PACIFIC

PACIFIC
MACHINERY & TOOL
STEEL COMPANY

Stock List and Reference Book

Serving the West Since 1912

METAL SERVICE CENTER FOR CARBON, ALLOY, TOOL, SPECIAL STEELS, METALS, STEEL TREATING & TESTING EQUIPMENT

ACKNOWLEDGMENTS

Credit is given to the following for their contribution:

Patrick M. Wall, Metallurgist

ASM International (ASM)

The American Iron & Steel Institute (AISI)

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A S M International

Society of Manufacturing Engineers

The Steel Service Center Institute

Comments and inquiries should be directed to:
Chief Metallurgist or Administrative and Operations Manager.

Price $25.00

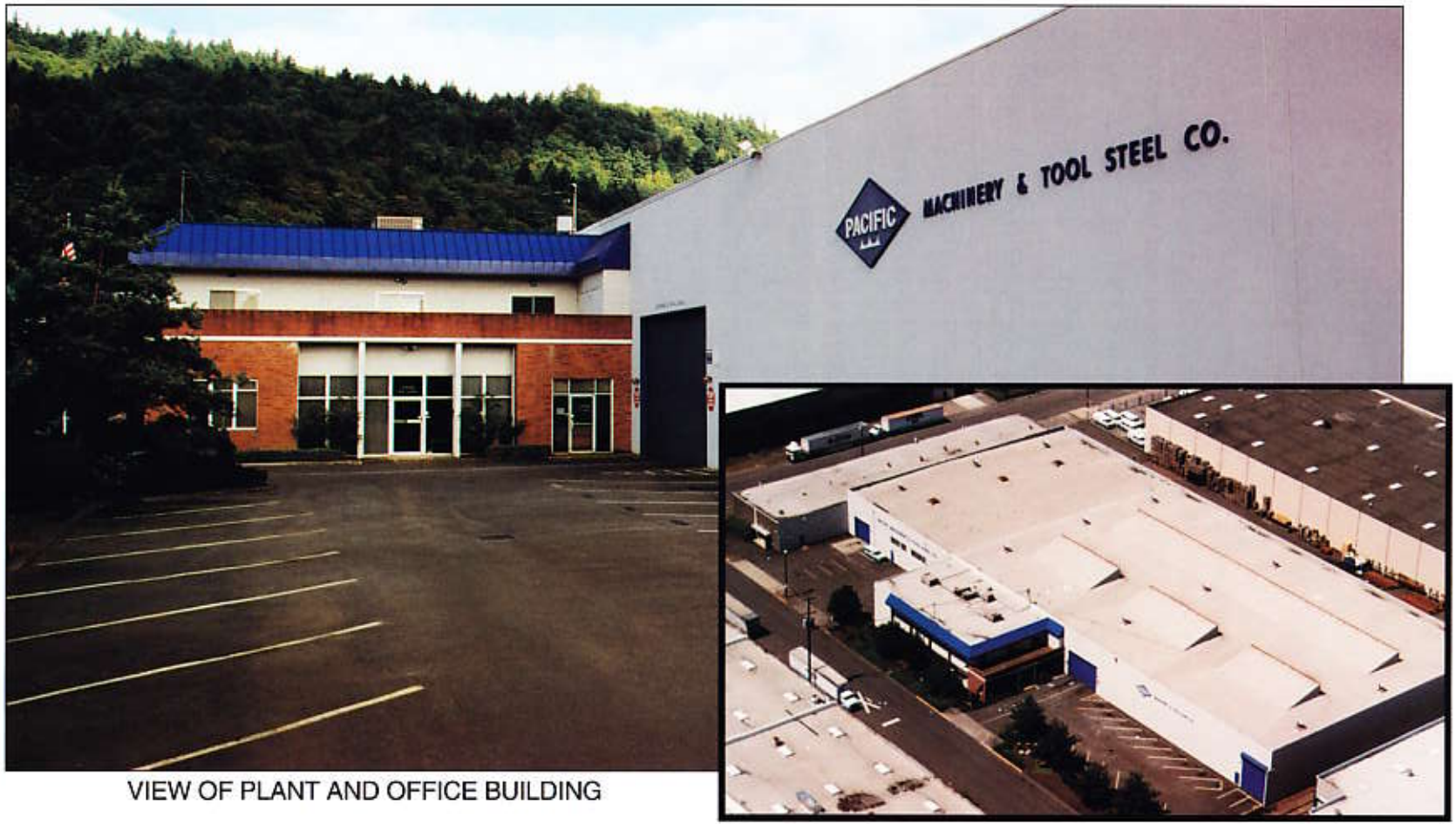
TO OUR VALUED CUSTOMERS

Pacific Machinery & Tool Steel Company is committed to serving your diverse requirements in engineering steels and metals by providing the best products available from reliable sources, accurate on-time delivery, and an array of processing services.

The information furnished in this **STOCK LIST and REFERENCE BOOK** has been designed to assist you in making the best judgement possible regarding our products. You will find a description and listing of the steels and metals we have on hand or are readily available. Also, you will find in the Technical Data Sections informative references pertinent to the machining and manufacturing industry.

Our metallurgist and experienced sales personnel supported by state-of-the-art data-processing equipment, mill laboratories and technical societies are available to assist in **your** profitability and success.

PACIFIC MACHINERY & TOOL STEEL CO.
Office and Plant
3445 N.W. Luzon Street
Portland, OR 97210-1694
Telephone (503) 226-7656
or
1-800-547-1091
FAX No. (503) 226-7588



VIEW OF PLANT AND OFFICE BUILDING

PROFILE

Pacific Machinery & Tool Steel Co. has played a vital role in the growth of the West since its formation in 1912 in Portland, Oregon. As industry has expanded, Pacific has continually pursued new and better ways to serve the needs of specialty steel users. Our commitment is to provide customers with the best specialty steels and quality workmanship, supported by skilled and knowledgeable personnel. This distinguishes Pacific as the **leading specialty metal service center in the West.**

Founded in 1912 by the late O.J. Ulrich, Pacific was originally an agency for a Chicago tool steel mill. The company maintained a small inventory of tool steel in its 25 x 50 foot space in downtown Portland, Oregon. Bars of tool steel, up to three inches in diameter, were shipped from Chicago by rail, then hack-sawed by hand for sale in small pieces to local machine shops and saw mills.

Over the years, as the wood products industry became more mechanized, other grades of specialty metal were added. At the time, these grades were known as "machinery steels," to distinguish them from other steels used in structural applications. Thus, the company's name—**Pacific Machinery & Tool Steel Company.**

Since those early days, Pacific has expanded to serve thousands of customers in the Western United States, from one-person machine shops to multimillion-dollar manufacturers. The company has moved three times in the Portland area and now does business from the Guilds Lake industrial district in Northwest Portland. Within its 86,000 square foot service center, **Pacific carries the largest and most diversified stock of specialty steels in the West.**

Pacific's marketing area includes Oregon, Washington, Idaho, California, Alaska, British Columbia, Alberta, Montana, Utah and Nevada. The company serves many different industries, including aerospace, agriculture, construction, electronics, food processing, foundry, hydraulic manufacturing and repair, machine shops, boat and shipbuilding and repair, metals processing, mining, materials handling, original equipment manufacturers, repair shops, transportation and wood products.

Our success in meeting customer needs reflects a unique operating philosophy. We emphasize **Total Quality Service** through processing, delivery and technical support. Our experienced and dedicated staff of professionals has the sincere interest to be of service to you.

"Horizons of opportunity" exist in this changing world. The Pacific Northwest and Pacific Machinery & Tool Steel Co. will continue to adapt to these changes for growth and success into the 21st century.

TERMS AND CONDITIONS OF SALE

For the mutual protection of our customers, hereinafter called the Buyer, and Pacific Machinery and Tool Steel Co., hereinafter called the Seller, the following terms and conditions are made a part of every sale with Pacific Machinery and Tool Steel Company. The Buyer's acceptance of all or any part of the goods described on the Seller's Sales Order shall constitute the Buyer's agreement to the Terms and Conditions contained herein and supersedes all previous agreements. The Terms and Conditions stated herein shall take precedence over any other Terms and Conditions and no contrary, additional or different Terms and Conditions shall be binding on the Seller unless accepted by the Seller in writing.

