

# encorem Metals 2016

## Product Manual



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## DISCLAIMER

This Product Manual is to be used for reference only. To the best of our knowledge the information contained in this book is accurate as indicated in the Limited Product Warranty section. Encore Metals assumes no responsibility for errors in, misinterpretation of, the information in this book or in its use.

## LIMITED PRODUCT WARRANTY

Encore Metals is a wholesaler of goods, and only warrants that products sold will conform to the express specifications referenced on applicable quotations, invoices or acknowledgements. The information and data in this manual has been compiled from various independent sources and the purchaser shall be solely responsible for determining the adequacy of the product for any and all uses to which the purchaser should apply the product.

Encore Metals makes no other warranty of any kind, express or implied, including no warranty of merchantability, fitness or particular purpose, usage or trade to any person or entity with regard to the products or services covered hereby and forbids the purchaser to represent otherwise to anyone with which it deals.

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.

Encore Metals shall not be liable under any circumstances, including, but not limited to, any claim for breach of warranty (express or implied), tort (including negligence) or strict liability, for any actual, incidental, contingent special or consequential damages howsoever caused but not limited to, no liability for loss of profits or revenue, loss of use of products, services or other items to be furnished to the purchaser, cost of capital, cost of substitute equipment, additional costs incurred by the purchaser at its plant or in the field (whether by way of correction or otherwise) or claims of the purchaser's customers or other third party for damages.

## 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.

## CONTACT INFORMATION

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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 1/2" diameter.	<ul style="list-style-type: none"> <li>- 3312 Annealed Round</li> <li>- 4130 Heat Treated Rounds, API 6A</li> <li>- 4140 Annealed Rounds</li> <li>- 4140 Annealed Hexagons, Squares, Flats</li> <li>- 4140 HTSR Rounds</li> <li>- 4140 Plate</li> <li>- 4140 Rc 22 max Rounds</li> <li>- 4140 Cold Finished Steel Chrome Plated Shafting &amp; HTSR Precision Ground &amp; Cold Drawn</li> <li>- 4145H Mod HTSR</li> <li>- 4150 Calcium Treated HTSR Rounds</li> <li>- 4330+V Modified, HTSR</li> <li>- 4340 Annealed Rounds, CQ and AQ, squares &amp; flats</li> <li>- 4340 HTSR Rounds, CQ and AQ</li> <li>- EN30B Quench &amp; Tempered Rounds, Annealed Rounds</li> <li>- 8620 Hot Rolled Rounds, and cold finished</li> <li>- 52100</li> </ul>
Aluminum		<ul style="list-style-type: none"> <li>- 6061 T6 Rounds</li> </ul>
Bronze Cast		<ul style="list-style-type: none"> <li>- SAE 660 Bearing Bronze (C93200, ASTM B505)</li> <li>- Alloy 954 Aluminum Bronze (C95400, ASTM B505)</li> </ul>
Carbon	<p>Carbon Steel Bars (Hot Rolled) are stocked from 1" to 24" diameter.</p> <p>Cold Finished Steel Bars are stocked from 1/8" to 8" diameter.</p>	<ul style="list-style-type: none"> <li>- 1018 Rounds</li> <li>- 1040/ 1045 Rounds</li> <li>- A105/A350-LF2</li> <li>- 1018 Cold Finished Steel Rounds, Squares, Flats</li> <li>- 12L14 Cold Finished Steel Rounds, Hexagons</li> <li>- 1045 Cold Finished Steel Precision Ground Shafting</li> <li>- 1045 Cold Finished Steel Chrome Plated Shafting (Imperial &amp; Metric)</li> <li>- 1045 Cold Finished Steel Induction Hardened, Chrome Plated Shafting (Imperial &amp; Metric)</li> <li>- 1144 Cold Finished Steel CD Hi-Strength</li> </ul>
Cast Iron		<ul style="list-style-type: none"> <li>- Continuous Cast Iron Bar – Ductile 65-45-12</li> </ul>

		<ul style="list-style-type: none"> <li>- Continuous Cast Iron Bar – Pearlitic Gray Iron - G2</li> <li>- Continuous Cast Iron Bar – 80-55-06</li> <li>- Continuous Cast Iron Bar – 100-70-02</li> </ul>
Specialty	<ul style="list-style-type: none"> <li>- 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.</li> </ul>	<ul style="list-style-type: none"> <li>- 4140 CD and Hot Finished Seamless Mechanical Tubing, L80 &amp; P100</li> <li>- Stainless Steel Ornamental Tubing</li> <li>- Non-Magnetic Drilling Components, Staballoy AG 17TM</li> <li>- Enhanced Corrosion Resistance Non-Magnetic Steel, Datalloy 2TM</li> <li>- Nickel/ Cobalt Alloys 400, 500</li> <li>- Nickel/ Cobalt Corrosion Resistant Alloys, C-276, C-22</li> <li>- Tool Steels Drilling/Mining</li> </ul>
Stainless Steel	<ul style="list-style-type: none"> <li>- Bars are stocked from 1/8" diameter to 12" diameter.</li> <li>- Sheets are stocked from 26 GA to 10 GA. Maximum width 60".</li> <li>- Plates are stocked from 3/16" to 3".</li> </ul>	<ul style="list-style-type: none"> <li>- T303 CD Rounds, Hexagons</li> <li>- T304/304L Rounds</li> <li>- T304 HRAP Flats, Slit Edge and Mill Edge</li> <li>- T304 CD/HRAP Hexagons</li> <li>- T304 HRAP Angles</li> <li>- T304/304L 2B and #4 Finish Sheet/Coil</li> <li>- T304/304L HRAP Sheet/Coil</li> <li>- T304/304L HRAP Plate</li> <li>- 309S Plate</li> <li>- T310/T310S Plate</li> <li>- T316/316L Rounds</li> <li>- T316L CG Rounds</li> <li>- T316L HRAP Angles</li> <li>- T316/316L PSQ Rounds</li> <li>- T316 HRAP Flats, Slit Edge and Mill Edge</li> <li>- T316 CD/HRAP Hexagons, Squares</li> <li>- T316/316L 2B Finish Sheet/Coil</li> <li>- T316/316L Plate, HRAP</li> <li>- T317L Plate, HRAP</li> <li>- T410 HT CG/RT Rounds &amp; NACE MR-01-75</li> <li>- T410 CG Rounds</li> <li>- T416 PSQ Rounds</li> <li>- T630/17-4PH Condition "A" Rounds</li> <li>- T630/17-4PH H1150 (NACE) Rounds</li> <li>- 15-5PH</li> <li>- Duplex 2205 (UNS S31803) Rounds</li> <li>- XM-19</li> <li>- 13% Chrome</li> <li>- 9Cr-1Mo</li> <li>- Alloy 20Cb3</li> <li>- Duplex 2304 Plate (UNS S32304)</li> <li>- Duplex 2205 Plate (UNS S31803/S32205)</li> <li>- 904L</li> <li>- 1925 HMo Plate (6% Molybdenum)</li> </ul>

# Alloy Steels

Alloy  
3312

Alloy AISI/SAE 3312 - a 3 ½% Nickel-Chromium Case Hardening Alloy Steel															
<b>Typical Analysis</b>	<table border="1"> <thead> <tr> <th>C</th> <th>Mn</th> <th>P</th> <th>S</th> <th>Si</th> <th>Ni</th> <th>Cr</th> </tr> </thead> <tbody> <tr> <td>.11</td> <td>.47</td> <td>.010</td> <td>.002</td> <td>.27</td> <td>3.33</td> <td>1.47</td> </tr> </tbody> </table>	C	Mn	P	S	Si	Ni	Cr	.11	.47	.010	.002	.27	3.33	1.47
C	Mn	P	S	Si	Ni	Cr									
.11	.47	.010	.002	.27	3.33	1.47									
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– 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/mm<sup>2</sup>) 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.</li> </ul>														
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– Heavy-duty gears, pinions, spline shafts, piston pins, transmission components, rock drilling bit bodies, plastic molds, etc.</li> </ul>														
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>– Forging               <ul style="list-style-type: none"> <li>– Commence 1215°C max.</li> <li>– Finish 925°C Bury in Mica.</li> </ul> </li> <li>– Annealing               <ul style="list-style-type: none"> <li>– 840°C Furnace cool</li> </ul> </li> <li>– Normalizing               <ul style="list-style-type: none"> <li>– 900°C Air cool</li> </ul> </li> <li>– Hardened &amp; 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.</li> <li>– 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.</li> </ul>														
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>– Typical as supplied, Annealed.</li> <li>– Tensile Strength – 102,000 psi               <ul style="list-style-type: none"> <li>– <math>\sigma_2</math>Tensile Strength – 704 N/mm</li> </ul> </li> <li>– Yield Strength – 80,000 psi               <ul style="list-style-type: none"> <li>– <math>\sigma_2</math>Yield Strength – 552 N/mm</li> </ul> </li> <li>– Elongation – 24%</li> <li>– Reduction of Area – 65%</li> <li>– Hardness – HB 212</li> <li>– Machinability – 40</li> </ul>														

Alloy AISI/SAE 3312	Mechanical Properties - UNCARBURIZED (Hardened & Tempered)	
	1" Dia	4" Dia
Tensile Strength, psi	136,000	131,500
Tensile Strength, N/mm <sup>2</sup>	938	907
Yield Strength, psi	117,500	108,000
Yield Strength, N/mm <sup>2</sup>	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)	
	1" Dia	4" Dia
Tensile Strength, psi	173,000	152,000
Tensile Strength, N/mm <sup>2</sup>	1,193	1,048
Yield Strength, psi	132,000	109,000
Yield Strength, N/mm <sup>2</sup>	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

<b>Alloy AISI/SAE 4130</b> <b>(UNS G 41300)</b>		<i>- a "30" Carbon Chromium-Molybdenum Alloy Steel</i>					
<b>Typical Analysis</b>	C	Mn	P	S	Si	Cr	Mo
	.30	.50	.015	.010	.25	.90	.20
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- We stock this quality of E-4130 to meet the regulations of API Spec.6A.</li> <li>- Bars are heat treated to Designation 75K and are Charpy V-notch impact- tested to Classification K.</li> <li>- Stocks also conform to NACE Standard MRO1- 75 with a maximum hardness of HRC22/HB235. E-4130 is readily machineable and weldable.</li> </ul>						
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Flanges, wellhead components, tool joints, etc.</li> </ul>						
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>- Forging                             <ul style="list-style-type: none"> <li>- Commence 1200°C max.</li> <li>- Finish 950°C</li> </ul> </li> <li>- Annealing                             <ul style="list-style-type: none"> <li>- 830°C/ 855°C Cool slowly in furnace</li> </ul> </li> <li>- Normalizing                             <ul style="list-style-type: none"> <li>- 870°C/ 930°C Cool in air</li> </ul> </li> <li>- Hardened &amp; Tempered: 840°C/ 870°C Water quench, 855°C/ 885°C Oil quench; 430°C/ 700°C According to properties required.</li> </ul>						
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- Annealed Typical</li> <li>- Tensile Strength – 80,000 psi</li> <li>- Yield Strength – 80,000 psi</li> <li>- Elongation – 28%</li> <li>- Reduction of Area – 57%</li> <li>- Hardness – 22 Rc Max, surface</li> </ul>						

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/mm <sup>2</sup>	727	737	717	710
Yield Strength, psi	78,480	80,000	77,400	78,000
Yield Strength, N/mm <sup>2</sup>	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	Mn	P	S	SI	Cr	Mo
	.40	.85	.020	.025	.25	.90	.20
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– 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</li> </ul>						
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– Recommended for use in high stress, abrasion/wear resistant applications such as gears, oil tools and machine tool components</li> </ul>						
<b>Condition</b>	<ul style="list-style-type: none"> <li>– As rolled surface finish, annealed alloy steel plate</li> </ul>						
<b>Plate Dimensions</b>	<ul style="list-style-type: none"> <li>– Available in gauge/width combinations from 1/4" x 96" to 4 1/4" x 72"</li> </ul>						



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')						
<b>Typical Analysis</b>	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
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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</li> </ul>							
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- All forms of close tolerance shafting: camshafts, drive shafts, mill shafts, motor shafts, pump shafts, bolts, pins, studs, etc</li> </ul>							
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- For 2 1/16" or 74.9 mm diameter bar and smaller,</li> <li>- ASTM A193, Grade B7 applies.</li> <li>- For 3" or 76.2 mm diameter and greater, ASTM A434,</li> <li>- Class BD or BC applies.</li> </ul>							

Alloy Cold Finished AISI 4140 PRECISION GROUND SHAFTING (UNS G 41400)	Size Tolerances - all tolerances are MINUS
1 1/2" 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 - Chromium-Molybdenum Alloy Machinery Steel (UNS G 41400/G 41442)								
<b>Typical Analysis</b>		C	Mn	P	S	Si	Cr	Mo
	<b>4140</b>	.40	.85	.020	.025	.25	.90	.20
		C	Mn	P	S	Si	Cr	Mo
	<b>4142</b>	.42	.83	.006	.005	.28	1.02	.22
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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<sup>2</sup>) for small sections and 140,000 psi (965 N/mm<sup>2</sup>) 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.</li> <li>- 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).</li> </ul>							
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>							
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>- Forging                             <ul style="list-style-type: none"> <li>- Commence 1200°C max.</li> <li>- Finish 950°C</li> </ul> </li> <li>- Annealing                             <ul style="list-style-type: none"> <li>- 815°C/ 850°C Cool slowly in furnace</li> </ul> </li> <li>- Normalizing                             <ul style="list-style-type: none"> <li>- 870°C/ 900°C Cool in air</li> </ul> </li> <li>- Hardened &amp; Tempered: 820°C/ 870°C Oil quench; Tempering- Not usually below 430°C and up to 700°C according to the properties required.</li> </ul>							

