stainless Steel T-303 (UNS S 30300)	*- 18-8 Chromium- Nickel Freemachining Stainless Steel* *- Available mainly in wire and bar form to ASTM A581 and A582*

Typical Analysis

C	Mn	P	S	Si	Cr	Ni	Mo
.15Max	2.0Max	.20Max	.15Min	1.0Max	17/19	8/10	.60Opt.

Characteristics

– A sulphur-bearing chromium-nickel austenitic steel, this grade offers excellent machinability, non-galling properties and good corrosion resistance. It is non-magnetic in the annealed condition and is not hardenable by heat treatment. However, tensile strength and hardness can be increased by cold working. Welding is not recommended for T-03, but if necessary use T-308 electrodes and the welds must be annealed. Machinability is rated at 60% - 100 surface feet per minute

Typical Applications

– Used almost exclusively for parts requiring machining and primarily in automatic screw machines. Bushings, fittings, shafts, valves, bolts and nuts

Corrosion and Heat Resistance

– T-303 has slightly less general corrosion resistance than T-302/T-304 due to the sulphur content. It has good resistance to scaling up to 870˚C in continuous service and to 760˚C in intermittent service

Stainless Steel T-303 (UNS S 30300)	Mechanical Properties - T-303 Bar sizes - Typical - Please note that ASTM A582 does not specify detailed mechanical properties (as above) except that the hardness shall not exceed HB 262. Accordingly mill test certificates will not usually show these details	
Spec	H.R. Ann	Ann &CF
Tensile Strength, psi	90,000	100,000
Tensile Strength, N/mm²	620	690
Yield Strength, psi	35,000	60,000
Yield Strength, N/mm²	241	414
Elongation (%)	50	40
Reduction of Area (%)	55	50
Hardness	163	229

Stainless Steel T-303 (UNS S 30300)	Mechanical Properties - T-303 Wire Sizes - ASTM A581 specifies tensile strength as follows	
Spec	Cond. 'A' - Annealed	Cond. 'B' - Cold Worked
Tensile Strength, psi	85,000/125,000	115,000/145,000
Tensile Strength, N/mm²	590/860	790/1000

Stainless Steel

T-304, T-304H, T-304L

Stainless Steel T-304, T-304H, T-304L (UNS S30400, S30409, S30403)	*- 18 - 10 Chromium-Nickel austenitic stainless steel* *- Available in most forms - sheets, plates & coils to ASTM A240; bar sections to ASTM A276 & A479*

Typical Analysis

T-304

C	Mn	P	S	Si	Cr	Ni	N
.08 Max	2.0 Max	.045 Max	.03 Max	1.0 Max	18/20	8/10.5	.1 Max.

T-304H

C	Mn	P	S	Si	Cr	Ni	N
.04/ .10	2.0 Max	.045 Max	.03 Max	1.0 Max	18/20	8/10.5	-

T-304L

C	Mn	P	S	Si	Cr	Ni	N
.03 Max	2.0 Max	.045 Max	.03 Max	.75 Max	18/20	8/12	.1 Max.

Characteristics

– Perhaps the most versatile and widely used general purpose austenitic stainless steel. It is excellent for forming, drawing and welding, and provides good corrosion resistance without post-weld annealing. The extra low carbon analysis of T-304L, which further restricts carbide precipitation during welding permits the use of this steel in corrosive service in the as-welded condition. T-304L is essential particularly where heavier sections are involved. T-304H is a modification with .04/.10 carbon and no nitrogen content. The mechanical test requirements are the same as T-304 but the 'H' type is not normally subject to intergranular corrosion testing. T-304 cannot be hardened by thermal treatment but it does work harden. It is non-magnetic when annealed. Machinability is approximately 45% - 75 surface feet per minute

Typical Applications

– These grades are used extensively in the dairy, beverage, brewing, wine and food industries where the highest degree of cleanliness is of prime importance. Chemical equipment and storage tanks, cryogenic vessels, sinks, saucepans and kitchen equipment, architectural trim, petroleum refinery equipment

Corrosion and Heat Resistance

– T-304 is highly resistant to strong oxidizing acids, such as nitric acid, and resists many organic and inorganic chemicals. Excellent for hot petroleum products. It has good scale resistance up to 900˚C in continuous service and 843˚C for intermittent service. T-304L would be equal and generally superior.

Stainless Steel T-304, T-304H, T-304L (UNS S30400, S30409, S30403)	Mechanical Properties - Bar - Typical at Room Temperature		
Bars	T-304	T-304H	T-304L
Tensile Strength, psi	85,000	85,000	83,000
Tensile Strength, N/mm²	586	586	572
Yield Strength, psi	35,000	35,000	34,000
Yield Strength, N/mm²	241	241	234
Elongation (%)	60	60	60
Hardness	149	149	146

Stainless Steel T-304, T-304H, T-304L (UNS S30400, S30409, S30403)	Mechanical Properties - Sheet - Typical at Room Temperature		
Sheet	T-304	T-304H	T-304L
Tensile Strength, psi	84,000	84,000	81,000
Tensile Strength, N/mm²	579	579	558
Yield Strength, psi	42,000	42,000	39,000
Yield Strength, N/mm²	290	290	270
Elongation (%)	55	55	55
Hardness	146 (80)	146 (80)	143 (79)

Stainless Steel T-304, T-304H, T-304L (UNS S30400, S30409, S30403)	Mechanical Properties - Plate - Typical at Room Temperature		
Plate	T-304	T-304H	T-304L
Tensile Strength, psi	82,000	82,000	79,000
Tensile Strength, N/mm²	565	565	545
Yield Strength, psi	35,000	35,000	33,000
Yield Strength, N/mm²	241	241	228
Elongation (%)	60	60	60
Hardness	149 (81)	149 (81)	143 (79)

Stainless Steel

T-310, T-310S

Stainless Steel T-310, T-310S (UNS S31000, S31008)	*- 25-20 Chromium-Nickel Heat Resisting Stainless Steel* *- Available in most forms - Sheets and plates to ASTM A240; bar sections to ASTM A276*
Typical Analysis	T-310: C .25 Max; Mn 2.0 Max; P .045 Max; S .030 Max; Si 1.5 Max; Cr 24/ 26; Ni 19 /22 T-310S: C .08 Max; Mn 2.0 Max; P .045 Max; S .030 Max; Si 1.5 Max; Cr 24/ 26; Ni 19/ 22
Characteristics	– These are austenitic chromium-nickel stainless steels with excellent oxidation resistance and capable of resisting temperatures up to 1150˚C in continuous service. They also provide good resistance to carburizing environments. T-310S is simply a low carbon modification which is to be preferred in welded construction.
Typical Applications	– Furnace parts, carburizing boxes, heat treating trays, oven linings, heat exchangers, gas turbine parts, jet engine rings.
Corrosion and Heat Resistance	– Primarily designed for heat resistance, T-310/T-310S are good to 1150˚C for continuous service and offer resistance to 1038˚C for intermittent service. They provide good resistance to thermal fatigue and cyclic heating. Excellent corrosion resistance at normal temperatures, with good resistance to carburizing and reducing environments at high temperatures.
Mechanical Properties	– Typical - at Room Temperature – Tensile Strength - 95,000 psi (655 N/mm^2) – Yield Strength - 45,000 psi (310 N/mm^2) – Elongation - 50% – Hardness - Rb 179 (89)

Stainless Steel

T-316, T-316L, T-316N

Stainless Steel T-316, T-316L, T-316N	*- 18-12-3 Chromium-Nickel-Molybdenum austenitic stainless steel.*
(UNS S31600, S31603, S31653)	*- Available in most forms & sheets, plates and coils to ASTM A240; bar sections to ASTM A276 & A479*

Typical Analysis

T-316

C	Mn	P	S	Si	Cr	Ni	Mo	N
.08 Max	2.0 Max	.045 Max	.030 Max	1.0 Max	16/18	10/14	2/3	.10 Max

T-316L

C	Mn	P	S	Si	Cr	Ni	Mo	N
.03 Max	2.0 Max	.045 Max	.030 Max	1.0 Max	16/18	10/14	2/3	.10 Max

T-316N

C	Mn	P	S	Si	Cr	Ni	Mo	N
.08 Max	2.0 Max	.045 Max	.030 Max	1.0 Max	16/18	10/14	2/3	.10/ .16

Characteristics

- In simple terms, T-316 is a molybdenum bearing T-304; the addition of molybdenum greatly increases its corrosion resistance and its mechanical properties at elevated temperatures. This combination of corrosion resistance and high creep and tensile strength, plus good cold forming and drawing properties makes T-316 suitable for a very wide range of applications.
- T-316L is a a low-carbon modification which minimizes carbide precipitation during welding and exposure to elevated temperatures in the 425˚C/815˚C range. It can be used in the as-welded condition. T-316N has a higher nitrogen content than T-316 to increase strength with minimum effect on ductility and corrosion resistance.
- T-316 is non-magnetic in the annealed condition and cannot be hardened by thermal treatment, but it does work harden. Machinability is approximately 42% - 70 surface feet per minute.
- T-316 is also available in Pump Shaft quality.

Typical Applications

- Widely used in the pulp and paper, chemical, petro-chemical, fertilizer and pharmaceutical industries. Heat exchangers, marine applications, aircraft industry, fittings, architectural components.

Corrosion and Heat Resistance

- T-316 is more resistant to corrosive conditions than any of the more commonly used stainless grades (but see T-317). Very good resistance to the sulphur compounds used in pulp and paper processing. Good resistance to sulphuric, sulphurous and phosphoric acids and salts, also hydrogen sulphide; but poor resistance to hydrocloric and hydrofluoric acids. Excellent scale resistance at temperatures up to 900˚C in continuous service and up to 850˚C for intermittent service.

Stainless Steel T-316, T-316L, T-316N (UNS S31600, S31603, S31653)	Mechanical Properties - Bar - Typical at Room Temperature		
Bars	T-316	T-316L	T-316N
Tensile Strength, psi	80,000	75,000	90,000
Tensile Strength, N/mm²	552	517	621
Yield Strength, psi	30,000	30,000	42,000
Yield Strength, N/mm²	207	207	290
Elongation (%)	60	60	55
Hardness	166 (86)	149 (81)	183 (90)

Stainless Steel T-316, T-316L, T-316N (UNS S31600, S31603, S31653)	Mechanical Properties - Sheet - Typical at Room Temperature		
Sheet	T-316	T-316L	T-316N
Tensile Strength, psi	84,000	79,000	90,000
Tensile Strength, N/mm²	579	545	621
Yield Strength, psi	42,000	38,000	48,000
Yield Strength, N/mm²	290	262	331
Elongation (%)	50	55	48
Hardness	149 (81)	146 (80)	170 (87)

Stainless Steel T-316, T-316L, T-316N (UNS S31600, S31603, S31653)	Mechanical Properties - Plate - Typical at Room Temperature		
Plate	T-316	T-316L	T-316N
Tensile Strength, psi	82,000	78,000	88,000
Tensile Strength, N/mm²	585	538	607
Yield Strength, psi	36,000	35,000	46,000
Yield Strength, N/mm²	248	241	317
Elongation (%)	55	58	50
Hardness	146 (80)	143 (79)	166 (86)

Stainless Steel
T-316, T-316L,
(UNS S31600, S31603,)
- Strain Hardened Bar, Centerless Ground

Typical Analysis

C	Mn	P	S	Si	Cr	Ni	Mo	N
.03 Max	2.0 Max	.045 Max	.030 Max	1.0 Max	16/18	10/14	2/3	.10 Max

Characteristics

- Cold drawn, centreless ground.
- Typical Surface Finish:
  - Clean, bright smooth finish; defect free.
  - Smoother finish than Smooth Turned. RMS
  - Finish: 30 max guaranteed.
- Straightness 0.0625” in 5 ft.

Typical Applications

- Boat shafting, cylinder rods, pulp, paper, chemical and petro chemical industries.

Size Range Rounds

- Tolerances - Plus or Minus in inches

– .125 - .317	– 000 to .001
– .318 - .500	– 000 to .0015
– .501 - .999	– 000 to .002
– 1.000 - 1.499	– 000 to .0025
– 1.500 - 3.499	– 000 to .003
– 3.500 - 6.750	– 000 to .004

Stainless Steel T-316, T-316L, (UNS S31600, S31603,)	Physical Properties - *Type Condition*			
	Tensile Min, psi (MPa)	*Yield Min, psi (MPa)*	*Elongation in 2" or 50mm*	*Reduction of area min.%*
316/316LStrain-Hardened	95000	75000	25	40
2" and under	[650]	[515]		
over 2" to 2 1/2"	90000	65000	30	40
(50.8 to 63.5mm) incl.	[620]	[450]		
over 2 1/2" to 3 1/2"	80000	55000	30	40
(63.5 to 88.9mm) incl.	[550]	[380]		
over 3 1/2" to 4"	80000	45000	30	60
(88.9 to 101.6mm) incl.	[550]	[310]		

Stainless Steel

T-317, T-317L

Stainless Steel T-317, T-317L (UNS S31700, S31703)	*- 20-13-4 Chromium-Nickel-Molybdenum austenitic stainless steel.* *- Available in most forms, but owing to low-volume usage not as readily available as T-316.*

Typical Analysis

T-317

C	Mn	P	S	Si	Cr	Ni	Mo	N
.08 Max	2.0 Max	.045 Max	.030 Max	1.0 Max	18/20	11/15	3/4	.10 Max

T-317L

C	Mn	P	S	Si	Cr	Ni	Mo	N
.03 Max	2.0 Max	.045 Max	.030 Max	1.0 Max	18/20	11/15	3/4	.10 Max

Characteristics

- Essentially similar to T-316; but the increased chromium, nickel and molybdenum content results in better corrosion resistance, higher tensile strength and higher creep strength than T-316.
- T-317L with .03% maximum carbon content is used to restrict carbide precipitation during welding and in applications where maximum corrosion resistance is required. In fact, for small quantities, T-317 is frequently available only as T-317L.
- T-317 is non-magnetic in the annealed condition and is non-hardenable by heat treatment. Machinability is 39% - 65 surface feet per minute.

Typical Applications

- Pulp and paper, chemical and pharmaceutical processing equipment and machinery.

Corrosion and Heat Resistance

- Significantly better corrosion resistance that T-316 in the same environments. Good oxidation resistance in continuous service to 925˚C and in intermitent service to 879˚C.

Stainless Steel T-317, T-317L (UNS S31700, S31703)	Mechanical Properties - Bar - Typical at Room Temperature	
Bars	T-317	T-317L
Tensile Strength, psi	85,000	85,000
Tensile Strength, N/mm²	586	586
Yield Strength, psi	40,000	35,000
Yield Strength, N/mm²	276	241
Elongation (%)	50	55
Hardness	160 (82)	146 (80)

Stainless Steel T-317, T-317L (UNS S31700, S31703)	Mechanical Properties - Sheet - Typical at Room Temperature	
Sheet	T-317	T-317L
Tensile Strength, psi	90,000	86,000
Tensile Strength, N/mm²	621	593
Yield Strength, psi	43,000	38,000
Yield Strength, N/mm²	296	262
Elongation (%)	45	55
Hardness	166 (86)	167 (83)

Stainless Steel T-317, T-317L (UNS S31700, S31703)	Mechanical Properties - Plate - Typical at Room Temperature	
Plate	T-317	T-317L
Tensile Strength, psi	85,000	82,000
Tensile Strength, N/mm²	586	565
Yield Strength, psi	48,000	43,000
Yield Strength, N/mm²	330	296
Elongation (%)	51	55.5
Hardness	166 (86)	167 (83)

Stainless Steel

T-410, T-410S

Stainless Steel T-410, T-410S (UNS S41000, S41008)	*- 12% Chromium hardenable martensitic stainless steel.* *- Available in most forms - sheet and plate to A176 and A240; bars to A276, A479 and A193 Grade B6*

Typical Analysis

T-410

C	Mn	P	S	Si	Cr
.15 Max	1.0 Max	.040 Max	.030 Max	1.0 Max	11.50/ 13.50

T-410S

C	Mn	P	S	Si	Cr
.03 Max	2.0 Max	.045 Max	.030 Max	1.0 Max	18/20

Characteristics

- T-410 is the basic chromium grade in the '400' series. It can be treated by conventional means to develop high strength properties with good ductility. In fact, it is in the heat treated condition that T-410 develops its maximum corrosion resistance, particularly when ground and polished. And when heat treated to HRC 18/22, with double tempering, per NACE MR01-75, resists corrosion in severe sour gas environments. Excellent for highly stressed parts needing moderate heat and corrosion resistance with high strength.
- T-410S limits the carbon content to .08% max for better weldability,mainly in sheet and plate.
- T-410 is magnetic in all conditions. It has better machining characteristics than the chromium-nickel grades and is rated at 54% - 90 surface feet per minute.

Typical Applications

- Machine parts, pump shafts, blast joints, blow-out preventers, pistons, valve parts, bolts, bushings, jet engine parts, rifle barrels, hardware, cutlery

Corrosion and Heat Resistance

- Resists atmospheric corrosion, mild alkalis and acids, food acids, rural and industrial atmospheres. Resists scaling at temperatures up to 675˚C in continuous service.

Heat Treatment

- Annealing - Heat to 850˚/900˚C for 30 min. per inch of section thickness and slow cool.
- Hardening - Heat to 950˚/1000˚C and quench in oil, water or air according to section and properties required.
- Tempering - According to properties required, but the range 400˚/580˚C should be avoided due to low impact values which result at these temperatures. Double tempered at 660˚/640˚C for SSC resistance.

Stainless Steel T-410, T-410S (UNS S41000, S41008)	Mechanical Properties - T-410 Annealed - Typical	
Spec	Bar	Plate
Tensile Strength, psi	75,000	70,000
Tensile Strength, N/mm²	517	483
Yield Strength, psi	40,000	35,000
Yield Strength, N/mm²	275	241
Elongation (%)	35	30
Reduction of Area (%)	68	68
Hardness	156	149

Stainless Steel T-410, T-410S (UNS S41000, S41008)	Mechanical Properties - T-410 Heat Treated - Typical		
Spec	Heat Treated to A276 Cond 'H 21/4"dia.	Heat Treated to A193 Grade B6 - 13/4" dia	Heat Treated to HRC22 max by double tempering at 1150˚F
Tensile Strength, psi	137,900	129,000	100,000
Tensile Strength, N/mm²	951	809	-
Yield Strength, psi	115,300	109,000	80,000
Yield Strength, N/mm²	795	752	-
Elongation (%)	24	22	20
Reduction of Area (%)	69	71	40
Hardness	285	269	Rc 20

Stainless Steel

T-416

Stainless Steel T-416 (UNS S41600)	*- 12% Chromium Free-Machining Hardenable Stainless Steel.* *Available mainly in wire and bar sections to ASTM A581 and A582.*

Typical Analysis

C	Mn	P	S	Cr	Mo (opt.)
.15 Max	1.25 Max	.06 Max	.15 Max	12/ 14	.60 Max

Characteristics

- T-416 is quite simply described as a free-machining modification of T- 410. The addition of phosphorus and sulphur is responsible for improved machinability, but results in some disadvantages such as lower impact values and poor weldability. However, the steel is designed for free- machining and it is the best of all the stainless steels. The rating is as high as 90% - 160 surface feet per minute.
- T-416 is mainly supplied in the annealed condition; but it responds to conventional heat treatment and a wide range of mechanical properties may be obtained. It is magnetic in all conditions.
- T-416 is also available in Pump Shaft quality.

Typical Applications

- T-416 is used in all applications demanding the mechanical properties and corrosion resistance of T-410 - plus the free-machining. Pump shafts, pistons, valves, automatic screw machined parts, nuts, bolts, studs.

Corrosion and Heat Resistance

- Maximum resistance is obtained by hardened material, ground and polished. Excellent resistance to fresh water, mild alkalis and acids, dry atmospheres, neutral and basic salts. Fair resistance to scaling up to 675˚C in continuous service.

Heat Treatment

- Annealing - Heat to 850˚/900˚C for 30 minutes per inch of section thickness. Cool slowly in furnace.
- Hardening - Heat to 950˚/1000˚C and quench large sections in oil. Small sections may be quenched in air.
- Tempering - According to mechanical properties required, but the range of 400˚/580˚C is not recommended.

Stainless Steel T-416 (UNS S41600)	**Mechanical Properties -** T-416 Annealed Bar sizes - Typical - Note that ASTM A582 does not specify detailed mechanical properties for T-416 except that in the annealed condition the hardness shall not exceed HB 262.	
Spec	H.R. Ann	Ann &CF
Tensile Strength, psi	75,000	85,000
Tensile Strength, N/mm²	517	586
Yield Strength, psi	40,000	50,000
Yield Strength, N/mm²	276	345
Elongation (%)	30	30
Reduction of Area (%)	60	45
Hardness	155	174

Stainless Steel T-416 (UNS S41600)	**Mechanical Properties -** T-416 Wire Sizes - ASTM A581 specifies tensile strength as follows		
Spec	Cond. 'A' - Annealed	Cond. 'T' - Intermediate Temper	Cond. 'H' - Hard Temper
Tensile Strength, psi	85,000/125,000	115,000/145,000	140,000/175,000
Tensile Strength, N/mm²	590/860	790/1000	1000/1210

Stainless Steel

T-316 Pump Shaft Quality (PSQ)

Stainless Steel T-316 Pump Shaft Quality — *- This grade is annealed, centreless ground and polished.*

Typical Analysis

C	Mn	P	S	Si	Cr	Ni	Mo	N
.8 Max	2.0 Max	.045 Max	.030 Max	1.0 Max	16/18	10/18	2/3 Max	.10

Characteristics

- In simple terms, T-316 is a molybdenum bearing T-304; the addition of molybdenum greatly increases its corrosion resistance and its mechanical properties at elevated temperatures. This combination of corrosion resistance and high creep and tensile strength, plus good cold forming and drawing properties makesT-316 suitable for a very wide range of applications.
- T-316L is a a low-carbon modification which minimizes carbide precipitation during welding and exposure to elevated temperatures in the 425˚C/815˚C range. lt can be used in the as-welded condition. T-316N has a higher nitrogen content than T-316 to increase strength with minimum effect on ductility and corrosion resistance.
- T-316 is non-magnetic in the annealed condition and cannot be hardened by thermal treatment, but it does work harden. Machinability is approximately 42% - 70 surface feet per minute.

Typical Applications

- Widely used in the pulp and paper, chemical, petro-chemical, Fertilizer and pharmaceutical industries. Heat exchangers, marine applications, aircraft industry, fittings, architectural components. Pump Shafts.

Corrosion and Heat Resistance

- T-316 is more resistant to corrosive conditions than any of the more commonly used stainless grades (but see T-317). Very good resistance to the sulphur compounds used in pulp and paper processing. Good resistance to sulphuric, sulphurous and phosphoric acids and salts, also hydrogen sulphide; but poor resistance to hydrochloric and hydrofluoric acids. Excellent scale resistance at temperatures up to 900˚C in continuous service, and up to 850˚C for intermittent service.

Mechanical Properties

- 75,000 psi minimum tensile strength
- 30,000 psi minimum yield
- 35% minimum elongation (in 2")
- 50% minimum reduction of area (R/A)

Tolerances

- Straightness Tolerance - 0.0015" per foot
- Maximum out-of-round - 1/2 total diameter tol.
- Diameter Tolerance:

Size	Tolerance
.875"-.999"	+0/- 0.0020"
1.000"-1.4375"	+0/- 0.0025"
1.4376"-4.000"	+0/- 0.0030"

Stainless Steel

T-416 Pump Shaft Quality (PSQ)

Stainless Steel T-416 Pump Shaft Quality	*- This grade is heat treated, centreless ground and polished.*

Typical Analysis

C	Mn	P	S	Cr	Mo	(opt.)
.15 Max	1.25 Max	.06 Max	.15 Min	12/14	.60 Max	

Characteristics

- T-416 is quite simply described as a free-machining modification of T- 410. The addition of phosphorus and sulphur is responsible for improved machinability, but results in some disadvantages such as lower impact values and poor weldability. However, the steel is designed for free- machining and it is the best of all the stainless steels. The rating is as high as 90% - 160 surface feet per minute.
- T-416 is mainly supplied in the annealed condition; but it responds to conventional heat treatment and a wide range of mechanical properties may be obtained. It is magnetic in all conditions.

Typical Applications

- T-416 is used in all applications demanding the mechanical properties and corrosion resistance of T-410 - plus the free machining. Pump shafts, pistons, valves, automatic screw machined parts, nuts, bolts, studs.

Corrosion and Heat Resistance

- Maximum resistance is obtained by hardened material, ground and polished. Excellent resistance to fresh water, mild alkalis and acids, dry atmospheres, neutral and basic salts. Fair resistance to scaling up to 675˚C in continuous service.

Mechanical Properties

- 100,000 psi minimum tensile strength
- 85,000 psi minimum yield
- 15% minimum elongation (in 2")
- 45% minimum reduction of area (R/A)
- 207-248 Brinell hardness

Tolerances

- Straightness Tolerance – 0.0015" per foot
- Maximum out-of-round – 1/2 total diameter tol.
- Diameter Tolerance:

Size	Tolerance
.750"-.999"	+0/- 0.0020"
1.000"-1.4375"	+0/- 0.0025"
1.4376"-4.000"	+0/- 0.0030"

Stainless Steel

17-4PH, T-630

Stainless Steel 17-4PH, T-630 (UNS S17400)	*- 17-4 Chromium-Nickel Precipitation/Age Hardening martensitic stainless steel* *-Available mainly in bar and plate - ASTM A564*

Typical Analysis

C	Mn	P	S	Si	Cr	Ni & Cu	Cb+Ta
.07 Max	1.0 Max	.04 Max	.30 Min	1.0 Max	15/17.5	3.0/5.0	.15/.45

Characteristics

- 17-4PH offers a unique combination of properties: high strength, excellent corrosion resistance, good fatigue strength, superior resistance to galling and seizing, easily heat treated by a short, simple low temperature treatment with minimal distortion and no scaling. Parts may be finish-machined before hardening. It has good fabrication characteristics and is easily weldable.
- T-630 is usually supplied in Condition 'A', commonly called solution treated, but it should be noted that it can be as hard as HB363, and is frequently HB 321/341. Also the steel should never be put into service in Condition'A' - the structure is untempered martensite, with low ductility and poor resistance to stress cracking.
- See the Data Section for machinability ratings of Condition A and Condition H1150.

Typical Applications

- Pump shafts, oil well valves, valve stems and bushings. Aircraft and missile fittings and components, marine propeller shafts and blades, pulp and paper mill equipment, orifice plates, chemical processing equipment, torsion bars, corrosion resistant gears.

Corrosion and Heat Resistance

- The corrosion resistance is comparable to T-302/304 in most environments - a wide variety of conditions in the petroleum, chemical, pulp and paper, dairy and food processing industries. May be used in service temperature up to 400°C.

Stainless Steel 17-4PH, T-630 (UNS S17400)	*- 17-4 Chromium-Nickel Precipitation/Age Hardening martensitic stainless steel* *-Available mainly in bar and plate - ASTM A564*

Heat Treatment

– Condition 'A' - Solution treated: Heated at 1038°C (plus/minus 15°) for 30 minutes. Air cool or oil quench. Brinell Hardness 363 max. This treatment is normally at the mill.

Precipitation Hardening or Aging Treatments

- Starting with Condition 'A' material

Condition	
H 900	1 hour at 900°F (482°C) Air Cool
H 925	4 hours at 925°F (496°C) Air Cool
H 1025	4 hours at 1025°F (552°C) Air Cool
H 1075	4 hours at 1075°F (579°C) Air Cool
H 1100	4 hours at 1100°F (593°C) Air Cool
H 1150	4 hours at 1150°F (621°C) Air Cool
H 1150M	2 hours at 1400°F (760°C) Air Cool then 4 hours at 1150°F (621°C) Air Cool

Heat Treatment to NACE MR0175

– The UNS S17400 precipitation hardening stainless steel is acceptable in SSC service when heat treated to HRC 33 maximum by one of the following procedures:

Procedure 1: Double age at 1150 F (620 C), NACE MR-01-75 (Alternate 1)

– 1. Solution anneal at 1900° F (1040° C) and air cool, or suitable liquid quench, to below 90° F (32° C).
– 2. Harden at 1150° F (620° C) for 4 hours at temperature (32° C) and cool in air.
– 3. Cool material to below 90° F (32° C) before the second hours at temperature and cool in air to below precipitation hardening step.
– 4. Harden at 1150° F (620° C) for 4 hours at temperature and cool in air.