1. **PRICES.** Prices as quoted by Seller are subject to change without notice. Seller's prices in effect at the time of shipment will govern at Seller's options.

2. **DELIVERY.** Seller will make every effort to maintain delivery dates; however, Seller shall not be liable for deliveries later than promised regardless of cause or for any damages suffered by the Buyer by reason of such late deliveries. In the event of delay or hindrance by public authority, existence of war, shortage of materials, fires, labor difficulties, accidents, delays in manufacture or transportation, acts of God, embargoes or any other causes beyond Seller's control. Seller shall have the right, at its option, to cancel the order, or any part thereof, without any resulting liability.

3. **TRANSPORTATION.** Prices as quoted for goods and services are Net F.O.B., Seller's warehouse, unless otherwise stated. The best judgement of the Seller will be used in routing shipments unless detailed instructions are given by Buyer. Upon delivery of goods by Seller to the carrier or to Buyer, all risk of loss is upon the Buyer, and Seller shall have no liability for failures in shipment or delivery.

4. **CLAIMS.** Claims for defective goods, shortages, delays, or for any other cause, shall be deemed waived and released by the Buyer, unless made in writing within ten days after arrival of the goods.

5. **WARRANTY.** SELLER WARRANTS ONLY THAT THESE GOODS ARE FREE FROM DEFECTS OF MATERIAL OR WORKMANSHIP. THIS WARRANTY IS EXPRESSLY MADE IN LIEU OF ANY AND ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING THE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR ANY PARTICULAR PURPOSE. CLAIMS, WARRANTY OR OTHERWISE, NOT MADE WITHIN TEN DAYS OF DELIVERY ARE INVALID. SELLER'S SOLE LIABILITY FOR WARRANTY CLAIMS OR ANY OTHER CLAIMS RESPECTING THESE GOODS, WHETHER IN CONTRACT, TORT, OR OTHERWISE, SHALL BE TO REPLACE, ALLOW CREDIT, OR REPAY THE PRICE OF GOODS ONLY AS SELLER CHOOSES, UPON PROMPT RETURN OF THE GOODS TO SELLER, AND THIS SHALL BE BUYER'S SOLE REMEDY. **SELLER SHALL NOT BE LIABLE FOR INJURIES TO PERSONS OR PROPERTY OR FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES OR COMMERCIAL LOSSES NOR FOR ANY OTHER LOSS OR DAMAGE ATTRIBUTABLE IN ANY WAY DIRECTLY OR INDIRECTLY TO THESE GOODS OR THE SELLER'S ACTIONS OR INACTIONS WITH RESPECT THERETO.** NO WAIVER ALTERATION OR MODIFICATION OF THE FOREGOING CONDITIONS SHALL BE VALID UNLESS MADE IN WRITING AND SIGNED BY AN EXECUTIVE OFFICER OF SELLER. UPON DELIVERY OF GOODS TO CARRIER OR BUYER ALL RISK OF LOSS IS UPON BUYER.

BUYER AGREES EFFECTIVELY TO INCLUDE THESE WARRANTY AND LIABILITY LIMITATIONS AND EXCLUSIONS IN ANY SUBSEQUENT DISPOSITION, USAGE, OR EMPLOYMENT OF THE GOODS HEREIN.

6. **SPECIAL ORDERS.** If any goods are sold by the Seller to meet the Buyer's particular specifications or requirements and is not part of the Seller's standard line offered to the trade in the usual course of the Seller's business, the Buyer agrees to accept standard trade tolerances, variations in respect to dimensions, weight, straightness, surface condition, composition, mechanical properties, over and under shipments as allowed by published standards in lieu of any specific agreements otherwise agreed to in writing between Buyer and Seller and which are acceptable to the third party from which Seller has obtained the goods. Special orders are not subject to cancellation or return without payment of Seller's cost.

7. **INDEMNITY.** The Buyer agrees to defend, protect, and save harmless the Seller against all suits at law or in equity and from all damages, claims, and demands for actual or alleged infringement of any United States or foreign patent and to defend any suit or actions which may be brought against the Seller for any alleged infringement because of the sale of the goods covered thereby.

TERMS AND CONDITIONS OF SALE — Continued

8. **GOODS AND SERVICES.** Goods and services furnished by the Seller are to be within the limits and of the sizes published by the Seller and subject to the Seller's standard tolerance for variations.

9. **CREDIT.** Performance by Seller is subject to the Buyer furnishing evidence of financial standing. If in Seller's judgment reasonable doubt exists as to the Buyer's sound financial standing, or if any portion of account is past due in payment, the Seller reserves the right, without liability and prejudice to Seller, to suspend current or further shipments or to require full or partial payment in advance until Seller has adequate assurance of Buyer's payment.

10. **TERMS OF PAYMENT.** Subject to the provisions of credit approval above, Buyer shall pay in accord with the terms as stated on the face hereof. Cash discount, if any, is 1% 10th/25th Net 30 Days.

Invoice Date	**Discount Payment Due**
1st through 15th	on or before 25th same month
16th through 31st	on or before 10th of following month

Invoices not discounted, due net 30 days from date of invoice.

In order to take advantage of the discount, Buyer must have payment **postmarked** no later than the last day of the discount period. **Discounts are not applicable to taxes, transportation or other services.**

11. **PAYMENT.** All payments are to be made to:

PACIFIC MACHINERY & TOOL STEEL COMPANY
3445 N.W. Luzon Street
Portland, OR 97210-1694

Payment should include remittance advice designating invoices and other charges being paid. If deductions are made, the discount amount, credit memo number, or customer debit memo number should also be shown. If remittance advice is not provided, payments will be applied against the oldest invoices on the account.

12. **INVOICES AND STATEMENTS.** The invoice is the Seller's receivable document and is mailed immediately after shipment. Statements will only be provided upon request or for reconciliation of account transactions.

13. **PAST DUE ACCOUNTS.** Payment of invoices is considered past due if payment is not made within 30 days of the date of the invoice. Any past due balance may result in a change of credit terms. Service charges of 2% will be added to all past due account balances.

14. **MINIMUM CHARGE.** An applicable minimum charge will be made on all orders.

15. **LAWS GOVERNING.** All orders will be governed by the laws of the State of Oregon. Buyer agrees to submit itself to the jurisdiction of the courts of Multnomah County, Oregon where the Seller has its executive office.

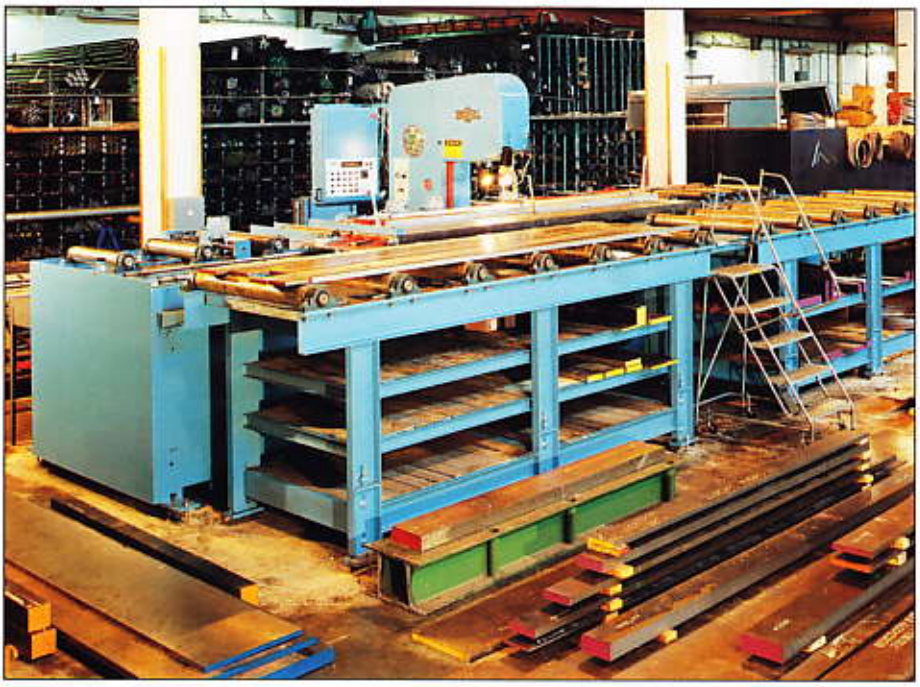
16. **TAXES.** In addition to the prices provided for herein, the Buyer shall pay all Federal, State, County and Municipal taxes imposed by reason of any sale. The Buyer is responsible to provide Seller with tax exemption certificates, if applicable. Discounts are not applicable.