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

- 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- Minimum 15 FT LB
  - Reduction Ratio – Minimum 4:1

**Mechanical Properties**

**Alloy AISI/SAE 4140/ 4142**  
**(UNS G 41400-G 41442)**

- 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 ASTM A434 CLBC/ 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	<ul style="list-style-type: none"> <li>- 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<sup>2</sup>) for small sections and 140,000 psi (965 N/mm<sup>2</sup>) 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.</li> <li>- 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).</li> </ul>							
Typical Applications	<ul style="list-style-type: none"> <li>- 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.</li> </ul>							
Typical Heat Treatment	<ul style="list-style-type: none"> <li>- Forging                             <ul style="list-style-type: none"> <li>- Commence 1200°C max.</li> <li>- Finish 950°C</li> </ul> </li> <li>- Annealing                             <ul style="list-style-type: none"> <li>- 815°C/ 850°C Cool slowly in furnace</li> </ul> </li> <li>- Normalizing                             <ul style="list-style-type: none"> <li>- 870°C/ 900°C Cool in air</li> </ul> </li> <li>- Hardened &amp; Tempered: 820°C/ 870°C Oil quench; Tempering Not usually below 430°C and up to 700°C according to the properties required.</li> </ul>							

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 ASTM A434 CLBD/ 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/mm <sup>2</sup>	1080	1032	969	1018
Yield Strength, psi	123,999	114,857	110,286	113,792
Yield Strength, N/mm <sup>2</sup>	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

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

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

## Alloy

### 4145 Drill Collar Bars

Alloy AISI 4145 H MODIFIED HTSR		- Solid Drill Collars to API Spec 7					
<b>Typical Analysis</b> 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	
<b>Characteristics</b>	<p>– 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.</p>						

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	
	Through 6 7/8" Dia	Over 6 7/8" Dia
Size - inches		
Tensile Strength, psi	140,00	135,000
Tensile Strength, N/mm <sup>2</sup>	965	930
Yield Strength, psi	110,000	100,000
Yield Strength, N/mm <sup>2</sup>	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

<b>Alloy AISI 4150</b> <b>CALCIUM TREATED</b> <b>HTSR</b>		<i>- a '50' Carbon Chromium-Molybdenum Alloy Steel with Improved Machinability</i>					
Typical Analysis	C	Mn	P	S	Si	Ni	Cr
	.50	.85	.020	.06/.1	.30	.95	.20
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- 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</li> </ul>						
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Shafts, gears, pinions, spindles, axles, bolting, etc</li> </ul>						
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>- Hardening - 860°C/1580°F. Water Quench</li> <li>- Tempering - 550°C/1022°F. Air Cool</li> <li>- Stress Relieving - 450°C/842°F</li> </ul>						
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- HTSR - Typical</li> <li>- Tensile Strength – 50,000 psi</li> <li>- Yield Strength – 23,000 psi</li> <li>- Elongation – 20%</li> <li>- Reduction of Area – 52%</li> <li>- Hardness – HB302/Rockwell 'C' 32</li> </ul>						

Alloy  
4330+V

<b>Alloy Grade 4330+V</b>		<i>- a Nickel-Chromium-Molybdenum-Vanadium Alloy Steel</i>								
<b>Typical Analysis</b>		C	Mn	P	S	Si	Ni	Cr	Mo	V
		.30	.85	.010	.005	.25	1.95	.90	.45	.08
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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 best selected for highly stressed and demanding fatigue applications. Grade 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.</li> </ul>									
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Highly stressed parts requiring enhanced toughness and fatigue properties</li> </ul>									
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- Grade 4330+V is available in two strength combinations:</li> <li>- Yield Strength, Minimum – 150/160 ( 10" Diameter Maximum)</li> <li>- Tensile Strength, Minimum –150,000 psi</li> <li>- % Elongation, Minimum – 160,000 psi</li> <li>- % Reduction of Area, Minimum – 14</li> <li>- C-V-N, Room Temperature – 50</li> <li>- Longitudinal ft-lbs, minimum – 45</li> </ul>									

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
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- 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.</li> <li>- 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.</li> </ul>							
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- High strength machine parts, heavy-duty shafting, high tensile bolts and studs, gears, axle shafts, crankshafts, boring bars and down-hole drilling components</li> </ul>							
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>- Forging                             <ul style="list-style-type: none"> <li>- Commence 1200°C max.</li> <li>- Finish 950°C</li> </ul> </li> <li>- Normalizing                             <ul style="list-style-type: none"> <li>- 870°C/ 900°C</li> </ul> </li> <li>- Hardened &amp; 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.</li> </ul>							
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- Annealed Typical</li> <li>- Tensile Strength – 80,000 psi</li> <li>- Yield Strength – 80,000 psi</li> <li>- Elongation – 28%</li> <li>- Reduction of Area – 57%</li> <li>- Hardness – 22 Rc Max, surface</li> </ul>							

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

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

<b>Alloy AISI/SAE 8620</b>		<i>- a Nickel-Chromium-Molybdenum Case Hardening Alloy Steel</i>							
<b>Typical Analysis</b>		C	Mn	P	S	Si	Ni	Cr	Mo
		.20	.80	.020	.0025	.25	.55	.50	.20
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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/mm<sup>2</sup>). 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.</li> </ul>								
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Heavy-duty gears, pinions, spline shafts, piston pins, transmission components, rock drilling bit bodies, plastic molds, etc.</li> </ul>								
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>- Forging               <ul style="list-style-type: none"> <li>- Commence 1200°C max.</li> <li>- Finish 950°C</li> </ul> </li> <li>- Annealing               <ul style="list-style-type: none"> <li>- 840°C Furnace cool</li> </ul> </li> <li>- Normalizing               <ul style="list-style-type: none"> <li>- 900°C Air cool</li> </ul> </li> <li>- Hardened &amp; Tempered (Uncarburized) - Heat to 816°/ 840°C, , oil or water quench, temper at 200°/650°C according to properties required</li> <li>- Carburizing - Direct oil quench - Carburize at 900°/925°C for eight hours (for .060 case depth). Oil quench. Temper at 150°/232°C               <ul style="list-style-type: none"> <li>- 150°C - Case hardness approx. RC 63</li> <li>- 232°C - Case hardness approx. RC 58.</li> </ul> </li> </ul>								
<b>Availability</b>	<ul style="list-style-type: none"> <li>- Grade 8620 is typically available Hot Rolled, As Rolled.</li> <li>- Larger diameters are Hot Forged, As Forged.</li> </ul>								

Alloy  
EN30B

Alloy EN30B - BS 970 GRADE 835M30 BAR		<i>- a 4 1/4% Nickel-Chromium-Molybdenum Alloy Steel</i>						
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
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- This product is stocked in two heat treat conditions:               <ul style="list-style-type: none"> <li>- Quench and tempered</li> <li>- Annealed</li> </ul> </li> <li>- EN30B may be carburized if extra wear resistance is required.</li> <li>- This steel may be calcium treated.</li> <li>- * EN30B is produced to AQ, AMS 2301 cleanliness level.</li> </ul>							
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Down-hole tools, heavy duty construction tools, rock drilling bit bodies, highly stressed gears and transmission components, heavy duty shafts and rolls.</li> </ul>							
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>- Forging – Commence 1200°C (2190°F) Max.</li> <li>- Double Annealing – Austenitize 850° to 865°C (1560°F to 1590°F)               <ul style="list-style-type: none"> <li>- For best, air Cool to approximately 40°C (100°F)</li> </ul> </li> <li>- Machinability: Double Anneal at 635°C to 650°C (1175°F to 1200°F)               <ul style="list-style-type: none"> <li>- Do not exceed 660°C (1220°F)</li> <li>- A Hardness of 269 HB Max is achievable.</li> </ul> </li> <li>- Normalize, Temper &amp; Stress Relieve - Austenitize 850°C to 865°C (1560°F to 1590°F).               <ul style="list-style-type: none"> <li>- Air cool to room temperature</li> <li>- Temper 530°C (990°F), air cool</li> <li>- Stress Relieve 500°C (930°F), air cool</li> </ul> </li> <li>- Hardened &amp; 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.</li> </ul>							
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- Measured at 1" below the surface</li> </ul>							



Alloy EN30B - BS 970		Mechanical Properties	
GRADE 835M30 BAR		- 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 Mn P S Si Cr
	.98/1.10 .25/.45 .025 Max .025 Max .15/.30 1.3/1.6
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- This high carbon, chromium alloy is stocked in the annealed condition.</li> <li>- This grade is manufactured by the electric furnace process. Typically the quenched hardness is 62 to 66 HRC depending mainly upon section thickness</li> </ul>
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- 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</li> </ul>
<b>Typical Mechanical Properties (Annealed)</b>	<ul style="list-style-type: none"> <li>- Yield – 85,000 psi</li> <li>- Tensile – 105,000 psi</li> <li>- Elongation – 17%</li> <li>- Reduction Area – 50%</li> <li>- BHN at surface– 228</li> </ul>

# Aluminum Extrusions

## Aluminum Squares and Rounds Only 6061

Aluminum 6061 - ASTM B221, AMS 4150		<i>- Alloy &amp; Temper 6061-T-6 Solution heat-treated and artificially aged.</i>							
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
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>								
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- General engineering and structural components. Trucks and trailers. Boats.</li> <li>- Furniture. Pipe fittings. Miscellaneous parts requiring good corrosion resistance.</li> </ul>								
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- Minimum Properties:                             <ul style="list-style-type: none"> <li>- UTS Yield – 38 ksi, 35 ksi</li> <li>- Elongation in 2" – 8%-10%</li> </ul> </li> <li>- Typical Properties:                             <ul style="list-style-type: none"> <li>- UTS Yield – 45 ksi, 41 ksi</li> <li>- Elongation in 2" – 12%-17%</li> <li>- Shear Strength – 30 ksi</li> </ul> </li> </ul>								

## 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	Sn	Pb	Zn
	83%	6.9%	7.0%	2.5%
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– Produced conforming to ASTM B505, SAE660 Bearing Bronze (Bars and Tubes). Produced oversized. to finish, machine to the nominal size ordered.</li> <li>– Density: 0.322 lb/in<sup>3</sup> at 68°F; 8.91 g/cm<sup>3</sup> at 20°C</li> </ul>			
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– <u>Industrial Machinery &amp; Equipment Market:</u> In-plant Equipment, Industrial Valves &amp; Fittings, Turbines, Off-highway Vehicles</li> <li>– <u>Products:</u> 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</li> <li>– <u>Transportation Equipment Market:</u> Automotive Non-electrical, Railroad, Marine, Aircraft</li> <li>– <u>Products:</u> Motors, General Hardware, Carburetor Assemblies, Fittings</li> <li>– <u>Military Market:</u> All Specified Military Applications</li> <li>– <u>Water Handling Equipment:</u> Alloys used in Marine service and products such as seawater piping, pumps, valves, etc</li> <li>– <u>Special Market (Fastest Growing Market) Products:</u> Food Processing Equipment, Hydraulic Seals, Plumbing Valves, Wear Plates and Guides.</li> </ul>			
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>– Yield – 18,000 psi</li> <li>– Tensile Strength – 35,000 psi</li> <li>– Elongation – 20%</li> <li>– Hardness – 60-70 HBN</li> </ul>			

## Bronze

### Aluminum Bronze Alloy 954

ALUMINUM BEARING BRONZE, ALLOY 954 (UNS C95400)			
Typical Analysis	Cu      Fe      Al		
	85%      4.0%      11.0%		
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– Produced conforming to ASTM B505, Alloy 954 Aluminum Bronze is produced oversized to finish, machine to the nominal size ordered.</li> <li>– Density: 0.340 lb/in<sup>3</sup> at 68°F; 9.41 g/cm<sup>3</sup> at 20°C</li> </ul>		
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– adjusting nuts</li> <li>– agitators</li> <li>– ball socket seats collets</li> <li>– blanks and rolls</li> <li>– boring tools</li> <li>– cam followers and slides</li> <li>– chuck Jaws</li> <li>– chutes</li> <li>– collets</li> <li>– cylinder mold tie rods</li> <li>– die rings</li> <li>– draw dies</li> <li>– fasteners</li> <li>– fingers</li> <li>– fittings</li> <li>– farming rolls and sections</li> </ul>	<ul style="list-style-type: none"> <li>– gibs and ways</li> <li>– guide pins</li> <li>– hold down bars</li> <li>– hydraulic valve parts</li> <li>– inserts</li> <li>– keys</li> <li>– lathe beds</li> <li>– liners</li> <li>– machine tool parts</li> <li>– mandrels</li> <li>– pickling hooks</li> <li>– pilots</li> <li>– piston guides</li> <li>– plastic mold applications</li> <li>– plungers</li> <li>– pump rods</li> </ul>	<ul style="list-style-type: none"> <li>– runout table slides</li> <li>– scraper blades</li> <li>– screw down nuts</li> <li>– shoes</li> <li>– slides</li> <li>– steel mill slippers</li> <li>– strike plates</li> <li>– support rails</li> <li>– brine slurry equipment tie rods</li> <li>– unscrewing mold components</li> <li>– wear plates and strips</li> <li>– welding jaws</li> <li>– wipers</li> <li>– wiping blocks</li> <li>– work rest blades</li> </ul>
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>– Yield – 35,000 psi</li> <li>– Tensile Strength – 85,000 psi</li> <li>– Elongation – 18%</li> <li>– Hardness – 140-170 HBN</li> </ul>		