Procedure 2: Double age, NACE MR-01-75 (Alternate 2)

– 1. Solution anneal at 1900° F (1040° C) and air cool, or suitable liquid quench, to below 90F (32° C).
– 2. Precipitation harden at 1400° F (760° C) for 2 hours at temperature and cool in air to below. 90° F (32° C) before second precipitation
– 3. Precipitation harden at 1150° F (620° C) for 4 hours at temperature and cool in air.

Stainless Steel 17-4PH, T-630 (UNS S17400)	Mechanical Properties - Minimum properties per ASTM A564						
Spec	H 900	H 925	H 1025	H1075	H1100	H1150	H1150D
Tensile Strength, psi	190,000	170,000	155,000	145,000	140,000	135,000	125,000
Tensile Strength, N/mm²	1310	1172	1069	1000	965	930	860
Yield Strength, psi	170,000	155,000	145,000	125,000	115,000	105,000	105,000
Yield Strength, N/mm²	1172	1069	1000	862	793	725	725
Elongation (%)	10	10	12	13	14	16	16
Reduction of Area (%)	40/35	44/38	45	45	45	50	50
Hardness HB(min.)	388	375	331	311	302	277	255
HRC						33 max	

Stainless Steel - Grade 2304 Duplex - URANUS 35N	*- a 23.04 Duplex stainless steel with PREN ≥ 24*

Typical Analysis

C	Cr	Ni	Mo	N	others
.02	23	4	.2	.1	S= .001

PREN = [Cr %] + 3.3 [Mo %] + 16 [N %] ≥ 24

Characteristics

- URANUS@ 35N (UR 35N) is a 23% Cr, 4% Nickel, Mo free duplex stainless steel (23.04). The alloy UR 35N has similar corrosion resistance properties similar to 316L. Furthermore, its mechanical properties ie. yield strength, are twice those of 304/316 austenitic grades. This allows the designer to save weight, particularly for properly designed pressure vessel applications.
- The alloy is particularly suitable for applications covering the -50°C/+300°C (-58°F/572°F) temperature range. Lower temperatures may also be considered, but need some restrictions, particularly for welded structures.
- With its duplex microstructure, low nickel and high chromium contents, the alloy has improved stress corrosion resistance properties compared to 304 and 316 austenitic grades.

Standards

- EURONORM - 1.4362 - X2 Cr Ni 23.4
- AFNOR - Z3 CN 23.04 Az
- DIN - W. Nr 1.4362
- ASTM - A240 - UNS S32304

Structure

- The chemical analysis of UR 35N is optimized to obtain a typical 50 α / 50 γ microstructure after solution annealing treatment at 950°/1050°C (1742/1922°F).
- The microstructure of UR 35N duplex is very stable compared to molybdenum containing duplex stainless steels. Intermetallic phases (α, x) are present only after 10 hours holding time in the 750°/850°C (1382°/1562°F) temperature range. Copper additions to UR 35N grade, when specified, increase the hardness of the steel after heat treatment in the 350/500°C (662/932°F) temperature range.

Applications

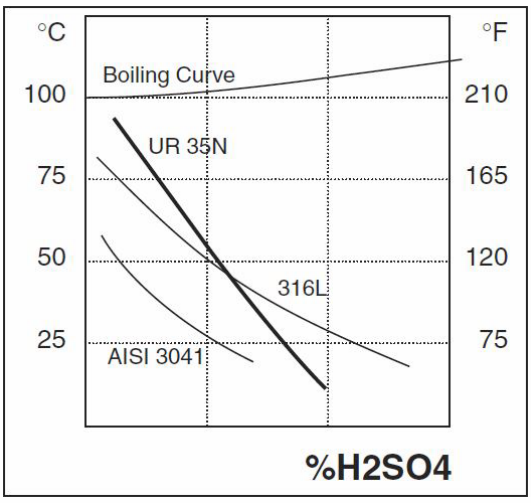
- Generally where 304 and 316L are used
- Pulp and paper industry (chip storage tank, white and black liquor tanks...
- Caustic solutions, organic acids (SCC resistance)
- Food industry
- Safety panels (high mechanical properties)
- Pressure vessels (weight savings...
- Mining (abrasion/corrosion).

Stainless Steel - Grade 2304 Duplex - URANUS 35N	Mechanical Properties - Tensile Properties (min values) - Values obtained for hot rolled plates (th ≤ 50 mm). UR 35N grade must not be used for a long time at temperatures higher than 300°C (572°F), where precipitation hardening phenomenon occurs.			
Temperature °C	20	100	200	300
Rp 0.2 MPa	400	330	280	230
Rp 1.0 MPa	440	365	310	260
Rm MPa	600	570	530	490
Temperature °F	68	212	392	572
YS 0.2% KSI	58	48	41	33
YS 1.0% KSI	64	53	45	38
UTS KSI	87	83	77	71
Elongation %	25	25	20	20

Stainless Steel - Grade 2304 Duplex - URANUS 35N	Mechanical Properties - Toughness values (KCV min values)			
Temperature °C	-50°C	20°C	-60°F	70°F
Single	75 J/cm	90 J/cm	54 J/cm	65 J/cm
Average (5)	90 J/cm	150 J/cm	65 J/cm	87 J/cm

Stainless Steel - Grade 2304 Duplex - URANUS 35N	Mechanical Properties - Hardness (Typical values) - Copper additions may be considered as UR 35N Cu may be hardenned by heat treatment to improve abrasion-corrosion resistance properties.		
Average (5)	HV10 180-230	HV10 180-230	HV10 180-230

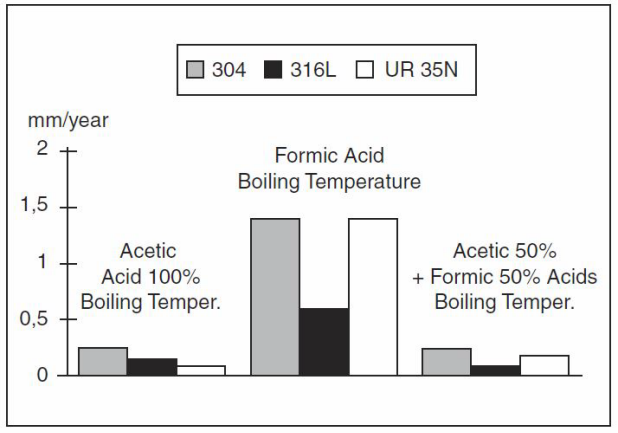
Stainless Steel - Grade 2304 Duplex - URANUS 35N	Physical Properties - Density : 7,800 kg/m3 - 0.28 lb/in^3			
Interval Temperature °C	200 - 100		20 - 200	20 - 300
Thermal expansion ax10-6K-1	13		13.5	14
Temperature °C	20	100	200	300
Resistivity (µΩ cm)	80	92	100	105
Thermal conductivity -1-1(W.m .K)	17	18	19	20
Specific heat (J.kg-1.K-1)	450	500	530	560
Young modulus E (GPa)	200	190	180	170
Shear modulus G (GPa)	75	73	70	67

Stainless Steel - Grade 2304 Duplex - URANUS 35N	Mechanical Properties Corrosion Resistance
General Corrosion	– Corrosion resistance to stagnant sulfuric acid (0,3 mm/year) 

Stainless Steel - Grade 2304 Duplex - URANUS 35N	Mechanical Properties Corrosion Resistance

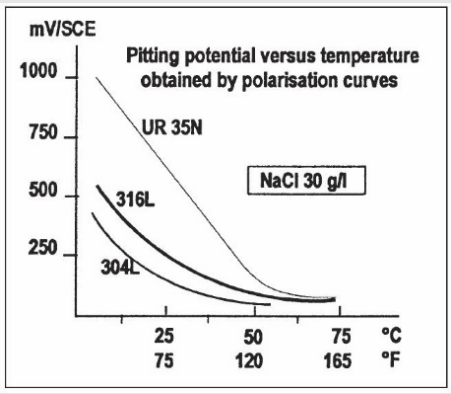
– General Corrosion

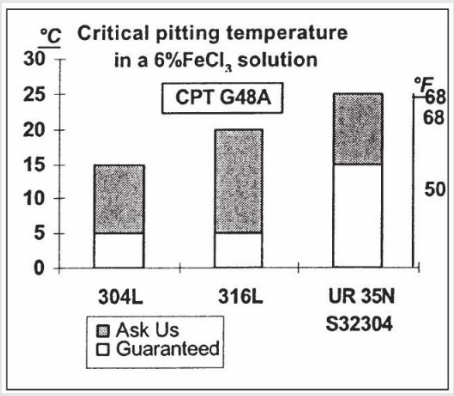
– Corrosion resistance, in different Organic acids



– Because of its high chromium content (23%) the corrosion resistance properties of UR 35N are almost equivalent to those of 316L.

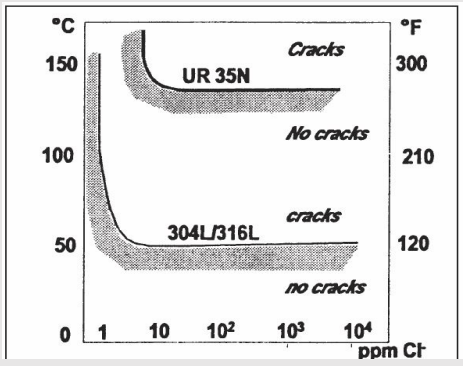
– Localized corrosion resistance:



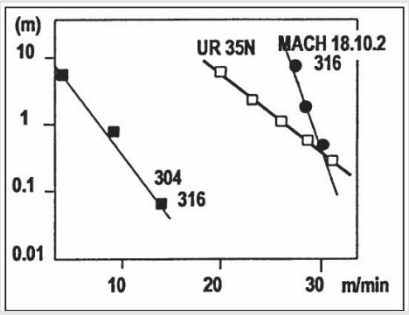


– The 23% chromium and 0.1N% additions explain why UR 35N duplex stainless steel behaves much better than 316L grade when considering pitting and crevice corrosion resistance.

– Stress corrosion resistance:



Stress corrosion resistance test results in chloride containing aqueous solutions (8ppm 02) PH = 7, >1000 h, applied stresses higher than the yield strength) show that UR 35N grade outperforms 304L and 316L grades, due to its high chromium additions and low nickel contents. This is a typical feature of duplex stainless steels. UR 45N performs still better than UR 35N in similar conditions.

Stainless Steel - Grade 2304 Duplex - URANUS 35N	Mechanical Properties
Other Corrosion Resistance Properties	– UR 35N duplex stainless steel successfully passes most of the standard IC test procedures such as ASTIVI A262E and C tests. Its corrosion rate in boiling nitric acid (65%) is higher than that of 316L grade. Due to its high yield strength, the alloy performs well in abrasion/corrosion applications.
Processing	– **Hot Forming**: Hot forming must be carried on in the 1150/900°C (2100/1650°F) temperature range. After forming, a new solution annealing treatment is recommended in the 950/1050°C (2100/1650°F) temperature range to fully restore corrosion resistance properties and mechanical properties. Parts of UR 35N must be supported carefully during heating to avoid creep deformation. – **Cold forming**: UR 35N may be cold formed without any problem. The same equipment as those used for the cold forming of 304 and 316 grades can be used. Due to its higher mechanical properties, including the yield strength, higher stresses are required for cold forming. A final solution annealing heat treatment is also recommended after cold forming in order to restore the mechanical and corrosion resistance properties, as described in 'hot forming'. – **Descaling**: Use the same solutions and pastes as for 304/316L grades. The pickling time will be higher than for austenitic grades due to the corrosion resistance properties of the alloy.
Machinability	– UR35N duplex exhibits improved machinability properties particularly when considering drilling. Its behaviour is equivalent to that of MACH 18.10.2(*) (316L grade with small sulphur additions and special melting process to control the shape and composition of inclusions). Furthermore UR 35N has better corrosion resistance and cleanliness properties as no sulphur additions are necessary. Localized corrosion resistance behaviour is improved.  (*) CLI - MACH 18.10.2 is a 316L type grade with improved machinability properties Total length (drilling) versus drilling speed
Welding	– UR 35N can be successfully welded by the following processes: TIG, manual and automatic– PLASMA, MIG, SMAW, SAW, FCAW. – The duplex microstructure renders the alloy less sensitive to hot cracking. – The welding parameters must be optimized to obtain a controlled ferrite level (20-70%). Typical recommended heat inputs are 10-25 KJ/cm with a 150°C (302°F) max interpass temperature. These conditions must be optimized taking into account the thickness of the products and welding equipment (Consult if necessary). We do not recommend pre-welding or post-welding heat treatments. Only complete solution annealing heat treatment may be considered (please, contact us).

Stainless Steel - Grade 2304 Duplex - URANUS 35N	Mechanical Properties Size Range		
Spec	**Hot Rolled Plates**	**Cold Rolled Plates**	**Clad Plates**
Thickness	5 to 150 mm 3/16" to 6"	2 to 14 mm 5/64" to 5/8"	6 to 150 mm 1/4" to 6"
Width	Up to 3300 mm Up to 130"	Up to 2300 mm Up to 90.5"	Up to 3300 mm Up to 130"
Length	Up to 12000 mm Up to 472"	Up to 8250 mm Up to 325"	Up to 14000 mm Up to 551"

NOTE: *This technical data and information represents our best knowledge at the time of printing. However, it may be subject to some slight variations due to our ongoing research programme on corrosion resistant grades. We therefore suggest that information be verified at time of enquiry or order.*

Furthermore, in service, real conditions are specific for each application. The data presented here is only for the purpose of description, and may only be considered as guarantees when our company has given written formal approval. Please contact us for further information.

Stainless Steel

2205 Duplex

Stainless Steel - 2205 Duplex (UNS S31803/S32205)	*- a Duplex Austenitic/ Ferritic stainless steel*

Typical Analysis

Fe	Cr	Mo	Ni	Si	Mn	C	N	P	S
Bal	21-23	2.5-3.5	4.5-6.5	1.0 Max	2.0 Max	.03 Max	.08-.2	.03 Max	.02 Max

Characteristics

- High Strength AND
- Duplex UNS S31803/S32205 is a ferritic-austenitic stainless combining high mechanical strength, ductility and hardness with excellent resistance to corrosion and erosion.

Mechanical Properties

- **Mechanical Test Requirements:**
  - Tensile - 90,000 psi min
  - Yield - 65,000 psi min
  - Elongation - 25 % min
  - Hardness - 293 HBN Max
- **Corrosion Resistance:**
  - The corrosion resistance of S31803/S32205, under most conditions of service, is superior to that of the fully austenitic type 304, 316 and 317L stainless steels. It has excellent resistance to sulfuric, phosphoric, nitric, and many other acids and salts.
  - Duplex UNS S31803/S32205 is highly resistant to acetic, formic and other organic acids and compounds. It is particularly suitable for the higher concentrations and temperatures where pitting and preferential corrosion are common causes of failure with most conventional austenitic stainless steels in the presence of chlorides and other impurities. Like the austenitic stainless steels, S31803 is not generally suitable for handling hydrochloric acid and other severely reducing acids and chemicals.
- **Stress-Corrosion Resistance:**
  - Resists Chloride Stress Corrosion Cracking
  - Duplex UNS S31803/S32205 has improved resistance to stress-corrosion cracking, crevice corrosion and pitting when compared to austenitic stainless steels such as types 304, 316, 317L and even the 20Cr-25Ni grades. It is highly resistant to stress-corrosion cracking in sodium chloride, seawater and many other environments.

Stainless Steel - 2205 Duplex (UNS S31803/S32205)	*- a Duplex Austenitic/ Ferritic stainless steel*
Fabrication	– Hot forming is carried out at 1150-950˚C. However, it should be borne in mind that the mechanical strength of the material is low at high temperatures. At temperatures below 950˚C embrittling can take place on account of the combination of strain and exposure in the sigma phase field. Quench annealing is normally required after hot forming.316, 317L and even the 20Cr-25Ni grades. It is highly resistant to stress-corrosion cracking in sodium chloride, seawater and many other environments. – Cold forming owing to the high yield strength of the steel, greater forces are normally required for the cold forming of S31803/ S32205 than for austenitic steels.
Machining	– High alloy duplex steels, such as S31803/S32205, are generally more difficult to machine than conventional austenitic stainless steels such as 17-12-2.5. Duplex steels have a somewhat different property profile than highly alloyed austenitic stainless steels. The main difference is that duplex grades are relatively easier to machine with high speed steel tools than with cemented carbide tools, compared to austenitic stainless steels with a similar alloy content.

Welding	– Duplex UNS S31803/ S32205 possesses good weldability. The following instructions should be followed:
	  – The material should be welded without preheating.
	  – The material should be allowed to cool between passes, preferably to below 150˚C.
	  – The recommended heat input in order to achieve a good balance between ferrite and austenite in the weld is 1.0-2.5 kJ/mm (aim at 30-60% ferrite). The energy input should be adjusted in proportion to the thickness of the material to be welded. A high energy input and slow cooling reduce the amount of ferrite.
	– Duplex UNS S31803/ S32205 can be welded using the following methods:
	  – Welding with covered electrodes (SMAW)
	  – Gas shielded arc welding such as GTAW (TIG), plasma, GMAW (MIG) and FCW.
	  – Submerged-arc welding (SAW)
	– Post weld heat treatment is not normally necessary. In cases where heat treatment is considered, for example for stress relieving, this should be carried out at 1020-1070˚C.

Stainless Steel - 2205 Duplex (UNS S31803/S32205)

- a Duplex Austenitic/ Ferritic stainless steel

Applications

- Because of its resistance to chloride pitting and stress-corrosion cracking, S31803/S32205 is finding wide use in place of austenitic stainless steels for handling solutions containing chlorides such as in marine scrubbers. As a result of its wear, erosion and corrosion resistance, S31803/S32205 is particularly suitable for pumps, agitators and other critical components handling hot corrosive slurries.
- Special mention should be made of its performance in the production of fertilizer grade phosphoric acid by the "wet" process where the alloy finds extensive application.
- Some of the areas or industries of present or potential use for S31803/S32205 products follow:

Chemical Process Industry:	- Equipment Handling Fatty Acids, Terephthalic Acid and Polytheonic Acid, Sulfuric Acid Protection, Tank Internals, Rakes, Fasteners in Uranium Extraction
Copper Smelting:	-Sulfuric Acid Production, Leaching Area, Precipitators, I.D. Fans, Wet Scrubbers, Tuyere Bars
Marine:	-Propeller Shaftings, Cutlass Bearings Seals, Rudders, Desalinization Equipment, Pump Parts, Feed Water Heaters, Fasteners for Off-Shore Platform Gauges
Oil & Gas:	-Injection Pumps, Processes for Treating Crude Oil i.e. Desalting, Desulfurization and Distillation, Mild Sour Gas Wells
Petrochemical:	-Styrene Monomer Wash Acid Equipment, PVC film Extrusion Dies, Solvent Recovery Absorbers, Low Density Polypropylene Dryer Baffles, Entrainment Separators, Handling Hot Organic Acids i.e. Acetic, Formic, Oxalic Acids With or Without Chlorides Present
Pollution Control:	-Centrifuges (Waste Water Clarification), Venturi Scrubbers for Sewage Incinerators, SO2 Scrubbers, Roast Gas Scrubbers (Fan and Vessels), Fans for Garbage Incinerators, Sodium Hypochlorite Scrubbers
Pulp & Paper	-Black Liquor Heater Tubes, Digester Blow Valves, Rotary Feed Valves, I.D. Fans, Brownstock Washers, Digester Strainer Plates, Agitator Assemblies (Bleach Plt Mixer), Cyclone Target Plates, Precipitators, Wet Scrubbers, Pump Parts, Recovery Furnace Boiler Tubes, Bleach Agitator Shafts
Wet Phosphoric Acid Production	-Digester Agitators, Mixing Tees, Vortex, Piping, Breakers, Centrifuge Parts, Pump Parts, Valves,
Urea Production	-Decomposer Tubes, Pump Parts, Valves, Bolts

Stainless Steel - 2205 Duplex (UNS S31803/S32205)	*- a Duplex Austenitic/ Ferritic stainless steel*
ASME Boiler & Pressure Vessel Code Case	– Duplex UNS S31803/S32205 sheet, strip, plate, bar, pipe and tubing are covered in ASME Boiler and Pressure Vessel Code, Section VIII, Division I.
Specifications	– Duplex UNS S31803/S32205 is covered by the following ASTM, ASME specifications: – ASTM A182/ASME SA-182: Forged or rolled alloy-steel pipe, flanges, forged fittings, and valves and parts for high temperature service – ASTM A240/ASME SA-240: Heat resisting Cr and CrNi stainless steel, plate, sheet, strip for fusion-welded unfired pressure vessels – ASTM A276: Stainless and heat resisting steel bars and shapes – ASTM A789: Seamless and welded ferritic/austenitic stainless steel tubing for general service – ASTM A790: Seamless and welded ferritic/austenitic stainless steel pipe

SECTION 2. TECHNICAL DATA & TERMS

Tolerances

Hot Rolled Carbon and Alloy Bars

Size Tolerances - Rounds and Squares			
Specified Sizes (Inches)	Size Tolerances (Inches)		Out of Round or Square (Inches)
	Over	Under	
To 5/16 incl.	0.005	0.005	0.008
Over 5/16 to 7/16 incl.	0.006	0.006	0.009
Over 7/16 to 5/8 incl.	0.007	0.007	0.010
Over 5/8 to 7/8 incl.	0.008	0.008	0.012
Over 7/8 to 1 incl.	0.009	0.009	0.013
Over 1 to 1 1/8 incl.	0.010	0.010	0.015
Over 1 1/8 to 1 1/4 incl.	0.011	0.011	0.016
Over 1 1/4 to 1 3/8 incl.	0.012	0.012	0.018
Over 1 3/8 to 1 1/2 incl.	0.014	0.014	0.021
Over 1 1/2 to 2 incl.	1/64	1/64	0.023
Over 2 to 2 1/2 incl.	1/32	0	0.023
Over 2 1/2 to 3 1/2 incl.	3/64	0	0.035
Over 3 1/2 to 4 1/2 incl.	1/16	0	0.046
Over 4 1/2 to 5 1/2 incl.	5/64	0	0.058
Over 5 1/2 to 6 1/2 incl.	1/8	0	0.070
Over 6 1/2 to 8 1/4 incl.	5/32	0	0.085
Over 8 1/4 to 9 1/2 incl.	3/16	0	0.100
Over 9 1/2 to 10 incl.	1/4	0	0.120

Out-of-round is the difference between the maximum diameters of the bar, measured at the same cross-section. Out-of-square is the difference in the two dimensions at the same cross-section of a square bar, each dimension being the distance between opposite sides.

Size Tolerances - Hexagons			
Specified Sizes (Inches)	Size Tolerances (Inches)		Out of Round or Square (Inches)
	Over	Under	
to 1/2 incl.	0.007	0.007	0.011
Over 1/2 to 1 incl.	0.010	0.010	0.015
Over 1 to 1 1/2 incl.	0.021	0.013	0.025
Over 1 1/2 to incl.	1/32	1/64	1/32
Over 2 to 2 1/2 incl.	3/64	1/64	3/64
Over 21/2 to 31/2 incl.	1/16	1/64	1/16

Out-of-hexagon section is the greatest difference between any two dimensions at the same cross-section between opposite faces.

Size Tolerances - Flats	Specified Widths (Inches)				
Thickness Tolerances, for Thickness Given Over and Under (Inches)	to 1 incl	Over 1 to 2 incl.	Over 2 to 4 incl.	Over 4 to 6 incl.	Over 6 to 8 incl.
0.203 to 0.230 excl.	0.007	0.007	0.008	0.009	*
0.203 to 1/4 excl.	0.007	0.007	0.008	0.009	0.015
1/4 to 1/2 incl.	0.008	0.0129	0.015	0.015	0.016
Over 1/2 to 1 incl.	0.010	0.015	0.020	0.020	0.25
Over 1 to 2 incl.	--	1/32	1/32	1/32	1/32
Over 2 to 3 incl.	--	--	3/64	1/16	1/16
Over 3	--	--	3/64	3/64	1/16
	Width Tolerance (Inches)				
Over	1/64	1/32	1/16	3/32	1/8
Under	1/64	1/32	1/32	1/16	3/32

Straightness Tolerances Rounds, Squares, Hexagons, Octagons, Flats, Spring Flats	
Standard	1/4 inch in any 5 feet, 1/4 x (number of feet of length ÷ 5)
Special	1/8 inch in any 5 feet, 1/8 x (number of feet of length ÷ 5)

Because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation has been performed after straightening.

Data - Tolerances

Cold Finished Carbon Bars

Tolerances -Cold Finished Carbon Bars	Minus Tolerances in Inches (No Plus Tolerances Apply) (All tolerances are in inches [B] and are minus [C])			
Specified Size	*Maximum of Carbon Range 0.28% less*	*Maximum of Carbon Range Over 0.28% to 0.55% incl.*	*Maximum of Carbon Range to 0.55% include, Stress Relieved or Annealed after Cold Finishing*	*Maximum of Carbon Range Over 0.55% or All grades Quenched and Tempered or Normalized and Tempered before Cold Finishing*
Round -Cold Drawn (to 4in.) or Turned and Polished				
To 1 1/2, incl.	0.002	0.003	0.004	0.005
Over 1 1/2 to 2 1/2, incl.	0.003	0.004	0.005	0.006
Over 2 1/2 to 4, incl.	0.004	0.005	0.006	0.007
Over 4 to 6, incl.	0.005	0.006	0.007	0.008
Over 6 to 8, incl.	0.006	0.007	0.008	0.009
Over 8 to 9, incl.	0.007	0.008	0.009	0.010
Hexagons				
To 3/4, incl.	0.002	0.003	0.004	0.006
Over 3/4 to 1 1/2, incl.	0.003	0.004	0.005	0.007
Over 1 1/2 to 1 1/2, incl.	0.004	0.005	0.006	0.008
Over 2 1/2 to 3 1/8 incl.	0.005	0.006	0.007	0.009
Over 3 1/8 to 4 incl.	0.005	0.006	---	---
Squares				
To 3/4, incl.	0.002	0.004	0.005	0.007
Over 3/4 to 1 1/2, incl.	0.003	0.005	0.006	0.008
1/8 1 1/2 to 2 1/2, incl.	0.004	0.006	0.007	0.009
Over 2 1/2 to 4, incl.	0.006	0.008	0.008	0.011
Over 4 to 5 incl.	0.010	----	----	----
Over 5 to 6 incl.	0.014	----	----	----

Tolerances -Cold Finished Carbon Bars	Minus Tolerances in Inches (No Plus Tolerances Apply) (All tolerances are in inches [B] and are minus [C])			
Specified Size	*Maximum of Carbon Range 0.28% less*	*Maximum of Carbon Range Over 0.28% to 0.55% incl.*	*Maximum of Carbon Range to 0.55% include, Stress Relieved or Annealed after Cold Finishing*	*Maximum of Carbon Range Over 0.55% or All grades Quenched and Tempered or Normalized and Tempered before Cold Finishing*
Flats				
To 3/4, incl.	0.003	0.004	0.006	0.008
Over 3/4 to 1 1/2, incl.	0.003	0.005	0.008	0.010
Over 1 1/2 to 3, incl.	0.005	0.006	0.010	0.012
Over 3 to 4 incl.	0.006	0.008	0.011	0.016
Over 4 to 6 incl.	0.008	0.010	0.012	0.020
Over 6	0.013	0.015	----	----
Size (In.) Cold Drawn Ground and Polished	**Turned, Ground and Polished**		**Tolerances from Specified Size, Minus Only (In.)**	
To 11/2, incl.	To 1 1/2, incl.		0.001	
Over 11/2 to 2 1/2, excl.	Over 1 1/2 to 2 1/2, excl.		0.0015	
2 1/2 to 3, incl.	2 1/2 to 3, incl.		0.002	
Over 3 to 4, incl.	Over 3 to 4, incl.		0.003	
----	Over 4 to 6, incl.		0.004A	
----	Over 6		0.005A	

A- For non-resulfurized steels (steels specified to maximum sulfur limits under 0.08%), or for steels thermally treated, the tolerance is increased by 0.001 in.