17. **CHANGES OR CANCELLATION.** An order once placed with and accepted by Seller can be cancelled or changed only with Seller's consent and upon terms that will indemnify Seller against loss.

18. **EXECUTION.** The Buyer's Purchase Order may be executed and transmitted to Seller by facsimile if necessary or convenient and, when so executed and transmitted, shall be deemed an original.

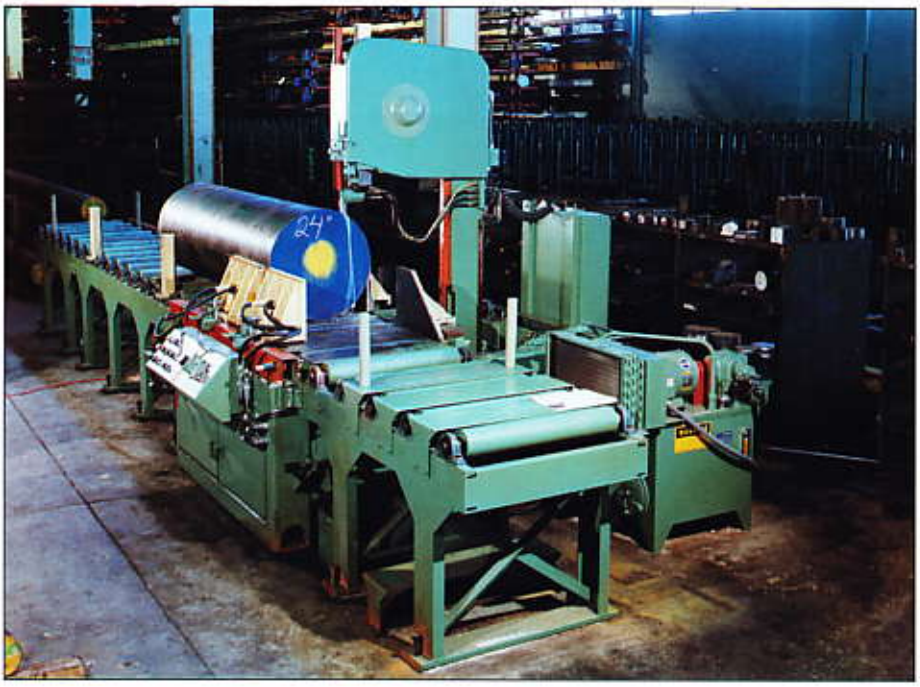
19. **REIMBURSEMENT AND ATTORNEY FEES.** In the event Buyer defaults in the performance of these Terms and Conditions of Sale, Buyer shall be liable to Seller for all loss, costs and expenses incurred by Seller by reason of the default including, without limitation, Seller's reasonable attorney's fees whether or not suit or action is instituted. If suit or action is filed to enforce any of these Terms and Conditions of Sale, Buyer promises to pay (1) Seller's reasonable attorney's fees to be fixed by the trial court and (2) if any appeal is taken from any decision of the trial court, such further sums as may be fixed by the appellate court.

20. **ENTIRE AGREEMENT.** The foregoing, shall constitute the complete and exclusive agreement between the parties, and it is expressly understood and agreed that no promises, provisions, terms, warranties, conditions, guaranties or obligations whatsoever, either expressed or implied other than as herein set forth or provided for shall be binding on either party.



SPECIAL SERVICES

Metal Cut to
Special Sizes to Meet
Your Requirements



PRODUCTION SAWING EQUIPMENT

QUANTITY	SAW DESCRIPTION	CAPACITY
1	Do-All C80 Automatic Band Saw	12" Round Solid or 12" x 12" Square
1	Do-All C305A Automatic Band Saw	12" Round Solid or 12" x 12" Square
1	Do-All C1212M Band Saw	12" Round Solid or 12" x 12" Square
1	Do-All C1213A Automatic Band Saw	12¾" Round Solid or 12" High x 13" Wide Rectangle
2	Do-All C1213 NC Controlled Band Saw	12¾" Round Solid or 12" High x 13" Wide Rectangle
1	Do-All C4100 NC Controlled Band Saw	16" Round Solid or 14" High x 16" Wide Rectangle
1	Do-All TF2525 Vertical Band Saw	25" Round Solid or 25" x 25" Square With Mitre Capability
1	Do-All 2608 NC Controlled Plate Saw	8" Thick x 24" Wide x 153" Length
1	Do-All/PM&TSCO 2618 Plate Saw	18" Thick x 25" Wide x 178" Length
1	Kasto BBS 460/1660 Block & Plate Automatic Bandsawing Machine	18" Thick x 65" Wide x 178" Length
1	WJ Savage C476 Wet Abrasive Saw Automatic	½" Round Minimum to 6" Round Solid

ADDITIONAL SERVICES

- Q/A Program
- Material Certification
- Material Safety Data Sheets
- Traceability
- Bar Coding Capability
- Technical Assistance
- Outside Processing
  - Machining
  - Grinding
  - Plating
  - Heat Treating
  - Honing

The West Coast's Leading Metal Service Center in Production Sawing Technology

SUGGESTIONS WHEN ORDERING

To assure quick and efficient execution of orders, it is desirable that complete specifications and information be given to our sales representatives. As a guide, we list below some of the details which should be used when transmitting orders.

ORDER DETAILS

Purchase Order Number.

Quantity; Bars or Pieces.

Size and shape. All dimensions of geometric shape required—diameter—thickness—width—length.* Gauges are preferably expressed in decimal thickness (i.e. .065") or with gauge number followed by name of gauge (i.e. No. 16 B.W.G., etc.). Tubing sizes should be expressed in outside diameter and wall or outside and inside diameters. Engineering drawing or sketch for parts showing finished dimensions.

Type, grade, or quality.

Finish. Surface condition (Hot Rolled, Cold Drawn, Ground, Polished, etc.).

Condition. In the case of tool and alloy steels, whether as rolled, annealed, heat treated, etc.

***Lengths.** Finished part lengths in order that nearest multiple lengths may be supplied with least waste to the user. Consideration should be given for cutting allowances.

Use or Application. When in doubt as to selection of proper metal, give purpose or function of finished part and how it is to be formed or manipulated.

COMPLETE ORDERS WILL INSURE ACCURACY AND EFFICIENCY

Trade Customs

All orders are accepted subject to inventory on hand, subject to prior sale.

Mill shipments are contingent upon mill conditions and carrier's schedule.

All sales are based on theoretical weight.

Prices are subject to adjustment to reflect prices in effect at the time of shipment.

Verbal orders for cut material are accepted at "customer's risk."

Material may be returned only after prior authorization and shipping instructions are obtained from Seller. All returns are subject to seller's terms and conditions.

All products shall be subject to standard industry specifications.

Machining allowance in size should be made for removing surface defects of cold drawn and hot rolled carbon, alloy and tool steels.

Our liability ceases when goods are transferred to transportation company in good order. Claims for loss or damage in transit should be placed with carrier. We will assist in settlement of such claims.

We suggest definite routing instructions should accompany all orders; otherwise, shipment will be made according to our best judgement.

All other Terms and Conditions of Sale will apply.

IMPORTANT NOTICE TO BUYERS

Federal Hazard Communications — Material Safety Data Sheets

Pacific Machinery & Tool Steel Company Hazard Communications Program has been designed to assist our customers in complying with the requirements of the Federal OSHA Hazard Communication Standard and other "Right-to-Know" regulations.

Data for Pacific's Material Safety Data Sheets are provided to us by usually reliable sources for use solely in health and safety educational training and not as material specifications.

Pacific makes no warranties, express or implied, including the **implied warranty of merchantability**, any implied warranty of fitness for a particular purpose or any implied warranties otherwise arising from course of contract, tort or otherwise. The conditions or methods of handling, storage, use and disposal of material are beyond the control and knowledge of Pacific, for which it assumes no responsibility, or liability for loss, damage or expense, for customer methods used. Material Safety Data Sheets (MSDS) for materials distributed by Pacific Machinery & Tool Steel Company are available upon request or if you have any questions concerning our MSDS program, please contact your representative or our office for assistance.