# Carbon Steels

Carbon

1018

Carbon AISI/SAE 1018 (UNS S10180) - a Special Quality Low-Carbon Machinery Steel					
<b>Typical Analysis</b>	C	Mn	P	S	Si
	.18	.57	.020	.030	.22
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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</li> </ul>				
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Bearing in mind the tensile strength of approximately 60,000 psi (414 N/mm<sup>2</sup>), the steel is suitable for a wide variety of general engineering parts, shafts, studs, bolts, tie-rods etc</li> </ul>				
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- Typical as supplied</li> <li>- Tensile Strength – 58,000 psi                             <ul style="list-style-type: none"> <li>- 2Tensile Strength – 400 N/mm<sup>2</sup></li> </ul> </li> <li>- Yield Strength – 32,000 psi                             <ul style="list-style-type: none"> <li>- 2Yield Strength – 220 N/mm<sup>2</sup></li> </ul> </li> <li>- Elongation – 25%</li> <li>- Reduction of Area – 50%</li> <li>- Hardness – HB 116</li> </ul>				
<b>Comment</b>	<ul style="list-style-type: none"> <li>- This product may also conform to the requirements of ASTM A36 complete with the mechanical property requirements detailed below</li> <li>- Tensile Strength – 58,000 – 80,000 psi</li> <li>- Yield Strength – 36,000 psi minimum, 250 Mpa minimum</li> <li>- Elongation minimum – 20%</li> </ul>				

Carbon  
1018 Cold Finished

Carbon AISI/SAE 1018 COLD FINISHED (UNS G10180)		- Cold Drawn '20' Carbon Steel, available in all bar sections			
<b>Typical Analysis</b>	1018	C	Mn	P	S
		.18	.70	.022	.024
	1020	C	Mn	P	S
		.20	.50	.017	.025
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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</li> </ul>				
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- All forms of shafting and machinery parts. When carburized -gears, pinions, king pins</li> </ul>				

Carbon AISI/SAE 1018 COLD FINISHED (UNS G10180)	Size Tolerances –Rounds Tolerances - all tolerances are MINUS
1 1/2" 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)



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

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

Carbon  
1040-1045

<b>Carbon AISI/SAE 1040-1045 (UNS G10400-G10450)</b> <span style="float: right;"><i>- a Special Bar Quality Medium-Carbon Machinery Steel</i></span>											
<b>Typical Analysis</b>	<table border="1" style="margin: auto;"> <thead> <tr> <th>C</th> <th>Mn</th> <th>P</th> <th>S</th> <th>Si</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">.40</td> <td style="text-align: center;">.75</td> <td style="text-align: center;">.020</td> <td style="text-align: center;">.030</td> <td style="text-align: center;">.25</td> </tr> </tbody> </table>	C	Mn	P	S	Si	.40	.75	.020	.030	.25
C	Mn	P	S	Si							
.40	.75	.020	.030	.25							
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- General purpose, fine grain, machinery steel suitable for a wide range of applications in the condition as supplied - approximately 90,000 psi (620 N/mm<sup>2</sup>) 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</li> </ul>										
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Shafts, axles, spindles, bolts, lightly stressed gears, machined parts of all types.</li> </ul>										
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>- Forging – Commence 1150°C Max finish 925°C.</li> <li>- Annealing – 800° to 830°C Surface cool               <ul style="list-style-type: none"> <li>- 870/ 915°C air Cool</li> </ul> </li> <li>- Normaling – 830°C to 850°C water quench</li> <li>- Hardening – 850°C to 870°C oil quench.</li> <li>- Tempering – 425°C to 870°C according to properties</li> </ul>										
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- Typical – as supplied</li> <li>- Tensile Strength – 90,000 psi (620 N/mm<sup>2</sup>)</li> <li>- Yield Strength – 23,000 psi (410 N/mm<sup>2</sup>)</li> <li>- Elongation – 25%</li> <li>- Reduction of Area – 50%</li> <li>- Hardness – HB 201</li> <li>- Machinability – 65</li> </ul>										

Carbon Cold Finished  
1045 TG&P

Carbon AISI 1045 PRECISION GROUND SHAFTING (UNS G 10450)		<i>- Ground and polished shafting supplied in fibre tubes</i>				
<b>Typical Analysis</b>	C	Mn	P	S	Si	
	.47	.75	.030	.035	.25	
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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/mm<sup>2</sup>). A first class product at an economical price. Cold finished product is manufactured in conformance to ASTM A108.</li> </ul>					
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- All forms of close tolerance shafting: camshafts, drive shafts, mill shafts, motor shafts, pump shafts, bolts, pins, studs etc.</li> </ul>					

Carbon AISI 1045 PRECISION GROUND SHAFTING (UNS G 10450)	Size Tolerances <i>- all tolerances are MINUS</i>
1 1/2" dia. (38.1 mm) and under	Minus 0.001" (.025 mm)
Over 1 1/2" dia. to 2 1/2" 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)

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

Carbon Cold Finished  
1045 Chrome Plated Shafting

Carbon AISI/SAE 1045 CHROME PLATED SHAFTING		<i>- This product is available in both imperial and metric sizes</i>				
<b>Typical Analysis</b>		C	Mn	P	S	Si
		.45	.75	.030	.040	.20
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>					
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Hydraulic shafting, pneumatic piston rods, pump shafting, etc</li> </ul>					
<b>Chrome Plating</b>	<ul style="list-style-type: none"> <li>- Finished thickness of – .0005" min per side (Winnipeg Branch: 0.001"min per side)</li> <li>- Hardness of chrome – Rockwell C 65/70</li> <li>- Surface finish – RMS 12 max</li> </ul>					

Carbon AISI/SAE 1045 CHROME PLATED SHAFTING	Size Tolerances
	<ul style="list-style-type: none"> <li>- Despite the chrome plating, the same fine minus tolerances of AISI 1045 Precision Ground Shafting apply</li> <li>- all tolerances are MINUS</li> </ul>
1 1/2" dia. (38.1 mm) and under	Minus 0.001" (.025 mm)
Over 1 1/2" dia. to 2 1/2" 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

<b>Carbon AISI/SAE 1045 INDUCTION HARDENED AND CHROME PLATED SHAFTING</b>		<i>- Induction Hardened and Chrome Plated Precision Ground Shafting, supplied in fibre tubes - This product is available in both imperial and metric sizes</i>				
<b>Typical Analysis</b>		C	Mn	P	S	Si
		.45	.75	.030	.040	.20
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- 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</li> </ul>					
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Hydraulic shafting, oil and water pump shafting, rotary pump shafts, and piston rods</li> </ul>					
<b>Chrome Plating</b>	<ul style="list-style-type: none"> <li>- Finished thickness of – .0005" min per side (Winnipeg Branch: 0.001"min per side)</li> <li>- Hardness of chrome – Rockwell C 65/70</li> <li>- Surface finish – RMS 12 max</li> </ul>					
<b>Induction Hardening</b>	<ul style="list-style-type: none"> <li>- Case Depth – .050" min</li> <li>- Case Hardness – Rockwell C50 min</li> </ul>					
<b>Tolerances</b>	<ul style="list-style-type: none"> <li>- Allowance is made for the chrome plating and standard minus tolerances</li> <li>- apply as ASTM A29, Table A1.12</li> <li>- See AISI 1045 Chrome Plated Shafting</li> </ul>					
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- Typical 75,000 psi minimum yield strength</li> </ul>					

Carbon Cold Finished  
1144

<b>Carbon AISI/SAE 1144 COLD DRAWN (UNS G 11440)</b>		<i>- A High-Strength Re-sulphurized Carbon/Manganese Steel (Available in round bar)</i>				
<b>Typical Analysis</b>		C	Mn	P	S	Si
		.44	1.50	.040	.28	.22
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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</li> </ul>					
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Arbors, keyed shafts, spindles, gears, pinions, pump shafts, machined parts in wide variety</li> </ul>					
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- Typical – as supplied, Not normally available over 4" dia. because of the cold working required</li> <li>- Tensile Strength – 125,000 psi (862 N/mm<sup>2</sup>)</li> <li>- Yield Strength – 100,000 psi (690 N/mm<sup>2</sup>)</li> <li>- Elongation – 12%</li> <li>- Reduction of Area – 20%</li> <li>- Hardness – HB 255</li> <li>- Machinability – 82</li> </ul>					
<b>Tolerances</b>	<ul style="list-style-type: none"> <li>- For cold finish tolerances See 1045 TG&amp;P</li> </ul>					

## Carbon

A105, A350 - LF2 DUAL

Carbon ASTM A105 & ASTM A350-LF2 DUAL CERTIFIED		<i>- a Special Quality Fine Grain Carbon-Manganese Steel for Piping Components</i>				
<b>Typical Analysis</b>	<b>A105 Spec.</b>	C	Mn	P	S	Si
		.35 max	.60/1.05	.040 max	.05 max0	.35 max
	<b>A350-LF2 Spec.</b>	C	Mn	P	S	Si
		.30 max	1.35 max	.035 max	.04 max0	.15/.30
	<b>A105/A350-LF2</b>	C	Mn	P	S	Si
		.20	1.24	.009	.021	.18
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- 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</li> </ul>					
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>					
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>- Forging – Commence 1150°C Max finish 925°C.</li> <li>- Annealing – 800° to 830°C Surface cool               <ul style="list-style-type: none"> <li>- 870/ 915°C air Cool</li> </ul> </li> <li>- Normaling – 830°C to 850°C water quench</li> <li>- Hardening – 850°C to 870°C oil quench.</li> <li>- Tempering – 425°C to 870°C according to properties</li> </ul>					



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/mm <sup>2</sup>	485	485-655	485-655	
Yield Strength, min psi	36,000	36,000	36,000	
Yield Strength Min, N/mm <sup>2</sup>	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

<b>Carbon AISI/SAE C12L14 COLD FINISHED (UNS G 12144)</b>	<i>- Low-Carbon Re-sulphurized and Leaded Free machining Steel (Screw Stock), available in rounds, hexagons and some squares</i>				
<b>Typical Analysis</b>	C	Mn	P	S	Pb
	.09	.95	.07	.30	.25
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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</li> </ul>				
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Fasteners, bushings, inserts, couplings</li> </ul>				

<b>Carbon AISI/SAE C12L14 COLD FINISHED (UNS G 12144)</b>	<b>Mechanical Properties</b>
	<ul style="list-style-type: none"> <li>- Expected minimum properties - Cold Drawn</li> <li>- No minimum values are specified.</li> </ul>
<b>Size</b>	1" dia. (25.4 mm) Cold Drawn
<b>Tensile Strength, psi</b>	87,500
<b>Tensile Strength, N/mm<sup>2</sup></b>	603
<b>Yield Strength, psi</b>	75,000
<b>Yield Strength, N/mm<sup>2</sup></b>	517
<b>Elongation (%)</b>	15
<b>Reduction of Area (%)</b>	42
<b>HB</b>	179
<b>Machinability</b>	195

# Cast Iron

## Continuously Cast Iron

### 65-45-12 Ductile Iron

Continuously Cast Iron 65-45-12 Ductile Iron						
Typical Analysis	C	Mn	P	S	Si	
	3.6-3.9	0.1-0.4	.10 max	.015 max	2.3-2.8	Percent
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– 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. .</li> </ul>					
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– 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..</li> </ul>					
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>– Because of its ferritic structure, this material is not intended for hardening</li> </ul>					
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>– 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.</li> <li>– Tensile tests are taken from the actual as-cast bar.</li> <li>– Tensile Strength (min)* - 65,000 psi</li> <li>– Yield Strength (min)* - 45,000psi</li> <li>– Elongation (min)* - 12%</li> <li>– * Determined as prescribed by ASTM standards.</li> </ul>					

<b>Continuously Cast Iron 65-45-12 Ductile Iron</b>		<b>Hardness</b> - Hardness properties listed are minimum, maximum across the bar. Hardness for shapes other than rounds will be supplied on request
<b>Bar Dia - inches</b>	<b>Bar Dia - centimeters</b>	<b>BHN min to max</b>
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	
<b>Characteristics</b>	– 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.
<b>Typical Applications</b>	– Hydraulic-pump rotors, gear blanks, rams, machine-tool gibs, foundry patterns plates, ways, collets, etc.
<b>Typical Heat Treatment</b>	– 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.
<b>Mechanical Properties</b>	– 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 Pearlitic Ductile Iron

Continuously Cast Iron 80-55-06 Partially Pearlitic Ductile Iron													
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>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.</li> </ul>												
<b>Typical Applications</b>	<table border="1"> <tr> <td>Fluid Power:</td> <td>Cylinder Blocks, Gerotors, Manifolds, Pistons, Glands, Rotors, Valve Bodies.</td> </tr> <tr> <td>Machinery:</td> <td>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.</td> </tr> <tr> <td>Transportation:</td> <td>Pulleys, Gears, Rail Spacers.</td> </tr> <tr> <td>Pump and Compressor:</td> <td>Gears, Housings, Liners, Pistons, Rotary Screws.</td> </tr> <tr> <td>Steel Mill:</td> <td>Guide Rolls, Pinch Rolls, Runout Table Rolls.</td> </tr> <tr> <td>Miscellaneous:</td> <td>Disamatic Pouring Rails, Dies, Pattern Plates, Core Boxes, Grinding Rolls, Mill Liners.</td> </tr> </table>	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.
Fluid Power:	Cylinder Blocks, Gerotors, Manifolds, Pistons, Glands, Rotors, Valve Bodies.												
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Steel Mill:	Guide Rolls, Pinch Rolls, Runout Table Rolls.												
Miscellaneous:	Disamatic Pouring Rails, Dies, Pattern Plates, Core Boxes, Grinding Rolls, Mill Liners.												
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>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.</li> </ul>												
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>The tensile strength is determined from a longitudinal test specimen taken from mid-radius of the as-cast bar.</li> <li>Tensile strength (min) - 80,000psi</li> <li>Yield strength (min) - 55,000psi</li> <li>Elongation (min) – 6%</li> <li>In bars under 1.5" diameter elongation will be 4-6%.</li> </ul>												