Data - Tolerances

Cold Finished Alloy Bars

Tolerances -Cold Finished Alloy Bars	All tolerances are in inches and are minus [B]			
Specified Size (in.[A])	*Maximum of Carbon Range 0.28% less*	*Maximum of Carbon Range Over 0.28% to 0.55% incl.*	*Maximum of Carbon Range to 0.55% include, Stress Relieved or Annealed after Cold Finishing*	*Maximum of Carbon Range over 0.55% with or without stress relieving or annealing after cold finishing. Also, all carbons quenched and tempered (heat treated), or normalized and tempered before Cold Finishing.*
Round -Cold Drawn (to 4 in.) or Turned and Polished				
To 1, include, in coils	0.002	0.003	0.004	0.005
Cut lengths: To 1 1/2, incl.	0.003	0.004	0.005	0.006
Over 1 1/2 to 2 1/2, incl.	0.004	0.005	0.006	0.007
Over 2 1/2 to 4, incl.	0.005	0.006	0.007	0.008
Over 4 to 6, incl.	0.006	0.007	0.008	0.009
Over 6 to 8, incl.	0.007	0.008	0.009	0.10
Over 6 to 9, incl.	0.008	0.009	0.10	0.011
Hexagons				
To 3/4, incl.	0.003	0.004	0.005	0.007
Over 3/4 to 1 1/2, incl.	0.004	0.005	0.006	0.008
Over 1 1/2 to 2 1/2, incl.	0.005	0.006	0.007	0.009
Over 2 1/2 to 3 1/8 incl.	0.006	0.007	0.008	0.10
Over 3 1/8 to 4 incl.	0.006	---	---	---

Tolerances -Cold Finished Alloy Bars	All tolerances are in inches and are minus [B]			
Specified Size (in.[A])	*Maximum of Carbon Range 0.28% less*	*Maximum of Carbon Range Over 0.28% to 0.55% incl.*	*Maximum of Carbon Range to 0.55% include, Stress Relieved or Annealed after Cold Finishing*	*Maximum of Carbon Range over 0.55% with or without stress relieving or annealing after cold finishing. Also, all carbons quenched and tempered (heat treated), or normalized and tempered before Cold Finishing.*
Squares				
To 3/4, incl.	0.003	0.005	0.006	0.006
Over 3/4 to 1 1/2, incl.	0.004	0.006	0.007	0.009
Over 1 1/2 to 2 1/2, incl.	0.005	0.007	0.008	0.010
Over 2 1/2 to 4, incl.	0.007	0.009	0.010	0.012
Over 4 to 5 incl.	0.011	----	----	----
Flats				
To 3/4, incl.	0.004	0.005	0.007	0.009
Over 3/4 to 1 1/2, incl.	0.005	0.006	0.009	0.011
Over 1 1/2 to 3, incl.	0.006	0.007	0.011	0.013
Over 3 to 4 incl.	0.007	0.009	0.012	0.017
Over 4 to 6 incl.	0.009	0.011	0.013	0.021
Over 6	0.014	---	----	----

Tolerances -Cold Finished Alloy Bars		Straightness Tolerances for Cold Finished Bars [A, B] *-All grades quenched and tempered or normalized and tempered to Brinell 302 max before cold finishing; and all grades stress relieved or annealed after cold finishing. Straightness tolerances are not applicable to bars having Brinell hardness exceeding 302.* *-Straightness Tolerances, in. (Maximum Deviation) from Straightness in any 10-ft Portion of the Bar*			
		Maximum of Carbon Range, 0.28% or Less		Maximum of Carbon Range, 0.28% or Less and All Grades Thermally Treated	
Size, in.	Length, ft.	Rounds	Squares, Hexagons & Octagons	Rounds	Squares, Hexagons & Octagons
Less than 5⁄8	less than 15	1⁄8	3⁄16	3⁄16	1⁄ 4
Less than 5⁄8	15 and over	1⁄8	5⁄16	5⁄16	3⁄ 8
5⁄8 and over	less than 15	1⁄16	1⁄ 8	1⁄ 8	3⁄16
5⁄8 and over	15 and over	1⁄8	3⁄16	3⁄16	1⁄ 4

Machining Allowance

Round Bar Stock

Hot Rolled Bars

- Alloy or special quality carbon steel bars, hot rolled 1.6% of diameter per side.

Cold Drawn Bars

- 0.001" per .062" (1.6%) of diameter per side, including leaded steels.
- 0.0015" per .062" (2.4%) of diameter per side, for free machining grades, except leaded steels.

Cold Drawn, Ground and Polished Bars

- .0005" per .062" (0.8%) of diameter per side, including leaded steels.
- .00075" per .062" (1.2%) of diameter per side, for free machining grades, except leaded steels.

Turned Bars

- This product requires finish machining to clean up the turning marks according to the following table:

Bar Size (Inches)			Minimum Removal Per Side (Inch)	Minimum Removal Per Diameter (Inch)
5/8	to 2	Incl.	.010	.020
Over 2	to 3	Incl.	.013	.026
Over 3	to 31/2	Incl.	.015	.030
Over 3 1/2	to 4	Incl.	.018	.036
Over 4	to 41/2	Incl.	.021	.042
Over 4 1/2	to 5	Incl.	.024	.048
Over 5	to 6	Incl.	.027	.054
Over 6	to 7	Incl.	.030	.060
Over 7	to 8	Incl.	.033	.066

Turned and Polished Turned, Ground and Polished Bars

- Bars ordered to these conditions are generally free of decarburization and surface imperfections. If total freedom from decarburization is required, it must be specified
- Turned, Ground and Polished Bars may be used in the as received condition.

Recommended Stock Removal for Aircraft Quality Alloys Subject to Magnetic Particle Inspection

Theoretical Weights

Theoretical Weights (In Pounds): Steel - ROUNDS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
1/8	.0035	042	.50	.84
5/32	.0554	.065	.78	1.31
3/16	.0078	.094	1.13	1.88
7/32	.0107	.128	1.54	2.56
1/4	.0139	.167	2.01	3.34
9/32	.0176	.211	2.54	4.23
5/16	.0218	.261	3.13	5.22
11/32	.0263	.316	3.79	6.32
3/8	.0313	.376	4.51	7.52
13/32	.0368	.441	5.29	8.82
7/16	.0426	.512	6.14	10.23
15/32	.0489	.587	7.05	11.75
31/64	.0523	.627	7.53	12.54
1/2	.0557	.668	8.02	13.36
17/32	.0629	.754	9.05	15.09
9/16	.0705	.846	10.15	16.91

Theoretical Weights (In Pounds): Steel - ROUNDS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
19/32	.0785	.942	11.31	18.85
39/64	.0827	.993	11.91	19.85
5/8	.0870	1.044	12.53	20.88
41/64	.0914	1.097	13.16	21.94
21/32	.0959	1.151	13.81	23.02
11/16	.1053	1.263	15.16	25.27
23/32	.1151	1.281	16.57	27.62
47/64	.1201	1.442	17.30	28.83
3/4	.1253	1.504	18.04	30.07
49/64	.1306	1.567	18.80	31.34
25/32	.1359	1.631	19.58	32.63
13/16	.1470	1.765	21.17	35.29
27/32	.1586	1.903	22.83	38.06
55/64	.1645	1.974	23.69	39.48
7/8	.1705	2.046	24.56	40.93
29/32	.1829	2.195	26.34	43.90

Theoretical Weights (In Pounds): Steel - ROUNDS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
15/16	.1958	2.349	28.19	46.98
31/32	.2090	2.508	31.10	50.17
63/64	.2158	2.590	31.08	51.80
1	.2227	2.673	32.07	53.46
1/64	.2294	2.752	33.03	55.05
1/32	.2369	2.843	34.11	56.85
1/16	.2515	3.017	36.21	60.35
1/8	.2819	3.383	40.59	67.66
3/16	.3141	3.769	45.23	75.38
1/4	.3480	4.176	50.12	83.53
5/16	.3837	4.604	55.25	92.09
3/8	.4211	5.053	60.64	101.1
7/16	.4603	5.523	66.28	110.5
1/2	.5012	6.014	72.17	120.3
9/16	.5438	6.526	78.31	130.5
5/8	.5882	7.058	84.70	141.2

Theoretical Weights (In Pounds): Steel - ROUNDS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
11/16	.6343	7.612	91.34	152.2
3/4	.6821	8.186	98.23	163.7
13/16	.7317	8.781	105.4	175.6
7/8	.7831	9.397	112.8	187.9
15/16	.8361	10.03	120.4	200.7
2	.8910	10.69	128.3	213.8
1/16	.9475	11.37	136.4	227.4
1/8	1.006	12.07	114.8	241.4
3/16	1.066	12.79	153.5	255.8
1/4	1.128	13.53	162.4	270.6
5/16	1.191	14.29	171.5	285.9
3/8	1.256	15.08	180.9	301.5
7/16	1.323	15.88	190.6	317.6
1/2	1.392	16.71	200.5	334.1
9/16	1.463	17.55	210.6	351.0
5/8	1.535	18.42	221.0	368.4

Theoretical Weights (In Pounds): Steel - ROUNDS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
11/16	1.609	19.31	231.7	386.1
3/4	1.684	20.21	242.6	404.3
13/16	1.762	21.14	253.7	422.9
7/8	1.841	22.09	265.1	441.9
15/16	1.922	23.06	276.8	461.3
3	2.005	24.06	288.7	481.1
1/16	2.089	25.07	300.8	501.4
1/8	2.75	26.10	313.2	522.0
3/16	2.263	27.16	325.9	543.1
1/4	2.353	28.23	338.8	564.6
5/16	2.444	29.33	351.9	586.6
3/8	2.537	20.45	365.3	608.9
7/16	2.632	31.58	379.0	631.7
1/2	2.729	32.74	392.9	654.8
9/16	2.827	33.92	407.1	678.4
5/8	2.927	35.12	421.5	702/9

Theoretical Weights (In Pounds): Steel - ROUNDS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
11/16	3.029	36.35	436.1	726.9
3/4	3.132	37.59	451.0	751.7
13/16	3.238	38.85	466.2	777.0
7/8	3.345	40.14	481.6	802.7
15/16	3.453	41.44	497.3	828.8
4	3.564	42.77	513.2	855.3
1/8	3.790	45.48	545.8	909.6
3/16	3.906	46.87	562.4	937.4
1/4	4.023	48.28	579.3	965.6
5/16	4.142	49.71	596.5	994.2
3/8	4.263	51.16	613.9	1023
7/16	4.386	52.63	631.6	1053
1/2	4.510	54.13	649.5	1083
9/16	4.637	55.64	667.7	1113
5/8	4.765	57.18	686.1	1143
11/16	4.894	58.73	704.8	1175

Theoretical Weights (In Pounds): Steel - ROUNDS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
3/4	5.026	60.31	723.7	1206
7/8	5.294	63.52	762.3	1270
15/16	5.430	65.15	781.9	1303
5	5.569	66.82	801.9	1336
1/8	5.850	70.21	842.4	1404
1/4	6.139	73.67	884.0	1473
7/16	6.345	77.22	926.6	1544
1/2	6.586	79.03	948.3	1581
1/4	6.738	80.86	970.2	1617
5/8	7.048	84.57	1015	1691
3/4	7.364	88.37	1060	1767
15/16	7.852	94.23	1131	1885
6	8.019	96.22	1155	1924
1/4	8.701	104.4	1253	2088
1/2	9.411	112.9	1355	2259
3/4	10.15	121.8	1461	2436

Theoretical Weights (In Pounds): Steel - ROUNDS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
7	10.91	131.0	1572	2619
1/4	11.71	140.5	1686	2810
1/2	12.53	150.4	1804	3007
3/4	13.38	160.5	1926	3211
8	14.26	171.1	2053	3421
1/4	15.16	181.9	2183	3638
1/2	16.09	193.1	2317	3862
3/4	17.05	204.6	2456	4093
9	18.04	216.5	2598	4330
1/4	19.06	228.7	2744	4574
1/2	20.10	241.2	2895	4824
3/4	21.17	254.1	3049	5082
10	22.27	267.3	3207	5346
1/4	23.40	280.8	3370	5616
1/2	24.56	294.7	3536	5894
3/4	25.74	308.9	3707	6178

Theoretical Weights (In Pounds): Steel - ROUNDS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
11	26.95	323.4	3881	6468
1/2	29.46	353.5	4242	7070
12	32.07	384.9	4619	7698
1/2	34.80	417.6	5012	8353
13	37.64	451.7	5421	9034
1/2	40.59	487.1	5845	9743
14	43.66	523.9	6287	10478
15	50.12	601.4	7217	12028
16	57.02	684.3	8211	13685
1/2	60.64	727.7	8732	14554
17	64.37	772.5	9269	15449
1/2	68.21	818.6	9823	15371
18	72.17	866.0	10392	17320
19	80.41	964.9	11579	19298
20	89.10	1069	12830	21383
21	98.23	1179	14145	23575

Theoretical Weights (In Pounds): Steel - ROUNDS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
22	107.8	1294	15524	25873
23	117.8	1414	16967	28279
24	128.3	1540	18475	30791
26	150.6	1807	21682	36137
28	174.6	2096	25148	41912

Theoretical Weights (In Pounds): Steel - SQUARES				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
1/8	.0044	.053	.64	1.06
3/16	.0100	.120	1.44	2.40
1/4	.0177	.213	2.55	4.25
5/16	.0277	.332	3.98	6.64
3/8	.0399	.479	5.74	9.57
7/16	.0543	.651	7.82	13.03
1/2	.0709	.851	10.21	17.02
9/16	.0897	1.077	12.92	21.54
5/8	.1108	1.329	15.95	26.59
11/16	.1340	1.609	19.30	32.17

Theoretical Weights (In Pounds): Steel - SQUARES				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
3/4	.1595	1.914	22.97	38.29
13/16	.1872	2.247	26.97	44.93
7/8	.2171	2.606	31.27	52.11
15/16	.2493	2.991	35.89	59.82
1	.2836	3.403	40.84	68.06
1/8	.3589	4.307	51.69	84.14
3/16	.3999	4.799	57.59	95.98
1/4	.4431	5.318	63.81	106.4
3/8	.5362	6.434	77.21	128.7
1/2	.6381	7.657	91.89	153.1
5/8	.7489	8.987	107.8	179.7
3/4	.8685	10.42	125.1	208.4
7/8	.9970	11.96	143.6	239.3
2	1.134	13.61	163.4	272.3
1/8	1.281	15.37	184.4	307.4
1/4	1.436	17.23	206.7	344.6

Theoretical Weights (In Pounds): Steel - SQUARES				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
3/8	1.600	19.20	230.4	383.9
1/2	1.773	21.27	255.2	425.4
5/8	1.954	23.45	281.4	469.0
3/4	2.145	25.74	308.0	514.7
7/8	2.344	28.13	337.6	562.6
3	2.552	30.63	367.5	612.6
1/4	2.996	35.95	431.4	718.9
1/2	3.474	41.69	500.3	833.8
3/4	3.988	47.86	574.3	957.2
4	4.538	54.45	653.4	1089
1/4	5.123	61.47	737.6	1229
1/2	5.743	68.91	827.0	1378
3/4	6.999	76.78	921.4	1536
5	7.090	85.08	1021	1702
1/2	8.579	102.9	1235	2059
6	10.21	122.5	1470	2450

Theoretical Weights (In Pounds): Steel - SQUARES				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
7	13.90	166.8	2001	3335
8	18.15	217.8	2614	4356
9	22.97	275.6	3308	5512
10	28.36	340.3	4084	6808
12	40.84	490.0	5880	9800
14	55.60	667.2	8804	13340
16	72.60	871.2	10456	17424
18	91.88	1102	13232	22048

Theoretical Weights (In Pounds): Steel - HEXAGONS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
3/16	.0086	.104	1.24	2.07
1/4	.0154	.184	2.21	3.68
5/16	.0240	.288	3.45	5.76
3/8	.0345	.415	4.97	8.29
7/16	.0470	.564	6.77	11.28
1/2	.0614	.737	8.84	14.74
9/16	.0777	.933	11.19	18.65
5/8	.0959	1.151	13.82	23.03
11/16	.1161	1.393	16.72	27.86
3/4	.1382	1.658	19.89	33.16
13/16	.1621	1.946	23.35	38.91
7/8	.1880	2.257	27.08	45.13
15/16	.2159	2.590	31.08	51.81
1	.2456	2.947	35.37	56.95
1/16	.2773	3.327	39.93	66.54
1/8	.3108	3.730	44.76	74.60

Theoretical Weights (In Pounds): Steel - HEXAGONS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
3/16	.3463	4.156	49.87	83.12
1/4	.3838	4.605	55.26	92.10
5/16	.4231	5.077	60.93	101.5
3/8	.4643	5.572	66.87	111.4
7/16	.5075	6.090	73.08	121.8
1/2	.5526	6.631	79.56	132.6
9/16	.5996	7.196	86.35	143.9
5/8	.6485	7.783	93.39	155.7
11/16	.6994	8.393	100.7	167.9
3/4	.7522	9.026	108.3	180.5
13/16	.8068	9.682	116.2	193.6
7/8	.8634	10.36	124.3	207.2
15/16	.9220	11.06	132.8	221.3
2	.9824	11.79	141.5	235.8
1/8	1.109	13.31	159.7	266.2
3/16	1.175	14.10	169.2	282.1

Theoretical Weights (In Pounds): Steel - HEXAGONS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
1/4	1.243	14.92	179.0	298.4
3/8	1.385	16.62	199.5	332.5
7/16	1.459	17.51	210.1	350.2
1/2	1.535	18.42	221.0	368.4
5/8	1.692	20.31	243.7	406.2
3/4	1.857	22.29	267.5	445.8
7/8	2.030	24.36	292.3	487.2
3	2.210	26.53	318.3	530.5
1/8	2.398	28.78	345.4	575.6
1/2	3.009	36.10	433.2	722.1
3/4	3.454	41.45	497.3	828.9
4	3.930	47.16	565.9	943.1

Theoretical Weights (In Pounds): Steel - OCTAGONS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
3/16	.0083	.099	1.19	1.98
1/4	.0147	.176	2.11	3.52
5/16	.0229	.275	3.30	5.51
3/8	.0330	.397	4.76	7.93
7/16	.0450	.540	6.48	10.79
1/2	.0587	.705	8.46	14.10
9/16	.0743	.892	10.70	17.84
5/8	.0918	1.101	13.21	22.02
11/16	.1110	1.333	16.00	26.66
3/4	.1322	1.586	19.03	31.72
13/16	.1551	1.861	22.33	37.22
7/8	.1799	2.159	25.91	43.18
15/16	.2065	2.478	29.74	49.56
1	.2349	2.819	33.83	56.38
1/16	.2652	2.183	38.20	63.66
1/8	.2974	3.568	42.82	71.36

Theoretical Weights (In Pounds): Steel - OCTAGONS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
3/16	.3313	3.976	47.71	79.52
1/4	.3671	4.405	52.86	88.10
5/16	.4047	4.857	58.28	97.14
3/8	.4442	5.330	63.96	106.6
7/16	.4855	5.826	69.91	116.5
1/2	.5286	6.343	76.12	126.9
9/16	.5736	6.883	82.60	137.7
5/8	.6204	7.445	89.34	148.9
11/16	.6690	8.028	96.34	160.6
3/4	.7195	8.634	103.6	172.7
13/16	.7718	9.262	111.1	185.4
7/8	.8260	9.912	118.9	198.2
15/16	.8819	10.58	127.0	211.6
2	.9298	11.28	135.4	225.6
1/8	1.061	12.73	152.8	254.6
3/16	1.124	13.49	161.9	269.8

Theoretical Weights (In Pounds): Steel - OCTAGONS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
1/4	1.189	14.27	171.2	285.4
3/8	1.325	15.90	190.8	318.0
7/16	1.396	16.75	201.0	335.0
1/2	1.468	17.62	211.4	352.4
5/8	1.619	19.43	233.2	388.6
3/4	1.777	21.32	255.8	426.4
7/8	1.942	23.30	279.6	466.0
3	2.114	25.37	304.4	507.4
1/8	2.294	27.53	330.4	550.6
1/2	2.878	34.54	414.5	690.8

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
1/16				
x 1/4	.0044	.053	.641	.06
3/8	.0066	.080	.961	.60
1/2	.0089	1.06	1.28	2.13
5/8	.0111	.133	1.60	2.66
3/4	.0133	.160	1.91	3.19
7/8	.0155	.186	2.23	3.72
1	.0177	.213	2.55	4.25
1 1/8	.0199	.239	2.87	4.79
1 1/4	.0222	.266	3.19	5.32
1 1/2	.0266	.319	3.83	6.38
1 3/4	.0310	.372	4.47	7.45
2	.0355	.425	5.11	8.41
2 1/2	.0443	.532	6.38	10.64
3	.0532	.638	7.66	12.76
3/32				

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
x 3/8				
1/2	.0100	.120	1.44	2.39
5/8	.0133	.160	1.91	3.19
3/4	.0166	.199	2.39	3.99
7/8	.0199	.239	2.87	4.79
1	.0233	.279	3.35	5.58
1 1/8	.0266	.319	3.83	6.38
1 1/4	.0299	.359	4.31	7.18
1 1/2	.0332	.399	4.79	7.98
1 3/4	.0399	.479	5.74	9.57
2	.0465	.558	6.70	11.17
2 1/2	.0532	.638	7.66	12.76
3	.0665	.798	9.57	15.95
1/8	.0798	.957	11.49	19.14
x 3/16				
1/4				

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
5/16	.0066	.080	.96	1.60
3/8	.0089	.106	1.28	2.13
1/2	.0111	.133	1.60	2.66
5/8	.0133	.160	1.91	3.19
3/4	.0177	.213	2.55	4.25
7/8	.0222	.266	3.19	5.32
1	.0266	.319	3.83	6.38
1 1/8	.0310	.372	4.47	7.45
1 1/4	.0355	.425	5.11	8.51
1 1/2	.0399	.479	5.74	8.57
1 3/4	.0443	0532	6.38	10.64
2	.0532	.638	7.66	12.76
2 1/4	.0620	.745	8.93	14.89
2 1/2	.0709	8.51	10.21	17.02
2 3/4	.0798	.957	11.49	19.14
3	.0886	1.064	12.76	21.27

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
3 1/2	.0975	1.170	14.04	23.40
4	.1064	1.276	15.31	25.52
4 1/2	.1241	1.489	17.87	29.78
5	.1418	1.702	20.42	34.03
6	.1595	1.914	22.97	38.29
12	.1773	2.127	25.52	42.74
	.2127	2.552	30.63	51.05
	.4254	5.105	61.26	102.1
1/4 x 5/16	.0222	.266	3.19	5.32
3/8	.0266	.319	3.83	6.38
1/2	.0355	.425	5.11	8.51
9/16	.0399	.479	5.74	9.57
5/8	.0443	.532	6.38	10.64
3/4	.0532	.638	7.66	12/76
7/8	.0620	.745	8.93	14.89
1	.0709	.851	10.21	17.02

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
1 1/8	.0798	.957	11.49	19.14
1 1/4	.0886	1.064	12.76	21.27
1 3/8	.0975	1.170	14.04	23.40
1 1/2	.1064	1.276	15.31	25.52
1 5/8	.1152	1.383	1.659	27.65
1 3/4	.1241	1.489	17.87	29.78
2	.1428	1.702	20.42	34.03
2 1/4	.1595	1914	22.97	38.29
2 1/2	.1773	2.127	25.52	42.54
2 3/4	.1950	2.340	28.08	46.79
3	.2127	2.552	30.63	51.05
3 1/4	.2304	2.765	33.18	55.30
3 1/2	.2482	2.978	35.73	59.76
3 3/4	.2659	3.191	38.29	63.81
4	.2836	3.403	40.84	68.86
4 1/2	.3191	3.829	45.94	76.56

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
5	.3545	4.254	51.05	85.08
5 1/2	.3900	4.679	56.15	93.59
6	.4254	5.105	61.26	102.1
7	.4963	5.956	71.47	119.1
8	.5672	6.806	81.68	136.1
10	.7090	8.508	102.1	170.2
12	.8508	10.21	122.5	204.2
5/16				
x 3/8				
1/2	.0332	.399	4.79	7.98
5/8	.0443	.532	6.38	10.64
3/4	.0554	.665	7.98	13.29
7/8	.0665	.798	9.57	15.95
1	.0775	.931	11.17	18.61
1 1/8	.0886	1.064	12.76	21.27
1 1/4	.0997	1.196	14.36	23.93

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
1 3/8	.1108	1.329	15.95	26.59
1 1/2	.1219	1.462	17.55	29.25
1 5/8	.1329	1.595	19.14	31.91
1 3/4	.1440	1.729	20.74	34.56
2	.1551	1.861	22.33	37.22
2 1/4	.1773	2.127	25.52	42.54
2 1/2	.1994	2.393	28.71	47.86
3	.2216	2.659	31.91	53.18
3 1/2	.2659	3.191	38.29	63.81
4	.3102	3.722	44.68	74.75
4 1/2	.3545	4.254	51.05	85.08
5	.3988	4.786	57.43	95.72
5 1/2	.4431	5.318	63.81	106.4
6	.4874	5.849	70.19	117.0
7	.5318	6.381	76.57	127.6
8	.6204	7.445	89.33	148.9

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
10	7090	8.508	102.1	170.2
12	.8863	10.64	127.6	212.7
3/8	1.064	12.76	153.1	255.2
x 7/16				
1/2				
5/8				
3/4	.0465	.558	6.70	11.17
7/8	.0532	.638	7.66	12.76
1	.0665	.798	9.57	15.95
1 1/8	.0798	.957	11.49	19.14
1 1/4	.0931	1.117	13.40	22.33
1 3/8	.1064	1.276	15.31	25.52
1 1/2	.1196	1.436	17.23	28.71
1 5/8	.1329	1.595	19.14	31.91
1 3/4	.1462	1.755	21.06	35.10
2	.1595	1.914	22.97	38.29

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
2 1/4	.1728	2.074	24.89	41.48
2 1/2	.1861	2.233	26.80	44.67
2 3/4	.2127	2.552	30.63	51.05
3	.2393	2.871	34.46	57.43
3 1/4	.2659	3.191	38.29	63.81
3 3/8	.2925	3.510	42.11	70.19
3 ½	.3191	3.829	45.94	76.57
	.3436	4.148	49.77	82.95
	.3589	4.307	51.69	86.14
	.3722	4.467	53.60	89.33
4	.4254	5.105	61.26	102.1
4 1/4	.4520	5.424	65.09	108.5
4 1/2	.4786	5.743	68.91	114.9
5	.5318	6.381	76.57	127.6
5 1/2	.5849	7.019	84.23	140.4
6	.6381	7.657	91.89	153.1

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
8	.8505	102.1	122.5	204.2
10	1.064	12.76	153.1	255.2
12	1.276	15.31	183.8	306.3
7/16				
x 1/2				
5/8	.0620	.745	8.93	14.89
3/4	.0775	.931	11.17	18.61
7/8	.0931	1.117	13.40	22.33
1	.1086	1.303	15.63	26.06
1 1/4	.1241	1.489	17.87	29.78
1 1/2	.1551	1.862	22.33	37.22
1 3/4	.1861	2.333	26.80	44.67
2	.2171	2.606	31.27	52.11
2 1/4	.2482	2.978	35.73	59.56
2 1/2	.2792	3.350	40.20	67.00
3	.3102	3.722	44.67	74.45

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
3 1/2	.3722	4.467	53.60	89.33
4	.4343	5.211	62.53	104.2
5	.4963	5.956	71.47	119.1
1/2	.6204	7.445	89.33	148.9
x 5/8				
3/4				
7/8	0886	1.064	12.76	21.27
1	.1064	1.276	15.31	25.52
1 1/8	.1241	1.489	17.81	29.78
1 1/4	.1418	1.702	20.42	34.03
1 3/8	.1595	1.914	22.97	38.29
1 1/2	.1773	2.127	25.52	42.54
1 5/8	.1950	2.340	28.08	46.79
1 3/4	.2127	2.552	30.63	51.05
2	.2304	2.765	33.18	55.30
2 1/4	.2482	2.978	25.73	59.56

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
2 1/2	2836	3.403	40.84	68.06
2 3/4	.3191	3.829	45.94	76.57
3	.3545	4.254	51.15	85.08
3 1/4	.3900	4.679	56.15	93.59
3 1/2	.4254	5.105	61.26	102.1
4	.4609	5.530	66.36	110.6
4 1/4	.4963	5.956	71.47	119.1
4 1/2	.5672	6.806	81.68	136.1
5	.6027	7.232	86.78	144.6
5 1/2	.6381	7.657	91.89	153.1
6	.7090	8.508	102.1	170.2
7	.7799	9.359	112.3	187.2
8	.8508	10.21	122.5	204.2
9	.9926	11.91	142.9	238.2
10	1.134	13.61	163.4	272.3
12	1.276	15.31	183.8	306.3