EMERGENCY SERVICE

Residential telephone numbers of our personnel, who will be glad to assist you in emergencies requiring service outside of our regular plant hours:

Your Sales Representative

OR

John Eichstadt ..... (503) 283-9513
Bob Esch ..... (503) 285-6540
Jim Long ..... (503) 655-3076
Ron Olsen ..... (503) 285-4905
Bill Pritchard ..... (503) 644-2623
Jerry Rich ..... (503) 631-7684
Pat Wall ..... (206) 696-4815

Regular Office and Plant Hours
8:00 a.m. to 5:00 p.m.
Monday through Friday

COLOR CODE

BAR ENDS PAINTED AS SHOWN IS OUR IDENTIFICATION OF GRADE

COLD FINISHED CARBON STEEL

1018 CD "Cold Rolled"	1045 Arrow-Ten® Ground & Polished	12L14+Se CD Selenium Modified Free Machining	STRESSPROOF® CD As Drawn Finish
1018 T&P Special Shafting Quality	1045 G&P Ring Gage Quality	1215 CD Screw Stock Quality	STRESSPROOF® Ground & Polished
1040/1045 T&P Special Shafting Quality	12L14 CD LA-LED®	SERIES 83™-420 CD Bismuth Modifed Free Machining	FATIGUE-PROOF® As Drawn Finish

HOT ROLLED CARBON STEEL

1018 Special Bar Quality	1045 Special & Commercial Quality	1060/70 Plow 1080/1095 Spring	1070/1090 High Carbon

COLD FINISHED ALLOY STEEL

ACRALLOY® HT SRD Ground & Polished	41L40 CD Annealed Leaded	86L20 CD Leaded	303 Stainless CD / CG / ST Free Machining
"e.t.d." 150® As Drawn Finish Ground & Polished	4130 CD Annealed Normalized	86L20 CD Ground & Polished	17-4 PH Stainless CG Condition H1075

HOT ROLLED ALLOY STEEL

4142 As Rolled Moly-Krome®	4142 Normalized Moly-Krome®	4150FM "Heat Treated" Resulfurized	5160 As Rolled Alloy Spring
4142 Annealed Moly-Krome®	4142 "Heat Treated" Moly-Krome®	4340 Annealed "Heat Treated"	8620 Carburizing Quality

CHROME PLATED STEEL

1045 S-CPO® .0005" Min. Chrome per side	1045 H-CPO® .001" Min. Chrome per side	1045/50 HS IHCP® 100 ksi Yield	STRESSPROOF® S-CPO®
1045/50 HS S-CPO® 100 ksi Yield	1045 HS H-CPO® 100 ksi Yield	1045/50 IHCP® Sizes over 4½" dia.	ACRALLOY® H-CPO®

ALLOY & CARBON PLATE

A 36 Structural As Rolled	1045 FM Carbon As Rolled Resulfurized	8620 Alloy As Rolled
1045 Carbon As Rolled	4140 Alloy Annealed, or Normalized & Tempered	A 514 ("T-1"®) Alloy "Heat Treated"

STEEL TUBING

Welded Mechanical	1026 DOM Mechanical	1026 DOM Mechanical SSID
1020 Welded Drive Line Quality	1026 DOM Mechanical Honed ID and Honed & Chromed ID	1026 Seamless Mechanical

TOOL & DIE STEEL

A 2 Annealed Air Hardening 5% Chrome	D 2 Annealed Air Hardening High Carbon/Chrome	O 6 Annealed Oil Hardening Graph-Mo®	Flat Ground Stock 01 & 06 A2 Low Carbon
A 6 Annealed Air Hardening Low Temperature	H 13 Annealed Air Hardening Hot Work	S 5 Annealed Oil Hardening Shock Resisting	Drill Rod W1 01, A2, D2 & S7
A 10 Annealed Air Hardening Graph-Air®	O 1 Annealed Oil Hardening	S 7 Annealed Air Hardening Shock Resisting	

COLOR CODE

COLD FINISHED BARS	PM&TS Co. COLOR CODE	PM&TS Co. GRADE CODE
CARBON GRADES:		
1018 Cold Drawn	Orange	200
1018 Turned & Polished	Orange w/ Black Stripe	202
1040/1045 Turned & Polished	Yellow w/ Green Stripe	212
1045 Ground & Polished, ARROW-TEN®	Green w/ Yellow Stripe	223
1045 Ring Gage Quality	Silver w/ Red Stripe	224
1137 Cold Drawn	Red w/ Black Stripe	232
1144 HD Cold Drawn	Copper w/ Black Stripe	235
1144 HD Ground & Polished	Copper w/ White Stripe	237
1215 Cold Drawn	Green w/ White Dot	270
12L14 Cold Drawn	Green	250
12L14+Se Cold Drawn	Brown	252
83™-420 & 1215Bi Cold Drawn	Pink	260
Super 1200® Cold Drawn	Turquoise	—
Fatigue-Proof® Cold Drawn	Blue	241
Stressproof® Cold Drawn	Copper	240
Stressproof® Ground & Polished	Copper w/ White Dot	243
A311 Thread Rolling Stock	Silver	246
ALLOY GRADES:		
4130 Annealed Cold Drawn	Blue w/ Red Dot	506
4130 Normalized Cold Drawn	Blue w/ White Cross	507
4130 As Drawn	Blue w/ Green Stripe	507
4140 Ground & Polished, Acralloy®	Half Orchid & Half Blue	503
4142 Annealed Cold Drawn	Orchid w/ Yellow Dot	508
41L40 Annealed Cold Drawn	Orchid	501
4150 Q&T Ground & Polished	Orchid & Blue w/ Yellow Stripe	520
86L20 Cold Drawn	Orchid w/ Orange Stripe	541
86L20 Ground & Polished	Orchid w/ Green Stripe	545
"e.t.d." 150® Cold Drawn	Yellow	511
"e.t.d." 150® Ground & Polished	Yellow w/ White Dot	513
STAINLESS GRADES:		
303 Cold Drawn	Red	570
303 Centerless Ground or Smooth Turned	Red	572
17-4PH Centerless Ground, Cond. H1075	Light Blue	582

COLOR CODE — Continued

COLD FINISHED BARS — Continued	PM&TS Co. COLOR CODE	PM&TS Co. GRADE CODE
CHROME PLATED SHAFTING:		
1045/1050 S-CPO®	Green w/ Black Stripe	225
1045/1050 S-CPO® HS	Half Green & Half Black	226
1045/1050 H-CPO®	Green w/ Red Stripe	227
1045/1050 H-CPO® HS	Half Green & Half Red	230
1045/1050 IHCP® HS & IHCP®	Half White & Half Black	228&229
Stressproof® S-CPO®	Half Copper & Half Black	245
Acralloy® S-CPO®	Half Orchid & Half Black	—
Acralloy® H-CPO®	Half Orchid & Half Red	505
Acralloy® IHCP®	Half Orchid & Half White	528
HOT FINISHED BARS		
CARBON GRADES:		
1018 Special Quality	Orange w/ White Cross	115
1045 Special & Commercial Quality	Yellow w/ Green Cross	120
1060/1070 Plow	Black	140
1070/1090 Electrite®	Red	150
1080/1095 Spring	White	160&165
ALLOY GRADES:		
4142 As Rolled	Orchid w/ White Stripe	410
4142 Annealed	Orchid w/ White Dot	412
4142 Normalized	Orchid w/ White Cross	411
4142 Quenched & Tempered	Half Orchid & Half White	413&415
4150FM Quenched & Tempered	Half Orchid & Half Yellow	423&425
4150 Quenched & Tempered	Orchid w/ Yellow Stripe	411
4340 Annealed	Blue w/ Yellow Dot	432
4340 Quenched & Tempered	Half Blue & Half Yellow	433
4340 Q&T to 325/370 HB	Half Blue & Half Green	434
5160 Spring	Orchid	440
8620 As Rolled	Orchid w/ Orange Cross	460&465
8640 As Rolled	Orchid w/ Red Cross	467
CAST IRON:		
Gray, Class 40	Green	192
Ductile, 65-45-12	Yellow	193
Ductile, 80-55-06	Light Blue	194
HOT FINISHED PLATES		
1045 As Rolled	Yellow	120
1045 Free Machining	Half Yellow & Half White	123
4140 Annealed	Orchid	400
8620 As Rolled	Half Orchid & Half Orange	460
A36 As Rolled	Green	—
A514 Quenched & Tempered	Red	470