## Continuously Cast Iron

### 100-70-02 Pearlitic Ductile Iron

<b>Continuously Cast Iron 100-70-02 Pearlitic Ductile Iron</b>													
<p><i>- Grade 100-70-02 is a non-inventoried item. A wide variety of sizes and shapes is available by special order</i></p>													
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>												
<b>Typical Applications</b>	<table border="1"> <tbody> <tr> <td>Fluid Power:</td> <td>Cylinder Blocks, Gerotors, Manifolds, Pistons, Glands, Rotors, Valve</td> </tr> <tr> <td>Machinery:</td> <td>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)</td> </tr> <tr> <td>Transportation:</td> <td>Pulleys, Gears, Rail Spacers, Hubs, Carriers, Camshafts</td> </tr> <tr> <td>Pump and Compressor:</td> <td>Gears, Housings, Liners, Pistons</td> </tr> <tr> <td>Steel Mill:</td> <td>Guide Rolls, Pinch Rolls, Runout Table Rolls.</td> </tr> <tr> <td>Miscellaneous:</td> <td>Disamatic Pouring Rails, Dies,</td> </tr> </tbody> </table>	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,
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Steel Mill:	Guide Rolls, Pinch Rolls, Runout Table Rolls.												
Miscellaneous:	Disamatic Pouring Rails, Dies,												
<b>Typical Heat Treatment</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>												
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- The tensile strength is determined from a longitudinal test specimen taken from mid-radius of the as-cast bar.</li> <li>- Tensile strength (min) - 100,000psi</li> <li>- Yield strength (min) - 70,000psi</li> <li>- Elongation (min) – 2%</li> </ul>												

**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.

<b>Bar Dia - inches</b>	<b>Bar Dia - millimeters</b>	<b>BHN min to max</b>
01.000 - 20.000	25 - 508	241 to 329



## Specialty

### Special Products

#### 4140 Mechanical Tubing

<b>Specialty - AISI 4140 MECHANICAL TUBING</b>		<i>- Heavy wall, seamless alloy tubing is available upon enquiry.</i>					
<b>Typical Analysis</b>	C	Mn	P	S	Si	Cr	Mo
	.38/.43	.75/.0	.35 Max	.04 Max	.15/.35	.8/.1	.15/.25
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- Two grades of seamless 4140 mechanical tubing are available, cold finished and hot rolled surface condition</li> <li>- This product is cold drawn or hot finished. Seamless alloy tubing with the mechanical properties created by a quench and temper.</li> </ul>						
<b>Typical Applications</b>	- Blast Joint						

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

Special Products

Stainless Steel Ornamental Tubing

<p><b>Specialty - Stainless Steel Ornamental Tubing</b></p>	<p>- Type 304 Stainless 180 grit finish                  - Also available in grades 301, 302, 304L, 316, 316L, 321, 409, 430, 434. Other grades available upon request.</p>						
<p><b>Typical Analysis</b></p>	<p>C</p>	<p>Mn</p>	<p>P</p>	<p>S</p>	<p>Si</p>	<p>Cr</p>	<p>Ni</p>
<p><b>Characteristics</b></p>	<p>- The advantages of this stainless steel tubular product include:</p> <ul style="list-style-type: none"> <li>- High strength to weight ratio</li> <li>- Cold working increases yield strength of the original metal</li> <li>- Ease of fabrication (bending, flattening, flanging, forming)</li> <li>- High corrosion resistance</li> <li>- Ease of maintenance</li> <li>- Available in a range of surface finishes</li> </ul>						
<p><b>Typical Applications</b></p>	<ul style="list-style-type: none"> <li>- Marine Equipment</li> <li>- Restaurant Equipment</li> <li>- Food Processing/Meat Packing</li> <li>- Medical</li> <li>- Automotive</li> <li>- Furniture</li> <li>- Construction supports, frames and buildings</li> <li>- Display cases</li> <li>- Racks and carts</li> </ul>						

## Special Products

### Staballoy AG17

<b>Specialty – Staballoy AG17</b>													
<i>- For Non-Magnetic Drilling Components</i>													
Nominal Analysis	<table border="1"> <thead> <tr> <th>C</th> <th>Mn</th> <th>Cr</th> <th>N<sub>2</sub></th> <th>Si</th> <th>Mo</th> </tr> </thead> <tbody> <tr> <td>.03</td> <td>20</td> <td>17</td> <td>.50</td> <td>.30</td> <td>.05</td> </tr> </tbody> </table>	C	Mn	Cr	N <sub>2</sub>	Si	Mo	.03	20	17	.50	.30	.05
C	Mn	Cr	N <sub>2</sub>	Si	Mo								
.03	20	17	.50	.30	.05								
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– 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.</li> <li>– 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.</li> <li>– Staballoy AG17TM is available with optional "XL" warranty against stress corrosion cracking.</li> </ul>												
<b>Physical Properties</b>	<ul style="list-style-type: none"> <li>– 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).</li> </ul>												
<b>Warranty</b>	<ul style="list-style-type: none"> <li>– Staballoy AG17TM XL treated drill collars are offered with a three year warranty against chloride induced stress corrosion cracking. Warranty conditions available on request.</li> </ul>												
<b>Galling</b>	<ul style="list-style-type: none"> <li>– Staballoy AG17TM has excellent galling resistance with critical galling pressure approximately 7 times that of the conventional austenitic 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 bearing austenitic stainless steel.</li> </ul>												
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>– 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..</li> </ul>												

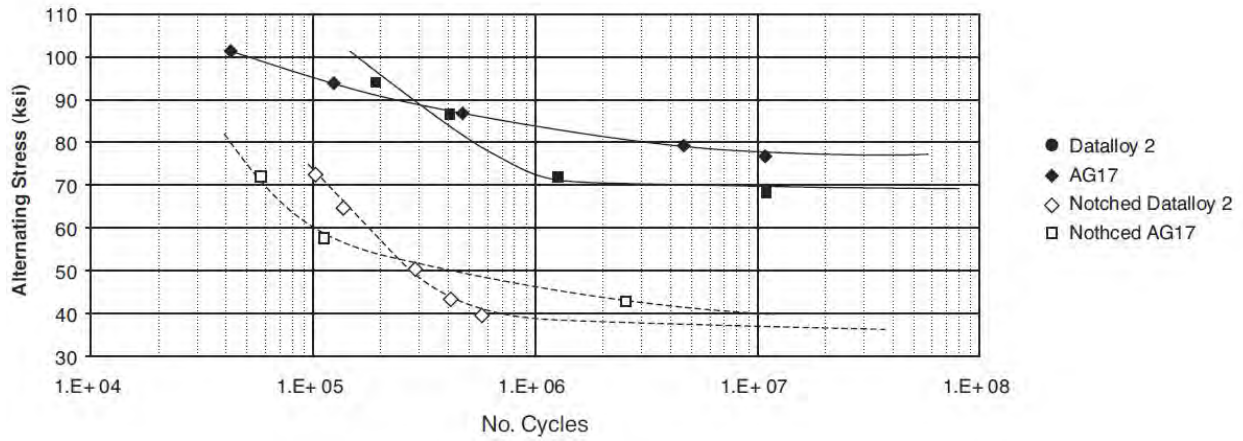
<b>Specialty – Staballoy AG17</b>		<b>Mechanical Properties</b>		
		- Test material taken from 1 inch below outer surface or mid-wall (whichever is the smaller value). Tensile test to BS EN 10002 Part 1 or ASTM A370. Impact Tests to BS EN 10045 Part 1 or ASTM E23.		
<b>Drill Collar Outside Diameter</b>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

<b>Specialty – Staballoy AG17</b>		<b>- For Non-Magnetic Drilling Components</b>		
<b>Stress Corrosion Cracking</b>	<ul style="list-style-type: none"> <li>- a) Intergranular Resistance to Intergranular Stress Corrosion Cracking is achieved by careful control of chemical composition. Freedom from susceptibility is demonstrated by testing to ASTM A262, Practice E.</li> <li>- b) Transgranular Staballoy AG17™ 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.</li> <li>- 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 further resist initiation of stress corrosion cracking</li> </ul>			
	<b>Corrodent</b>	<b>Stress MPa (ksi)</b>	<b>Test Duration (Hours)</b>	
	<b>60% CaCl<sub>2</sub> @ 130°C</b>	301 (43.8)	> 5000 (not cracked)	
	<b>Magnesium Chloride mud (20%) @ 115°C</b>	300 (43.5)	> 2000 (not cracked)	
	<b>Saturated NaCl @ 106°C</b>	400 (43.5)	> 2000 (not cracked)	
- (Samples of the constant strain tensile type)				

Special Products  
Datalloy 2

<b>Specialty –Datalloy 2</b>		<i>- an Enhanced Corrosion Resistance Non-Magnetic Steel</i>						
<b>Typical Analysis</b>		C	Mn	Cr	N	Si	Mo	Ni
		.03	15.1	15.3	0.4	.30	2.1	2.3
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- 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.</li> <li>- The increased nickel content of Datalloy 2TM does not adversely affect its resistance to Stress Corrosion Cracking or its galling performance.</li> <li>- Datalloy 2TM complies, as a minimum, to the mechanical property requirements of API 7.</li> <li>- The material is also available in a "High Strength" condition with a guaranteed minimum of 140 ksi 0.2% proof strength.</li> </ul>							
<b>Structure</b>	<ul style="list-style-type: none"> <li>- Datalloy 2TM is a highly stable, austenitic stainless steel with a maximum magnetic permeability of 1.005.</li> <li>- 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.</li> <li>- Forging parameters are carefully designed to produce optimum pitting corrosion resistance through microstructural control.</li> </ul>							
<b>Physical Properties</b>	Modulus of Elasticity		200 GPa					
	Poisson's Ratio		0.4					
	Coefficient of Thermal Expansion		16 x 10 <sup>-6</sup> m/m/°K					
	Resistivity		680 μΩmm					
	Thermal Conductivity		0.035 W/m°K					
	Density		7.65 g/cm <sup>3</sup>					
	Relative Magnetic Permeability		1.005 max					
<b>Fatigue Performance</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- 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.</li> </ul>							

### Fatigue Performance



Specialty –Datalloy 2	Fatigue Performance
<b>Material</b>	<b>0.2% Proof Strength</b>
Datalloy 2TM	105 ksi
Staballoy AG17TM	116 ksi

Specialty –Datalloy 2	Mechanical Properties	
	Standard Strength.	
Size	< 7 inches (Min-Typical)	> 7 inches (Min-Typical)
<b>0.2% Proof Stress (ksi)</b>	110-125	100-115
<b>UTS Stress (ksi)</b>	120-148	110-135
<b>Elongation %</b>	18-33	20-35
<b>Reduction of Area (%)</b>	45-70	50-72
<b>Longl. CVN at RT (J)</b>	60-170	60-190
<b>Hardness (HBN)</b>	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											
<b>Pitting Corrosion</b>	<p>– 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.</p>												
	<table border="1"> <caption>PREN Values for Various Materials</caption> <thead> <tr> <th>Material</th> <th>Approximate PREN Value</th> </tr> </thead> <tbody> <tr> <td>11% Cr Mo</td> <td>15</td> </tr> <tr> <td>304 (L)</td> <td>19</td> </tr> <tr> <td>Cr-Mn Steels</td> <td>21</td> </tr> <tr> <td>Datalloy 2</td> <td>28</td> </tr> </tbody> </table>			Material	Approximate PREN Value	11% Cr Mo	15	304 (L)	19	Cr-Mn Steels	21	Datalloy 2	28
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Specialty –Datalloy 2

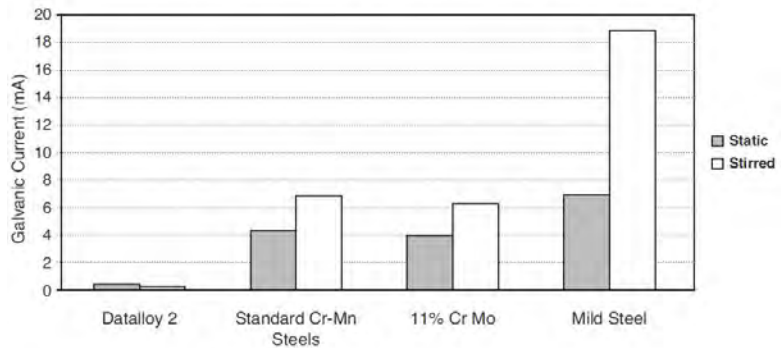
Mechanical Properties

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.