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
	1.418	17.02	204.2	340.3
	1.702	20.42	245.0	408.4
5/8				
x 3/4	.13291	.595	19.14	31.91
7/8	.1551	.1861	22.33	37.22
1	.1773	2.127	25.52	42.54
1 1/8	.1994	2.393	28.71	47.86
1 1/4	.2216	2.659	31.91	53.18
1 3/8	.2437	2.925	35.10	58.49
1 1/2	.2659	3.191	38.29	63.81
1 3/4	.3102	3.722	44.67	74.57
2	.3545	4.254	51.05	85.08
2 1/4	.3988	4.786	57.43	95.72
2 1/2	.4431	5.318	63.81	106.4
2 3/4	.4874	5.849	70.19	117.0
3	.5318	6.381	76.57	127.6

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
3 1/4	.5761	6.913	82.95	138.3
3 1/2	.6204	7.445	89.33	148.9
4	.7090	8.508	102.1	170.2
4 1/2	.7976	9.572	114.9	191.4
5	.8863	10.64	127.6	212.7
5 1/2	.9749	11.70	140.4	234.0
6	1.064	12.76	153.1	255.2
7	1.241	14.89	178.7	297.8
8	1.418	17.02	204.2	340.3
10	1.773	21.27	255.2	425.5
12	2.127	25.52	306.3	510.5
3/4				
x 7/8	.1861	2.233	26.80	44.67
1	.2127	2.552	30.63	51.05
1 1/8	.2393	2.871	34.46	57.43
1 1/4	.2659	3.191	38.29	63.81

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
1 3/8	.2925	3.510	42.11	70.19
1 1/2	.3191	3.829	45.94	76.57
1 5/8	.3456	4.148	49.77	82.95
1 3/4	.3722	4.467	53.60	89.33
2	.4254	5.105	61.26	102.1
2 1/4	.4786	5.743	68.91	114.9
2 1/2	.5318	6.381	76.57	127.6
2 3/4	.5849	7.019	84.23	140.4
3	.6381	7.657	91.89	153.1
3 1/4	.6913	8.295	99.54	165.9
3 1/2	.7445	8.993	107.2	178.7
4	.8508	10.21	122.5	204.2
4 1/2	.9572	11.49	137.8	229.7
5	1.064	12.76	153.1	255.2
5 1/2	1.170	14.04	168.5	280.8
6	1.276	15.31	183.8	306.3

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
7	1.489	17.87	214.4	357.3
8	1.702	20.42	245.0	408.4
9	1.914	22.97	275.7	459.4
10	2.127	25.52	306.3	510.5
12	2.552	30.63	367.5	612.6
7/8				
1	2482	2.978	35.73	59.56
1 1/8	.2792	3.350	40.20	67.00
1 1/4	.3102	3.722	44.67	74.45
1 3/8	.3412	4.094	49.13	81.89
1 1/2	.3722	4.467	53.60	89.33
1 3/4	.4343	5.211	62.53	104.2
2	.4963	5.956	71.47	119.1
2 1/4	.5583	6.700	80.40	134.0
2 1/2	.6204	7.445	89.33	148.9
2 5/8	.6514	7.817	93.80	156.3

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
2 3/4	.6824	8.189	98.27	163.8
3	.7445	8.933	107.2	178.1
3 1/2	.8685	10.42	125.1	208.4
4	.9926	11.91	142.9	238.2
4 1/2	1.117	13.40	160.8	268.0
4 3/4	1.179	14.14	169.7	282.9
5	1.241	14.89	178.7	297.8
6	1.489	17.87	214.4	357.3
7	1.737	20.84	250.1	416.9
8	1.985	23.82	285.9	476.4
12	2.975	35.73	428.4	714.7
1				
x11/8				
1 1/4				
1 3/8	.3191	3.829	45.94	76.57
1 1/2	.3545	4.254	51.15	85.08

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
1 3/4	.3900	4.679	56.15	93.59
2	.4254	5.105	61.26	102.1
2 1/4	.4963	5.956	71.47	119.1
2 1/2	.5672	6.806	81.68	136.1
2 3/4	.6381	7.657	91.89	153.1
3	.7090	8.508	102.1	170.2
3 1/4	.7799	9.459	112.3	187.2
3 1/2	.8508	10.21	122.5	204.2
4	.9217	11.06	132.7	221.2
4 1/2	.9926	11.91	142.9	238.2
5	1.134	13.61	163.4	272.3
5 1/2	1.276	15.31	183.8	306.2
6	1.418	17.02	204.2	340.3
7	1.560	18.72	224.6	374.4
8	1.702	20.42	245.0	408.4
9	1.985	23.82	285.9	476.4

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
10	2.269	27.23	326.7	544.5
12	2.552	30.63	367.6	612.6
1-1/8	2.836	34.03	408.4	680.6
x2	3.403	40.84	490.1	816.8
3				
4				
4 1/2				
5	.6381	7.657	91.89	153.1
6	.9572	11.49	137.8	229.7
8	1.276	15.31	306.3	
	1.436	17.23	206.7	344.6
	1.595	19.14	229.7	382.9
	1.914	22.97	275.7	459.4
	2.552	30.63	367.5	612.6
1-1/4				
x11/2	.5318	6.381	76.57	127.6

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
1 3/4	.6204	7.445	89.33	148.9
2	.7090	8.508	102.1	170.2
2 1/4	.7976	9.572	114.9	191.4
2 1/2	.8863	10.64	127.6	212.7
2 3/4	.9749	11.70	140.4	234.0
3	1.064	12.76	153.1	255.2
3 1/4	1.152	13.82	165.8	276.4
3 1/2	1.241	14.89	178.7	297.8
4	1.418	17.02	204.2	340.3
4 1/2	1.595	19.14	229.7	382.9
5	1.773	21.27	255.2	425.4
5 1/2	1.950	23.40	280.8	467.9
6	1.217	25.52	306.3	510.5
7	2.482	29.78	357.3	595.6
8	2.836	34.03	408.4	680.6
10	3.545	42.54	510.5	850.8

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
12	4.254	51.05	612.6	1021
1-1/2				
x13/4				
2				
2 1/4	.7445	8.933	107.2	178.7
2 1/2	.8508	10.21	122.5	204.2
2 3/4	.9572	11.49	137.8	229.7
3	1.064	12.76	153.1	255.2
3 1/2	1.170	14.04	168.5	280.8
4	1.276	15.31	183.8	306.3
4 1/2	1.489	17.87	214.4	357.3
5	1.702	20.42	245.0	408.4
5 1/2	1.914	22.97	275.7	459.4
6	2.127	25.52	306.3	510.5
7	2.340	28.08	336.9	561.5
8	2.552	30.63	367.5	612.6

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
10	2.978	35.73	428.8	714.7
12	3.403	40.84	490.1	816.8
	4.254	51.05	612.6	1021
	5.105	61.26	735.1	1225
1-3/4				
x2	.9926	11.91	142.9	238.2
2 1/4	1.117	13.40	160.8	268.0
2 1/2	1.241	14.89	178.7	297.8
2 3/4	1.365	16.38	196.5	327.6
3	1.489	17.87	214.4	357.3
3 1/2	1.737	20.84	250.1	416.9
4	1.985	23.82	285.9	476.4
4 1/2	2.233	26.80	321.6	536.0
5	2.482	29.78	357.3	595.6
6	2.978	35.73	428.8	714.7
2				

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
x11/4				
2 1/2	1.276	15.31	183.8	306.3
2 3/4	1.418	17.02	204.2	340.3
3	1.560	18.72	224.6	374.4
3 1/2	1.702	20.42	245.0	408.4
4	1.985	23.82	285.9	476.4
4 1/2	2.269	27.23	326.7	544.5
5	2.552	30.63	367.5	612.6
6	2.836	34.03	408.4	680.6
7	3.403	40.84	490.1	816.8
8	3.970	47.64	571.7	952.9
10	4.538	54.45	653.4	1089
12	5.672	68.06	816.8	1361
2-1/2	6.806	81.68	980.1	1634
x23/4				
3				

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
3 1/2	1.914	23.40	80.8	468.0
4	2.127	25.52	306.3	510.5
4 1/2	2.482	29.78	357.3	595.6
5	2.836	34.03	408.4	680.6
6	3.191	38.29	459.4	765.7
8	3.545	42.54	510.5	850.8
9	4.254	51.05	612.6	1021
10	5.672	68.06	816.8	1361
12	6.381	76.57	918.9	1531
3	7.090	85.08	1021	1702
x31/2	8.508	102.1	1225	2042
4	1.914	23.40	80.8	468.0
4 1/2				
5				
6	2.978	35.73	428.8	714.7
7	3.403	40.83	490.1	816.8

Theoretical Weights (In Pounds): Steel - FLATS				
Size in Inches.	Per Inch	Per Foot	12-Ft Bar	20-Ft Bar
8	4.254	35.73	428.8	714.7
10	5.105	40.83	490.1	816.8
	5.957	45.95	551.3	918.9
	6.806	51.05	612.6	1021
	8.508	61.26	735.1	1225

Chemical Composition

Chemical Composition - Carbon Steels *(Heat Chemical Ranges and Limits, percent)*				
AISI/SAE	Carbon	Manganese	Phosphorus, max	Sulfur, max
1005	0.06	0.35 max	0.040	0.050
1006	0.08 max	0.25-0.40	0.040	0.050
1008	0.10 max	0.30-0.50	0.040	0.050
1010	0.08-0.13	0.30-0.60	0.040	0.050
1011	0.08-0.13	0.60-0.90	0.040	0.050
1012	0.10-0.15	0.30-0.60	0.040	0.050
1013	0.11-0.16	0.50-0.80	0.040	0.050
1015	0.13-0.18	0.30-0.60	0.040	0.050
1016	0.13-0.18	0.60-0.90	0.040	0.050
1017	0.15-0.20	0.30-0.60	0.040	0.050
1018	0.15-0.20	0.60-0.90	0.040	0.050
1019	0.15-0.20	0.70-1.00	0.040	0.050
1020	0.18-0.23	0.30-0.60	0.040	0.050
1021	0.18-0.23	0.60-0.90	0.040	0.050
1022	0.18-0.23	0.70-1.00	0.040	0.050
1023	0.20-0.25	0.30-0.60	0.040	0.050

Chemical Composition - Carbon Steels *(Heat Chemical Ranges and Limits, percent)*				
AISI/SAE	Carbon	Manganese	Phosphorus, max	Sulfur, max
1025	0.22-0.28	0.30-0.60	0.040	0.050
1029	0.25-0.31	0.60-0.90	0.040	0.050
1030	0.28-0.34	0.60-0.90	0.040	0.050
1034	0.32-0.38	0.50-0.80	0.040	0.050
1035	0.32-0.38	0.60-0.90	0.040	0.050
1037	0.32-0.38	0.70-1.00	0.040	0.050
1038	0.35-0.42	0.60-0.90	0.040	0.050
1039	0.37-0.44	0.70-1.00	0.040	0.050
1040	0.37-0.44	0.60-0.90	0.040	0.050
1042	0.40-0.47	0.60-0.90	0.040	0.050
1043	0.40-0.47	0.70-1.00	0.040	0.050
1044	0.43-0.50	0.30-0.60	0.040	0.050
1045	0.43-0.50	0.60-0.90	0.040	0.050
1046	0.43-0.50	0.70-1.00	0.040	0.050
1049	0.46-0.53	0.60-0.90	0.040	0.050
1050	0.48-0.55	0.60-0.90	0.040	0.050

Chemical Composition - Carbon Steels *(Heat Chemical Ranges and Limits, percent)*				
AISI/SAE	Carbon	Manganese	Phosphorus, max	Sulfur, max
1053	0.48-0.55	0.70-1.00	0.040	0.050
1055	0.50-0.60	0.60-0.90	0.040	0.050
1059	0.55-0.65	0.50-0.80	0.040	0.050
1060	0.55-0.65	0.60-0.90	0.040	0.050
1064	0.60-0.70	0.50-0.80	0.040	0.050
1065	0.60-0.70	0.60-0.90	0.040	0.050
1069	0.65-0.75	0.40-0.70	0.040	0.050
1070	0.65-0.75	0.60-0.90	0.040	0.050
1071	0.65-0.70	0.75-1.05	0.040	0.050
1074	0.70-0.80	0.50-0.80	0.040	0.050
1075	0.70-0.80	0.40-0.70	0.040	0.050
1078	0.72-0.85	0.30-0.60	0.040	0.050
1080	0.75-0.88	0.60-0.90	0.040	0.050
1084	0.80-0.93	0.60-0.90	0.040	0.050
1086	0.80-0.93	0.30-0.50	0.040	0.050
1090	0.85-0.98	0.60-0.90	0.040	0.050
1095	0.90-1.03	0.30-0.50	0.040	0.050

Chemical Composition - Carbon Steels *(Heat Chemical Ranges and Limits, percent)* *- Resulfurized Carbon Steels*				
AISI/SAE	Carbon	Manganese	Phosphorus, max	Sulfur, max
1108	0.08-0.13	0.60-0.80	0.040	0.08-0.13
1109	0.08-0.13	0.60-0.90	0.040	0.08-0.13
1110	0.08-0.13	0.30-0.60	0.040	0.08-0.13
1116	0.14-0.13	1.10-1.40	0.040	0.16-0.23
1117	0.14-0.20	1.00-1.30	0.040	0.08-0.13
1118	0.14-0.20	1.30-1.60	0.040	0.08-0.13
1119	0.14-0.20	1.00-1.30	0.040	0.24-0.33
1132	0.27-0.34	1.35-1.65	0.040	0.08-0.13
1137	0.32-0.39	1.35-1.65	0.040	0.08-0.13
1139	0.35-0.43	1.35-1.65	0.040	0.13-0.20
1140	0.37-0.44	0.70-1.00	0.040	0.08-0.13
1141	0.37-0.45	1.35-1.65	0.040	0.08-0.13
1144	0.40-0.48	1.35-1.65	0.040	0.24-0.33
1145	0.42-0.49	0.70-1.00	0.040	0.04-0.07
1146	0.42-0.49	0.70-1.00	0.040	0.08-0.13
1151	0.48-0.55	0.70-1.00	0.040	0.08-0.13

Chemical Composition - Carbon Steels *(Heat Chemical Ranges and Limits, percent) - Rephosphorized and Resulfurized Carbon Steels*					
AISI/SAE	Carbon	Manganese	Phosphorus, max	Sulfur, max	Lead
1211	0.13 max	0.60-0.90	0.07-0.12	0.10-0.15	---
1212	0.13 max	0.70-1.00	0.07-0.12	0.16-0.23	---
1213	0.13 max	0.70-1.00	0.07-0.12	0.24-0.33	---
1215	0.09 max	0.75-1.05	0.04-0.09	0.26-0.35	---
12L13	0.13 max	0.70-1.00	0.07-0.12	0.24-0.33	0.15-0.35
12L14	0.15 max	0.85-1.15	0.04-0.09	0.26-0.35	0.15-0.35
12L15	0.09 max	0.75-1.05	0.04-0.09	0.26-0.35	0.15-0.35

Chemical Composition - Carbon Steels *(Heat Chemical Ranges and Limits, percent)* *- High-Manganese Carbon Steels*					
AISI/SAE	Former Designation	Carbon	Manganese	Phosphorus, max	Sulfur, max
1513	---	0.10-0.16	1.10-1.40	0.040	0.050
1518	---	0.15-0.21	1.10-1.40	0.040	0.050
1522	---	0.18-0.24	1.10-1.40	0.040	0.050
1524	1024	0.19-0.25	1.35-1.65	0.040	0.050
1525	---	0.23-0.29	0.80-1.10	0.040	0.050
1526	---	0.22-0.29	1.10-1.40	0.040	0.050
1527	1027	0.22-0.29	1.20-1.50	0.040	0.050
1536	1036	0.30-0.37	1.20-1.50	0.040	0.050
1541	1041	0.36-0.44	1.35-1.65	0.040	0.050
1547	---	0.43-0.51	1.35-1.65	0.040	0.050
1548	1048	0.44-0.52	1.10-1.40	0.040	0.050
1551	1051	0.45-0.56	0.85-1.15	0.040	0.050
1552	1052	0.47-0.55	1.20-1.50	0.040	0.050
1561	1061	0.55-0.65	0.75-1.05	0.040	0.050
1566	1066	0.60-0.71	0.85-1.15	0.040	0.050
1572	1072	0.65-0.76	1.00-1.30	0.040	0.050

Chemical Composition - Alloy Steels *(Heat Chemical Ranges and Limits, percent)*								
AISI/SAE	C	Mn	P max	S max	Si	Ni	Cr	Mo
1330	0.28-0.33	1.60-1.90	0.035	0.040	0.15 to 0.35	---	---	---
1335	0.33-0.38	1.60-1.90	0.035	0.040	0.15 to 0.35	---	---	---
1340	0.38-0.43	1.60-1.90	0.035	0.040	0.15 to 0.35	---	---	---
1345	0.43-0.48	1.60-1.90	0.035	0.040	0.15 to 0.35	---	---	---
3312	0.08-0.13	0.45-.060	0.025	0.025	0.20 to 0.35	3.25-3.75	1.40-1.75	---
4012	0.09-0.14	0.75-1.00	0.035	0.040	0.15 to 0.35	---	---	0.15-0.25
4023	0.09-0.25	0.70-0.90	0.035	0.040	0.15 to 0.35	---	---	0.15-0.25
4024	0.20-0.25	0.70-0.90	0.035	0.035-0.050	0.15 to 0.35	---	---	0.20-0.30
4027	0.25-0.30	0.70-0.90	0.035	0.040	0.15 to 0.35	---	---	0.20-0.30
4028	0.25-0.30	0.70-0.90	0.035	0.035-0.050	0.15 to 0.35	---	---	0.20-0.30
4032	0.30-0.35	0.70-0.90	0.035	0.040	0.15 to 0.35	---	---	0.20-0.30
4037	0.35-0.40	0.70-0.90	0.035	0.040	0.15 to 0.35	---	---	0.20-0.30
4042	0.40-0.45	0.70-0.90	0.035	0.040	0.15 to 0.35	---	---	0.20-0.30
4047	0.45-0.50	0.70-0.90	0.035	0.040	0.15 to 0.35	---	---	0.20-0.30
4118	0.18-0.23	0.70-0.90	0.035	0.040	0.15 to 0.35	---	0.40-0.60	0.08-0.15
4130	0.28-0.33	0.40-0.60	0.035	0.040	0.15 to 0.35	---	0.70-1.10	0.15-0.25

Chemical Composition - Alloy Steels *(Heat Chemical Ranges and Limits, percent)*								
AISI/SAE	C	Mn	P max	S max	Si	Ni	Cr	Mo
4135	0.33-0.38	0.70-0.90	0.035	0.040	0.15 to 0.35	---	0.80-1.10	0.15-0.25
4137	0.35-0.40	0.70-0.90	0.035	0.040	0.15 to 0.35	---	0.80-1.10	0.15-0.25
4140	0.38-0.43	0.75-1.00	0.035	0.040	0.15 to 0.35	---	0.80-1.10	0.15-0.25
4142	0.40-0.45	0.75-1.00	0.035	0.040	0.15 to 0.35	---	0.80-1.10	0.15-0.25
4145	0.43-0.48	0.75-1.00	0.035	0.040	0.15 to 0.35	---	0.80-1.10	0.15-0.25
4147	0.45-0.50	0.75-1.00	0.035	0.040	0.15 to 0.35	---	0.80-1.10	0.15-0.25
4150	0.48-0.53	0.75-1.00	0.035	0.040	0.15 to 0.35	---	0.80-1.10	0.15-0.25
4161	0.56-0.64	0.75-1.00	0.035	0.040	0.15 to 0.35	---	0.70-0.90	0.15-0.25
4320	0.17-0.22	0.45-0.65	0.035	0.040	0.15 to 0.35	1.65-2.00	0.40-0.60	0.20-0.30
4340	0.38-0.43	0.60-0.80	0.035	0.040	0.15 to 0.35	1.65-2.00	0.70-0.90	0.20-0.30
4419	0.18-0.23	0.45-0.65	0.035	0.040	0.15to 0.35	---	---	0.45-0.60
4422	0.20-0.25	0.70-0.90	0.035	0.040	0.15 to 0.35	---	---	0.35-0.45
4427	0.24-0.29	0.70-0.90	0.035	0.040	0.15 to 0.35	---	---	0.35-0.45
4615	0.13-0.18	0.45-0.65	0.035	0.040	0.15 to 0.35	1.65-2.00	---	0.20-0.30
4620	0.17-0.22	0.45-0.65	0.035	0.040	0.15 to 0.35	1.65-2.00	---	0.20-0.30
4621	0.18-0.23	0.70-0.90	0.035	0.040	0.15 to 0.35	1.65-2.00	---	0.20-0.30

Chemical Composition - Alloy Steels *(Heat Chemical Ranges and Limits, percent)*								
AISI/SAE	C	Mn	P max	S max	Si	Ni	Cr	Mo
4626	0.24-0.29	0.45-0.65	0.035	0.040	0.15 to 0.35	0.15 to 0.35	---	0.15-0.25
4718	0.16-0.21	0.70-0.90	0.035	0.040	0.15 to 0.35	0.15 to 0.35	0.35-0.55	0.30-0.40
4720	0.17-0.22	0.50-0.70	0.035	0.040	0.15 to 0.35	0.15 to 0.35	0.35-0.55	0.15-0.25
4815	0.13-0.18	0.40-0.60	0.035	0.040	0.15 to 0.35	0.15 to 0.35	---	0.20-0.30
4817	0.15-0.20	0.40-0.60	0.035	0.040	0.15 to 0.35	0.15 to 0.35	---	0.20-0.30
4820	0.18-0.23	0.50-0.70	0.035	0.040	0.15 to 0.35	0.15 to 0.35	---	0.20-0.30
5015	0.12-0.17	0.30-0.50	0.035	0.040	0.15 to 0.35	0.15 to 0.35	0.30-0.50	---
5046	0.43-0.48	0.75-1.00	0.035	0.040	0.15 to 0.35	0.15 to 0.35	0.20-0.35	---
5115	0.13-0.18	0.70-0.90	0.035	0.040	0.15 to 0.35	0.15 to 0.35	0.70-0.90	---
5120	0.17-0.22	0.70-0.90	0.035	0.040	0.15 to 0.35	0.15 to 0.35	0.70-0.90	---
5130	0.28-0.33	0.70-0.90	0.035	0.040	0.15 to 0.35	0.15 to 0.35	0.80-1.10	---
5132	0.30-0.35	0.60-0.80	0.035	0.040	0.15 to 0.35	0.15 to 0.35	0.75-1.00	---
5135	0.33-0.38	0.60-0.80	0.035	0.040	0.15 to 0.35	0.15 to 0.35	0.80-1.05	---
5140	0.38-0.43	0.70-0.90	0.035	0.040	0.15 to 0.35	0.15 to 0.35	0.70-0.90	---
5145	0.43-0.48	0.70-0.90	0.035	0.040	0.15-0.35	0.15-0.35	0.70-0.90	---
5147	0.46-0.51	0.70-0.90	0.035	0.040	0.15-0.35	0.15-0.35	0.85-1.15	---

Chemical Composition - Alloy Steels *(Heat Chemical Ranges and Limits, percent)*								
AISI/SAE	C	Mn	P max	S max	Si	Ni	Cr	Mo
5150	0.48-0.53	0.70-0.90	0.035	0.040	0.15-0.35	---	0.70-0.90	---
5155	0.51-0.59	0.70-0.90	0.035	0.040	0.15-0.35	---	0.70-0.90	---
5160	0.56-0.61	0.75-1.00	0.035	0.040	0.15-0.35	---	0.70-0.90	---
50100	0.98-1.10	0.25-0.45	0.025	0.025	0.15-0.35	---	0.40-0.60	---
51100	0.98-1.10	0.25-0.45	0.025	0.025	0.15-0.35	---	0.90-1.15	---
52100	0.98-1.10	0.25-0.45	0.025	0.025	0.15-0.35	---	1.30-1.60	---
6118	0.16-0.21	0.50-0.70	0.035	0.040	0.15-0.35	---	0.50-0.70	(0.10-0.15 V)
6150	0.48-0.53	0.70-0.90	0.035	0.040	0.15-0.35	---	0.80-1.10	(0.15 min V)
8115	0.13-0.18	0.70-0.90	0.035	0.040	0.15-0.35	0.20-0.40	0.30-0.50	0.08-0.15
8615	0.13-0.18	0.70-0.90	0.035	0.040	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8617	0.15-0.20	0.70-0.90	0.035	0.040	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8620	0.18-0.23	0.70-0.90	0.035	0.040	0.15-0.35	0.34-0.60	0.34-0.60	0.15-0.25
8622	0.20-0.25	0.70-0.90	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.60	0.15-0.25
8625	0.23-0.28	0.70-0.90	0.035	0.040	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8627	0.25-0.30	0.70-0.90	0.035	0.040	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8630	0.28-0.33	0.70-0.90	0.035	0.040	0.15-0.35	0.34-0.60	0.34-0.60	0.15-0.25

Chemical Composition - Alloy Steels *(Heat Chemical Ranges and Limits, percent)*								
AISI/SAE	C	Mn	P max	S max	Si	Ni	Cr	Mo
8637	0.35-0.40	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.60	0.15-0.25
8640	0.38-0.43	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.60	0.15-0.25
8642	0.40-0.45	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.60	0.15-0.25
8645	0.43-0.48	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.60	0.15-0.25
8650	048-0.53	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.60	0.15-0.25
8655	0.51-0.59	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.60	0.15-0.25
8660	0.56-0.64	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.60	0.15-0.25
8720	0.18-0.23	0.70-0.90	0.035	0.040	0.15-0.35	0.40-0.70	0.40-0.60	0.20-0.30
8740	0.38-0.43	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.70	0.40-0.60	0.20-0.30
8822	0.20-0.25	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.70	0.40-0.60	0.30-0.40
9254	0.51-0.59	0.60-0.80	0.035	0.040	1.20-1.60	---	0.40-0.60	---
9255	0.51-0.59	0.70-0.95	0.035	0.040	1.80-2.20	---	0.40-0.60	---
9260	0.56-0.64	0.75-1.00	0.035	0.040	1.80-2.20	---	---	---
9310	0.08-0.13	0.45-0.65	0.025	0.025	0.15-0.30	3.00-3.50	1.00-1.40	0.08-0.15

Chemical Composition - Alloy Steels *(Heat Chemical Ranges and Limits, percent)* *- Standard Boron Steels*								
AISI/SAE	C	Mn	P max	S max	Si	Ni	Cr	Mo
50B44	0.43-0.48	0.75-1.00	0.035	0.040	0.15 to 0.35	---	0.20-0.60	---
50B46	0.44-0.49	0.75-1.00	0.035	0.040	0.15 to 0.35	---	0.20-0.35	---
50B50	0.48-0.53	0.75-1.00	0.035	0.040	0.15 to 0.35	---	0.40-0.60	---
50B60	0.56-0.64	0.75-1.00	0.035	0.040	0.15 to 0.35	---	0.40-0.60	---
51B60	0.56-0.64	0.75-1.00	0.035	0.040	0.15 to 0.35	---	0.70-0.90	---
81B45	0.43-0.48	0.75-1.00	0.035	0.040	0.15 to 0.35	0.20-0.40	0.35-0.55	0.08-0.15
94B17	0.15-0.20	0.75-1.00	0.035	0.040	0.15 to 0.35	0.30-0.60	0.30-0.50	0.08-0.15
94B30	0.28-0.33	0.75-1.00	0.035	0.040	0.15 to 0.35	0.30-0.60	0.30-0.50	0.08-0.15

NOTES

1. Grades shown in the table above with prefix letter E are normally made only by the basic electric-furnace process. All others are normally

manufactured by the basic open-hearth or basic-oxygen but may be manufactured by the basic electric furnace process with adjustments in phosphorus

and sulfur.

2. The phosphorus and sulfur limitations for each process are as follows:

	Maximum, percent	
	Phosphorus	**Sulfur**
Basic electric	0.025	0.025
Basic open-hearth or basic oxygen	0.035	0.040
Acid electric	0.050	0.050
Acid open-hearth	0.050	0.050

3. 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 percent; nickel, 0.25 percent; chromium, 0.20 percent and molybdenum, 0.06 percent.

4. Standard alloy 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, for example, 41 L 40. A heat analysis for lead is not determinable, since lead is added to the ladle

stream while each ingot is poured.