COLOR CODE — Continued

TUBING	PM&TS Co. COLOR CODE	PM&TS Co. GRADE CODE
1010 HREW or CREW	Black	303
1020 HREW Drive Line	White	328
1026 DOM	Green	320
1026 Honed ID	Red	322
1026 DOM Special Smooth ID	Light Blue	321
1026 Seamless Cold Drawn	Black	300
1026 Seamless Hot Finished	Brown	301
Alloy Tubing	Orchid	601&602
Chrome-Plated-ID DOM	Red	325

TOOL & DIE STEELS

WATER HARDENING:

W1	Yellow	920

OIL HARDENING:

O1	Silver	820
O6	Silver w/ Black Stripe	830
S5	Light Blue	880

AIR HARDENING:

A2	White w/ Red Stripe	720
A6	White w/ Green Stripe	730
A10	Silver w/ Blue Stripe	740
D2	White	710
H13	Black w/ Yellow Stripe	760
S7	Yellow w/ Blue Stripe	780

DRILL ROD:

W1	Black	922,924&927
O1	Pink	822&824

NOTE: For drill rod other than W1 or O1 use the color code listed for the grade.

ZINCALOY® Bushing Stock (ZA®-12)	Blue	Z20&Z30
NON-STOCK ITEMS	Fluorescent Orange	*

PACIFIC'S TRUCK-TRANSPORT FLEET

INDEX

WEIGHT CALCULATIONS FOR THIS CATALOG

All weights listed are theoretical and have been calculated using industry accepted values for density.

MATERIAL	DENSITY
Steel	0.2836 $^{lb}/_{in^3}$
Cast Iron	0.2600 $^{lb}/_{in^3}$
Zincaloy®	0.2180 $^{lb}/_{in^3}$

Calculations have been carried to four decimal places and rounded to final significant figures. Theoretical size for weight calculations are determined as outlined below:

CARBON & ALLOY STEEL

COLD FINISHED BARS — Theoretical size is based on nominal dimensions.

HOT FINISHED BARS — Theoretical size is based on nominal dimensions plus the average of any oversize tolerance as follows:

Rounds

thru 2" dia — nominal

>2" to 3¼" dia — nominal plus average AISI tolerance

3¼" thru 11" dia — nominal plus average RTOS tolerance

over 11" dia — nominal plus ¼"

Squares & Hexagons

thru 2" — nominal

over 2" — nominal plus average AISI tolerance

Flats — nominal plus average AISI width tolerance

Round Edge Flats (Spring Steel) — nominal size with the round edge radius equal to 75% of nominal thickness

TUBING — Theoretical site is based on nominal OD and wall thickness

Honed Tubing — nominal OD and maximum honed ID

HOT FINISHED PLATE SE®-BARS (SAW EDGE) — theoretical size is based on nominal dimensions plus average thickness and width tolerances

CAST IRON

CONTINUOUS CAST BARS — theoretical size is based on nominal diameter plus average stock allowance

ZINCALOY® BAR STOCK

SOLID ROUNDS — theoretical size is based on nominal diameter plus finishing allowance

HOLLOW ROUNDS — theoretical size is based on nominal OD plus finishing allowance and nominal ID minus finishing allowance

TOOL STEEL

BARS & PLATE — theoretical size is based on nominal diameter or nominal width and thickness

SECTION INDEX
HOT FINISHED CARBON & ALLOY STEEL

CARBON STEEL BARS

ALLOY STEEL BARS

FORGINGS

PLATE & SE®-BARS (SAW EDGE)

TOLERANCES

ROUGH TURNED OVERSIZE HOT ROLLED ROUNDS

PACIFIC MACHINERY & TOOL STEEL CO. offers premium rough turned oversize hot rolled carbon and alloy steel round bars. These bars are centerless turned from oversize stock to meet standard AISI hot rolled diameter tolerances. Turning removes seams and decarburization normally found on regular hot rolled bar surfaces. It allows clean up at nominal diameter so that the next larger size is not required and significant weight savings can be realized. Additionally, these bars are calcium treated for improved machinability and extended tool life. They are vacuum degassed and ultrasonic tested for soundness. Grades stocked are 1018, 1045, 4142 annealed or quenched and tempered, 4150FM, 4340 annealed or quenched and tempered high strength and 8620.

The following table shows weight savings possible when machining PACIFIC's rough turned oversize instead of the next larger diameter standard hot rolled bar.

WEIGHT SAVINGS for SELECTED SIZES			
DIAMETER (INCHES)	AVE. WT. PER FT.		WEIGHT SAVINGS USING R.T.O.S.
	HOT ROLLED	ROUGH TURNED OVERSIZE	
3 1/2 3 3/4	38.21	33.46	4.75 lb/ft
4 4 1/4	48.99	43.90	5.09 lb/ft
4 1/2 4 3/4	61.30	55.40	5.90 lb/ft
5 5 1/4	74.77	68.58	6.19 lb/ft
5 1/2 5 3/4	90.30	82.79	7.51 lb/ft
6 6 1/4	106.51	99.64	6.87 lb/ft
6 1/2 6 3/4	124.62	116.62	8.00 lb/ft
7 7 1/4	143.54	134.95	8.59 lb/ft
7 1/2 7 3/4	163.79	154.61	9.18 lb/ft
8 8 1/4	185.38	175.61	9.77 lb/ft
8 1/2 9	221.04	198.01	23.03 lb/ft
9 9 1/2	246.01	221.68	24.33 lb/ft
9 1/2 10	274.01	246.69	27.32 lb/ft
10 10 1/2	301.75	273.12	28.62 lb/ft
NOTE: Straightness tolerances have not been considered in these examples.			

1018 SPECIAL QUALITY

AISI/SAE 1018 — Low Carbon

PACIFIC 1018 is the standard analysis for low carbon machinery steels and is best known for use in "cold rolled" bars. PACIFIC's hot rolled 1018 offers consistent machinability with good weldability. This special quality 1018 meets ASTM A576 special bar requirements and is vacuum degassed, calcium treated and ultrasonic tested for soundness. These bars are rough turned oversize to finish at nominal size for economical machining. This grade can be surface hardened by carburizing but does not respond to through hardening heat treatment.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S
.15/.20	.60/.90	.040 max	.050 max

TYPICAL PROPERTIES: Approximate—not for specification

Tensile, psi	Yield, psi	Elong.	Hardness	Machinability
65,000	42,000	35%	137HB	55%

PROCESSING TEMPERATURES: Typical

Forge: 2300°F max Normalize: 1625/1725°F Case Harden: 1500/1700°F

1018 CARBON STEEL ROUNDS

CONDITION	COLOR CODE
As Rolled	Orange with White Cross

STOCK SIZES — Rough Turned Oversize

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
3½	33.46	669.1	6½	116.6	2,332.5
4	43.90	877.9	7	135.0	2,669.0
4½	55.40	1,107.9	8	175.6	3,512.1
5	68.58	1,371.7	9	221.7	4,433.6
5½	82.79	1,655.8	10	273.1	5,462.4
6	99.64	1,992.7			

SEE PAGE A•21 FOR TOLERANCES

1045 SPECIAL & COMMERCIAL QUALITY CARBON STEEL

AISI/SAE 1045 — Medium Carbon

PACIFIC 1045is a medium carbon steel and therefore has higher strength than 1018. It is extensively used where the higher strength and toughness of alloy grades are not required. Commercial quality is stocked in smaller diameters. Sizes 3¼" through 11" diameter are special quality rough turned oversize bars which have been vacuum degassed, calcium treated and ultrasonic tested for soundness. Forged bars which are rough turned oversize are stocked in large diameter sizes 12" through 18". This medium carbon grade can be through hardened in small sections and can be surface hardened by flame or induction in virtually all diameters. Welding generally requires preheating in the 400°F range. (See WELDABILITY article page I•42.)