Galvanic Corrosion Against a Copper Electrode

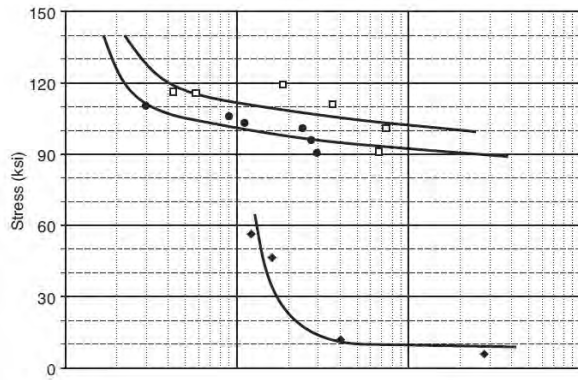


**Stress Corrosion Cracking**

- Stress corrosion cracking (SCC) is caused by the combined action of stress and a corrosive medium. The stress can be externally applied or can arise 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 modern NMDC manufacture by strict analytical control during steel Material from all Allvac Ltd (Jessop Saville Oilfield Products) collars is tested to ASTM A262 practice E to ensure freedom from sensitisation.
- **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 further resist initiation of stress corrosion cracking

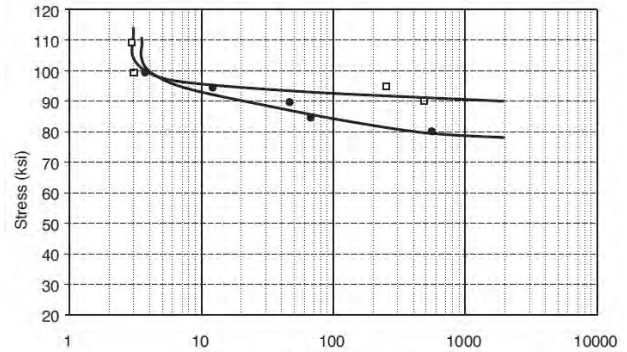


**SCC Performance**  
in Saturated NaCl @ 106 °C



● Datalloy 2  
◆ 304  
□ Staballoy Ag17

**SCC Performance**  
in 32% MgCl @ 120 °C



● Datalloy 2  
□ Staballoy Ag17

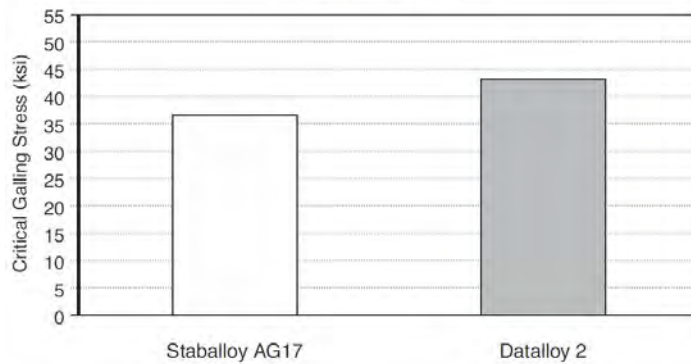
**Specialty –Datalloy 2**

**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 2™ is superior to that of other Cr-Mn steels.

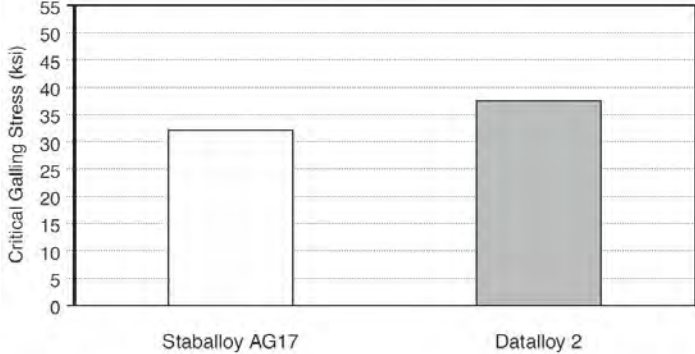
**Self-Mated Stress**

ASTM G98 - Button on Block

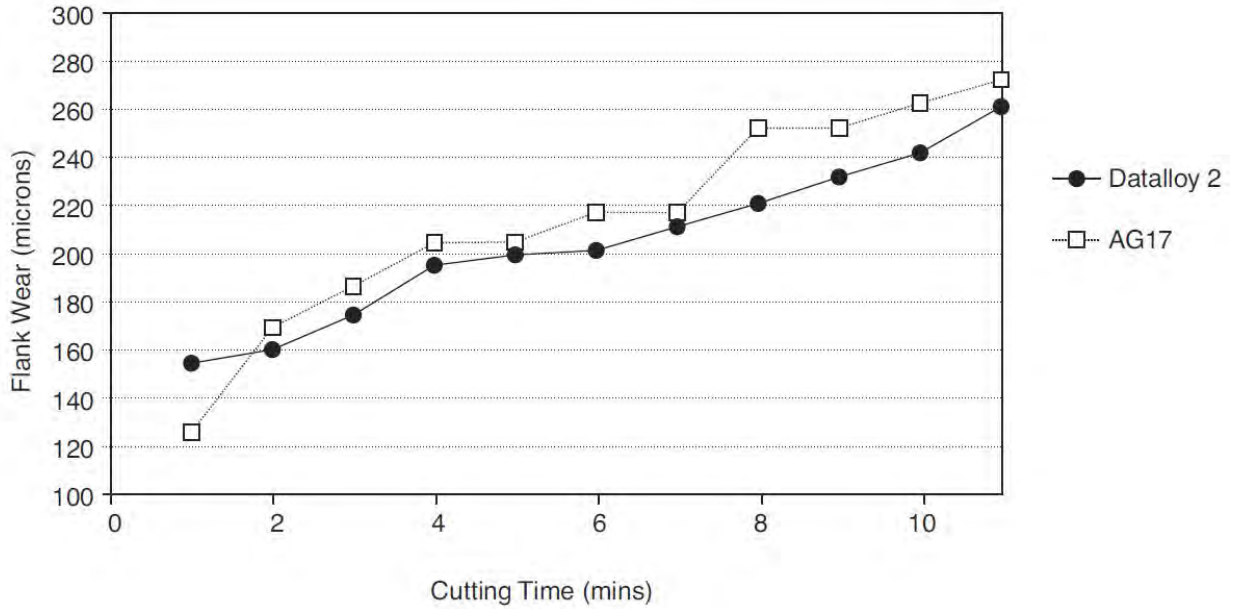


– Standard A.S.T.M. G98 test conditions, contact area = 123mm<sup>2</sup>, no lubricant 4-1/2" IF connections. Torque applied without lubrication.

Specialty –Datalloy 2

<p><b>Galling Resistance</b></p>	<p style="text-align: center;"><b>Self-Mated Stress</b> Full Scale Connection Testing</p>  <p>– 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.</p>
<p><b>Quality Assurance</b></p>	<ul style="list-style-type: none"> <li>– All collars meet API 7 specified properties and conditions as a minimum standard</li> <li>– Each collar is mechanically tested</li> <li>– Each collar is tested for magnetic 'hotspots' using a Foerster EC Probe. Maximum deflection guaranteed less than <math>\pm 0.5\mu T/100mm</math>.</li> <li>– Each collar is ultrasonically examined along its entire length</li> <li>– Certification includes all relevant physical, chemical, mechanical, magnetic and ultrasonic results</li> </ul>
<p><b>Supply Forms</b></p>	<ul style="list-style-type: none"> <li>– 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.</li> <li>– Material can be supplied solid, bored, semi-finished or fully machined to drawing.</li> <li>– Datalloy 2™ is usually supplied in the strain hardened condition.</li> <li>– Arrangements can be made to supply an annealed product, but at reduced strength levels.</li> <li>– 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.</li> </ul>
<p><b>Machinability</b></p>	<ul style="list-style-type: none"> <li>– Datalloy 2 exhibits comparable machinability to Allvac Ltd (Jessop Saville Oilfield Products) grade Staballoy AG 17™. 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.</li> <li>– 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.</li> </ul>

**Machineability Testing**



Machinability				
Specialty –Datalloy 2		– 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

## Nickel Alloys

### 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
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>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.</li> </ul>						
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>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.</li> </ul>						

ALLOY 400 (UNS N04400)	Tensile Properties – Form and Condition - Nominal Room Temperature				
	Tensile Strength	Yield Strength	Elongation	Hardness	Hardness
	1000 psi	1000 psi	%	Brinell (3000 kg)	Rockwell B
<b>Rod and Bar</b>					
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	85-20c
<b>Plate</b>					
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
<b>Sheet</b>					
Annealed	70-85	30-45	45-35	-	65-80
Cold-Rolled, Hard	100-120	90-110	15-2	-	93 min <sub>a</sub>
<b>Strip Cold-Rolled</b>					
Annealed	70-85	25-45	55-35	-	68 max <sub>a</sub>
Spring Temper	100-140	90-130	15-2	-	98 min <sub>a</sub>
<b>Tube and Pipe, Seamless</b>					
Cold-Drawn, Annealed	70-85	25-45	50-35	-	75 max <sub>a</sub>
Cold-Drawn, Stress-Relieved	85-120	55-100	35-15	-	85-100 <sub>a</sub>
Heat-Exchanger, Annealed	70-85	28-45	50-35	-	75 max <sub>a</sub>
Heat-Exchanger, Stress-Relieved	85-105	55-90	35-15	-	85-97 <sub>a</sub>
Hot-Extruded	-b	-b	-b	-b	-b
No. 1 Temper (Annealed)	85 max	30-45	45-30	-	73 max <sub>a</sub>
No. 2 Temper (Half Hard)	85-105	55-80	30-10	-	75-97 <sub>a</sub>
No. 3 Temper (Full-Hard)	110-130	90-110	10-3	-	95-27 <sub>c</sub>

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

<b>ALLOY 400 (UNS N04400)</b>	<b>Impact Strength (Charpy V-Notch) (ft-lb)</b>			
	<b>Temper</b>	<b>75°F</b>	<b>-20°F</b>	<b>-112°F</b>
<b>Hot-Rolled</b>	219	-	213	196
<b>Cold Drawn, Annealed</b>	216	212	219	212
<b>Weld as Welded</b>	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
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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 Ni<sub>3</sub>(Ti, Al) are precipitated throughout the matrix. The thermal processing used to effect precipitation is commonly called age hardening or aging.</li> <li>- 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.</li> <li>- 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.</li> <li>- 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.</li> </ul>								
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>								

ALLOY 500 (UNS N05500)	Mechanical Properties – Form and Condition - Nominal Ranges				
	Tensile Strength	Yield Strength	Elongation	Hardness Brinell	Hardness Rockwell
	1000 psi	1000 psi	%	(3000 kg)	
<b>Rod and Bar</b>					
Hot-Finished	90-155	40-110	45-20	140-315	75B-35C
Hot-Finished, Aged <sub>b</sub>	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 <sub>b</sub>	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 <sub>b</sub>	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 <sub>b</sub>	130-190	85-120	30-20	250-315	24-35C
<b>Sheet, Cold-Rolled,</b>					
Annealed	90-105	40-65	45-25	-	85B Max
<b>Strip, Cold-Rolled</b>					
Annealed	90-105	90-105	90-105	-	85B max
Annealed and Aged <sub>b</sub>	130-170	130-170	130-170	-	24C min
Spring Temper	145-165	145-165	145-165	-	25C min
Spring Temper and Aged <sub>b</sub>	170-220	170-220	170-220	-	34C min
<b>Tube and Pipe Seamless</b>					
Hot Finished	-c	-c	-c	-c	-c
Cold-Drawn, Annealed	90-110	90-110	90-110	90-110	90-110
Cold-Drawn, and Aged <sub>b</sub>	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 <sub>b</sub>	140-220	140-220	140-220	140-220	140-220
<b>Plate</b>					
Hot Finished	90-135	90-135	90-135	90-135	90-135
Hot Finished and Aged <sub>b</sub>	140-180	140-180	140-180	140-180	140-180



<b>Tensile Properties – Form and Condition</b>						
<i>- Nominal Room Temperature</i>						
<b>ALLOY 500 (UNS N05500)</b>	<i>Tensile Strength</i>	<i>Yield Strength</i>	<i>Elongation</i>	<i>Hardness</i>	<i>Hardness</i>	
	<i>1000 psi</i>	<i>1000 psi</i>	<i>%</i>	<i>Brinell</i>	<i>Rockwell B</i>	
<b>Wire-Cold-Drawn</b>						
<b>Annealed</b>	80-110	80-110	80-110	80-110	80-110	
<b>Annealed and Aged<sup>b</sup></b>	120-150	120-150	120-150	120-150	120-150	
<b>Spring Temper</b>	145-190	145-190	145-190	145-190	145-190	
<b>Spring Temper, Aged<sup>b</sup></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.											
<b>Nominal Analysis</b>		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											
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>												
<b>Product Forms</b>	<ul style="list-style-type: none"> <li>- HASTELLOY® alloy C-22 is available in the form of plate, sheet, strip, billet, bar, wire, covered electrodes, pipe and tubing.</li> <li>- Wrought forms of this alloy are furnished in the solution heat-treated condition unless otherwise specified.</li> </ul>												
<b>Corrosion Resistance</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- 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.</li> <li>- 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.</li> </ul>												
<b>Fabrication</b>	<ul style="list-style-type: none"> <li>- <b>Heat Treatment:</b> 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.</li> <li>- <b>Forming:</b> 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.</li> </ul>												

**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
  - • SO<sub>2</sub> 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).

<b>Tensile Properties – Form and Condition</b>				
<i>- Average tensile data, solution heat- treated</i>				
<b>ALLOY C-22 (UNS NO6022)</b>	<b>Test Temp °F (°C)</b>	<b>Ultimate Tensile Strength Ksi</b>	<b>Yield Strength at 0.2% offset, Ksi</b>	<b>Elongation in 2 in. (50.8 mm), percent</b>
<b>Sheet 0.028-.0125 in. (0.71-3.2mm) thick</b>	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
<b>Plate 1/4"-3/4" in. (6.4-19.1mm) thick</b>	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

<b>Strength Properties –Condition - PLATE</b> - Average impact strength - V -Notch Impact Strength				
<b>ALLOY C-22 (UNS NO6022)</b>				
<b>Room Temperature -320°F (-196°C)</b>				
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

## Nickel Alloy

### C-276 Corrosion Resistant - Hastelloy®

<b>ALLOY C-276 (UNS N10276)</b>		<i>- HASTELLOY® and HAYNES® are registered trademarks of Haynes International, Inc.</i>										
<b>Nominal Analysis</b>	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										
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>											
<b>Product Forms</b>	<ul style="list-style-type: none"> <li>- HASTELLOY® alloy-276 is available in the form of plate, sheet, strip, billet, bar, wire, covered electrodes, pipe and tubing.</li> <li>- Available in Wrought Form</li> </ul>											
<b>Corrosion Resistance</b>	<ul style="list-style-type: none"> <li>- Outstanding Corrosion Resistance in the as-Welded Condition</li> <li>- 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.</li> <li>- 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.</li> <li>- 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.</li> </ul>											

<b>ALLOY C-276 (UNS N10276)</b>	- HASTELLOY® and HAYNES® are registered trademarks of Haynes International, Inc.
<b>Fabrication</b>	- 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.
<b>Heat Treatment</b>	- 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.
<b>ASME Boiler and Pressure Vessel Code</b>	- 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.