5. Boron steels contain .0005/.003 percent boron.

Compositions of Standard Carbon H-Steels and Standard Carbon Boron H-Steels					
AISI/SAE	C	Mn	P max	S max	Si
Standard Carbon H-Steels					
1038H	0.34-0.43	0.50-1.00	0.040	0.050	0.15-0.30
1045H	0.42-0.51	0.50-1.00	0.040	0.050	0.15-0.30
1522H	0.17-0.25	1.00-1.50	0.040	0.050	0.15-0.30
1524H	0.18-0.26	1.25-1.75(a)	0.040	0.050	0.15-0.30
1526H	0.21-0.30	1.25-1.75(a)	0.040	0.050	0.15-0.30
1541H	0.35-0.45	0.70-1.20	0.040	0.050	0.15-0.30
Standard Carbon Boron H-Steels					
15B21H	0.17-0.24	0.70-1.20	0.040	0.050	0.15-0.30
15B35H	0.31-0.39	1.00-1.50	0.040	0.050	0.15-0.30
15B37H	0.30-0.39	1.25-1.75(a)	0.040	0.050	0.15-0.30
15B41H	0.35-0.45	0.50-1.00	0.040	0.050	0.15-0.30
15B48H	0.43-0.53	1.00-1.50	0.040	0.050	0.15-0.30
15B62H	0.54-0.67	1.00-1.50	0.040	0.050	0.40-0.60

(a) Standard AISI-SAE H-Steels with 1.75 manganese maximum are classified as carbon steels.

Compositions of Standard Alloy H-Steels (Percentage)								
AISI/SAE	C	Mn	P max	S max	Si	Ni	Cr	Mo
1330H	0.27-0.33	1.45-2.05	0.035	0.040	0.15-0.30	---	---	---
1335H	0.32-0.38	1.45-2.05	0.035	0.040	0.15-0.30	---	---	---
1340H	0.37-0.44	1.45-2.05	0.035	0.040	0.15-0.30	---	---	---
1345H	0.42-0.49	1.45-2.05	0.035	0.040	0.15-0.30	---	---	---
4027H	0.24-0.30	0.60-1.00	0.035	0.040	0.15-0.30	---	---	0.20-0.30
4038H	0.24-0.30	0.60-1.00	0.035	0.035-0.050	0.15-0.30	---	---	0.20-0.30
4032H	0.29-0.35	0.60-1.00	0.035	0.040	0.15-0.30	---	---	0.20-0.30
4037H	0.34-0.41	0.60-1.00	0.035	0.040	0.15-0.30	---	---	0.20-0.30
4042H	0.39-0.46	0.60-1.00	0.035	0.040	0.15-0.30	---	---	0.20-0.30
4047H	0.44-0.51	0.60-1.00	0.035	0.040	0.15-0.30	---	0.30-0.70	0.20-0.30
4118H	0.17-0.23	0.60-1.00	0.035	0.040	0.15-0.30	---	0.75-1.20	0.20-0.30
4130H	0.27-0.33	0.30-0.70	0.035	0.040	0.15-0.30	---	0.75-1.20	0.15-0.25
4135H	0.32-0.38	0.60-1.10	0.035	0.040	0.15-0.30	---	0.75-1.20	0.15-0.25
4137H	0.34-0.41	0.60-1.10	0.035	0.040	0.15-0.30	---	0.75-1.20	0.15-0.25
4140H	0.37-0.44	0.65.1.10	0.035	0.040	0.15-0.30	---	0.75-1.20	0.15-0.25
4142H	0.39-0.46	0.65-1.10	0.035	0.040	0.15-0.30	---	0.75-1.20	0.15-0.25
4145H	0.42-0.49	0.65-1.10	0.035	0.040	0.15-0.30	---	0.75-1.20	0.15-0.25
4147H	0.44-0.51	0.65-1.10	0.035	0.040	0.15-0.30	---	0.75-1.20	0.15-0.25

Compositions of Standard Alloy H-Steels (Percentage)

AISI/SAE	C	Mn	P max	S max	Si	Ni	Cr	Mo
4150H	0.47-0.54	0.65-1.10	0.035	0.040	0.15-0.30	---	0.65-0.95	0.15-0.25
4161H	0.55-0.65	0.65-1.10	0.035	0.040	0.15-0.30	1.55-2.00	0.35-0.65	0.25-0.35
4320H	0.17-0.23	0.40-0.70	0.035	0.040	0.15-0.30	1.55-2.00	0.65-0.95	0.20-0.30
4340H	0.37-0.44	0.55-0.90	0.035	0.040	0.15-0.30	1.55-2.00	0.65-0.95	0.20-0.30
4620H	0.17-0.23	0.35-0.75	0.035	0.040	0.15-0.30	0.65-1.05	---	0.20-0.30
4626H	0.23-0.29	0.40-0.70	0.035	0.040	0.15-0.30	0.85-1.25	0.30-0.60	0.15-0.25
4720H	0.17-0.23	0.45-0.75	0.035	0.040	0.15-0.30	3.20-3.80	---	0.15-0.25
4815H	0.12-0.18	0.30-0.70	0.035	0.040	0.15-0.30	3.20-3.80	---	0.20-0.30
4817H	0.14-0.20	0.30-0.70	0.035	0.040	0.15-0.30	3.20-3.80	---	0.20-0.30
4820H	0.17-0.23	0.40-1.80	0.035	0.040	0.15-0.30	---	0.13-0.43	0.20-0.30
5046H	0.43-0.50	0.65-1.10	0.035	0.040	0.15-0.30	---	0.60-1.00	---
5120H	0.17-0.23	0.60-1.00	0.035	0.040	0.15-0.30	---	0.75-1.23	---
5130H	0.27-0.33	0.60-1.00	0.035	0.040	0.15-0.30	---	0.65-1.13	---
5132H	0.29-0.35	0.50-0.90	0.035	0.040	0.15-0.30	---	0.70-1.15	---
5135H	0.32-0.38	0.50-1.00	0.035	0.040	0.15-0.30	---	0.60-1.00	---
5140H	0.37-0.44	0.60-1.00	0.035	0.040	0.15-0.30	---	0.60-1.00	---
5150H	0.47-0.54	0.60-1.00	0.035	0.040	0.15-0.30	---	0.60-1.00	---
5155H	0.50-0.60	0.60-1.00	0.035	0.040	0.15-0.30	---	0.60-1.00	---

Compositions of Standard Alloy H-Steels (Percentage)

AISI/SAE	C	Mn	P max	S max	Si	Ni	Cr	Mo
5160H	0.55-0.65	0.65-1.00	0.035	0.040	0.15-0.30	---	0.40-0.80	0.10-0.15
6118H	0.15-0.21	0.40-0.80	0.035	0.040	0.15-0.30	---	0.40-0.80	---
6150H	0.47-0.54	0.60-1.00	0.035	0.040	0.15-0.30	---	0.75-1.20	---
8617H	0.14-0.20	0.60-0.95	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8620H	0.17-0.23	0.60-0.95	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8622H	0.19-0.25	0.60-0.95	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8625H	0.22-0.28	0.60-0.95	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8627H	0.24-0.30	0.60-0.95	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8630H	0.27-0.33	0.60-0.95	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8637H	0.34-0.41	0.70-1.05	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8640H	0.37-0.44	0.70-1.05	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8642H	0.39-0.46	0.70-1.05	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8645H	0.42-0.49	0.70-1.05	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8650H	0.47-0.54	0.70-1.05	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8655H	0.50-0.60	0.70-1.05	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8660H	0.55-0.65	0.70-1.05	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
8720H	0.17-0.23	0.60-0.95	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.20-0.30
8740H	0.37-0.44	0.70-1.05	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.20-0.30

Compositions of Standard Alloy H-Steels (Percentage)								
AISI/SAE	C	Mn	P max	S max	Si	Ni	Cr	Mo
8822H	0.19-0.25	0.70-1.05	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.30-0.40
9260H	0.55-0.65	0.65-1.10	0.035	0.040	1.70-2.20	---	---	---
9310H	0.07-0.13	0.40-0.70	0.035	0.040	0.15-0.30	2.95-3.55	1.00-1.45	0.08-0.15

Compositions of Standard Born (Alloy) H-Steels								
AISI/SAE	C	Mn	P max	S max	Si	Ni	Cr	Mo
50B40H	0.37-0.44	0.65-1.10	0.035	0.040	0.15-0.30	---	0.30-0.70	--
50B44H	0.42-0.49	0.65-1.10	0.035	0.040	0.15-0.30	---	0.30-0.70	---
50B46H	0.43-0.50	0.65-1.10	0.035	0.040	0.15-0.30	---	0.13-0.43	---
50B50H	0.47-0.54	0.65-1.10	0.035	0.040	0.15-0.30	---	0.30-0.70	---
50B60H	0.55-0.65	0.65-1.10	0.035	0.040	0.15-0.30	---	0.30-0.70	---
51B60H	0.55-0.65	0.65-1.10	0.035	0.15-0.30	---	0.60-1.00	---	---
81B45H	0.42-0.49	0.70-1.05	0.035	0.040	0.15-0.030	0.15-0.45	0.30-0.60	0.15-0.25
86B30H	0.27-0.33	0.60-0.95	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.15-0.25
86B45H	0.42-0.49	0.70-1.05	0.035	0.040	0.15-0.30	0.35-0.75	0.35-0.65	0.08-0.15
94B15H	0.12-0.18	0.70-1.05	0.035	0.040	0.15-0.30	0.25-0.65	0.25-0.55	0.08-0.15
94B17H	0.14-0.20	0.70-1.05	0.035	0.040	0.15-0.30	0.25-0.65	0.25-0.65	0.08-0.15
94B39H	0.27	0.33	0.70-0.33	0.70-1.05	0.035	0.25-0.65	0.25-0.55	0.08-0.15

Conversion for Impact Energy Values											
Joules	Ft-Lbs	Joules	Ft-Lbs	Joules	Ft-Lbs	Joules	Ft-Lbs	Joules	Ft-Lbs	Joules	Ft-Lbs
10	7	26	19	42	31	58	43	74	55	90	66
11	8	27	20	43	32	59	44	75	55	91	67
12	9	28	21	44	33	60	44	76	56	92	68
13	10	29	21	45	33	61	45	77	57	93	69
14	10	30	22	46	34	62	46	78	58	94	69
15	11	31	23	47	35	63	47	79	58	95	70
16	12	32	24	48	36	64	47	80	59	96	71
17	13	33	24	49	37	65	48	81	60	97	72
18	13	34	25	50	37	66	49	82	61	98	72
19	14	35	26	51	38	67	49	83	61	99	73
20	15	36	27	52	38	68	50	84	62	100	74
21	16	37	27	53	39	69	51	85	63	---	---
22	16	38	28	54	40	70	52	86	63	---	---
23	17	39	29	55	41	71	52	87	64	---	---
24	18	40	30	56	41	72	53	88	65	---	---
25	18	41	30	57	42	73	54	89	66	---	---

Compositions of Standard Stainless Steels (Percentage)									
Type	UNS Designation	C	Mn	Si	Cr	Ni	P	S	Other
Austenitic types									
201	S20100	0.15	5.5-7.5	1.00	16.0-18.0	3.5-5.5	0.06	0.03	0.25 N
202	S20200	0.15	7.5-10.0	1.00	17.0-19.0	4.0-6.0	0.06	0.03	0.25 N
205	S20500	0.12-0.25	14.0-15.5	1.00	16.5-18.0	1.0-1.75	0.06	0.03	0.32-0.40 N
301	S30100	0.15	2.00	1.00	16.0-18.0	6.0-8.0	0.045	0.03	---
302	S30200	0.15	2.00	1.00	17.0-19.0	8.0-10.0	0.045	0.03	---
3302B	S30215	0.15	2.00	2.0-3.0	17.0-19.0	8.0-10.0	0.045	0.03	---
303	S30300	0.15	2.00	1.00	17.0-19.0	8.0-10.0	0.20	0.15 min	0.6 Mo(b)
303Se	S30323	0.15	2.00	1.00	17.0-19.0	8.0-10.0	0.20	0.06	0.15 min Se
304	S30400	0.08	2.00	1.00	18.0-20.0	8.0-10.5	0.045	0.03	---
304H	330409	0.04-0.10	2.00	1.00	18.0-20.0	8.0-10.5	0.045	0.03	---
304L	S30403	0.03	2.00	1.00	18.0-20.0	8.0-12.0	0.045	0.03	---
304LN	S30453	0.03	2.00	1.00	18.0-20.0	8.0-12.0	0.045	0.03	0.10-0.16 N
302Cu	S30430	0.08	2.00	1.00	17.0-19.0	8.0-10.0	0.045	0.03	3.0-4.0 Cu
304N	S30451	0.08	2.00	1.00	18.0-20.0	8.0-10.5	0.045	0.03	0.10-0.16 N
305	S30500	0.12	2.00	1.00	17.0-19.0	10.5-13.0	0.045	0.03	---
308	S30800	0.08	2.00	1.00	19.0-21.0	10.0-12.0	0.045	0.03	---

Compositions of Standard Stainless Steels (Percentage)

Type	UNS Designation	C	Mn	Si	Cr	Ni	P	S	Other
309	S30900	0.20	2.00	1.00	22.0-24.0	12.0-15.0	0.045	0.03	---
309S	S30908	0.08	2.00	1.00	22.0-24.0	12.0-15.0	0.045	0.03	---
310	S31000	0.25	2.00	1.50	24.0-26.0	19.0-22.0	0.045	0.03	---
310S	S31008	0.08	2.00	1.50	24.0-26.0	19.0-22.0	0.045	0.03	---
314	S31400	0.25	2.00	1.5-3.0	23.0-26.0	19.0-22.0	0.045	0.03	---
316	S31600	0.08	2.00	1.00	16.0-18.0	10.0-14.0	0.045	0.03	2.0-3.0 Mo
316F	S31620	0.08	2.00	1.00	16.0-18.0	10.0-14.0	0.20	0.10 min	1.75-2.5 Mo
316H	S31609	0.04-0.10	2.00	1.00	16.0-18.0	10.0-14.0	0.045	0.03	2.0-3.0 Mo
316L	S31603	0.03	2.00	1.00	16.0-18.0	10.0-14.0	0.045	0.03	2.0-3.0 Mo
316LN	S31653	0.03	2.00	1.00	16.0-18.0	10.0-14.0	0.045	0.03	2.0-3.0 Mo; 0.10-0.16 N
316N	S31651	0.08	2.00	1.00	16.0-18.0	10.0-14.0	0.045	0.03	2.0-3.0 Mo; 0.10-0.16 N
317	S31700	0.08	2.00	1.00	18.0-20.0	11.0-15.0	0.045	0.03	3.0-4.0 Mo
317L	S31703	0.03	2.00	1.00	18.0-20.0	11.0-15.0	0.045	0.03	3.0-4.0 Mo
321	S32100	0.08	2.00	1.00	17.0-19.0	9.0-12.0	0.045	0.03	5 x %C min Ti
321H	S32109	0.04-0.10	2.00	1.00	17.0-19.0	9.0-12.0	0.045	0.03	5 x %C min Ti
330	N08330	0.08	2.00	0.75-1.5	17.0-20.0	34.0-37.0	0.04	0.03	---
347	S34700	0.08	2.00	1.00	17.0-19.0	9.0-13.0	0.045	0.03	10 x %C min Nb

Compositions of Standard Stainless Steels (Percentage)

Type	UNS Designation	C	Mn	Si	Cr	Ni	P	S	Other
347H	S34709	0.04-0.10	2.00	1.00	17.0-19.0	9.0-13.0	0.045	0.03	8 x %C min - 1.0 max Nb
348	S34800	0.08	2.00	1.00	17.0-19.0	9.0-13.0	0.045	0.03	0.2 Co; 10 x %C min Nb; 0.10 Ta
348H	S34809	0.04-0.10	2.00	1.00	17.0-19.0	9.0-13.0	0.045	0.03	0.2 Co; 8 x %C min - 1.0 max Nb; 0.10 Ta
384	S38400	0.08	2.00	1.00	15.0-17.0	17.0-19.0	0.045	0.03	---
Ferritic types									
405	S40500	0.08	1.00	1.00	11.5-14.5	---	0.04	0.03	0.10-0.30 A1
409	S40900	0.08	1.00	1.00	10.5-11.75	0.50	0.045	0.045	6 x %C min - 0.75 max Ti
429	S42900	0.12	1.00	1.00	14.0-16.0	---	0.04	0.03	---
430	S43000	0.12	1.00	1.00	16.0-18.0	---	0.04	0.03	---
430F	S43020	0.12	1.25	1.00	16.0-18.0	---	0.06	0.15 min	0.6 Mo(b)
430FSe	S43023	0.12	1.25	1.00	16.0-18.0	---	0.06	0.06	0.15 min Se
434	S43400	0.12	1.00	1.00	16.0-18.0	---	0.04	0.03	0.75-1.25 MO
436	S43600	0.12	1.00	1.00	16.0-18.0	---	0.04	0.03	0.75-1.25 Mo; 5 X %C MIN - 0.70 max Nb
439	S43035	0.07	1.00	1.00	17.0-19.0	0.50	0.04	0.03	0.15 A1; 12 x %C min - 1.10 Ti
442	S44200	0.20	1.00	1.00	18.0-23.0	---	0.04	0.03	---
444	S44400	0.025	1.00	1.00	17.5-19.5	1.00	0.04	0.03	1.75-2.50 Mo; 0.025 N; 0.2 + 4 (%C + %N) min - 0.8 max (Ti + Nb)

Compositions of Standard Stainless Steels (Percentage)									
Type	UNS Designation	C	Mn	Si	Cr	Ni	P	S	Other
446	S44600	0.20	1.50	1.00	23.0-27.0	---	0.04	0.03	0.25 N
Duplex (ferritic-austenitic) type									
329	S32900	0.20	1.00	0.75	23.0-28.0	2.50-5.00	0.040	0.030	.00-2.00 Mo
Martensitic types									
403	S40300	0.15	1.00	0.50	11.513.0	---	0.04	0.03	---
410	S41000	0.15	1.00	1.00	11.5-13.5	---	0.04	0.03	---
414	S41400	0.15	1.00	1.00	11.5-13.5	1.25-2.50	0.04	0.03	---
416	S41623	0.15	1.25	1.00	12.0-14.0	---	0.06	0.15 min	0.6 Mo(b)
416Se	S41600	0.15	1.25	1.00	12.0-14.0	---	0.06	0.06	0.15 min Se
420	S42000	0.15 min	1.00	1.00	12.0-14.0	---	0.04	0.03	---
420F	S42020	0.15 min	1.25	1.00	12.0	14.0	---	0.06	0.15 min 0.6 Mo(b)
422	S42200	0.20-0.25	1.00	0.75	11.5-13.5	0.5-1.0	0.04	0.03	0.75-1.25 Mo; 0.75-1.25 W; 0.15-0.3 V
431	S43100	0.20	1.00	1.00	15.0-17.0	1.25-2.50	0.04	0.03	---
440A	S44002	0.60-0.75	1.00	1.00	16.0-18.0	---	0.04	0.03	0.75 Mo
440B	S44003	0.75-0.95	1.00	1.00	16.0-18.0	---	0.04	0.03	0.75 Mo
440C	S44004	0.95-1.20	1.00	1.00	16.0-18.0	---	0.04	0.03	0.75 Mo

Compositions of Standard Stainless Steels (Percentage)									
Type	UNS Designation	C	Mn	Si	Cr	Ni	P	S	Other
Precipitation-hardening types									
PH 13-8 Mo	S13800	0.05	0.20	0.10	12.25-13.25	7.5-8.5	0.01	0.008	2.0-2.5 Mo; 0.90-1.35 A1; 0.01 N
15-5 PH	S15500	0.07	1.00	1.00	14.0-15.5	3.5-5.5	0.04	0.03	2.5-4.5 Cu; 0.15-0.45 Nb
17-4 PH	S17400	0.07	1.00	1.00	15.5-17.5	3.0-5.0	0.04	0.03	3.0-5.0 cu; 0.15-0.45 Nb
17-7 PH	S17700	0.09	1.00	1.00	16.0-18.0	6.5-18.0	6.5-7.75	0.04	0.040.75-1.5 A1

(a) Single values are maximum values unless otherwise indicated.

(b) Optional

Conversion

Conversion for Stress Values ksi to MPa

The middle column of figures contains the reading (in MPa or ksi) to be converted. If converting from ksi to MPa equivalent in

the column headed "MPa". If converting from MPa to ksi, read the ksi equivalent in the column headed "ksi".

ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
0.14504	1	6.895	3.9160	27	186.16	7.6870	53	365.42	11.603	80	551.58
0.29008	2	13.790	4.0611	28	193.05	7.8320	54	372.32	11.748	81	558.48
0.43511	3	20.684	4.2061	29	199.95	7.9771	55	379.21	11.893	82	565.37
0.58015	4	27.579	4.3511	30	206.84	8.1221	56	386.11	12.038	83	572.26
0.72519	5	34.474	4.4962	31	213.74	8.2672	57	393.00	12.183	84	579.16
0.87023	6	41.369	4.6412	32	220.63	8.4122	58	399.90	12.328	85	586.05
1.0153	7	48.263	4.7862	33	227.53	8.5572	59	406.79	12.473	86	592.95
1.1603	8	55.158	4.9313	34	234.42	8.7023	61	413.69	12.168	87	599.84
1.3053	9	62.053	5.0763	35	241.32	8.8473	62	420-58	12.763	88	606.74
1.4504	10	68.948	5.2214	36	248.21	8.992	63	427.47	12.909	89	613.63
1.5954	11	75.842	5.3664	37	255.11	9.1374	64	434.37	13.053	90	620.53
1.7405	12	82.737	5.5114	38	262.00	9.2824	65	441.26	13.198	91	627.42
1.8855	13	89.632	5.6565	39	268.90	9.4275	66	448.16	13.343	92	634.32
2.0305	14	96.527	5.8015	40	275.79	9.5725	67	455.05	13.489	93	641.21
2.1756	15	103.42	5.9465	41	282.69	9.8626	68	468.84	13.634	94	648.11
2.3206	16	110.32	6.0916	42	289.58	10.008	69	475.74	13.779	95	655.00
2.4656	17	117.21	6.2366	43	296.47	10.153	70	482.63	13.924	96	661.90
2.6107	18	124.11	6.3817	44	303.37	10.298	71	489.53	14.069	97	668.79
2.7557	19	131.00	6.5267	45	310.26	10.443	72	496.42	14.214	98	675.69
2.9008	20	137.90	6.6717	46	317.16	10.588	73	503.32	14.359	99	682.58
3.0458	21	144.79	6.8168	47	324.05	10.732	74	510.21	14.504	100	689.48
3.1908	22	151.68	6.9618	48	330.95	10.878	75	517.11	15.954	110	758.42
3.3359	23	158.58	7.1068	49	337.84	11.023	76	524.00	17.405	120	827.37
3.4809	24	165.47	7.2519	50	344.74	11.168	77	530.90	18.855	130	896.32
3.6259	25	172.37	7.3969	51	351.63	11.313	78	537.79	20.305	140	965.27

3.7710	26	179.26	7.5420	52	358.53	11.458	79	544.69	21.756	150	1034.2

Conversion for Stress Values ksi to MPa

The middle column of figures contains the reading (in MPa or ksi) to be converted. If converting from ksi to MPa equivalent in

the column headed "MPa". If converting from MPa to ksi, read the ksi equivalent in the column headed "ksi".

ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
23.206	160	1103.2	66.717	460	3171.6	107.33	740	---	153.74	1060	---
24.656	170	1172.1	68.168	470	3240.5	108.78	750	---	156.64	1080	---
26.107	180	1241.1	69.618	480	3309.5	110.23	760	---	159.54	1100	---
27.557	190	1310.0	71.068	490	3378.4	111.68	770	---	162.44	1120	---
29.008	200	1379.0	72.519	500	3447.4	113.13	780	---	165.34	1140	---
30.458	210	1447.9	40.611	280	1930.5	114.58	790	---	168.24	1160	---
31.908	220	1516.8	73.969	510	---	116.03	800	---	171.14	1180	---
33.359	230	1585.8	75.420	520	---	117.48	810	---	174.05	1200	---
34.809	240	1654.7	76.870	530	---	118.93	820	---	176.95	1220	---
36.259	250	1723.7	78.320	540	---	120.38	830	---	179.85	1240	---
37.710	260	1792.6	79.771	550	---	121.83	840	---	182.75	1260	---
40.611	280	1930.5	81.221	560	---	123.28	850	---	185.65	1280	---
42.061	290	1999.5	82.672	570	---	124.73	860	---	188.55	1300	---
43.511	300	2068.4	84.122	580	---	126.18	870	---	191.45	1320	---
44.962	310	2137.4	85.572	590	---	127.63	880	---	194.35	1340	---
46.412	320	2206.3	87.023	600	---	129.08	890	---	197.25	1360	---
47.862	330	2275.3	88.473	610	---	130.53	900	---	200.15	1380	---
49.313	340	2344.2	89.923	620	---	131.98	910	---	203.05	1400	---
50.763	350	2413.2	91.374	630	---	133.43	920	---	205.95	1420	---
52.214	360	2482.1	92.824	640	---	134.89	930	---	208.85	1440	---
53.664	370	2551.1	94.275	650	---	136.34	940	---	211.76	1460	---
55.114	380	2620.0	95.725	660	---	137.79	950	---	214.66	1480	---
56.565	390	2689.0	97.175	670	---	139.24	960	---	217.56	1500	---
58.015	400	2757.9	98.626	680	---	140.69	970	---	220.46	1520	---
59.465	410	2826.9	100.08	690	---	142.14	980	---	223.36	1540	---
60.916	420	2895.8	101.53	700	---	143.59	990	---	226.26	1560	---
62.366	430	2964.7	102.98	710	---	145.04	1000	---	229.16	1580	---

63.817	440	3033.7	104.43	720	---	147.94	1020	---	232.06	1600	---
65.267	450	3102.6	105.88	730	---	150.84	1040	---	234.96	1620	---

Conversion for Stress Values ksi to MPa

The middle column of figures contains the reading (in MPa or ksi) to be converted. If converting from ksi to MPa equivalent in

the column headed "MPa". If converting from MPa to ksi, read the ksi equivalent in the column headed "ksi".

ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
237.86	1640	---	269.77	1860	---	304.58	2100	---	336.49	2320	---
240.76	1660	---	272.67	1880	---	307.48	2120	---	339.39	2340	---
243.66	1680	---	275.57	1900	---	310.38	2140	---	342.29	2360	---
246.56	1700	---	278.47	1920	---	313.28	2160	---	345.19	2380	---
249.46	1720	---	281.37	1940	---	316.18	2180	---	348.09	2400	---
182.75	1260	---	284.27	1960	---	319.08	2200	---	350.99	2420	---
252.37	1740	---	287.17	1980	---	321.98	2220	---	353.89	2440	---
255.27	1760	---	290.08	2000	---	324.88	2240	---	356.79	2460	---
258.17	1780	---	292.98	2020	---	327.79	2260	---	359.69	2480	---
261.07	1800	---	295.88	2040	---	330.69	2280	---	362.59	2500	---
263.97	1820	---	298.78	2060	---	307.48	2120	---	339.39	2340	---
266.87	1840	---	301.68	2080	---	333.59	2300	---			

1 ksi = 6.894757 MPa 1 psi = 6.894757 kPa

Temperature Conversion Table

The middle columns of numbers (in boldface type) contain the temperature readings (˚F or ˚C) to be converted. When converting from degrees Fahrenheit to degrees Celsius, read the Celsius equivalent in the column headed "C". When converting from Celsius to Fahrenheit, read the Fahrenheit equivalent in the column headed "F".

ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
---	-458	-272.22	---	-402	-241.11	---	-346	-210.00	---	-290	-178.89
---	-456	-271.11	---	-400	-240.00	---	-344	-208.89	---	-288	-177.78
---	-454	-270.00	---	-398	-238.89	---	-342	-207.78	---	-286	-176.67
---	-452	-268.89	---	-396	-237.78	---	-340	-206.67	---	-284	-175.56
---	-450	-267.78	---	-394	-236.67	---	-338	-205.56	---	-282	-174.44
---	-448	-266.67	---	-392	-235.56	---	-336	-204.44	---	-280	-173.33
---	-446	-265.56	---	-390	-234.44	---	-334	-203.33	---	-278	-172.22
---	-444	-264.44	---	-388	-233.33	---	-332	-202.22	---	-276	-171.11
---	-442	-263.33	---	-386	-232.22	---	-330	-201.11	---	-274	-170.00
---	-440	-262.22	---	-384	-231.11	---	-328	-200.00	-457.6	-272	-168.89
---	-438	-261.11	---	-382	-230.00	---	-326	-198.89	-454.0	-270	-167.78
---	-436	-260.00	---	-380	-228.89	---	-324	-197.78	-450.4	-268	-166.67
---	-434	-258.89	---	-378	-227.78	---	-322	-196.67	-446.8	-266	-165.56
---	-432	-257.78	---	-376	-226.67	---	-320	-195.56	-443.2	-264	-164.44
---	-430	-256.67	---	-374	-225.56	---	-318	-194.44	-439.6	-262	-163.33
---	-428	-255.56	---	-372	-224.44	---	-316	-193.33	-436.0	-260	-162.22
---	-426	-254.44	---	-370	-223.33	---	-314	-192.22	-432.4	-258	-161.11
---	-424	-253.33	---	-368	-222.22	---	-312	-191.11	-428.8	-256	-160.00
---	-422	-252.22	---	-366	-221.11	---	-310	-190.00	-425.2	-254	-158.89
---	-420	-251.11	---	-364	-220.00	---	-308	-188.89	-421.6	-252	-157.78
---	-418	-250.00	---	-362	-218.89	---	-306	-187.78	-418.0	-250	-156.67
---	-416	-248.89	---	-360	-217.78	---	-304	-186.67	-414.4	-248	-155.56
---	-414	-247.78	---	-358	-216.67	---	-302	-185.56	-410.8	-246	-154.44
---	-412	-246.67	---	-356	-215.56	---	-300	-184.44	-407.2	-244	-153.33
---	-410	-245.56	---	-354	-214.44	---	-298	-183.33	-403.6	-242	-152.22
---	-408	-244.44	---	-352	-213.33	---	-296	-182.22	-400.0	-240	-151.11
---	-406	-243.33	---	-350	-212.22	---	-294	-181.11	-396.4	-238	-150.00
---	-404	-242.22	---	-348	-211.11	---	-292	-180.00	-392.8	-236	-148.89

Temperature Conversion Table

The middle columns of numbers (in boldface type) contain the temperature readings (˚F or ˚C) to be converted. When converting from degrees Fahrenheit to degrees Celsius, read the Celsius equivalent in the column headed "C". When converting from Celsius to Fahrenheit, read the Fahrenheit equivalent in the column headed "F".

ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
-389.2	-238	-150.00	---	-182	-118.89	-194.8	-126	-87.78	-94.0	-70	-56.67
-385.6	-236	-148.89	---	-180	-117.78	-191.2	-124	-86.67	-90.4	-68	-55.56
-382.0	-234	-147.78	---	-178	-116.67	-187.6	-122	-85.56	-86.8	-66	-54.44
-378.4	-232	-146.67	---	-176	-115.56	-184.0	-120	-84.44	-83.2	-64	-53.33
-374.8	-230	-145.56	---	-174	-114.44	-180.4	-118	-83.33	-79.6	-62	-52.22
-371.2	-228	-144.44	---	-172	-113.33	-176.8	-116	-82.22	-76.0	-60	-51.11
-367.6	-226	-143.33	---	-170	-112.22	-173.2	-114	-81.11	-72.4	-58	-50.00
-364.0	-224	-142.22	---	-168	-111.11	-169.6	-112	-80.00	-68.8	-56	-48.89
-360.4	-222	-141.11	---	-166	-110.00	-166.0	-110	-78.89	-65.2	-54	-47.78
-356.8	-220	-140.00	---	-164	-108.89	-162.4	-108	-77.78	-61.6	-52	-46.67
-353.2	-218	-138.89	---	-162	107.78	-158.8	-106	-76.67	-58.0	-50	-45.56
-349.6	-216	-137.78	---	-160	-106.67	-155.2	-104	-75.56	-54.4	-48	-44.44
346.0	-214	-136.67	---	-158	-105.56	-151.6	-102	-74.44	-50.8	-46	-43.33
-342.4	-212	-135.56	---	-156	-104.44	-148.0	-100	-73.33	-47.2	-44	-42.22
-338.8	-210	-134.44	---	-154	-103.33	-144.4	-98	-72.22	-43.6	-42	-41.11
-335.2	-208	-133.33	---	-152	-102.22	-140.8	-96	-71.11	-40.0	-40	-40.00
-331.6	-206	-132.22	---	-150	-101.11	-137.2	-94	-70.00	-36.4	-38	-38.89
-328.0	-204	-131.11	---	-148	-100.00	-133.6	-92	-68.89	-32.8	-36	-37.78
-324.4	-202	-130.00	---	-146	-98.89	-130.0	-90	-67.78	-29.2	-34	-36.67
-320-8	-200	-128.89	---	-144	-97.78	-126.4	-88	-66.67	-25.6	-32	-35.56
-317.2	-198	-127.78	---	-142	-96.67	-122.8	-86	-65.56	-22.0	-30	-34.44
-313.6	-196	-126.67	---	-140	-95.56	-119.2	-84	-64.44	-18.4	-28	-33.33
-310.0	-194	-125.56	---	-138	-94.44	-115.6	-82	-63.33	-14.8	-26	-32.22
-306.4	-192	-124.44	---	-136	-93.33	-112.0	-80	-62.22	-11.2	-24	-31.11
-302.8	-190	-123.33	---	-134	-92.22	-108.4	-78	-61.11	-7.6	-22	-30.00
-299.2	-188	-122.22	---	-132	-91.11	-104.8	-76	-60.00	-4.0	-20	-28.89
-295.6	-186	-121.11	---	-130	-90.00	-101.2	-74	-58.89	-.04	-18	-27.78

-292.0	-184	-120.00	---	-128	-88.89	-97.6	-72	-57.78	+3.2	-16	-26.67

Temperature Conversion Table

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ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
+6.8	-14	-25.56	107.6	42	5.56	197.6	92	33.33	298.4	148	64.44
+10.4	-12	-24.44	111.2	44	6.67	201.2	94	34.44	302.0	150	.56
+14.0	-10	-23.33	114.8	46	7.78	204.8	96	35.56	305.6	152	66.67
+17.6	-8	-22.22	118.4	48	8.89	208.4	98	36.67	309.2	154	67.78
+21.2	-6	-21.11	122.0	50	10.00	212.0	100	37.78	312.8	156	68.89
+24.8	-4	-20.00	125.6	52	11.11	215.6	102	38.89	316.4	158	70.00
+28.4	-2	-18.89	129.2	54	12.22	219.2	104	40.00	320.0	160	71.11
+32.0	0	-17.78	132.8	56	13.33	222.8	106	41.11	323.6	162	72.22
+35.6	2	-16.67	136.4	58	14.44	226.4	108	42.22	327.2	164	73.33
+39.2	4	-15.56	140.0	60	15.56	230.0	110	43.33	330.8	166	74.44
+42.8	6	-14.44	143.6	62	16.67	233.6	112	44.44	334.4	168	75.56
+46.4	8	-13.33	147.2	64	17.78	237.2	114	45.56	338.0	170	76.67
+50.0	10	-12.22	150.8	66	18.89	240.8	116	46.67	341.6	172	77.78
+53.6	12	-11.11	154.4	68	20.00	244.4	118	47.78	345.2	174	78.89
+57.2	14	-10.00	158.0	70	21.11	248.0	120	48.89	348.8	176	80.00
+60.8	16	-8.89	161.6	72	22.22	251.6	122	50.00	352.4	178	81.11
+64.4	18	-7.78	165.2	74	23.33	255.2	124	51.11	356.0	180	82.22
+68.0	20	-6.67	168.8	76	24.44	258.8	126	52.22	359.6	182	83.33
+71.6	22	-5.56	172.4	78	25.56	262.4	128	53.33	363.2	184	84.44
+75.2	24	-4.44	176.0	80	26.67	266.0	130	54.44	366.8	186	85.56
+78.8	26	-3.33	179.6	82	27.78	296.6	132	55.56	370.4	188	86.67
+82.4	28	-2.22	183.2	84	28.89	273.2	134	56.67	374.0	190	87.78
+86.0	30	-1.11	186.8	86	30.00	276.8	136	57.78	377.6	192	88.89
+89.6	32	+0.00	190.4	88	31.11	280.4	138	58.89	381.2	194	90.00
+93.2	34	+1.11	194.0	90	32.22	284.0	140	60.00	384.8	196	91.11

+96.8	36	+2.22	---	92	5.56	287.6	142	61.11	388.4	198	92.22
+100.4	38	+3.33	---	94	6.67	291.2	144	62.22	392.0	200	93.33
+104.0	40	+4.44	---	96	7.78	294.8	146	63.33	395.6	202	94.44

Temperature Conversion Table

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ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
+6.8	-14	-25.56	107.6	42	5.56	197.6	92	33.33	298.4	148	64.44
+10.4	-12	-24.44	111.2	44	6.67	201.2	94	34.44	302.0	150	.56
+14.0	-10	-23.33	114.8	46	7.78	204.8	96	35.56	305.6	152	66.67
+17.6	-8	-22.22	118.4	48	8.89	208.4	98	36.67	309.2	154	67.78
+21.2	-6	-21.11	122.0	50	10.00	212.0	100	37.78	312.8	156	68.89
+24.8	-4	-20.00	125.6	52	11.11	215.6	102	38.89	316.4	158	70.00
+28.4	-2	-18.89	129.2	54	12.22	219.2	104	40.00	320.0	160	71.11
+32.0	0	-17.78	132.8	56	13.33	222.8	106	41.11	323.6	162	72.22
+35.6	2	-16.67	136.4	58	14.44	226.4	108	42.22	327.2	164	73.33
+39.2	4	-15.56	140.0	60	15.56	230.0	110	43.33	330.8	166	74.44
+42.8	6	-14.44	143.6	62	16.67	233.6	112	44.44	334.4	168	75.56
+46.4	8	-13.33	147.2	64	17.78	237.2	114	45.56	338.0	170	76.67
+50.0	10	-12.22	150.8	66	18.89	240.8	116	46.67	341.6	172	77.78
+53.6	12	-11.11	154.4	68	20.00	244.4	118	47.78	345.2	174	78.89
+57.2	14	-10.00	158.0	70	21.11	248.0	120	48.89	348.8	176	80.00
+60.8	16	-8.89	161.6	72	22.22	251.6	122	50.00	352.4	178	81.11
+64.4	18	-7.78	165.2	74	23.33	255.2	124	51.11	356.0	180	82.22
+68.0	20	-6.67	168.8	76	24.44	258.8	126	52.22	359.6	182	83.33
+71.6	22	-5.56	172.4	78	25.56	262.4	128	53.33	363.2	184	84.44
+75.2	24	-4.44	176.0	80	26.67	266.0	130	54.44	366.8	186	85.56
+78.8	26	-3.33	179.6	82	27.78	296.6	132	55.56	370.4	188	86.67
+82.4	28	-2.22	183.2	84	28.89	273.2	134	56.67	374.0	190	87.78
+86.0	30	-1.11	186.8	86	30.00	276.8	136	57.78	377.6	192	88.89

+89.6	32	+0.00	190.4	88	31.11	280.4	138	58.89	381.2	194	90.00
+93.2	34	+1.11	194.0	90	32.22	284.0	140	60.00	384.8	196	91.11
+96.8	36	+2.22	---	92	5.56	287.6	142	61.11	388.4	198	92.22
+100.4	38	+3.33	---	94	6.67	291.2	144	62.22	392.0	200	93.33
+104.0	40	+4.44	---	96	7.78	294.8	146	63.33	395.6	202	94.44

Temperature Conversion Table

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ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
399.2	204	95.56	500.0	260	126.67	600.8	316	157.78	701.6	372	188.89
402.8	206	96.67	503.6	262	127.78	604.4	318	158.89	705.2	374	190.00
406.4	208	97.78	507.2	264	128.89	608.0	320	160.00	708.8	376	191.11
410.0	210	98.89	510.8	266	130.00	611.6	322	161.11	712.4	378	192.22
413.6	212	100.00	514.4	268	131.11	615.2	324	162.22	716.0	380	193.33
417.2	214	101.11	518.0	270	132.22	618.8	326	163.33	719.6	382	194.44
420.8	216	102.22	521.6	272	133.33	622.4	328	164.44	723.2	384	195.56
424.4	218	103.33	525.2	274	134.44	626.0	330	165.56	726.8	386	196.67
428.0	220	104.44	528.8	276	135.56	629.6	332	166.67	730.4	388	197.78
431.6	222	105.56	532.4	278	136.67	633.2	334	167.78	734.0	390	198.89
435.2	224	106.67	536.0	280	137.78	636.8	336	168.89	737.6	392	200.00
438.8	226	107.78	539.6	282	138.89	640.4	338	170.00	741.2	394	201.11
442.4	228	108.89	543.2	284	140.00	644.0	340	171.11	744.8	396	202.22
446.0	230	110.00	546.8	286	141.11	647.6	342	172.22	748.4	398	203.33
449.6	232	111.11	550.4	288	142.22	651.2	344	173.33	752.0	400	204.44
453.2	234	112.22	554.0	290	143.33	654.8	346	174.44	755.6	402	205.56
456.8	236	113.33	557.6	292	144.44	658.4	348	175.56	759.2	404	206.67
460.4	238	114.44	561.2	294	145.56	662.0	350	176.67	762.8	406	207.78
464.0	240	115.56	564.8	296	146.67	665.6	352	177.78	766.4	408	208.89
467.6	242	116.67	568.4	298	147.78	669.2	354	178.89	770.0	410	210.00
471.2	244	117.78	572.0	300	148.89	672.8	356	180.00	773.6	412	211.11

474.8	246	118.89	575.6	302	150.00	676.4	358	181.11	777.2	414	212.22
478.4	248	120.00	579.2	304	151.11	680.0	360	182.22	780.8	416	213.33
482.0	250	121.11	582.8	306	152.22	683.6	362	183.33	784.4	418	214.44
485.6	252	122.22	586.4	308	153.33	687.2	364	184.44	788.0	420	215.56
489.2	254	123.33	590.0	310	154.44	690.8	366	185.56	791.6	422	216.67
492.8	256	124.44	593.6	312	155.56	694.4	368	186.67	795.2	424	217.78
496.4	258	125.56	597.2	314	156.67	698.0	370	187.78	798.8	426	218.89

Temperature Conversion Table

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ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
802.4	428	220.00	903.2	484	251.11	1004.0	540	282.22	1436.0	780	415.56
806.0	430	221.11	906.8	486	252.22	1007.6	542	283.33	1454.0	790	421.11
809.6	432	222.22	910.4	488	253.33	1011.2	544	284.44	1472.0	800	426.67
813.2	434	233.33	914.0	490	254.44	1014.8	546	285.56	1490.0	810	432.22
816.8	436	224.44	917.6	492	255.56	1018.4	548	286.67	1508.0	820	437.78
820.4	438	225.56	921.2	494	256.67	1022.0	550	287.78	1526.0	830	443.33
824.0	440	226.67	924.8	496	257.78	1040.0	560	293.33	1544.0	840	448.89
827.6	442	227.78	928.4	498	258.89	1058.0	570	298.89	1562.0	850	454.44
831.2	444	228.89	932.0	500	260.00	1076.0	580	304.44	1580.0	860	460.00
834.8	446	230.00	935.6	502	261.11	1094.0	590	310.00	1598.0	870	465.56
838.4	448	231.11	939.2	504	262.22	1112.0	600	315.56	1616.0	880	471.11
842.0	450	232.22	942.8	506	263.33	1130.0	610	321.11	1634.0	890	476.67
845.6	452	233.33	946.4	508	264.44	1148.0	620	326.67	1652.0	900	482.22
849.2	454	234.44	950.0	510	265.56	1166.0	630	332.22	1670.0	910	487.78
852.8	456	235.56	953.6	512	266.67	1184.0	640	337.78	1688.0	920	493.33
856.4	458	236.67	957.2	514	267.78	1202.0	650	343.33	1706.0	930	498.89
860.0	460	237.78	960.8	516	268.89	1220.0	660	348.89	1742.0	940	504.44
863.6	462	238.89	964.4	518	270.00	1238.0	670	354.44	1742.0	950	510.00
867.2	464	240.00	968.0	520	271.11	1256.0	680	360.00	1760.0	960	515.56

870.8	466	241.11	971.6	522	272.22	1274.0	690	365.56	1778.0	970	521.11
874.4	468	242.22	975.2	524	273.33	1292.0	700	371.11	1796.0	980	526.67
878.0	470	243.33	978.8	526	274.44	1310.0	710	376.67	1814.0	990	532.22
881.6	472	244.44	982.4	528	275.56	1328.0	720	382.22	1832.0	1000	537.78
885.2	474	245.56	986.0	530	276.67	1346.0	730	387.78	1850.0	1850.0	543.33
888.8	476	246.67	989.6	532	277.78	1364.0	740	393.33	1868.0	1868.0	548.89
892.4	478	247.78	993.2	534	278.89	1382.0	750	398.89	1886.0	1886.0	554.44
896.0	480	248.89	996.8	536	280.00	1400.0	760	404.44	1904.0	1904.0	560.00
899.6	482	250.00	1000.4	538	281.11	1418.0	770	410.00	1922.0	1922.0	565.56

Temperature Conversion Table

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ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
1940.0	1060	571.11	2444.0	1340	726.67	2948.0	1620	882.22	3452.0	1900	1037.8
1958.0	1070	576.67	2462.0	1350	732.22	2966.0	1630	887.78	3470.0	1910	1043.3
1976.0	1080	582.22	2480.0	1360	737.78	2984.0	1540	893.33	3488.0	1920	1048.9
1994.0	1090	587.78	2498.0	1370	743.33	3002.0	1650	898.89	3506.0	1930	1054.4
2012.0	1100	593.33	2516.0	1380	748.89	3020.0	1660	904.44	3524.0	1940	1060.0
2030.0	1110	598.89	2534.0	1390	754.44	3038.0	1670	910.00	3542.0	1950	1065.6
2048.0	1120	604.44	2552.0	1400	760.00	3056.0	1680	915.56	3560.0	1960	1071.1
2066.0	1130	610.0	2570.0	1410	765.56	3074.0	1690	921.11	3578.0	1970	1076.6
2084.0	1140	615.56	2588.0	1420	771.11	3092.0	1700	926.67	3596.0	1980	1082.2
2102.0	1150	621.11	2606.0	1430	776.67	3110.0	1710	932.22	3614.0	1990	1087.8
2120.0	1160	626.67	2624.0	1440	782.22	3128.0	1720	937.78	3632.0	2000	1093.3
2138.0	1170	632.22	2642.0	1450	787.78	3146.0	1730	943.33	3650.0	2010	1098.9
2156.0	1180	637.78	2660.0	1460	793.33	3164.0	1740	948.89	368.0	2020	1104.4
2174.0	1190	643.33	2678.0	1470	798.89	3182.0	1750	954.44	3686.0	2030	1110.0
2192.0	1200	648.89	2696.0	1480	804.44	3200.0	1760	960.00	3704.0	2040	1115.6
2210.0	1210	654.44	2714.0	1490	810.00	3218.0	1770	965.56	3722.0	2050	1121.1
2228.0	1220	660.00	2732.0	1500	815.56	3236.0	1780	971.11	3740.0	2060	1126.7

2246.0	1230	665.56	2750.0	1510	821.11	3254.0	1790	976.67	3758.0	2070	1132.2
2264.0	1240	671.11	2768.0	1520	826.67	3272.0	1800	982.22	3776.22	2080	1137.8
2282.0	1250	676.67	2786.0	1530	832.22	3290.0	1810	987.78	3794.0	2090	1143.3
2300.0	1260	682.22	2804.0	1540	837.78	3308.0	1820	993.33	3812.0	2100	1148.9
2318.0	1270	687.78	2822.0	1550	843.33	3326.0	1830	998.89	3830.0	2110	1154.4
2336.0	1280	693.33	2840.0	1560	848.89	3344.0	1840	1004.4	3848.0	2120	1160.0
2354.0	1290	698.89	2858.0	1570	854.44	3362.0	1850	1010.0	3866.0	2130	1165.6
2372.0	1300	704.44	2876.0	1580	860.00	3380.0	1860	1015.6	3884.0	2140	1171.1
2390.0	1310	710.00	2894.0	1590	865.56	3398.0	1870	1021.1	3902.0	2150	1176.7
2408.0	1320	715.56	2912.0	1600	871.11	3416.0	1880	1026.7	3920.0	2160	1182.2
2426.0	1330	721.11	2930.0	1610	876.67	3434.0	1890	1032.2	3938.0	2170	1187.8

Temperature Conversion Table

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ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
3956.0	2180	1193.3	4460.0	2460	1348.9	4964.0	2740	1504.4	5468.0	3020	1660.0
3974.0	2190	1198.9	4478.0	2470	1354.4	4982.0	2750	1510.0	5486.0	3030	1665.6
3992.0	2200	1204.4	4496.0	2480	1360.0	5000.0	2760	1515.6	5504.0	3040	1671.1
4010.0	2210	1210.0	4514.0	2490	1365.6	5018.0	2770	1521.1	5522.0	3050	1676.7
4028.0	2220	1215.6	4532.0	2500	1371.1	5036.0	2780	1526.7	5540.0	3060	1682.2
4046.0	2230	1221.1	4550.0	2510	1376.7	5054.0	2790	1532.2	5558.0	3070	1687.8
4064.0	2240	1226.7	4568.0	2520	1382.2	5072.0	2800	1537.8	5576.0	3080	1693.3
4082.0	2250	1232.2	4586.0	2530	1387.8	5090.0	2810	1543.3	5594.0	3090	1698.9
4100.0	2260	1237.8	4604.0	2540	1393.3	5108.0	2820	1548.9	5612.0	3100	1704.4
4118.0	2270	1243.3	4622.0	2550	1398.9	5126.0	2830	1554.4	5702.0	3150	1732.2
4136.0	2280	1248.9	4640.0	2560	1404.4	5144.0	2840	1560.0	5792.0	3200	1760.0
4154.0	2290	1254.4	4658.0	2570	1410.0	5162.0	2850	1565.6	5882.0	3250	1787.8
4172.0	2300	1260.0	4676.0	2580	1415.6	5180.0	2860	1571.1	5972.0	3300	1815.6
4190.0	2310	1265.6	4694.0	2590	142.1	5198.0	2870	1576.7	6062.0	3350	1843.3
4208.0	2320	1271.1	4712.0	2600	1426.7	5216.0	2880	1582.2	6152.0	3400	1871.1

4226.0	2330	1276.6	4730.0	2610	1432.2	5234.0	2890	1587.8	6242.0	3450	1989.9
4244.0	2340	1282.2	4748.0	2620	1437.8	5252.0	2900	1593.3	6332.0	3500	1926.7
4262.0	2350	1287.8	4766.0	2630	1443.3	5270.0	2910	1598.9	6422.0	3550	1954.4
4280.0	2360	1293.3	4784.0	2640	1448.9	5288.0	292	1604.4	6512.0	3600	1982.2
4298.0	2370	1298.9	4802.0	2650	1454.4	5306.0	2930	1610.0	6602.0	3650	2010.0
4316.0	2380	1304.4	4820.0	2660	1460.0	5324.0	2940	1615.6	6692.0	3700	2037.8
4334.0	2390	1310.0	4838.0	2670	1465.6	5342.0	2950	1621.1	6782.0	3750	2065.6
4352.0	2400	1315.6	4856.0	2680	1471.1	5360.0	2960	1626.7	6872.0	3800	2093.3
4370.0	2410	1321.1	4874.0	2690	1476.7	5378.0	2970	1632.2	6962.0	3850	2121.1
4388.0	2420	1326.7	4892.0	2700	1482.2	5396.0	2980	1637.8	7052.0	3900	2148.9
4406.0	2430	1332.2	4910.0	2710	1487.8	5414.0	2990	1643.3	7142.0	3950	2176.7
4424.0	2440	1337.8	4928.0	2720	1493.3	5432.0	3000	1648.9	7232.0	4000	2204.4
3956.0	2450	1343.3	4946.0	2730	1498.9	5450.0	3010	1654.4	7322.0	4050	2232.2

Temperature Conversion Table

The middle columns of numbers (in boldface type) contain the temperature readings (˚F or ˚C) to be converted. When converting from degrees Fahrenheit to degrees Celsius, read the Celsius equivalent in the column headed "C". When converting from Celsius to Fahrenheit, read the Fahrenheit equivalent in the column headed "F".

ksi		MPa	ksi		MPa	ksi		MPa	ksi		MPa
7412.0	4100	2260.0	8312.0	4600	2537.8	9212.0	5100	2815.6	10112.0	5600	3093.3
7502.0	4150	2287.8	8402.0	4650	2565.6	9302.0	5150	2843.3	10202.0	5650	3121.1
7592.0	4200	2315.6	8492.0	4700	2593.3	9392.0	5200	2871.1	10292.0	5700	3148.9
7682.0	4250	2343.3	8582.0	4750	2621.1	9482.0	5250	2898.9	10382.0	5750	3176.7
7772.0	4300	2371.1	8672.0	4800	2648.9	9572.0	5300	2926.7	10472.0	5800	3204.4
7862.0	4350	2398.9	8762.0	4850	2676.7	9662.0	5350	2954.4	10562.0	5850	3232.2
7952.0	4400	2426.7	8852.0	4900	2704.4	9752.0	5400	2982.2	10652.0	5900	3260.0
8042.0	4450	2454.4	8942.0	4950	2732.2	9842.0	5450	3010.0	10742.0	5950	3287.8
8132.0	4500	2482.2	9032.0	500	2760.0	9932.0	5500	3037.8	10832.0	6000	3315.6
8222.0	4550	2510.0	9122.0	5050	2787.8	10022.0	5550	3065.6			

Hardness Conversions

Approximate relations between Brinell, Rockwell, Shore, Vickers and Firth hardness and the tensile strengths of S.A.E.

carbon and alloy construction steels.

C	A	15-N	30-N	VICKERS	KNOOP	BRINELL	
150 kg Braie	60 kg Braie	16 kg N Braie	30 kg N Braie	10 kg 136° Diamond	500 Gr. & over	3000 kg 10mm Ball	Approx. Tensile Strength
Rockwell	Rockwell Superficial	Rockwell	Rockwell	Vickers	Knoop	Brinell** (Standard Ball)	ksi
68	85.6	93.2	84.4	940	920	-	inexact
67	85.0	92.9	83.6	900	895	-	and
66	84.5	92.5	82.8	865	870	-	only
65	83.9	92.2	81.9	832	846	-	for
64	83.4	91.8	81.1	800	822	-	steel
63	82.8	91.4	80.1	772	799	-	
62	82.3	91.1	79.3	746	776	-	
61	81.8	90.7	78.4	720	754	-	
60	81.2	90.2	77.5	697	732	-.	
59	80.7	89.8	76.5	674	710	-	351
58	80.1	89.3	75.7	653	690	615	338
57	79.6	88.90	74.8	633	670	595	325
56	79.0	88.3	73.9	613	650	577	313
55	78.5	87.9	73.0	595	630	560	301
54	78.0	87.4	72.0	577	612	543	292
53	77.4	86.9	71.2	560	594	525	283
52	76.8	86.4	70.2	544	576	512	273
51	76.3	85.9	69.4	528	558	496	264
50	75.9	85.5	68.5	513	542	481	255
49	75.2	85.0	676.6	498	526	469	246
48	74.7	84.5	66.7	484	510	451	238
47	74.1	83.9	65.8	471	495	442	229
46	73.6	83.5	64.8	458	480	432	221
45	73.1	83.0	64.0	446	466	421	215
44	72.5	82.5	63.1	434	452	409	208
42	71.5	81.5	61.3	412	426	390	194
40	70.4	80.4	59.5	392	402	371	182
38	69.4	79.4	57.7	372	380	353	171
36	68.4	78.3	55.9	354	360	336	161
34	67.4	77.2	54.2	336	342	319	152
32	66.3	76.1	52.1	318	326	301	146
30	65.3	75.0	50.4	302	311	286	138
28	64.3	73.9	48.6	286	297	271	131
26	63.3	72.8	46.8	272	284	258	125
24	62.4	71.6	45.0	260	272	247	119
22	61.5	70.5	43.2	248	261	237	115
20	60.5	69.4	41.5	238	251	226	110

Hardness Conversions (Continued)

B 100 kg 1/16" Ball	F 60 kg 1/16" Ball	30-T 30 kg 1/16" Ball	A 60 kg & Over	Knoop 500 Gr.	Br'L 3000 kg	Tensile Strength	
Braie	Braie	Braie	Braie		10 mm Ball		
Rockwell	Rockwell	Rockwell Superficial	Rockwell	Knoop	Brinell	Thousand lbs. per sq. in.	
100	-	83.1	61.5	251	240	116	
99	-	82.5	60.9	246	234	114	
98	-	81.8	60.2	241	228	109	
97	-	81.1	59.5	236	222	104	
96	-	80.4	58.9	231	216	102	
95	-	70.8	58.3	226	210	100	
94	-	79.1	57.6	221	205	98	
93	-	78.4	57.0	216	200	94	
92	-	77.8	56.4	211	195	92	
91	-	77.1	55.8	206	190	90	
90	-	76.4	55.2	201	185	89	
89	-	75.8	54.6	196	180	88	
88	-	75.1	54.0	192	176	86	
87	-	74.4	53.4	188	172	84	
86	-	73.8	52.8	184	169	83	
85	-	73.1	52.3	180	165	82	
84	-	72.4	51.7	176	162	81	
83	-	71.8	51.1	173	159	80	
82	-	71.1	50.6	170	156	77	
81	-	70.4	50.0	167	153	73	
80	-	69.7	49.5	164	150	72	
79	-	69.1	48.9	161	147	70	
78	-	68.4	48.4	158	144	69	
77	-	67.7	47.9	155	141	68	
76	-	67.1	47.3	152	139	67	
75	99.6	66.4	46.8	150	137	66	
74	99.1	65.7	46.3	147	135	65	
72	98.0	64.4	45.3	143	130	63	
71	96.8	63.1	44.3	139	125	61	
68	95.6	61.7	43.3	135	121	59	

All relative hardness values on this card are averages of tests on various metals whose different properties prevent establishment of exact mathematical conversions. These values are consistent with ASTM E 140Tables 1 and 2 and for non-austenitic steels. It is recommended that ASTM standards E 140, E 10, E18, E92,E110, E384 and A 370 (involving hardness tests on metals) be reviewed prior to interpreting hardness conversion values.