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S
.43/.50	.60/.90	.040 max	.050 max

TYPICAL PROPERTIES: Approximate—not for specification

Tensile, psi	Yield, psi	Elong.	Hardness	Machinability
95,000	58,000	23%	201HB	57%

PROCESSING TEMPERATURES: Typical

Forge: 2275°F max Normalize: 1550/1650°F Harden: 1500/1575°F

SEE PAGE H•7-10 FOR HEAT TREATING INFORMATION

ROUND BARS — See next page for stock sizes.

FLATS & SQUARES (Sawed from Plate)
See HOT ROLLED PLATE section page A•19.

1045 CARBON STEEL ROUNDS

CONDITION	COLOR CODE
As Rolled	Yellow with Green Cross

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
5/8	1.04	20.9	5 1/2	82.79	1,655.8
3/4	1.50	30.1	5 3/4	91.64	1,832.9
7/8	2.05	40.9	6	99.64	1,992.7
1	2.67	53.5	6 1/4	108.0	2,159.3
1 1/8	3.38	67.7	6 1/2	116.6	2,332.5
1 1/4	4.18	83.5	6 3/4	125.6	2,512.4
1 3/8	5.05	101.1	7	135.0	2,699.0
1 1/2	6.01	120.3	7 1/4	144.6	2,892.2
1 3/4	8.19	163.7	7 1/2	154.6	3,092.2
1 7/8	9.40	187.9	7 3/4	164.9	3,298.8
2	10.69	213.8	8	175.6	3,512.1
2 1/8	12.43	248.6	8 1/4	186.6	3,732.1
2 1/4	13.91	278.2	8 1/2	198.0	3,960.1
2 3/8	15.48	309.5	8 3/4	209.7	4,193.5
2 1/2	17.13	342.5	9	221.7	4,433.6
2 3/4	20.91	418.2	9 1/4	234.0	4,680.4
3	24.81	496.3	9 1/2	246.7	4,933.8
* 3 1/4	28.90	577.9	10	273.1	5,462.4
* 3 1/2	33.46	669.1	10 1/2	300.8	6,016.1
3 3/4	38.65	772.9	11	329.8	6,596.6
4	43.90	877.9	12	401.1	8,021.9
4 1/4	49.48	989.6	13	469.3	9,385.1
4 1/2	55.40	1,107.9	14	542.8	10,855.2
4 3/4	61.98	1,239.6	16	705.8	14,166.1
5	68.58	1,371.7	16 1/2	749.9	14,998.1
5 1/4	75.52	1,510.4	18	890.2	17,804.6

* 3 1/4 and 3 1/2 stocked in both Hot Rolled and Rough Turned Oversize.

SEE PAGE A•21 FOR TOLERANCES

NOTE 1: Hot Rolled — Stocked through 3 1/2" diameter.
NOTE 2: Rough Turned Oversize — Stocked 3 1/4" through 11" diameter.
NOTE 3: Press Forged and Rough Turned — Stocked 12" through 18" diameter.

1060/1070 PLOW STEEL

AISI/SAE 1060/1070

PACIFIC Plow Steel has higher carbon and therefore higher wear resistance than 1045. As the name implies this grade has been used extensively for agricultural applications. It can be forged and is weldable with adequate preheat (See WELDABILITY article page I•42). Different grades may be stocked within the 1060/1070 range depending on availability.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

	C	Mn	P	S
1060	.55/.65	.60/.90	.040 max	.050 max
1065	.60/.70	.60/.90	.040 max	.050 max
1070	.65/.75	.60/.90	.040 max	.050 max

TYPICAL PROPERTIES: Approximate—not for specification

Tensile, psi	Yield, psi	Elong.	Hardness
104,000	60,000	18%	229HB

PROCESSING TEMPERATURES: Typical

Forge: 2175°F max Normalize: 1625°F Harden: 1500/1550°F

1060/1070 PLOW STEEL FLATS & SQUARES

CONDITION	COLOR CODE
As Rolled	Black

STOCK SIZES

SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
1/4 x 1	0.85	17.1	1/2 x 2	3.40	68.1
1/4 x 1 1/4	1.06	21.3	1/2 x 4	6.81	136.1
1/4 x 1 1/2	1.28	25.5	1/2 x 6	10.21	204.2
1/4 x 3	2.55	51.0	5/8 x 1 1/2	3.19	63.8
3/8 x 1 1/2	1.91	38.3	5/8 x 2	4.25	85.1
3/8 x 2	2.55	51.0	1 x 4	13.61	272.3
3/8 x 2 1/2	3.19	63.8	2 1/4 sq	17.23	344.6

SEE PAGE A•22 FOR TOLERANCES

1070/1095 CARBON SPRING STEEL

AISI/SAE 1070/1095 — High Carbon

PACIFIC high carbon steel is often used where high hardness and/or good wear resistance is needed. This includes springs, forged tools, agricultural applications, etc. The spring steel sizes are normally stocked in the 1080/1095 analysis range, while the hexagon stock is usually in the lower carbon 1070/1080 range. Heat treatment is necessary to achieve spring temper and best wear properties.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

	C	Mn	P	S
1075	.70/.80	.40/.70	.040 max	.050 max
1084	.80/.93	.60/.90	.040 max	.050 max
1095	.90/1.03	.30/.50	.040 max	.050 max

PROCESSING TEMPERATURES: Typical

Forge: 2100°F max Anneal: 1450/1525°F Harden: 1450/1500°F

1070/1095 HIGH CARBON SQUARES, HEXAGONS and FLATS

SHAPE	CONDITION	COLOR CODE
Hex	As Rolled	Red
Flat, Rd. & Sq.	As Rolled	White

STOCK SIZES

SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
3/4 sq	1.91	38.3	1/8 x 3/4	0.32	6.4
7/8 sq	2.61	52.1	1/8 x 1	0.43	8.5
1 sq	3.40	68.1	1/8 x 1 1/4	0.53	10.6
3/4 hex	1.66	33.2	1/8 x 1 1/2	0.64	12.8
7/8 hex	2.26	45.1	1/8 x 2	0.85	17.0
1 hex	2.95	58.9	1/8 x 2 1/2	1.08	21.5
1 1/8 hex	3.76	75.1	3/16 x 1	0.64	12.8
1 1/4 hex	4.63	92.7	3/16 x 1 1/4	0.80	16.0
			3/16 x 1 1/2	0.96	19.1
			1/4 x 1	0.85	17.0
			1/4 x 3	2.58	51.6
			3/8 x 2	2.55	51.0

See page A•16 for 5160 Alloy Spring Steel and Section C for cold finished Spring Steels.

SEE PAGE A•21-22 FOR TOLERANCES

MOLY-KROME® ALLOY STEEL
AISI/SAE 4142

PACIFIC MOLY-KROME® is available in four conditions: heat treated (quenched and tempered), annealed, normalized and as rolled. It is a widely used medium carbon alloy steel which is relatively inexpensive considering the hardenability it offers. AISI/SAE 4142 has been a standard of the industry for many moderate to severe service applications. It is readily machined, easily forged and exhibits good response to heat treating by furnace, flame and induction hardening.MOLY-KROME® can also be nitrided and is weldable using proper procedures (See WELDABILITY OF STEELS page I•43-45). Both annealed and heat treated (Q & T) rounds in sizes 3¼" through 11" are rough turned oversize, calcium treated, vacuum degassed and ultrasonic tested. Flat and square bars are either hot rolled to size or saw cut to width from hot rolled 4140 plate.

MOLY-KROME® HEAT TREATED: This grade is quenched and tempered at the mill to a strong, tough yet machinable condition and usually requires no further heat treatment after finish machining (unless surface hardened by flame or induction). Mechanical properties are tested and certified by the supplying mill to ASTM standards A193, grade B7 and A434, class BC. (See 4340 Heat Treated for higher strength ASTM A434, Class BD.)

MINIMUM MECHANICAL PROPERTIES

DIAMETER	TENSILE STRENGTH		YIELD STRENGTH		ELONGATION	
(INCHES)	A193, B7	A434,BC	A193, B7	A434,BC	A193, B7	A434,BC
thru 1½	125,000	130,000	105,000	110,000	16%	16%
over 1½ thru 2½	125,000	125,000	105,000	105,000	16%	16%
over 2½ thru 4	115,000	115,000	95,000	95,000	16%	16%
over 4 thru 7	110,000	110,000	75,000	85,000	18%	16%
over 7 thru 9½	N.A.	105,000	N.A.	80,000	N.A.	15%

All values are minimum requirements and strengths are given in pounds per square inch.