<b>ALLOY C-276 (UNS N10276)</b>	<b>Strength Properties –Condition - PLATE</b>		
	<i>- Average impact strength - U -Notch Impact Strength</i>		
	<b>Room Temperature -320°F (-196°C)</b>		
<b>Condition</b>	ft.-lb	J	J
<b>Heat-treated at 2050°F (1121°C) Rapid Quenched</b>	263*	357	-
<b>Aged 100 hrs. at:</b>	500°F (260°C)	250	339
	1000°F (538°C)	96	130
<b>Aged 1000 hrs. at:</b>	1000°F (538°C)	64	87
<b>As-Welded:</b>	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 to 0.187 in. (1.6 to 4.7mm) thick	Heat-treated at 2050°F (1121°C) Rapid Quenched	400 (204) <sup>1</sup>	100.8 (695)	42.1 (290)	56
		600 (316) <sup>2</sup>	97.0 (669)	37.7 (260)	64
		800 (427) <sup>2</sup>	95.0 (655)	34.8 (240)	65
		1000 (538) <sup>2</sup>	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) <sup>2</sup>	98.9 (682)	38.2 (263)	61
		600 (316) <sup>2</sup>	94.3 (650)	34.1 (235)	66
		800 (427) <sup>2</sup>	91.5 (631)	32.7 (225)	60
		1000 (538) <sup>2</sup>	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

Special Products

AISI 01

<b>Specialty – AISI 01 Cold Work Grades Tool Steels</b>		<i>- Rounds, Flats, Plates, Drill Rod, Precision Ground Flats</i>																			
<b>Typical Analysis</b>	C	Mn	Cr	V	W																
	.95	1.1	.6	.1	.6																
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- Good edge holding ability</li> <li>- High hardenability, Low distortion in Heat-Treating.</li> </ul>																				
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Blanking and forming dies for short to medium production runs.</li> <li>- Measuring Tools, gauges, jogs and fixtures, Shear Blades</li> </ul>																				
<b>Typical Heat Treatment</b>	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															
<b>Property Tolerances</b>	<ul style="list-style-type: none"> <li>- Standard Tolerances – Length: 36 inches</li> </ul> <p><b>AISI 01 Ground and Polished Drill Rod</b></p> <table border="1"> <tr> <td>Size Range</td> <td>+/-</td> </tr> <tr> <td>2.000 to .500</td> <td>.001</td> </tr> <tr> <td>.499 to .125</td> <td>.0005</td> </tr> <tr> <td>.124 and less</td> <td>.0003</td> </tr> </table> <p><b>Precision Ground Flat Stock</b></p> <table border="1"> <tr> <td>Thickness</td> <td>+/- .001</td> </tr> <tr> <td>Width</td> <td>Up to 6" + .005/- .000</td> </tr> <tr> <td></td> <td>Over 6" to 8" + .008/- .000</td> </tr> <tr> <td>Length</td> <td>+ .250" - .000"</td> </tr> </table>					Size Range	+/-	2.000 to .500	.001	.499 to .125	.0005	.124 and less	.0003	Thickness	+/- .001	Width	Up to 6" + .005/- .000		Over 6" to 8" + .008/- .000	Length	+ .250" - .000"
Size Range	+/-																				
2.000 to .500	.001																				
.499 to .125	.0005																				
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Length	+ .250" - .000"																				

## Special Products – Tool Steels

### AISI A2, AISI D2

Specialty – AISI A2,								
<b>Typical Analysis</b>	C	Cr	Mo	V				
	1.0	5.3	1.1	0.2				
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– Higher hardenability</li> <li>– Very low distortion in heat treatment, high wear resistance and toughness</li> </ul>							
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– Blanking and forming dies</li> <li>– Cold pilger mandrels, Cold coining dies, Punches, shear blades</li> </ul>							
<b>Typical Heat Treatment</b>	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,								
<b>Typical Analysis</b>	C	Cr	Mo	V				
	1.55	12	.7	1.0				
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– Highest wear resistance combined with good toughness</li> <li>– Best edge holding quality and dimensional stability after tempering</li> </ul>							
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– Thread Rolling dies, Cold extrusion tools</li> <li>– Blanking and forming dies, precision blanking dies</li> <li>– Circular Shear Blades, Deep drawing tools</li> </ul>							
<b>Typical Heat Treatment</b>	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

## Special Products – Tool Steels

### AISI S7, AISI H13 and H13 ESR

Specialty – AISI S7									
<b>Typical Analysis</b>	C	Cr	Mo						
	.5	3.25	1.4						
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– Most commonly used shock resisting tool steel</li> <li>– Very good toughness with medium hardenability</li> </ul>								
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– Trimming Tools, Ejectors, Shear Blades, Chippers,</li> <li>– Hammers, Swaging Dies</li> </ul>								
<b>Typical Heat Treatment</b>	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										
<i>- Hot Work Grades</i>										
<b>Typical Analysis</b>	C	Si	Cr	Mo	V					
	.40	1.0	5.3	1.4	1.0					
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– High hot tensile strength, hot wear resistance and toughness</li> <li>– Good thermal conductivity and resistance to hot cracking</li> <li>– Excellent machinability due to additional calcium treatment</li> </ul>									
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– Universal applicable Hot Work Tool Steel for pressure diecasting dies</li> <li>– Metal extrusion tools for processing light metals</li> <li>– Forging Dies, Moulds, Worms and Cylinders for processing plastics</li> <li>– For highest demands H13 ESR is suggested</li> </ul>									
<b>Typical Heat Treatment</b>	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/mm <sup>2</sup> 1910			
	Tempering									
	°C	100	200	300	400	500	550	600	650	700
	HRC	53	52	52	54	56	54	50	42	32
N/m <sup>2</sup>	1850	1790	1790	1910	2050	1910	1670	1330	1020	

## Special Products – Tool Steels

### AISI M2, AISI P20

<b>Specialty – AISI M2</b>		<i>- High Speed Steels</i>				
<b>Typical Analysis</b>		C	Si	Cr	V	W
		.90	4.1	5.	1.9	6.4
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– Standard high speed steel grade with balanced alloy composition</li> <li>– High toughness and good cutting power</li> </ul>					
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– 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</li> </ul>					
<b>Typical Heat Treatment</b>	Soft annealing 820-860 °C		1st preheating °C up to approx. 400 in an air circulating furnace			
			2 <sup>nd</sup> and 3 <sup>rd</sup> 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			

<b>Specialty – AISI P20</b>		<i>- Plastic Mould Steels</i>						
<b>Typical Analysis</b>		C	Mn	Cr	Mo			
		.40	1.5	1.9	.20			
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– Quenched and tempered, Hardness as Supplied 280 to 325 HB</li> <li>– Excellent machinability due to additional calcium Treatment</li> <li>– Good polishability, Suitable for Texturing</li> </ul>							
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– Plastic Injection Moulds, Mould Frames, Pressure Casting Dies, Pultrusion Dies</li> </ul>							
<b>Typical Heat Treatment</b>	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/mm <sup>2</sup> 1730			
	Tempering							
	°C	100	200	300	400	500	600	700
	HRC	51	50	48	46	42	36	28
	N/mm <sup>2</sup>	1730	1670	1570	1480	1330	1140	920

## Special Products – Tool Steels

### P20 + S, 420 and 420 ESR

Specialty – AISI P20 +S		- Plastic Mould Grades				
<b>Typical Analysis</b>		C	Mn	Cr	Mo	S
		.40	1.5	1.9	.20	.05
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– Hardness as supplied 280-325 BH</li> <li>– Improved machinability to P20 with good polishability</li> </ul>					
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– Plastic Moulds, Mould Frames and Pressure Casting Dies</li> <li>– Sleeves of Recipients</li> </ul>					
<b>Typical Heat Treatment</b>	– Refer to Information for P20					

Specialty – AISI 420 and 420 ESR		- Plastic Mould Grades				
<b>Typical Analysis</b>		C	Cr			
		.42	13			
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– Corrosion resistance plus good polishability</li> <li>– Good machinability due to the additional calcium treatment</li> <li>– For severe applications 420 ESR is suggested</li> </ul>					
<b>Typical Applications</b>	– Moulds for processing corrosive plastics					
<b>Typical Heat Treatment</b>	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

<b>Stainless Steel T-303 (UNS S 30300)</b>		<i>- 18-8 Chromium- Nickel Freemachining Stainless Steel - Available mainly in wire and bar form to ASTM A581 and A582</i>						
Typical Analysis	C	Mn	P	S	Si	Cr	Ni	Mo
	.15Max	2.0Max	.20Max	.15Min	1.0Max	17/19	8/10	.60Opt.
<b>Characteristics</b>	– 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							
<b>Typical Applications</b>	– Used almost exclusively for parts requiring machining and primarily in automatic screw machines. Bushings, fittings, shafts, valves, bolts and nuts							
<b>Corrosion and Heat Resistance</b>	– 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							



<b>Stainless Steel T-303 (UNS S 30300) Mechanical Properties - T-303 Bar sizes – Typical</b> - 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/mm <sup>2</sup>	620	690
Yield Strength, psi	35,000	60,000
Yield Strength, N/mm <sup>2</sup>	241	414
Elongation (%)	50	40
Reduction of Area (%)	55	50
Hardness	163	229

<b>Stainless Steel T-303 (UNS S 30300) Mechanical Properties - T-303 Wire Sizes</b> - 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/mm <sup>2</sup>	590/860	790/1000

## Stainless Steel

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

<b>Stainless Steel T-304, T-304H, T-304L</b> <b>(UNS S30400, S30409, S30403)</b>		<i>- 18 - 10 Chromium-Nickel austenitic stainless steel</i> <i>- Available in most forms - sheets, plates &amp; coils to ASTM A240; bar sections to ASTM A276 &amp; A479</i>							
<b>Typical Analysis</b>	<b>T-304</b>	<b>C</b> .08 Max	<b>Mn</b> 2.0 Max	<b>P</b> .045 Max	<b>S</b> .03 Max	<b>Si</b> 1.0 Max	<b>Cr</b> 18/20	<b>Ni</b> 8/10.5	<b>N</b> .1 Max.
	<b>T-304H</b>	<b>C</b> .04/ .10	<b>Mn</b> 2.0 Max	<b>P</b> .045 Max	<b>S</b> .03 Max	<b>Si</b> 1.0 Max	<b>Cr</b> 18/20	<b>Ni</b> 8/10.5	<b>N</b> -
	<b>T-304L</b>	<b>C</b> .03 Max	<b>Mn</b> 2.0 Max	<b>P</b> .045 Max	<b>S</b> .03 Max	<b>Si</b> .75 Max	<b>Cr</b> 18/20	<b>Ni</b> 8/12	<b>N</b> .1 Max.
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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</li> </ul>								
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- 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</li> </ul>								
<b>Corrosion and Heat Resistance</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>								

<b>Stainless Steel T-304, T-304H, T-304L</b> <b>(UNS S30400, S30409, S30403)</b>		<b>Mechanical Properties - Bar</b> - Typical at Room Temperature		
		<b>Bars</b>	T-304	T-304H
<b>Tensile Strength, psi</b>		85,000	85,000	83,000
<b>Tensile Strength, N/mm<sup>2</sup></b>		586	586	572
<b>Yield Strength, psi</b>		35,000	35,000	34,000
<b>Yield Strength, N/mm<sup>2</sup></b>		241	241	234
<b>Elongation (%)</b>		60	60	60
<b>Hardness</b>		149	149	146

<b>Stainless Steel T-304, T-304H, T-304L</b> <b>(UNS S30400, S30409, S30403)</b>		<b>Mechanical Properties - Sheet</b> - Typical at Room Temperature		
		<b>Sheet</b>	T-304	T-304H
<b>Tensile Strength, psi</b>		84,000	84,000	81,000
<b>Tensile Strength, N/mm<sup>2</sup></b>		579	579	558
<b>Yield Strength, psi</b>		42,000	42,000	39,000
<b>Yield Strength, N/mm<sup>2</sup></b>		290	290	270
<b>Elongation (%)</b>		55	55	55
<b>Hardness</b>		146 (80)	146 (80)	143 (79)

<b>Stainless Steel T-304, T-304H, T-304L</b> <b>(UNS S30400, S30409, S30403)</b>			
<b>Mechanical Properties - Plate</b> - Typical at Room Temperature			
<b>Plate</b>	<b>T-304</b>	<b>T-304H</b>	<b>T-304L</b>
<b>Tensile Strength, psi</b>	82,000	82,000	79,000
<b>Tensile Strength, N/mm<sup>2</sup></b>	565	565	545
<b>Yield Strength, psi</b>	35,000	35,000	33,000
<b>Yield Strength, N/mm<sup>2</sup></b>	241	241	228
<b>Elongation (%)</b>	60	60	60
<b>Hardness</b>	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						
<b>Typical Analysis</b>	T-310	C	Mn	P	S	Si	Cr	Ni
		.25 Max	2.0 Max	.045 Max	.030 Max	1.5 Max	24/ 26	19/ 22
	T-310S	C	Mn	P	S	Si	Cr	Ni
		.08 Max	2.0 Max	.045 Max	.030 Max	1.5 Max	24/ 26	19/ 22
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– 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.</li> </ul>							
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>– Furnace parts, carburizing boxes, heat treating trays, oven linings, heat exchangers, gas turbine parts, jet engine rings.</li> </ul>							
<b>Corrosion and Heat Resistance</b>	<ul style="list-style-type: none"> <li>– 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.</li> </ul>							
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>– Typical – at Room Temperature</li> <li>– Tensile Strength – 95,000 psi (655 N/mm<sup>2</sup>)</li> <li>– Yield Strength – 45,000 psi (310 N/mm<sup>2</sup>)</li> <li>– Elongation – 50%</li> <li>– Hardness – Rb 179 (89)</li> </ul>							