Hardness Conversions (Continued)

B 100 kg 1/16" Ball	F 60 kg 1/16" Ball	30-T 30 kg 1/16" Ball	A 60 kg & Over	Knoop 500 Gr.	Br'L 3000 kg	Tensile Strength	
Braie	Braie	Braie	Braie		10 mm Ball		
Rockwell	Rockwell	Rockwell Superficial	Rockwell	Knoop	Brinell	Thousand lbs. per sq. in.	
66 64 62 60 58	94.5 93.4 92.2 91.1 90.0	60.4 59.0 57.7 56.4 55.0	42.3 41.4 40.4 39.5 38.6	131 127 124 120 117	117 114 110 107 104	Even for steel, tensile strength relation to hardness is inexact unless determined for specific material. See ASTM A370	* Below Brinell 101 tests were made with only 500 kg lodad and 10 mm ball. ** Above Brinell 451 HB tests were made with 10 mm carbide ball.
56 54 52 50 48	88.8 87.7 86.5 85.4 84.3	53.7 52.4 51.0 49.7 48.3	37.7 36.8 35.9 35.0 34.1	114 111 109 107 105	101 *87 *85 *83 *81		
46 44 42 40 38	83.1 82.0 80.8 79.7 78.6	47.0 45.7 44.3 43.0 41.6	33.3 32.4 31.6 30.7 29.9	103 101 99 97 95	*79 *78 *76 *74 *73		
36 34 32 30	77.4 76.3 75.2 74.0	40.3 39.0 37.6 36.3	29.1 28.2 27.4 26.6	93 91 89 87	*71 *70 *68 *67		

Glossary of Terms

ACID STEEL
Steel melted in a furnace that has an acid bottom and lining and under a slag that is dominantly siliceous.

AGE HARDENING
A process of aging that increases hardness and strength and ordinarily decreases ductility. Age hardening usually follows rapid cooling or cold working.

AGING
Change in a metal by which its structure recovers from an unstable condition produced by quenching or by cold working such as cold reduction. The change in structure is marked by changes in physical properties. Aging which takes place slowly at room temperature may be accelerated by slight increase in temperature. See "strain aging".

AIR HARDENING STEEL
An alloy steel that is hardened by cooling in air from a temperature higher than the transformation range; also called self hardening steel.

ALLOY
A substance that has metallic properties and is composed of two or more chemical elements of which at least one is a metal.

ALLOYING ELEMENT
Chemical elements constituting an alloy; in steels, usually limited to the metallic elements added to modify the properties of steel.

ALLOY STEEL
Steel containing significant quantities of alloying elements (other than carbon and the commonly accepted amounts of manganese, silicon, sulfur and phosphorus) added to effect changes in the mechanical or physical properties.

ANNEALING
A process involving heating and cooling, usually applied to induce softening. The term also refers to treatments intended to alter mechanical or physical properties, produce a definite microstructure. or remove gases. When applicable, the following more specific terms should be used: black annealing, blue annealing, box annealing, bright annealing, full annealing, graphitizing, isothermal annealing, malleablizing, process annealing, spheroidizing, stabilizing annealing.

Definitions of some of these are given in their alphabetical positions in this glossary. When applied to ferrous alloys, the term "annealing", without qualifications, implies full annealing. Any process of annealing will usually reduce stresses, but if the treatment is applied for the sole purpose of such relief, it should be designated as "stress relieving".

ARTIFICIAL AGING
An aging treatment above room temperature.

AUSTEMPERING
A trade name for a patented heat treating process that consists in quenching a ferrous alloy from a temperature above the transformation range, in a medium having a rate of heat abstraction sufficiently high to prevent the formation of high-temperature transformation products; and in maintaining the alloy, until transformation is complete, at a temperature below that of pearlite formation and above that of martensite formation.

AUSTENITE
A solid solution in which gamma iron is the solvent; characterized by a face-centered cubic crystal structure.

AUSTENITIC STAINLESS STEEL
Steel having the microstructure substantially wholly austenitic at normal temperature: usually a steel of the chromium nickel type.

AUSTENITIZING
This is the process of forming austenite by heating ferrous alloy into the transformation range (partial austenitizing) or above the transformation range (complete austenitizing).

BALL MILL
A mill in which material is finely ground by rotation in a steel drum along with pebbles or steel balls. The grinding action is provided by the collision of the balls with one another and with the shell of the mill.

BANDED STRUCTURE
A segregated structure of nearly parallel bands aligned in the direction of working.

BASIC OXYGEN PROCESS
The family of named steelmaking processes in which certain oxidizable constituents in the charge serve as fuel for the melting and refining of the charge. High purity oxygen is injected through a lance against a charge and reacts to physically stir the bath and burn to oxidize the carbon, silicon, manganese, and even iron contents to predictable levels, thus creating the heat and refining the steel. Liquid fuels or fluxes may be injected along with the oxygen.

BASIC STEEL
Steel melted in a furnace that has a basic bottom and lining, and under a slag that is dominantly basic.

BAND TESTS
Various tests used to determine the ductility of sheet or plate that is subjected to bending. These tests may include determination of the minimum radius or diameter required to make satisfactory bend and the number of repeated bends that the material can withstand without failure when it is bent through a given angle and over a definite radius.

BESSEMER PROCESS
A process for making steel by blowing air through molten pig iron contained in a suitable vessel, and thus causing rapid oxidation mainly of silicon and carbon.

BILLET
See bloom.

BLANKING
Shearing out a piece of sheet metal in preparation for deep drawing.

BLAST FURNACE
A shaft furnace in which solid fuel is burned with an air blast to smelt ore in a continuous operation. Where the temperature must be high, as in the production of pig iron, the air is preheated. Where the temperature can be lower, as in smelting copper, lead and tin ores, a smaller furnace is economical, and preheating of the blast is not required.

BLISTER
A raised spot on the surface of metal, caused by expansion of gas in a subsurface zone during heat treatment; Very fine blisters are called "pinhead" or "pepper blisters". BLOOM (slab, billet). Semi-finished products hot rolled from ingots and rectangular in cross section, with rounded corners. The chief differences are in cross-sectional area, in ratio of width to thickness, and in the intended uses. The American Iron and Steel Products Manual Section 2 (1943) classify general usage thus:

Thickness Cross-Sectional

Type	Width, inches	inches	Area, sq. inches
Bloom	Width equals thickness*		36+ (min)
Billet	1 1/2 (min)	1 1/2 (min)	21/4 to 36
Slab	2 x thickness (min)	11/2 (min)	16 (mm)*

* Generally

Blooms, slabs and billets of rerolling quality are intended for hot rolling into common products such as shapes, plates, strip, bars, wire rod, sheet and black plate. Blooms, slabs and billets of forging quality are intended for conversion into forgings or other products to be heat treated.

BLOWHOLE
A hole produced in a casting when gas, entrapped while the mould is being filled, or evolved during the solidification of metal, fails to escape and is held in pockets.

BLUE ANNEALING
A process of softening ferrous alloys in the form of hot rolled sheet, by heating in the open furnace to a temperature within the transformation range and then cooling in air. The formation of a bluish oxide on the surface is incidental.

BLUE BRITTLENESS
Reduced ductility occurring as a result of strain aging, when certain ferrous alloys are worked between 300 and 700°F. This phenomenon may be observed at the working temperature or subsequently at lower temperatures.

BOX ANNEALING
A process of annealing a ferrous alloy in a suitable closed metal container, with or without packing material, in order to minimize oxidation. The charge is usually heated slowly to a temperature below the transformation range, but sometimes above, or within it, and is then cooled slowly. This process is also called "close annealing" or "pot annealing".

BRAKE

A piece of equipment used for bending sheet; also called a "bar folder". If operated manually, it is called a "hand-brake"; if power driven, it is called a "press-brake".

BRAZING
Joining metals by fusion or nonferrous alloys that have melting points above 800°F but lower than those of the metals being joined. This may be accomplished by means of a torch (torch brazing), in a furnace (furnace brazing) or by dipping in a molten flux bath (dip or flux brazing). The filler metal is ordinarily in rod form in torch brazing; whereas in furnace and dip brazing the work material is first assembled and the filler metal may then be applied as wire, washers, clips, bands, or may be integrally bonded, as in brazing sheet.

BRIGHT ANNEALING
A process of annealing usually carried out in a controlled furnace atmosphere so that surface oxidation is reduced to a minimum and the surface remains relatively bright.

BRINELL HARDNESS TEST
A test for determining the hardness of a material by forcing a hard steel or carbide ball of specified diameter into it under a specified load. The result is expressed as the Brinell hardness number, which is the value obtained by dividing the applied load in kilograms by the surface area of the resulting impression in square millimeters.

BRITTLE CRACK PROPAGATION
A very sudden propagation of a crack with the absorption of no energy except that stored elastically in the body. Microscopic examination may reveal some deformation even though it is not noticeable to the unaided eye.

BRITTLE FRACTURE
Fracture with little or no plastic deformation.

BRITTLENESS
A tendency to fracture without appreciable deformation.

BROACHING
Multiple shaving, accomplished by pushing a tool with stepped cutting edges along the work, particularly through holes.

BURNT
A term applied to a metal permanently damaged by having been heated to a temperature close to the melting point.

CAMBER
Curvature in the plane of rolled sheet or strip, or in the plane of the web of structural shapes.

CAPPED STEEL
Semi-killed steel cast in a bottle-top mold and covered with a cap fitting into the neck of the mold. The cap causes the top metal to solidify. Pressure is built up on the sealed-in molten metal and results in a surface condition much like that of rimmed steel.

CARBIDE
A compound of carbon with one or more metallic elements.

CARBON STEEL

Steel that owes its properties chiefly to the presence of carbon, without substantial amounts of other alloying elements; also termed "ordinary steel", straight carbon steel", plain carbon steel".

CARBURIZING
A process that introduces carbon into a solid ferrous alloy by heating the metal in contact with a carbonaceous material solid, liquid or gas-to a temperature above the transformation range and holding at that temperature. Carburizing is generally followed by quenching to produce a hardened case.

CASE
In a ferrous alloy, the surface layer that has been made substantially harder than the interior or core by a process of case hardening.

CASE HARDENING
A process of hardening a ferrous alloy so that the surface layer or case is made substantially harder than the interior or core. Typical case-hardening processes are carburizing and quenching, cyaniding, carbonitriding, nitriding, induction hardening and flame hardening.

CAST IRON
An iron containing carbon in excess of the solubility in the austenite that exists in the alloy at the eutectic temperature.

CAST STEEL
Any object made by pouring molten steel into moulds.

CAST STRUCTURE
The structure, on a macroscopic or microscopic scale, of a cast alloy that consists of cord dendrites and, in some alloys, a network of other constituents.

CATHODIC PROTECTION
The use of a particular metal as cathode in the corrosion cell as a means of protecting that metal against electro-chemical corrosion. This may be accomplished by the attachment of a more anodic metal or by the use of an applied potential.

CEMENTITE
A compound of iron and carbon known as "iron carbide" which has the approximate chemical formula Fe3C and is characterized by an orthorhombic crystal structure.

CHARGE
(1) The liquid and solid materials fed into a furnace for its operation. (2) Weights of various liquid and solid materials put into a furnace during one feeding cycle.

CHARPY TEST
A pendulum type single-blow impact test in which the specimen, usually notched, is supported at both ends as a simple beam and broken by a falling pendulum. The energy absorbed, as determined by the subsequent rise of the pendulum, is a measure of impact strength or notch toughness.

CHECK ANALYSIS
Chemical analysis made of drillings taken from semi-finished or finished products. The units are subject to certain specified variations from the ladle analysis.

CHIPPING
A method for removing seams and other surface defects with chisel or gouge so that such defects will not be worked into the finished product. Chipping is often employed to remove metal that is excessive but not defective. Removal of defects by gas cutting is known as "deseaming" or "scarfing".

CLINK
Internal crack, usually resulting from improper heating of cold steel.

CLUSTER MILL
A rolling mill where each of the two working rolls of small diameter is supported by two or more backup rolls.

COERCIVE FORCE
The magnetizing force that must be applied in the direction opposite to that of the previous magnetizing force in order to remove residual magnetism; thus, an indicator of the "strength" of magnetically hard materials.

COIL BREAK
Sharp bend in the surface of coiled strip, leaving a distinct mark after flattening. See "fluting".

COLD DRAWING
Method of cold working applied to bars, involving pulling of the bar through dies of smaller aperture than the original bar size.

COLD SHORT
The characteristic of metals that are brittle at ordinary or low temperatures.

COLD SHUT
(1) A discontinuity that appears on the surface of cast metal as a result of two streams of liquid meeting and failing to unite. Pouring the metal when it is too cold may cause such a discontinuity. (2) On a forging, a portion of the surface that is separated by oxide from the main body of metal.

COLD WORK
Plastic deformation at such temperatures and rates that substantial increases occur in the strength and hardness of the metal. Visible structural changes include changes in grain shape and, in some twinning or banding.

COLD WORKING
Deforming a metal plastically at such a temperature and rate that strain hardening occurs. The upper limit of temperature for this process is the recrystallization temperature.

COLUMNAR STRUCTURE
A coarse structure of parallel columns of grains, which is caused by highly directional solidification resulting from sharp thermal gradients.

COMBINED CARBON

The carbon that is combined with iron or alloying elements to form carbide in cast iron or steel.

COMPRESSIVE STRENGTH
Yield-The maximum stress that a metal, subjected to compression, can withstand without a predefined amount of deformation. Ultimate-the maximum stress that a brittle material can withstand without fracture when subjected to compression.

CONTINUOUS CASTING
A casting technique in which an ingot, billet, tube or other shape is continuously solidified while it is being poured, so that its length is not determined by mould dimensions.

CONTINUOUS MILL
A rolling mill consisting of a number of stands of synchronized rolls (in tandem) in which metal undergoes successive reductions as it passes through the various stands.

CONTROLLED COOLING
A process of cooling from an elevated temperature in a predetermined manner, to avoid hardening, cracking or internal damage, or to produce a desired microstructure. This cooling usually follows the final hot forming operation.

COOLING STRESSES
Stresses developed by uneven contraction or external constraint of metal during cooling; also those stresses resulting from localized plastic deformation during cooling, and retained.

CORE
In a ferrous alloy, the interior portion that is substantially softer than the surface layer or case, after case hardening.

CORE LOSS
The total of hysteresis and eddy current loss measured on standard laminations of electrical steel.

CORE PLATING
Insulating varnish or surface applied to electrical steels, to improve interlamination resistance and to aid punching properties.

CORROSION
Gradual chemical or electrochemical attack on a metal by atmosphere, moisture, or other agents.

CREEP
The flow or plastic deformation of metals held for long periods of time at stresses lower than the normal yield strength. The effect is particularly important if the temperature of stressing is in the vicinity of the recrystallization temperature of the metal.

CREEP LIMIT
(1) The maximum stress that will cause less than a specified quantity of creep in a given time. (2) The maximum nominal stress under which the creep strain rate decreased continuously with time under constant load and at constant temperature. Sometimes used synonymously with creep strength.

CREEP STRENGTH
(1) The constant nominal stress that will cause a specified quantity of creep in a given time at constant temperature. (2) The constant nominal stress that will cause a specified creep rate at constant temperature.

CRITICAL COOLING RATE
The minimum rate of continuous cooling just sufficient to prevent undesired transformations. For steel, the slowest rate at which it can be cooled from above the upper critical temperature to prevent the decomposition of austenite at any temperature above the temperature at which the transformation of austenite to martensite starts during cooling.

CRITICAL POINT
Transformation temperature is the term preferred.

CRITICAL RANGE OR CRITICAL TEMPERATURE RANGE
Synonymous with transformation range, which is preferred.

CRITICAL STRAIN
The percentages strain at which, or immediately higher than which, large grain growth occurs during heating.

CRITICAL TEMPERATURE
Transformation temperature is the term preferred.

CROP
The end or ends of an ingot that contain the pipe or other defects to be cut off and discarded; also termed "crop end" and "discard".

CROSS-COUNTRY MILL
A rolling mill in which the mill stands are so arranged that their tables are parallel with a transfer (or cross-over) table connecting them. They are used for rolling structural shapes, rails and any special form of bar stock not rolled in the ordinary bar mill.

CROSS ROLLING
The rolling of sheet so that the direction of rolling is changed about 90° from the direction of the previous rolling.

CROWN
In the center of metal sheet or strip, thickness, greater than at the edge.

CRYSTAL
A physically homogeneous solid in which the atoms, ions or molecules are arranged in a three-dimensional repetitive pattern

CRYSTALLIZATION
The formation of crystals by the atoms assuming definite positions in a crystal lattice. This is what happens when a liquid metal solidifies. (Fatigue, the failure of metals under repeated stresses, is sometimes falsely attributed to crystallization).

CUP FRACTURE (CUP AND CONE FRACTURE)
Fracture, frequently seen in tensile test pieces of a ductile material, in which the surface of failure on one portion shows a central flat area of failure in tension, with an exterior extended rim of failure in shear.

DECARBURIZATION
The loss of carbon from the surface of a ferrous alloy as a result of heating in a medium that reacts with the carbon.

DEEP DRAWING
Forming cup-shaped particles or shells by using a punch to force sheet metal into a die.

DEEP ETCHING
Macro-etching; etching, for examination at a low magnification, in a reagent that attacks the metal to much greater extent than normal for microscopic examination. Gross features may be developed abnormal grain size, segregation, cracks or grain flow.

DEFECT
Internal or external flaw or blemish. Harmful defects can render material unsuitable for specific end use.

DEOXIDATION
Elimination of oxygen in liquid steel, usually by introduction of aluminum or silicon or other suitable element. This term is also used to denote reduction of surface scale (iron oxide)
.

DESEAMING
See chipping.

DIRECTIONAL PROPERTIES
Anisotropic condition where physical and mechanical properties vary, depending on the relation of the test axis to a specific direction of the metal; a result of preferred orientation or of fibering of inclusions during the working.

DIRECT QUENCHING
A process of quenching carburized parts directly from the carburizing operation.

DISCARD
See crop.

DRAWING
See tempering.

DRAWING QUALITY STEEL
Usually plate, sheet or strip of suitable temper for making various shapes involving severe stretching of the material.

DROP FORGING
Forming metal, usually under impact, by compression within dies designed to produce the required shape. The term is ordinarily used synonymously with hot die forging.

DROP HAMMER
A forging machine that employs the impact resulting from the action of gravity, with or without added steam or air pressure, on a falling ram.

DUCTILITY
The property that permits permanent deformation before fracture by stress in tension.

DIAMOND PYRAMID HARDNESS TEST
An indentation hardness test employing a 136° diamond pyramid indenter and variable loads enabling the use of one hardness scale for all ranges of hardness from very soft lead to tungsten carbide.

DIRECT CHILL (DC) CASTING
A continuous method of making ingots or billets for sheet or extrusion by pouring the metal into a short mould. The base of the mould is a platform that is gradually lowered while the metal solidifies, the frozen shell of metal acting as a retainer for the liquid cooled by the impingement of water directly on the mould or on the walls of the solid metal as it is lowered. The length of the ingot is limited by the depth to which the platform can be lowered: therefore, it is often called semi-continuous casting.

EAR
A wavy projection formed in the course of deep drawing, as a result of directional properties or anisotropy of the sheet.

ELASTIC LIMIT
The maximum stress that a material will withstand without permanent deformation. (Almost never determined experimentally; yield strength is customarily determined).

ELECTRIC FURNACE
A melting furnace with a shallow hearth and a low roof in which the charge is melted and refined by an electric arc between one or more electrodes and the charged material. The electrodes normally are suspended through the roof. No liquid or gaseous fuel is usually used; however, gaseous oxygen may be injected into the bath.

ELONGATION
The amount of permanent extension in the vicinity of the fracture in the tension test; usually expressed as a percentage of the original gauge length, as 25% in 2 in. Elongation may also refer to the amount of extension at any stage in any process that elongates a body continuously, as in rolling.

EMBOSSING
Raising a design in relief against a surface.

EMBRITTLEMENT
Reduction in the normal ductility of a metal due to a physical or chemical change.

ENDURANCE LIMIT
The maximum stress that a metal will withstand without failure during a specified large number of cycles of stress. If the term is employed without qualification, the cycles of stress are usually such as to produce complete reversal of flexural stress.

END USE
Specific detailed part to be made. End use is described by aspecific phrase like "steel stiffener for back plate of model A refrigerator". End uses are not indicated by wide general terms such as "for refrigerators" or "for shipbuilding".

EQUILIBRIUM
A dynamic condition of balance between atomic movements, where the resultant is zero and the condition appears to be one of rest rather than change.

ERICHSEN TEST
A cupping test in which a piece of sheet metal, restrained except at the centre, is deformed by a cone-shaped spherical-end plunger until fracture occurs. The height of the cup in millimeters at fracture is a measure of the ductility.

EXTENSOMETER
Device, usually mechanical, for indicating the deformation of metal while it is subjected to stress.

EXTRUSION
Conversion of a billet into lengths of uniform cross-section by forcing the plastic metal through a die orifice of the desired cross-sectional outline. In "direct extrusion", the die and ram are at opposite ends of the billet, and the product and ram travel in the same direction. In "indirect extrusion" (rare), the die is at the ram end of the billet and the product travels through and in the opposite direction to the hollow ram. A "stepped extrusion" is a single product with one or more abrupt cross-section changes and is obtained by interrupting the extrusion by die changes. "Impact extrusion" (cold extrusion) is the process or resultant product of a punch striking an unheated slug in a confining die. The metal flow may be either between the punch and die or through another opening. "Hot extrusion" is similar to cold extrusion except that a preheated slug is used and the pressure application is slower.

FATIGUE
The tendency for a metal to break under conditions of repeated cyclic stressing considerably below the ultimate tensile strength.

FATIGUE CRACK OF FAILURE
A fracture starting from a nucleus where there is an abnormal concentration of cyclic stress and propagating through the metal. The surface is smooth and frequently shows concentric (sea shell) markings with a nucleus as a center.

FATIGUE LIFE
The number of cycles of stress than can be sustained prior to failure for a stated test condition.

FATIGUE LIMIT
The maximum stress that a metal will withstand without failure for a specified large number of cycles of stress. Usually synonymous with endurance limit.

FATIGUE RATIO
The ratio of the fatigue limit for cycles of reversed flexural stress to the tensile strength.

FATIGUE STRENGTH
The maximum stress that can be sustained for a specified number of cycles without failure, the stress being completely reversed within each cycle unless otherwise stated.

FERRITE
A solid solution in which alpha iron is the solvent, and which is characterized by a body-centered cubic crystal structure.

FERRITIC STAINLESS STEEL
Steel having the microstructure substantially wholly ferritic at normal temperature: usually a steel of the chromium type.

FERRO-ALLOY
An alloy or iron that contains a sufficient amount of one or more chemical elements-such as manganese, chromium, or siliconto be useful as an agent for introducing these elements into steel by ad-mixture with molten steel.

FILLET
A concave junction of two (usually perpendicular) surfaces.

FINISHED STEEL
Steel that is ready for the market without further work or treatment. Blooms, billets, slabs, sheet bars, and wire rods are termed "semi-finished".

FINISHED TEMPERATURE
The temperature at which hot mechanical working of metal is completed.

FISHTAIL
An overlapping at the back end of rolled sheet or bar.

FLAKES
Internal fissures in ferrous metals. In a fractured surface these fissures may appear as sizable areas of silvery brightness and coarse texture; in wrought products such fissures may appear as short discontinuities on an etched section. Also called "shatter cracks", "chrome cracks", "fish eyes" and "snowflakes".

FLAME HARDENING
A process of hardening a ferrous alloy by heating it above the transformation range by means of a high-temperature flame, and then cooling as required.

FLANGE
(1) A projection of metal on formed objects. (2) The parts of a channel at right angles to the central section or web.

FLASH
A thin fin of metal formed at the sides of a forging or weld when a small portion of metal is forced out between the edges of the forging or welding dies.

FLATNESS

Relative term for the measure of deviation of flat rolled material from a plane surface: usually determined as the height of ripples of waves above a horizontal level surface.

FLUTING
Kinking or breaking caused by the curving of metal strip on a radius so small, in relation to the thickness, as to stretch the outer surface well beyond its elastic limit.

FRACTURE TEST
Breaking a piece of metal for the purpose of examining the fractured surface to determine the structure or carbon content of the metal or to detect the presence of internal defects.

FULL ANNEALING
A softening process in which a ferrous alloy is heated to a temperature above the transformation range and, after being held for a sufficient time at this temperature, is cooled slowly to a temperature below the transformation range. The alloy is ordinarily allowed to cool slowly in the furnace, although it may be removed and cooled in some medium that ensures a slow rate of cooling.

GRAIN GROWTH
An increase in the grain size of metal.

GRAIN REFINER
Any material added to a liquid metal for the purpose of producing a finer grain size in the subsequent casting, or of retaining fine grains during the heat treatment of wrought structures.

GRAINS
Individual crystals in metals.

GRAPHITIZING
A heating and cooling process by which the combined carbon in cast iron or steel is transformed. Wholly or partly, to graphitic or free carbon.

HARDENABILITY
In a ferrous alloy, the property that determines the depth and distribution of hardness induced by quenching.

HARDENING
Any process for increasing the hardness of metal by suitable treatment, usually involving heating and cooling.

HARDNESS
Defined in terms of the method of measurement. (1) Usually the resistance to indentation. (2) Stiffness or temper of wrought products. (3) Machinability characteristics.

HARDNESS TESTS
(A) Brinell Hardness - A hardness test performed on a Brinell hardness testing machine. The smooth surface of a specimen is indented with a spherical-shaped hardened steel ball of known diameter by means of a predetermined load applied to the ball. The diameter of the impression is measured in millimeters with a micrometer microscope, and the reading is compared with a chart to determine the Brinell Hardness number (BHn).

(B) Rockwell Hardness - A hardness test performed on a Rockwell hardness testing machine. Hardness is determined by a dial reading which indicates the depth of penetration of a steel ball or diamond cone when a load is applied.
(C) Scleroscope or Shore Hardness A hardness test performed on a Shore Scleroscope Hardness Tester. The hardness is determined by the rebound of a diamond pointed hammer (or tup) when it strikes the surface of a specimen. The hammer (or tup) is enclosed in a glass tube and the height of the rebound is read either against a graduated scale inscribed on the tube, or on a dial, depending on the model instrument used.

HEARTH
The bottom portion of certain furnaces, such as the blast furnace, air furnace and other reverberatory furnaces, in which the molten metal is collected or held.

HEAT TREATMENT
A combination of heating and cooling operations, timed and applied to a metal or alloy in the solid state in a way that will produce desired properties. Heating for the sole purpose of hot working is excluded from the meaning of this definition.