Hardness is approximately 28 HRC mean for diameters under 9½", and those over 9½" are ordered to a range of 269/321 HB (approximately 28/34 HRC). All bars through 6½" diameter are stress relieved after mechanical straightening.

MOLY-KROME ANNEALED®: Pearlitic annealing produces the best machinability, the lowest hardness, the most stress free condition and the lowest strength for MOLY-KROME®. Parts made with the annealed condition generally require heat treating prior to being placed in service. Therefore, Annealed MOLY-KROME® is usually considered for parts requiring higher mechanical properties than offered by the heat treated grade; parts are machined and then heat treated. Heat treating data is given on page H•172-173.

MOLY-KROME® ALLOY STEEL — Continued
AISI/SAE 4142

MOLY-KROME® NORMALIZED: Heating above the critical temperature and cooling in still air produces the normalized structure. This refines the as rolled grain structure and gives mechanical properties between the quenched and tempered and the annealed conditions. This has been the traditional condition for stocking hot rolled flats and squares. Normalized MOLY-KROME® can be heat treated to higher strength/hardness levels by quenching and tempering.

MOLY-KROME® AS ROLLED (NATURAL): These bars have no controlled thermal treatment after hot rolling. Consequently machinability is inconsistent, as are mechanical properties. This condition should be considered for hot forging applications where further heat treating will be required for finished parts.

TYPICAL APPLICATIONS:

Arbors	Crank Shafts	Load Arms	Shackles
Axles	Cutter Heads	Mandrels	Shafts
Bolts	Gears	Molds	Tools
Boring Bars	Hammers	Nuts	Spindles
Cams	Hooks	Racks	Studs
Clevises	Jigs	Rollers	U-Bolts

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S	Cr	Mo
.40/.45	.75/1.10	.035 max	.040 max	.80/1.10	.15/.25

TYPICAL PROPERTIES: Approximate—not for specification

Condition	Tensile, psi	Yield, psi	Hardness	Mach.
Annealed	95,000	60,000	197HB	57%
Normalized*	115,000/145,000	70,000/100,000	241/302HB	55%
Heat Treated (Q & T)	130,000	105,000	269HB	55%

* Normalized properties depend on section size. Ranges are for ½" through 4".

PROCESSING TEMPERATURES: Typical

Forge: 2200°F max Normalize: 1550/1650°F Anneal: 1475/1585°F
Harden: 1525/1575°F Temper: 750/1275°F and 350/450°F

SEE PAGE H•172-173 FOR HEAT TREATING INFORMATION

41L40 is the free machining version of MOLY-KROME®. It is offered in the annealed cold drawn condition. See page B•18 of the COLD DRAWN SECTION.

MOLY-KROME® ALLOY STEEL ROUNDS
AISI/SAE 4142

CONDITION	COLOR CODE
Heat Treated (Q & T)	Half Orchid & Half White
Annealed	Orchid with White Dot
As Rolled	Orchid with White Stripe

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	HEAT TREATED	ANNEALED	AS ROLLED
1/2	0.67	13.4	—	HR	—
9/16	0.85	16.9	—	HR	—
5/8	1.04	20.9	HR	HR	—
11/16	1.26	25.3	—	HR	—
3/4	1.50	30.1	HR	HR	HR
13/16	1.77	35.3	—	HR	—
7/8	2.05	40.9	HR	HR	—
15/16	2.35	47.0	—	HR	—
1	2.67	53.5	HR	HR	HR
1 1/8	3.38	67.7	HR	HR	HR
1 3/16	3.77	75.4	HR	—	—
1 1/4	4.18	83.5	HR	HR	HR
1 3/8	5.05	101.1	HR	HR	HR
1 1/2	6.01	120.3	HR	HR	HR
1 5/8	7.06	141.2	HR	HR	HR
1 3/4	8.19	163.7	HR	HR	HR
1 7/8	9.40	187.9	HR	HR	HR
2	10.69	213.8	HR	HR	HR
2 1/4	13.91	278.2	HR	HR	HR
2 3/8	15.48	309.5	HR	HR	—
2 1/2	17.13	342.5	HR	HR	HR
2 5/8	19.08	381.6	HR	—	—
2 3/4	20.91	418.2	HR	HR	HR
3	24.81	496.3	HR	HR	HR
3 1/4	28.90	577.9	RTOS	RTOS	—
3 1/2	33.46	669.1	RTOS	RTOS	—
3 5/8	36.15	723.0	RTOS	—	—
3 3/4	38.65	772.9	RTOS	RTOS	—
4	43.90	877.9	RTOS	RTOS	—

Continued on next page

SEE PAGE A•21FOR TOLERANCES

NOTE 1: Hot Rolled (HR)
NOTE 2: Rough Turned Oversize (RTOS)

MOLY-KROME® ALLOY STEEL ROUNDS — Continued
AISI/SAE 4142

CONDITION	COLOR CODE
Heat Treated (Q & T)	Half Orchid & Half White
Annealed	Orchid with White Dot

STOCK SIZES				
DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	HEAT TREATED	ANNEALED
4	43.90	877.9	RTOS	RTOS
4 1/4	49.48	989.6	RTOS	RTOS
4 1/2	55.40	1,107.9	RTOS	RTOS
4 3/4	61.98	1,239.6	RTOS	RTOS
5	68.58	1,371.7	RTOS	RTOS
5 1/4	75.52	1,510.4	RTOS	RTOS
5 1/2	82.79	1,655.8	RTOS	RTOS
5 3/4	91.64	1,832.9	RTOS	RTOS
6	99.64	1,992.7	RTOS	RTOS
6 1/4	108.0	2,159.3	RTOS	RTOS
6 1/2	116.6	2,332.5	RTOS	RTOS
6 3/4	125.6	2,512.4	RTOS	RTOS
7	135.0	2,699.0	RTOS	RTOS
7 1/4	144.6	2,892.2	RTOS	RTOS
7 1/2	154.6	3,092.2	RTOS	RTOS
7 3/4	164.9	3,298.8	RTOS	RTOS
8	175.6	3,512.1	RTOS	RTOS
8 1/2	198.0	3,960.1	RTOS	RTOS
9	221.7	4,433.6	RTOS	RTOS
9 1/2	246.7	4,933.8	RTOS	RTOS
10	273.1	5,462.4	RTOS	RTOS
11	329.8	6,596.6	RTOS	—
12	401.1	8,021.9	PF	PF
13	469.3	9,385.1	PF	—
14	542.8	10,855.2	PF	PF
16	705.8	14,166.1	PF	—
18	890.2	17,804.6	PF	—

SEE PAGE A•21 FOR TOLERANCES

NOTE 1: Rough Turned Oversize (RTOS)
NOTE 2: Press Forged and Rough Turned (PF)

MOLY-KROME® ALLOY STEEL FLATS, SQUARES & HEXAGONS

AISI/SAE 4142

SHAPE	CONDITION	COLOR CODE
Flats & Squares	Normalized	Orchid with White Cross
Hexagons	Annealed	Orchid with White Dot

STOCK SIZES — FLATS & SQUARES

SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
1/2 x 4	6.86	137.2	1 1/2 sq	7.66	153.1
3/4 x 2	5.10	102.1	1 1/2 x 2	10.21	204.2
3/4 x 2 1/2	6.46	129.2	1 1/2 x 3	15.47	309.5
1 sq	3.40	68.0	1 1/2 x 4	20.58	411.6
1 x 2	6.81	136.1	1 1/2 x 5	25.68	513.7
1 x 3	10.32	206.3	1 1/2 x 6	30.79	615.8
1 x 4	13.72	274.4	2 sq	13.83	276.5
1 x 5	17.12	342.5	2 x 3	20.63	412.6
1 x 6	20.53	410.5	2 x 4	27.44	548.8
1 1/8 sq	4.31	86.1	2 x 6	41.05	821.0
1 1/4 sq	5.32	106.4	2 1/4 sq	17.71	354.2
1 1/4 x 2 1/2	10.77	215.4	2 1/2 sq	21.81	436.1
1 1/4 x 3	12.90	257.9	2 1/2 x 6	51.31	1,026.3
1 1/4 x 4	17.14	343.0	3 sq	31.11	622.2
1 1/4 x 5	21.40	428.1	3 x 5	51.37	1,027.4
1 1/4 x 6	25.66	513.1	3 x 6	61.58	1,231.5
1 1/4 x 7	29.91	598.2	3 1/2 sq	42.81	856.3
1 1/2 sq	7.66	153.1	4 sq	55.31	1,106.1

SEE: HOT ROLLED PLATE section for saw edge 4140 annealed/N&T flat and square bars.