Stainless Steel

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

<b>Stainless Steel T-316, T-316L, T-316N</b> <b>(UNS S31600, S31603, S31653)</b>		<p>- 18-12-3 Chromium-Nickel-Molybdenum austenitic stainless steel.</p> <p>- Available in most forms &amp; sheets, plates and coils to ASTM A240; bar sections to ASTM A276 &amp; A479</p>								
<b>Typical Analysis</b>	<b>T-316</b>	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
	<b>T-316L</b>	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	
	<b>T-316N</b>	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	
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- T-316L is 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.</li> <li>- 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.</li> <li>- T-316 is also available in Pump Shaft quality.</li> </ul>									
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Widely used in the pulp and paper, chemical, petro-chemical, fertilizer and pharmaceutical industries. Heat exchangers, marine applications, aircraft industry, fittings, architectural components.</li> </ul>									
<b>Corrosion and Heat Resistance</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>									

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/mm <sup>2</sup>	552	517	621	
Yield Strength, psi	30,000	30,000	42,000	
Yield Strength, N/mm <sup>2</sup>	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/mm <sup>2</sup>	579	545	621	
Yield Strength, psi	42,000	38,000	48,000	
Yield Strength, N/mm <sup>2</sup>	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/mm <sup>2</sup>	585	538	607	
Yield Strength, psi	36,000	35,000	46,000	
Yield Strength, N/mm <sup>2</sup>	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												
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- Cold drawn, centreless ground.</li> <li>- Typical Surface Finish:                             <ul style="list-style-type: none"> <li>- Clean, bright smooth finish; defect free.</li> <li>- Smoother finish than Smooth Turned. RMS</li> <li>- Finish: 30 max guaranteed.</li> </ul> </li> <li>- Straightness 0.0625" in 5 ft.</li> </ul>																				
<b>Typical Applications</b>	- Boat shafting, cylinder rods, pulp, paper, chemical and petro chemical industries.																				
<b>Size Range Rounds</b>	- Tolerances – Plus or Minus in inches <table border="1" style="width: 100%; border-collapse: collapse;"> <tbody> <tr> <td style="width: 50%;">- .125 - .317</td> <td style="width: 50%;">- 000 to .001</td> </tr> <tr> <td>- .318 - .500</td> <td>- 000 to .0015</td> </tr> <tr> <td>- .501 - .999</td> <td>- 000 to .002</td> </tr> <tr> <td>- 1.000 - 1.499</td> <td>- 000 to .0025</td> </tr> <tr> <td>- 1.500 - 3.499</td> <td>- 000 to .003</td> </tr> <tr> <td>- 3.500 - 6.750</td> <td>- 000 to .004</td> </tr> </tbody> </table>									- .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
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- 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. %
<b>316/316L Strain-Hardened</b>	95000	75000	25	40
<b>2" and under</b>	[650]	[515]		
<b>over 2" to 2 1/2"</b>	90000	65000	30	40
<b>(50.8 to 63.5mm) incl.</b>	[620]	[450]		
<b>over 2 1/2" to 3 1/2"</b>	80000	55000	30	40
<b>(63.5 to 88.9mm) incl.</b>	[550]	[380]		
<b>over 3 1/2" to 4"</b>	80000	45000	30	60
<b>(88.9 to 101.6mm) incl.</b>	[550]	[310]		

Stainless Steel  
T-317, T-317L

<b>Stainless Steel T-317, T-317L (UNS S31700, S31703)</b>		<p>- 20-13-4 Chromium-Nickel-Molybdenum austenitic stainless steel.</p> <p>- Available in most forms, but owing to low-volume usage not as readily available as T-316.</p>								
<b>Typical Analysis</b>	<b>T-317</b>	<b>C</b>	<b>Mn</b>	<b>P</b>	<b>S</b>	<b>Si</b>	<b>Cr</b>	<b>Ni</b>	<b>Mo</b>	<b>N</b>
		.08 Max	2.0 Max	.045 Max	.030 Max	1.0 Max	18/20	11/15	3/4	.10 Max
	<b>T-317L</b>	<b>C</b>	<b>Mn</b>	<b>P</b>	<b>S</b>	<b>Si</b>	<b>Cr</b>	<b>Ni</b>	<b>Mo</b>	<b>N</b>
		.03 Max	2.0 Max	.045 Max	.030 Max	1.0 Max	18/20	11/15	3/4	.10 Max
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- 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.</li> <li>- T-317 is non-magnetic in the annealed condition and is non-hardenable by heat treatment. Machinability is 39% - 65 surface feet per minute.</li> </ul>									
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- Pulp and paper, chemical and pharmaceutical processing equipment and machinery.</li> </ul>									
<b>Corrosion and Heat Resistance</b>	<ul style="list-style-type: none"> <li>- Significantly better corrosion resistance than T-316 in the same environments. Good oxidation resistance in continuous service to 925°C and in intermittent service to 879°C.</li> </ul>									

<b>Stainless Steel T-317, T-317L (UNS S31700, S31703)</b>		
<b>Mechanical Properties - Bar</b> - Typical at Room Temperature		
Bars	T-317	T-317L
Tensile Strength, psi	85,000	85,000
Tensile Strength, N/mm <sup>2</sup>	586	586
Yield Strength, psi	40,000	35,000
Yield Strength, N/mm <sup>2</sup>	276	241
Elongation (%)	50	55
Hardness	160 (82)	146 (80)

<b>Stainless Steel T-317, T-317L (UNS S31700, S31703)</b>		
<b>Mechanical Properties - Sheet</b> - Typical at Room Temperature		
Sheet	T-317	T-317L
Tensile Strength, psi	90,000	86,000
Tensile Strength, N/mm <sup>2</sup>	621	593
Yield Strength, psi	43,000	38,000
Yield Strength, N/mm <sup>2</sup>	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/mm <sup>2</sup>	586	565	
Yield Strength, psi	48,000	43,000	
Yield Strength, N/mm <sup>2</sup>	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	<ul style="list-style-type: none"> <li>- 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.</li> <li>- T-410S limits the carbon content to .08% max for better weldability, mainly in sheet and plate.</li> <li>- 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.</li> </ul>						
Typical Applications	<ul style="list-style-type: none"> <li>- Machine parts, pump shafts, blast joints, blow-out preventers, pistons, valve parts, bolts, bushings, jet engine parts, rifle barrels, hardware, cutlery</li> </ul>						
Corrosion and Heat Resistance	<ul style="list-style-type: none"> <li>- Resists atmospheric corrosion, mild alkalis and acids, food acids, rural and industrial atmospheres. Resists scaling at temperatures up to 675°C in continuous service.</li> </ul>						
Heat Treatment	<ul style="list-style-type: none"> <li>- Annealing - Heat to 850°/900°C for 30 min. per inch of section thickness and slow cool.</li> <li>- Hardening - Heat to 950°/1000°C and quench in oil, water or air according to section and properties required.</li> <li>- 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.</li> </ul>						

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/mm <sup>2</sup>	517	483	
Yield Strength, psi	40,000	35,000	
Yield Strength, N/mm <sup>2</sup>	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 2 1/4" dia.	Heat Treated to A193 Grade B6 - 1 3/4" dia	Heat Treated to HRC22 max by double tempering at 1150°F	
Tensile Strength, psi	137,900	129,000	100,000	
Tensile Strength, N/mm <sup>2</sup>	951	809	-	
Yield Strength, psi	115,300	109,000	80,000	
Yield Strength, N/mm <sup>2</sup>	795	752	-	
Elongation (%)	24	22	20	
Reduction of Area (%)	69	71	40	
Hardness	285	269	Rc 20	

Stainless Steel  
T-416

<b>Stainless Steel T-416 (UNS S41600)</b>		<i>- 12% Chromium Free-Machining Hardenable Stainless Steel. Available mainly in wire and bar sections to ASTM A581 and A582.</i>				
Typical Analysis	C	Mn	P	S	Cr	Mo (opt.)
	.15 Max	1.25 Max	.06 Max	.15 Max	12/ 14	.60 Max
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- 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.</li> <li>- T-416 is also available in Pump Shaft quality.</li> </ul>					
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>					
<b>Corrosion and Heat Resistance</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>					
<b>Heat Treatment</b>	<ul style="list-style-type: none"> <li>- Annealing - Heat to 850°/900°C for 30 minutes per inch of section thickness. Cool slowly in furnace.</li> <li>- Hardening - Heat to 950°/1000°C and quench large sections in oil. Small sections may be quenched in air.</li> <li>- Tempering - According to mechanical properties required, but the range of 400°/580°C is not recommended.</li> </ul>					

**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/mm <sup>2</sup>	517	586
Yield Strength, psi	40,000	50,000
Yield Strength, N/mm <sup>2</sup>	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/mm <sup>2</sup>	590/860	790/1000	1000/1210



## Stainless Steel

### T-316 Pump Shaft Quality (PSQ)

<b>Stainless Steel T-316 Pump Shaft Quality</b> <span style="float: right;"><i>- This grade is annealed, centreless ground and polished.</i></span>																												
<b>Typical Analysis</b>	<table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr> <th>C</th> <th>Mn</th> <th>P</th> <th>S</th> <th>Si</th> <th>Cr</th> <th>Ni</th> <th>Mo</th> <th>N</th> </tr> </thead> <tbody> <tr> <td>.8</td> <td>2.0</td> <td>.045</td> <td>.030</td> <td>1.0</td> <td>16/18</td> <td>10/18</td> <td>2/3</td> <td>.10</td> </tr> <tr> <td>Max</td> <td>Max</td> <td>Max</td> <td>Max</td> <td>Max</td> <td></td> <td></td> <td>Max</td> <td></td> </tr> </tbody> </table>	C	Mn	P	S	Si	Cr	Ni	Mo	N	.8	2.0	.045	.030	1.0	16/18	10/18	2/3	.10	Max	Max	Max	Max	Max			Max	
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<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- T-316L is 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.</li> <li>- 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.</li> </ul>																											
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>																											
<b>Corrosion and Heat Resistance</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>																											
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- 75,000 psi minimum tensile strength</li> <li>- 30,000 psi minimum yield</li> <li>- 35% minimum elongation (in 2")</li> <li>- 50% minimum reduction of area (R/A)</li> </ul>																											
<b>Tolerances</b>	<ul style="list-style-type: none"> <li>- Straightness Tolerance – 0.0015" per foot</li> <li>- Maximum out-of-round – 1/2 total diameter tol.</li> <li>- Diameter Tolerance:</li> </ul> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="text-align: center;">Size</th> <th style="text-align: center;">Tolerance</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">.875"-.999"</td> <td style="text-align: center;">+0/- 0.0020"</td> </tr> <tr> <td style="text-align: center;">1.000"-1.4375"</td> <td style="text-align: center;">+0/- 0.0025"</td> </tr> <tr> <td style="text-align: center;">1.4376"-4.000"</td> <td style="text-align: center;">+0/- 0.0030"</td> </tr> </tbody> </table>	Size	Tolerance	.875"-.999"	+0/- 0.0020"	1.000"-1.4375"	+0/- 0.0025"	1.4376"-4.000"	+0/- 0.0030"																			
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## Stainless Steel

### T-416 Pump Shaft Quality (PSQ)

<b>Stainless Steel T-416 Pump Shaft Quality</b>													
<i>- This grade is heat treated, centreless ground and polished.</i>													
<b>Typical Analysis</b>	<table border="1"> <thead> <tr> <th>C</th> <th>Mn</th> <th>P</th> <th>S</th> <th>Cr</th> <th>Mo (opt.)</th> </tr> </thead> <tbody> <tr> <td>.15 Max</td> <td>1.25 Max</td> <td>.06 Max</td> <td>.15 Min</td> <td>12/14</td> <td>.60 Max</td> </tr> </tbody> </table>	C	Mn	P	S	Cr	Mo (opt.)	.15 Max	1.25 Max	.06 Max	.15 Min	12/14	.60 Max
C	Mn	P	S	Cr	Mo (opt.)								
.15 Max	1.25 Max	.06 Max	.15 Min	12/14	.60 Max								
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- 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.</li> </ul>												
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>												
<b>Corrosion and Heat Resistance</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>												
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- 100,000 psi minimum tensile strength</li> <li>- 85,000 psi minimum yield</li> <li>- 15% minimum elongation (in 2")</li> <li>- 45% minimum reduction of area (R/A)</li> <li>- 207-248 Brinell hardness</li> </ul>												
<b>Tolerances</b>	<ul style="list-style-type: none"> <li>- Straightness Tolerance – 0.0015" per foot</li> <li>- Maximum out-of-round – 1/2 total diameter tol.</li> <li>- Diameter Tolerance: <table border="1"> <thead> <tr> <th>Size</th> <th>Tolerance</th> </tr> </thead> <tbody> <tr> <td>.750"-.999"</td> <td>+0/- 0.0020"</td> </tr> <tr> <td>1.000"-1.4375"</td> <td>+0/- 0.0025"</td> </tr> <tr> <td>1.4376"-4.000"</td> <td>+0/- 0.0030"</td> </tr> </tbody> </table> </li> </ul>	Size	Tolerance	.750"-.999"	+0/- 0.0020"	1.000"-1.4375"	+0/- 0.0025"	1.4376"-4.000"	+0/- 0.0030"				
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Stainless Steel  
17-4PH, T-630