HOLD DOWN
The tool that exerts pressure normal to a sheet blank during deep drawing, in order to prevent wrinkling.

HOMOGENOUS
Usually defined as having identical characteristics throughout. However, physical homogeneity may require only an identity of lattice type throughout, while chemical homogeneity requires uniform distribution of alloying elements.

HOMOGENIZING
A process of heat treatment at high temperature intended to eliminate or decrease chemical segregation by diffusion.

HOT FORMING
Working operations, such as bending and drawing sheet and plate, forging, pressing, and heading, performed on metal heated to temperatures above room temperature.

HOT SHORTNESS.
Brittleness in hot metal.

HOT TOP
See sinkhead.

HOT QUENCHING
A process of quenching in a medium at a temperature substantiallyhigher than atmospheric temperature.

HOT WORKING
Plastic deformation of metal at such a temperature and rate that strain hardening does not occur. The lower limit of temperature for this process is the recrystallization temperature.

HYDROGEN EMBRITTLEMENT

A condition of low ductility resulting from hydrogen absorption and internal pressure developed subsequently.

IMPACT ENERGY (IMPACT VALUE)
The amount of energy required to fracture a material, usually measured by means of an Izod or Charpy test. The type of specimen and testing conditions affect the values and therefore should be specified.

IMPACT TEST
A test to determine the energy absorbed in fracturing a test bar at high velocity. The test may be in tension or in bending, or it may properly be a notch test if a notch is present, creating multiaxial stresses.

INCIDENTAL ELEMENTS
Small quantities of non-specified elements commonly introduced into product from the use of scrap metal with the raw materials.

INCLUSIONS
Particles of impurities (usually oxides, sulfides, silicates and such) that are held mechanically, or are formed during solidification or by subsequent reaction within the solid metal.

INDUCTION HARDENING
A process of hardening a ferrous alloy by heating it above the transformation range by means of electrical induction, and cooling as required.

INGOT
A casting intended for subsequent rolling or forging.

INTERGRANULAR CORROSION
A type of electrochemical corrosion that progresses preferentially along the grain boundaries of an alloy, usually because the grain boundary regions contain material anodic to the central regions of the grains.

IRON
(1) Element No. 26 of the periodic system, the average atomic weight of the naturally occurring isotopes being 55.85 (2) Ironbase materials not falling into the steel classification.

ISOTHERMAL ANNEALING
A process in which a ferrous alloy is heated to produce a structure partly or wholly austenitic, and is then cooled to and held at a temperature that causes transformation of the austenite to a relatively soft ferrite-carbide aggregate.

ISOTHERMAL TRANSFORMATION
The process of transforming austenite in a ferrous alloy to ferrite or a ferrite-carbide aggregate at any constant temperature within the transformation range.

IZOD TEST
A pendulum type of single-blow impact test in which the specimen, usually notched, is fixed at one end and broken by a falling pendulum. The energy absorbed, as measured by the subsequent rise of the pendulum, is a measure of impact strength or notch toughness.

KALDO PROCESS
One of the family of basic oxygen steelmaking processes which uses an inclined, rotating cylindrical furnace in which oxygen is injected through a lance in the centre line of the furnace. This furnace uses a basic refractory lining and normally no fuels or fluxes are injected with the oxygen.

KILLED STEEL
Steel deoxidized with a strong deoxidizing agent such as silicon or aluminum in order to reduce the oxygen content to a minimum so that no reaction occurs between carbon and oxygen during solidification.

LADLE ANALYSIS
Chemical analysis made from samples obtained during original casting of ingots. This is normally to controlling analysis for satisfying the specifications.

LAMINATIONS
Defects resulting from the presence of blisters, seams or foreign inclusions aligned parallel to the worked surface of a metal.

LAP
A surface defect appearing as a seam, caused by folding over hot metal, fins or sharp corners and then rolling or forging them into the surface, but not welding them.

L-D PROCESS
One of the basic oxygen steelmaking processes using a vertical cylindrical furnace in which oxygen is injected from above by a lance. The furnace has a basic refractory lining. Some variations of this process include the injection of liquid or gaseous fuels and fluxes along with the gaseous oxygen.

LEVELLING
Flattening rolled metal sheet. See roller flattening.

LONGITUDINAL DIRECTION
The direction in a wrought metal product parallel to the direction of working (drawing, extruding, rolling).

LÜDER'S LINES OR LÜDER LINES
(stretcher strains, flow figures) Elongated markings that appear on the surface of some materials, particularly iron and low carbon steel, when deformed just past the yield point. These markings lie approximately parallel to the direction of maximum shear stress and are the result of localized yielding. They consist of depressions when produced in tension and of elevations when produced in compression. They may be made evident by localized roughening of a polished surface or by localized flaking from an oxidized surface.

MACROSCOPIC
Visible either with the naked eye or under low magnification (as great as about 10 diameters).

MACROSTRUCTURE
The structure of metals as revealed by macroscopic examination.

MALLEABILITY
The property that determines the ease of deforming a metal when the metal is subjected to rolling or hammering. The more malleable metals can be hammered or rolled into thin sheet more easily than others.

MALLEABILIZING
A process of annealing white cast iron in such a way that the combined carbon is wholly or partly transformed to graphite or free carbon or, in some instances, part of the carbon is removed completely.

MANNESMANN PROCESS
A process used for piercing tube billets in making seamless tubing. The billet is rotated between two heavy rolls mounted at an angle, and is forced over a fixed mandrel. Billets are called "tube rounds".

MARTEMPERING
The process of quenching an austenitized ferrous alloy in a medium at a temperature in the upper portion of the temperature range of martensite formation, or slightly above that range, and holding in the medium until the temperature throughout the alloy is substantially uniform. The alloy is then allowed to cook in air through the temperature range of martensite formation.

MARTENSITE
An unstable constituent in quenched steel, formed without diffusion and only during cooling below a certain temperature known as the Ms (or Ar") temperature. The structure is characterized by its acicular appearance on the surface of a polished and etched specimen. Martensite is the hardest of the transformation products of austenite. Tetragonality of the crystal structure is observed when the carbon content is greater than about 0.05%.

MARTENSITIC STAINLESS STEEL
Steel having the microstructure substantially wholly martensitic at normal temperature: usually a steel of medium carbon high alloy type.

MECHANICAL PROPERTIES
Those properties of a material that reveal the elastic and inelastic reaction when force is applied, or that involve the relationship between stress and strain; for example, the modulus of elasticity, tensile strength and fatigue limit. These properties have often been designated as "physical properties", but the term "mechanical properties" is preferred.

MECHANICAL WORKING
Subjecting metal to pressure exerted by rolls, dies, presses, or hammers, to change its form or to affect the structure and consequently the mechanical and physical properties.

MERCHANT MILL
A mill, consisting of a group of stands of three rolls each arranged in a straight line and driven by one power unit, used to roll rounds, squares or flats of smaller dimensions that would be rolled on the bar mill.

METALLOGRAPHY

The science concerning the constitution and structure of metals and alloys as revealed by the microscope.

MICROSTRUCTURE
The structure of polished and etched metal and alloy specimens as revealed by the microscope.

MODULUS OF ELASTICITY
The slope of the elastic portion of the stress-strain curve in mechanical testing. The stress is divided by the unit elongation. The tensile of compressive elastic modulus is called "Young's modulus"; the torsional elastic modulus is known as the "shear modulus", or "modulus of rigidity".

NITIRIDING
A process of case hardening in which a ferrous alloy, usually of special composition, is heated in an atmosphere of ammonia or in contact with nitrogenous material to produce surface hardening by the absorption of nitrogen, without quenching.

NON-SCALLOPING QUALITY
Steel specially made to be substantially free from scallops or ears during pressing and drawing.

NORMALIZING
A process in which a ferrous alloy is heated to a suitable temperature above the transformation range and is subsequently cooled in still air at room temperature.

NORMAL SEGREGATION
Concentration of alloying constituents that have low melting points, in those portions of a casting that solidfy last.

NOTCH BRITTLENESS
Susceptibility of a material to brittleness in areas containing a groove, scratch, sharp fillet or notch.

NOTCH SENSITIVITY
The reduction caused in nominal strength, impact or static, by the presence of a stress concentration, usually expressed as the ratio of the notched to the unnotched strength.

OPEN HEARTH FURNACE
A furnace for melting metal, in which the bath is heated by the convection of hot gases over the surface of the metal and by radiation from the roof.

ORANGE PEEL EFFECT
A surface roughening encountered in forming products from metal stock that has a coarse grain size, also referred to as "pebbles" and "alligator skin".

ORIENTATION
The angular relationship between the axis of a crystal and an external reference system. The orientation of individual crystals is most conveniently represented by poles of simple planes plotted stereo-graphically.

OUT-OF-ROUND

Deviation of cross section of a round bar from a true circle: normally measured as difference between maximum and minimum diameters at the same cross section of the bar.

OUT-OF-SQUARE
For square bars this is the deviation of cross section from a true square; normally measured as the difference between the two diagonal dimensions at one cross section. For structural shapes, the term out-of-square indicates the deviation from a right angle of the plane of flanges in relation to the plane of webs.

OVERHEATED
A term applied when, after exposure to an excessively high temperature, a metal develops an undesirably coarse grain structure but is not permanently damaged. Unlike a burnt structure, the structure produced by overheating can be corrected by suitable heat treatment, by mechanical work, or by a combination of the two.

PEARLITE
The lamellar aggregate of ferrite and carbide. **Note:** It is recommended that this word be reserved for the microstructures consisting of thin plate or lamellae-that is, those that may have a pearly luster in white light. The lamellae can be very thin and resolvable only with the best microscopic equipment and technique.

PERMEABILITY
(1) Magnetic permeability, the ratio of the magnetic induction to the intensity of the magnetizing field. (2) In a mould, the porosity of foundry sands and the ability of trapped gases to escape through the sand.

PHYSICAL PROPERTIES
Those properties familiarly discussed in physics exclusive of those described under mechanical properties; for example, density, electrical conductivity, coefficient of thermal expansion. This term has often been used to describe mechanical properties but this usage is not recommended. See mechanical properties.

PICKLE
Chemical or electrochemical removal of surface oxides.

PIG IRON
Iron produced by reduction of iron ore in the blast furnace.

PINHOLE POROSITY
Very small holes scattered through a casting, possibly by micro-shrinkage or gas evolution during solidification.

PIPE
A cavity formed by contraction in metal (especially ingots) during solidification of the last portion of liquid metal.

PIT
A sharp depression in the surface of metal.

PLASTIC DEFORMATION
Permanent distortion of a material under the action of applied stresses.

PLASTICITY

The ability of a metal to be deformed extensively without rupture.

POISSON'S RATIO
The absolute value of the ratio of the transverse strain to the corresponding axial strain, in a body subjected to uniaxial stress; usually applied to elastic conditions.

POROSITY
Unsoundness caused in cast metals by the presence of blowholes and shrinkage cavities.

POSTHEATING
A process used immediately after welding, whereby heat is applied to the weld zone either for tempering or for providing a controlled rate of cooling, in order to avoid a hard or brittle structure.

PRECIPITATION HARDENING
A process of hardening an alloy in which a constituent precipitates from a supersaturated solid solution. See also age hardening and aging.

PREFERRED ORIENTATION
In a polycrystalline structure, a departure from crystallographic randomness.

PREHEATING
(1) A general term used to describe heating applied as a preliminary to some further thermal or mechanical treatment. (2) A term applied specifically to tool steel to describe a process in which the steel is heated slowly and uniformly to a temperature below the hardening temperature and is then transferred to a furnace in which the temperature is substantially above the preheating temperature.

PRIMARY MILL
A mill for rolling ingots or the rolled products of ingots to blooms, billets or slabs. This type of mill is often called a blooming mill and sometimes a cogging mill.

PROCESS ANNEALING
In the sheet and wire industries, a process by which a ferrous alloy is heated to a temperature close to, but below, the lower limit of the transformation range and is subsequently cooled. This process is applied in order to soften the alloy for further cold working.

PROOF STRESS
In a test, stress that will cause a specified permanent deformation in a material, usually 0.01% or less.

PROPORTIONAL LIMIT
The greatest stress that the material is capable of sustaining without a deviation from the law of proportionality of stress to strain (Hooke's Law).

QUENCH HARDENING
A process of hardening a ferrous alloy of suitable composition by heating within or above the transformation range and cooling at a rate sufficient to increase the hardness substantially. The process usually involves the formation of martensite.

QUENCHING

A process of rapid cooling from an elevated temperature by contact with liquids, gases or solids.

QUENCHING CRACK
A fracture resulting from thermal stresses induced during rapid cooling or quenching; frequently encountered in alloys that have been overheated and liquated and are thus "hot short".

RECRYSTALLIZATION
A process whereby the distorted grain structure of cold worked metals is replaced by a new, strain-free grain structure during annealing above a specific minimum temperature.

RED SHORTNESS
Brittleness in steel when it is red hot.

REDUCTION IN AREA
The difference between the original cross-sectional area and that of the smallest area at the point of rupture; usually stated as a percentage of the original area; also called "contraction of area".

REFINING TEMPERATURE
A temperature, usually just higher than the transformation range, employed in the heat treatment of steel to refine the structure - in particular, the grain size.

RESIDUAL STRESS
Macroscopic stresses that are set up within a metal as the result of non-uniform plastic deformation. This deformation may be caused by cold working or by drastic gradients of temperature from quenching or welding.

RESQUARED
Flat rolled material (plate, sheet or strip) firstly cut to approximate size and finally resheared to very close tolerance: also any material having been cut to equally close tolerances as to dimensions and squareness, by whatever method.

REVERBERATORY FURNACE
A furnace with a shallow hearth, usually non-regenerative, having a roof that deflects the flame and radiates heat toward the hearth or the surface of the charge.

RIMMED STEEL
An incompletely deoxidized steel normally containing less than 0.25% C and having the following characteristics: (a) During solidification an evolution of gas occurs sufficient to maintain a liquid ingot top ("open" steel) until a side and bottom rim of substantial thickness has formed. If the rimming action is intentionally stopped shortly after the mould is filled, the product is termed capped steel. (b) After complete solidification, the ingots consists of two distinct zones - a rim somewhat purer than when poured and a core containing scattered blowholes, a minimum amount of pipe and an average percentage of metalloids somewhat higher than when poured and markedly higher in the upper portion of the ingot.

ROCKWELL HARDNESS TEST
A test for determining the hardness of a material based upon the depth of penetration of a specified penetration into the specimen under certain arbitrarily fixed conditions of test.

ROLLER FLATTENING OR ROLLER LEVELLING
The process in which a series of staggered rolls of small diameter is used to remove bow and waves from sheet. While passing through the rolls, the sheet is bent back and forth slightly and is delivered approximately flat.

ROLLER STRAIGHTENING
A process involving a series of staggered rolls of small diameter, between which rod, tubing and shapes are passed for the purpose of straightening. The process consists of a series of bending operations.

ROLL FORMING
(1) An operation used in forming sheet. Strips of sheet are passed between rolls of definite settings that bend the sheet progressively into structural members of various contours, sometimes called "moulded sections". (2) A process of coiling sheet into open cylinders.

ROLLING
Reducing the cross-sectional area of metal stock, or otherwise shaping metal products, through the use of rotating rolls.

ROLLING MILLS
Machines used to decrease the cross-sectional area of metal stock and produce certain desired shapes as the metal passes between rotating rolls mounted in a framework comprising a basic unit called a stand. Cylindrical rolls produce flat shapes; grooved rolls produce rounds, squares and structural shapes. Among rolling mills may be listed the billet mill, blooming mill, breakdown mill, plate mill, sheet mill, slabbing mill, strip mill and temper mill.

SCAB
(Scabby) A blemish caused on a casting by eruption of gas from the mould face, or by uneven mould surfaces; or occurring where the skin from a blowhole has partly burned away and is not welded.

SCALING
Surface oxidation caused on metals by heating in air or in other oxidizing atmospheres.

SCALLOPS
See "ears".

SCARFING
Cutting surface areas of metal objects, ordinarily by using a gas torch. The operation permits surface defects to be cut from ingots, billets, or the edges of plate that is to be beveled for butt welding. See chipping.

SCLEROSCOPE TEST
A hardness where the loss in kinetic energy of a falling metal "tup", absorbed by indentation upon the impact of the tup on the metal being tested, is indicated by the height of rebound.

SEAM
On the surface of metal, a crack that has been closed but not welded; usually produced by some defect either in casting or in working, such as blowholes that have become oxidized or

folds and laps that have been formed during working. Seam also refers to lap joints, as in seam welding.

SEGREGATION
In an alloy object, concentration of alloying elements at specific regions, usually as a result of the primary crystallization of one phase with the subsequent concentration of other elements in the remaining liquid. Micro segregation refers to normal segregation on a microscopic scale whereby material richer in alloying elements freezes in successive layers on the dendrites (coring) and in the constituent network. Macro segregation refers to gross differences in concentration (for example, from one area of an ingot to another) which may be normal, inverse or gravity segregation.

SEMIKILLED STEEL
Steel incompletely deoxidized, to permit evolution of sufficient carbon monoxide to offset solidification shrinkage.

SHEARED EDGES
Sheared edge is obtained when rolled edge is removed by rotary slitter or mechanical shear.

SHORTNESS
A form of brittleness in metal. It is designated as "cold", "hot", and "red" to indicate the temperature range in which the brittleness occurs.

SINGLE-STAND MILL
A rolling mill of such design that the product contacts only two rolls at a given moment. Contrast with "tandem mill".

SINKHEAD OR HOT TOP
A reservoir insulated to retain heat and to hold excess molten metal on top of an ingot mold, in order to feed the shrinkage of the ingot. Also called "shrink head" or "feeder head".

SINTERING
(1) The bonding of adjacent surfaces of particles in a mass of metal powders or a compact, by heating. (2) A shaped body composed of metal powders and produced by sintering with or without prior compacting.

SKELP
A plate of steel or wrought iron from which pipe or tubing is made by rolling the skelp into shape longitudinally and welding the edges together.

SKIN
A thin surface layer that is different from the main mass of a metal object, in composition, structure or other characteristics.

SLAB
See bloom.

SLAG
A nonmetallic product resulting from the mutual dissolution of flux and nonmetallic impurities in smelting and refining operations.

SOAKING

Prolonged heating of a metal at a selected temperature.

SPHEROIDIZING
Any process of heating and cooling that produces a rounded or globular form of carbide in steel. Spheroidizing methods frequently used are: (1) Prolonged holding a temperature just below Ae1. (2) Heating and cooling alternately between temperatures that are just above and just below Ae1. (3) Heating to a temperature above Ae1. or Ae3. and then cooling very slowly in the furnace, or holding at a temperature just below Ae1. (4) Cooling at a suitable rate from the minimum temperature at which all carbide is dissolved, to prevent the re-formation of a carbide network, and then reheating in accordance with method 1 or 2 above (applicable to hypereutectoid steel containing a carbide network).

STEEL
An iron base alloy, malleable in some temperature range as initially cast, containing manganese, usually carbon, and often other alloying elements. In carbon steel and low-alloy steel, the maximum carbon is about 2.0%; in high-alloy steel, about 2.5%. The dividing line between low-alloy and high-alloy steels is generally regarded as being about 5% metallic alloying elements. Steel is to be differentiated from two general classes of "irons": the cast irons, on the high-carbon side, and the relatively pure irons such as ingot iron, carbonyl iron, and electrolytic iron, on the low-carbon side. In some steels containing extremely low carbon, the manganese content is the principal differentiating factor, steel usually containing at least 0.25%; ingot iron contains considerably less.

STRAIGHTNESS
Measure of adherence to or deviation from a straight line, normally expressed as sweep or camber, according to the plane.

STRAIN AGING
Aging induced by cold working. See aging.

STRAIN ENERGY
(1) The work done in deforming a body. (2) The work done in deforming a body within the elastic limit of the material. It is more properly elastic strain energy and can be recovered as work rather than heat.

STRAIN HARDENING
An increase in hardness and strength caused by plastic deformation at temperatures lower than the recrystallization range.

STRESS
The load per unit of area. Ordinarily stress-strain curves do not show the true stress (load divided by area at that moment) but a fictitious value obtained by using the original area.

STRESS-CORROSION CRACKING
Failure by cracking under combined action of corrosion and stress, either external (applied) or internal (residual). Cracking may be either intergranular or transgranular, depending on metal and corrosive medium.

STRESS RAISERS
Factors such as sharp changes in contour or surface defects, which concentrate stresses locally.

STRESS RELIEVING
A process of reducing residual stresses in a metal object by heating the object to a suitable temperature and holding for a sufficient time. This treatment may be applied to relieve stresses induced by casting, quenching, normalizing, machining, cold working, or welding.

STRETCHER FLATTENING OR STRETCHER LEVELLING
A process for removing bow and warpage from sheet by applying a uniform tension at the ends so that the piece is elongated to a definite amount of permanent set.

STRETCHER LEVELLED FLATNESS
Steel sheets or strip subjected to stretcher levelling thereby acquire a high degree of flatness (together with some increase of stiffness). When the same degree of flatness is procured by other methods like roller levelling, it is then described as "stretcher levelled standard of flatness".

STRETCHER STRAINS
See "Lüder lines".

SWEEP
Curvature in structural and other similar shapes normal to the plane of the web.

TANDEM MILL
A rolling mill consisting of two or more stands arranged so that the metal being processed travels in a straight line from stand to stand. In continuous rolling, the various stands are synchronized so that the strip may be rolled in all stands simultaneously. Contrast with "single-stand mill".

TEMPER
A measure of the mechanical characteristics of cold rolled steel strip obtained by various degrees of cold working.

TEMPERING
A process of reheating quench-hardened or normalized steel to a temperature below the transformation range, and then cooling at any rate desired.

TEMPER BRITTLENESS
Brittleness that results when certain steels are held within, or are cooled slowly through, a certain range of temperature below the transformation range. The brittleness is revealed by notched bar impact tests at room temperature or lower temperatures.

TEMPER ROLLING
This is a skin-rolling of steel sheet or strip when cold, to impart a required degree of stiffness, hardness or surface condition. It should not be confused with "cold rolling" which implies cold reduction on terms of thickness.

TENSILE STRENGTH
The value obtained by dividing the maximum load observed during tensile straining by the specimen cross-sectional area before straining. Also called "ultimate strength".

THERMAL FATIGUE
Fracture resulting from the presence of temperature gradients which vary with time in such a manner as to produce cyclic stresses in a structure.

TOLERANCES
Allowable variations from specified dimensions.

TOUGHNESS
Property of absorbing considerable energy before fracture; usually represented by the area under a stress-strain curve, and therefore involving both ductility and strength.

TRACE
Extremely small quantity of an element, usually too small to determine quantitatively.

TRANSFORMATION RANGE OR TRANSFORMATION TEMPERATURE RANGE
The temperature interval within which austenite forms while ferrous alloys are being heated. Also the temperature interval within which austenite disappears while ferrous alloys are being cooled. The two ranges are distinct, sometimes overlapping but never coinciding. The limiting temperatures of the ranges depend on the composition of the alloy and on the rate of change of temperature, particularly during cooling. See transformation temperature.

TRANSFORMATION TEMPERATURE
The temperature at which a change in phase occurs. The term is sometimes used to denote the limiting temperature of a transformation range. The following symbols are used for iron and steel:

- Ac_1 The temperature at which austenite begins to form during heating.
- Ac_3 The temperature at which transformation of ferrite to austenite is completed during heating. AcCM In hypereutectoid steel, the temperature at which solution of cementite in austenite is completed during heating.
- Ar_1 The temperature at which transformation of austenite to ferrite or to ferrite plus cementite is completed during cooling.
- Ar_3 The temperature at which austenite begins to transform to ferrite during cooling.
- Ar_{CM} In hypereutectoid steel, the temperature at which solution of cementite in austenite is completed during heating.
- A_4 The temperature at which austenite transforms to delta ferrite during heating; the reverse process occurs during cooling.
- M_s (or Ar") The temperature at which transformation of austenite to martensite starts during cooling.
- M_f The temperature at which transformation of austenite to martensite is completed during cooling.
- Note: All these changes (except the formation of martensite) occur at lower temperatures during cooling than during heating, and depend on the rate of change of temperature. The temperatures of phase changes at equilibrium are denoted by the symbols Ae1 Ae3 AeCM and Ae4.

TRANSVERSE
Literally "across" signifying a direction or plane perpendicular to the direction of working.

ULTIMATE STRENGTH
See tensile strength.

UNIVERSAL MILL
A rolling mill in which rolls with a vertical axis roll the edges of the metal stock between some of the passes through the horizontal rolls.

UNIVERSAL MILL PLATE
Plate rolled on a universal mill having vertical (edge) rolls as well as horizontal rolls; also any plate having characteristics identical to plate produced on a universal mill.

UPSETTING
(1) A metal working operation similar to forging. (2) The process of axial flow under axial compression of metal, as in forming heads on rivets by flattening the end of wire.

VICKERS HARDNESS TEST
Same as a "diamond pyramid hardness test".

WELDING
A process used to join metals by the application of heat. Fusion welding, which includes gas, arc, and resistance welding, requires that the parent metals be melted. This distinguishes fusion welding from brazing. In pressure welding joining is accomplished by the use of heat and pressure without melting. The parts that are being welded are pressed together and heated simultaneously, so that recrystallization occurs across the interface.

WOODY FRACTURE
Fractures having a fibrous appearance.

YIELD POINT
In mild or medium-carbon steel, the stress at which a marked increase in deformation occurs without increase in load. In other steels, and in nonferrous metals this phenomenon is not observed. See Yield Strength.

YIELD STRENGTH
The stress at which a material exhibits a specified limiting deviation from proportionality of stress to strain. An offset of 0.2% is used for many metals such as aluminum-base and magnesium-base alloys, while a 0.5% total elongation under load is frequently used for copper alloys.

YOUNG'S STRENGTH
The modulus of elasticity in tension or compression.

SECTION 3. SERVICES

Services Overview

Saw Cutting
We have an extensive range of fully automated that saws that can handle a cutting range of **up to 32" diameter**. Our experienced operators and service capabilities allow us to offer multiple piece orders and close tolerance cutting available as requested. We are open to custom cutting inquiries as requested - please inquire

Plasma Arc Cutting
Our high definition plasma cutting capabilities can accommodate stainless steel grades from 1875" **up to 2" thick** x 96" wide x 240" long. This high production machine has a tight tolerance and gives us the ability to cut squares, rectangles, rounds, rings or most custom profiles. We can process and nest drawings sent to us in PDF, DXF and Solid-works files.

Trepanning
We have an extensive range of automated Trepan Machines that can accommodate round or square stock from 2" to 32" in diameter. Our machines have the capabilities of drilling hole sizes from **1" to 10" ID's** and bar **lengths from 6" to 22'**. We have the expertise of drilling multiple grades of steel, aluminum and cast producing high quality hole finishes.

Plate Saw
Our plate saws can handle ½" to 12" thick plates **up to 20 ft. long**. Saw cutting produces smoother, straighter squares and rectangles than plasma arc, without a heat affected zone, which reduces insert breakage and enhances machinability.

Delivery Services
Encore Metals offers same or next day delivery on most in-stock items. Delivery is free to local and selected regional locations on qualifying orders. Our team of contracted and commercial delivery services are selected for their reliable, safety-conscious service.

Packaging
Encore Metals' packaging is designed for safe handling as well as product protection and identification. Material is sorted by finish and bundled with appropriate protection. Short, cut pieces are skidded, banded, and shrink-wrapped to your handling capabilities. Sheet products are shipped with protective coverings, and corner and edge protection. Inquire for custom packaging requirements.

QUALITY ASSURANCE

You can count on Encore Metals for materials of the highest quality, all at the best value. As an industry leader, we continue to leverage our experience, new technologies, and progressive ideas to drive our future. At Encore Metals, we realize it takes a lot more than materials to provide these kinds of results - It takes the desire and ability and commitment to make a difference.

We are convinced that successful application of the principles and techniques of quality management result in reduced costs, improved quality, and improved relationships between Encore Metals and our customers. Our customer's satisfaction, quality products, and services will continue to be the expected standard for our future.

Our suppliers are all mills of high repute with facilities that employ the latest steelmaking technology. As a result, our products are backed by the most advanced metallurgical and research facilities available.

Encore Metals maintains an ISO 9001:2008 registered quality assurance program to assure traceability of our products and performance of services dedicated to quality and to the needs of our customers.

A copy of our Quality Assurance Policy is available upon request.