<b>Stainless Steel 17-4PH, T-630 (UNS S17400)</b> - 17-4 Chromium-Nickel Precipitation/Age Hardening martensitic stainless steel -Available mainly in bar and plate - ASTM A564																	
Typical Analysis	<table border="1"> <thead> <tr> <th>C</th> <th>Mn</th> <th>P</th> <th>S</th> <th>Si</th> <th>Cr</th> <th>Ni &amp; Cu</th> <th>Cb+Ta</th> </tr> </thead> <tbody> <tr> <td>.07 Max</td> <td>1.0 Max</td> <td>.04 Max</td> <td>.30 Min</td> <td>1.0 Max</td> <td>15/17.5</td> <td>3.0/5.0</td> <td>.15/.45</td> </tr> </tbody> </table>	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
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										
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- 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.</li> <li>- 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.</li> <li>- See the Data Section for machinability ratings of Condition A and Condition H1150.</li> </ul>																
<b>Typical Applications</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>																
<b>Corrosion and Heat Resistance</b>	<ul style="list-style-type: none"> <li>- 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.</li> </ul>																

**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/mm <sup>2</sup>	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/mm <sup>2</sup>	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

### 2304 Duplex

<b>Stainless Steel – Grade 2304 Duplex - URANUS 35N</b>													
<i>- a 23.04 Duplex stainless steel with PREN ≥ 24</i>													
<b>Typical Analysis</b>	<table border="1"> <thead> <tr> <th>C</th> <th>Cr</th> <th>Ni</th> <th>Mo</th> <th>N</th> <th>others</th> </tr> </thead> <tbody> <tr> <td>.02</td> <td>23</td> <td>4</td> <td>.2</td> <td>.1</td> <td>S= .001</td> </tr> </tbody> </table> <p> <math>PREN = [Cr \%] + 3.3 [Mo \%] + 16 [N \%] \geq 24</math> </p>	C	Cr	Ni	Mo	N	others	.02	23	4	.2	.1	S= .001
C	Cr	Ni	Mo	N	others								
.02	23	4	.2	.1	S= .001								
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>– 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.</li> <li>– 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.</li> <li>– 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.</li> </ul>												
<b>Standards</b>	<ul style="list-style-type: none"> <li>– EURONORM – 1.4362 - X2 Cr Ni 23.4</li> <li>– AFNOR – Z3 CN 23.04 Az</li> <li>– DIN – W. Nr 1.4362</li> <li>– ASTM – A240 - UNS S32304</li> </ul>												
<b>Structure</b>	<ul style="list-style-type: none"> <li>– 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).</li> <li>– The microstructure of UR 35N duplex is very stable compared to molybdenum containing duplex stainless steels. Intermetallic phases (α, χ) 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.</li> </ul>												
<b>Applications</b>	<ul style="list-style-type: none"> <li>– Generally where 304 and 316L are used</li> <li>– Pulp and paper industry (chip storage tank, white and black liquor tanks...)</li> <li>– Caustic solutions, organic acids (SCC resistance)</li> <li>– Food industry</li> <li>– Safety panels (high mechanical properties)</li> <li>– Pressure vessels (weight savings...)</li> <li>– Mining (abrasion/corrosion).</li> </ul>												

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
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 hardened 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/m <sup>3</sup> - 0.28 lb/in <sup>3</sup>			
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)		
	<p>The graph plots corrosion resistance against the concentration of sulfuric acid (%H<sub>2</sub>SO<sub>4</sub>) and temperature. The y-axis has two scales: °C (25, 50, 75, 100) and °F (75, 120, 165, 210). The x-axis is %H<sub>2</sub>SO<sub>4</sub> (0 to 100). A 'Boiling Curve' is shown at the top. Three curves represent different stainless steel grades: UR 35N (top curve), 316L (middle curve), and AISI 3041 (bottom curve). All curves show that corrosion resistance decreases as the concentration of sulfuric acid increases and as the temperature increases.</p>		

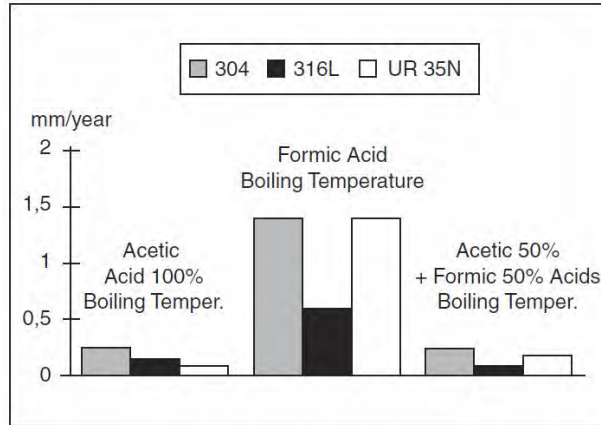


**Stainless Steel  
– Grade 2304  
Duplex -  
URANUS 35N**

**Mechanical Properties  
Corrosion Resistance**

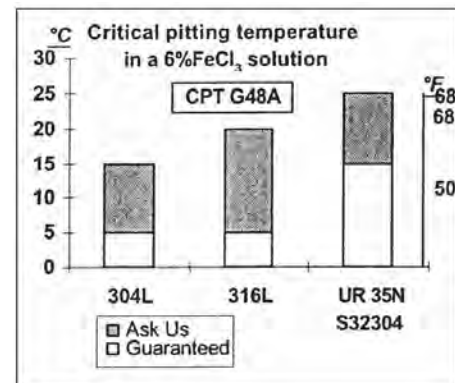
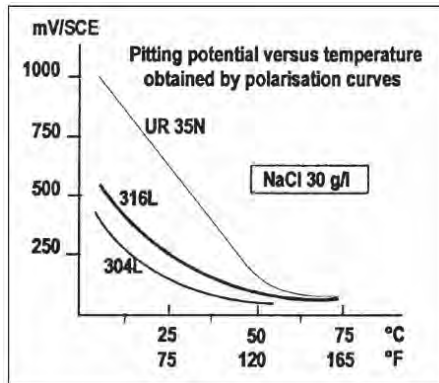
**– General  
Corrosion**

– Corrosion resistance, in different Organic acids



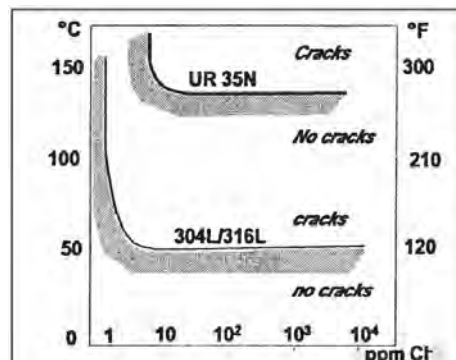
– Because of its high chromium content (23%) the corrosion resistance properties of UR 35N are almost equivalent to those of 316L.

– 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 O<sub>2</sub>) 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.

<p><b>Stainless Steel – Grade 2304 Duplex - URANUS 35N</b></p>	<p><b>Mechanical Properties</b></p>																				
<p><b>Other Corrosion Resistance Properties</b></p>	<ul style="list-style-type: none"> <li>– 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.</li> </ul>																				
<p><b>Processing</b></p>	<ul style="list-style-type: none"> <li>– <b>Hot Forming:</b> 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.</li> <li>– <b>Cold forming:</b> 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'.</li> <li>– <b>Descaling:</b> 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.</li> </ul>																				
<p><b>Machinability</b></p>	<ul style="list-style-type: none"> <li>– 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.</li> </ul> <div data-bbox="483 1171 881 1478"> <table border="1"> <caption>Approximate data from the graph: Total length (drilling) vs drilling speed</caption> <thead> <tr> <th>Drilling Speed (m/min)</th> <th>304 (m)</th> <th>316 (m)</th> <th>UR 35N (m)</th> <th>MACH 18.10.2 316 (m)</th> </tr> </thead> <tbody> <tr> <td>10</td> <td>~0.5</td> <td>~0.5</td> <td>~5</td> <td>~5</td> </tr> <tr> <td>20</td> <td>~0.2</td> <td>~0.2</td> <td>~2</td> <td>~2</td> </tr> <tr> <td>30</td> <td>~0.1</td> <td>~0.1</td> <td>~1</td> <td>~1</td> </tr> </tbody> </table> </div> <p>(*) CLI - MACH 18.10.2 is a 316L type grade with improved machinability properties</p> <p>Total length (drilling) versus drilling speed</p>	Drilling Speed (m/min)	304 (m)	316 (m)	UR 35N (m)	MACH 18.10.2 316 (m)	10	~0.5	~0.5	~5	~5	20	~0.2	~0.2	~2	~2	30	~0.1	~0.1	~1	~1
Drilling Speed (m/min)	304 (m)	316 (m)	UR 35N (m)	MACH 18.10.2 316 (m)																	
10	~0.5	~0.5	~5	~5																	
20	~0.2	~0.2	~2	~2																	
30	~0.1	~0.1	~1	~1																	
<p><b>Welding</b></p>	<ul style="list-style-type: none"> <li>– UR 35N can be successfully welded by the following processes: TIG, manual and automatic– PLASMA, MIG, SMAW, SAW, FCAW.</li> <li>– The duplex microstructure renders the alloy less sensitive to hot cracking.</li> <li>– 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).</li> </ul>																				

Stainless Steel – Grade 2304 Duplex - URANUS 35N		Mechanical Properties Size Range		
Spec	Hot Rolled Plates	Cold Rolled Plates	Clad Plates	
<b>Thickness</b>	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"	
<b>Width</b>	Up to 3300 mm Up to 130"	Up to 2300 mm Up to 90.5"	Up to 3300 mm Up to 130"	
<b>Length</b>	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

<b>Stainless Steel – 2205 Duplex</b> (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
<b>Characteristics</b>	<ul style="list-style-type: none"> <li>- High Strength AND</li> <li>- Duplex UNS S31803/S32205 is a ferritic-austenitic stainless combining high mechanical strength, ductility and hardness with excellent resistance to corrosion and erosion.</li> </ul>									
<b>Mechanical Properties</b>	<ul style="list-style-type: none"> <li>- <b><u>Mechanical Test Requirements:</u></b> <ul style="list-style-type: none"> <li>- Tensile – 90,000 psi min</li> <li>- Yield – 65,000 psi min</li> <li>- Elongation – 25 % min</li> <li>- Hardness – 293 HBN Max</li> </ul> </li> <li>- <b><u>Corrosion Resistance:</u></b> <ul style="list-style-type: none"> <li>- 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.</li> <li>- 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.</li> </ul> </li> <li>- <b><u>Stress-Corrosion Resistance:</u></b> <ul style="list-style-type: none"> <li>- Resists Chloride Stress Corrosion Cracking</li> <li>- 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.</li> </ul> </li> </ul>									

**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, SO <sub>2</sub> 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 Pit 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

<b>Stainless Steel – 2205 Duplex</b> (UNS S31803/S32205)		<i>- a Duplex Austenitic/ Ferritic stainless steel</i>
<b>ASME Boiler &amp; Pressure Vessel Code Case</b>	– Duplex UNS S31803/S32205 sheet, strip, plate, bar, pipe and tubing are covered in ASME Boiler and Pressure Vessel Code, Section VIII, Division I.	
<b>Specifications</b>	– 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 2 1/2 to 3 1/2 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.
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 <sup>B</sup> and are minus <sup>C</sup> )			
	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
<b>Round –Cold Drawn (to 4in.) or Turned and Polished</b>				
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
<b>Hexagons</b>				
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	---	---
<b>Squares</b>				
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 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	----	----	----

<b>Tolerances –Cold Finished Carbon Bars</b>	<b>Minus Tolerances in Inches (No Plus Tolerances Apply)</b> (All tolerances are in inches <sup>B</sup> and are minus <sup>C</sup> )			
<b>Specified Size</b>	<i>Maximum of Carbon Range 0.28% less</i>	<i>Maximum of Carbon Range Over 0.28% to 0.55% incl.</i>	<i>Maximum of Carbon Range to 0.55% include, Stress Relieved or Annealed after Cold Finishing</i>	<i>Maximum of Carbon Range Over 0.55% or All grades Quenched and Tempered or Normalized and Tempered before Cold Finishing</i>
<b>Flats</b>				
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	----	----
<b>Size (In.) Cold Drawn Ground and Polished</b>	<b>Turned, Ground and Polished</b>		<b>Tolerances from Specified Size, Minus Only (In.)</b>	
To 1 1/2, incl.	To 1 1/2, incl.		0.001	
Over 1 1/2 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 <sup>B</sup>			
Specified Size (in. <sup>A</sup> )	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.
<b>Round –Cold Drawn (to 4in.) or Turned and Polished</b>				
To 1, include, in coils	0.002	0.003	0.004	0.005
<b>Cut lengths:</b> 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
<b>Hexagons</b>				
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	---	---	---

<b>Tolerances –Cold Finished Alloy Bars</b>		<b>All tolerances are in inches and are minus <sup>B</sup></b>			
<b>Specified Size (in.<sup>A</sup>)</b>	<i>Maximum of Carbon Range 0.28% less</i>	<i>Maximum of Carbon Range Over 0.28% to 0.55% incl.</i>	<i>Maximum of Carbon Range to 0.55% include, Stress Relieved or Annealed after Cold Finishing</i>	<i>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.</i>	
				<b>Squares</b>	
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	----	----	----	
<b>Flats</b>					
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 <sup>A, B</sup>**

*-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

## 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  $Fe_3C$  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 a specific 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 that 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 silicon to be useful as an agent for introducing these elements into steel by admixture 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 substantially higher 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  $M_s$  (or  $A_r''$ ) 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 or compressive elastic modulus is called "Young's modulus"; the torsional elastic modulus is known as the "shear modulus", or "modulus of rigidity".

**NITRIDING**

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 solidify last.

**NOTCH BRITTLINESS**

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.  $Ac_{CM}$  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  $Ae_1$   $Ae_3$   $Ae_{CM}$  and  $Ae_4$ .

## **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.