STOCK SIZES — HEXAGONS

SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
1	2.95	58.9	1 7/8	10.45	209.0
1 1/8	3.76	75.1	2	11.88	237.6
1 1/4	4.63	92.7	2 1/4	15.13	302.6
1 3/8	5.60	112.1	2 3/8	16.84	336.9
1 1/2	6.67	133.3	2 1/2	18.65	373.0
1 5/8	7.86	157.1	2 3/4	22.67	453.4
1 3/4	9.11	182.1	3	26.94	538.8

SEE PAGE A•21-23 FOR TOLERANCES

FORGINGS

AISI, ASTM & SAE Grades

Forgings are available in virtually any grade of carbon or alloy steel, stainless steel or tool steel. They can be smooth forged or rough machined and are available in all thermal conditions. Contact the Pacific Machinery & Tool Steel sales department for more information, or better yet, send us your drawing.

AIRCRAFT QUALITY STEEL

AMS, MIL & FED Specs

Aircraft quality grades are not stocked but are generally available on short notice. Please call or fax your inquiry.

SPECIALTY ITEMS

Non-Stock Steel & Non-Ferrous Metals

Pacific can locate and supply many hard to find items for you. Our sales and purchasing departments have developed an extensive list of specialty suppliers. Grades and types we source for customers include:

- STAINLESS STEELS
- ALUMINUM
- STEEL SHEET & COIL
- TITANIUM ALLOYS
- STEEL PIPE
- SUPER ALLOYS
- COPPER, BRONZE & BRASS
- NICKEL ALLOYS
- STRUCTURAL STEEL
- REFRACTORY ALLOYS

REQUEST OUR PRODUCT BROCHURE ON HOT FINISHED CARBON & ALLOY STEEL BARS.

4150FM ALLOY STEEL

AISI/SAE 4150 Modified — Resulfurized, Quenched & Tempered

PACIFIC 4150FM is a high strength chromium-molybdenum alloy which is readily machined in the heat treated condition. The controlled addition of sulfur gives 4150FM its unique free machining characteristics. Also in sizes 3¼" through 11" diameters it is calcium treated for additional ease of machining and extended tool life. These sizes are also rough turned oversize to clean up at nominal size. This saves the expense of machining the next larger size, as required with most hot rolled bars. 4150FM is not as weldable as 4142 because of the higher carbon content. However, it is weldable with proper procedures (See WELDABILITY OF STEELS, page I•43-45). It can also be induction hardened. Sizes through 6½" diameter are stress relieved after machine straightening.

TYPICAL APPLICATIONS:

Arbors	Crusher Shafts	Pins
Axles	Cutter Heads	Shafts
Boring Bars	Mandrels	Spindles

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S	Cr	Mo
.48/.53	.75/1.30	.035 max	.06/.10	.70/1.10	.15/.25

TYPICAL PROPERTIES: Approximate—not for specification

Diameter	Tensile, psi	Yield, psi	Elong.	Hardness	Machinability
2"	146,000	124,000	18%	302HB	60%
4"	143,000	117,000	16%	302HB	60%
6"	140,000	110,000	16%	293HB	60%
8"	136,000	102,000	16%	293HB	60%

PROCESSING TEMPERATURES: Typical

Forge: 2200°F max Normalize: 1525/1625°F Anneal: 1450/1550°F

Harden: 1500/1575°F max Temper: 750/1275°F and 350/450°F

SEE PAGE H•23-24 FOR HEAT TREATING INFORMATION

FOR QUALITY HOT FINISHED CARBON & ALLOY STEEL BARS INSIST ON PACIFIC PRODUCTS.

4150FM ALLOY STEEL ROUNDS

AISI/SAE 4150 Modified — Resulfurized, Quenched & Tempered

CONDITION	COLOR CODE
Heat Treated (Q & T)	Half Orchid & Half Yellow

STOCK SIZES					
DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
1/2	0.67	13.4	4 1/2	55.40	1,107.9
5/8	1.04	20.9	4 3/4	61.98	1,239.6
3/4	1.50	30.1	5	68.58	1,371.7
7/8	2.05	40.9	5 1/4	75.52	1,510.4
1	2.67	53.5	5 1/2	82.79	1,655.8
1 1/8	3.38	67.7	5 3/4	91.64	1,832.9
1 1/4	4.18	83.5	6	99.64	1,992.7
1 3/8	5.05	101.1	6 1/4	108.0	2,159.3
1 1/2	6.01	120.3	6 1/2	116.6	2,332.5
1 5/8	7.06	141.2	6 3/4	125.6	2,512.4
1 3/4	8.19	163.7	7	135.0	2,699.0
2	10.69	213.8	7 1/4	144.6	2,892.2
2 1/8	12.25	245.0	7 1/2	154.6	3,092.2
2 1/4	13.74	274.4	7 3/4	164.9	3,298.8
2 1/2	16.91	338.3	8	175.6	3,512.1
2 5/8	19.08	381.6	8 1/4	186.6	3,732.1
2 3/4	20.91	418.2	8 1/2	198.0	3,960.1
3	24.81	496.3	9	221.7	4,433.6
3 1/4	28.90	577.9	9 1/	246.7	4,933.8
3 1/2	33.46	669.1	10	273.1	5,462.4
3 5/8	36.15	723.0	11	329.8	6,596.6
3 3/4	38.65	772.9	12	401.1	8,021.9
4	43.90	877.9	13	469.3	9,385.1
4 1/4	49.48	989.6			

SEE PAGE A•21 FOR TOLERANCES

NOTE 1: Hot Rolled bars are stocked through 3" diameter.
NOTE 2: Rough Turned Oversize bars are stocked in 3 1/4" through 11" diameters.
NOTE 3: Press Forged bars are stocked in diameters 12" and over.

4340 ALLOY STEEL ROUNDS

AISI/SAE 4340 — Commercial Quality

PACIFIC 4340 is available in two conditions: heat treated (quenched and tempered) to high strength or annealed for ease of machining and subsequent heat treatment. It is a nickel-chromium-molybdenum medium carbon alloy steel with deep hardenability. It can be through hardened in large sections. When properly hardened, 4340 exhibits a good combination of strength, ductility and toughness; this is the material to which other ultra-strength steels are compared. PACIFIC 4340 Heat Treated bars are hardened to 285/331 HB and meet ASTM A 434, Class BD:

ASTM A 434, CLASS BD

DIAMETER	TENSILE STRENGTH	YIELD STRENGTH	ELONGATION
over 2 1/2" thru 4"	140,000 psi	110,000 psi	14 %
over 4" thru 7"	135,000 psi	105,000 psi	14 %
over 7" thru 9 1/2"	130,000 psi	100,000 psi	14 %

NOTE: All values listed are minimum requirements.

4340 is weldable but only with proper precautions; because of its high hardenability, it requires both preheat and postheat in virtually all welding applications (See WELDABILITY OF STEELS, page I•43-45). It can be induction hardened or nitrided after quenching and tempering.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S	Ni	Cr	Mo
.38/.43	.60/.80	.035 max	.040 max	1.65/2.00	.70/.90	.20/.30

PROCESSING TEMPERATURES: Typical

Forge: 2200°F max Normalize: 1550/1650°F Anneal: 1475/1575°F
Harden: 1475/1550°F Temper: 400/1200°F

SEE PAGE H•25-26 FOR HEAT TREATING INFORMATION

4340 ALLOY STEEL ROUNDS

CONDITION	COLOR CODE
Annealed	Blue with Yellow Dot
Heat Treated (Q&T)	Half Blue & Half Yellow

STOCK SIZES

DIAMETER (INCHES)	CONDITION ANN.	CONDITION H.T.	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	DIAMETER (INCHES)	CONDITION ANN.	CONDITION H.T.	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
1 1/2	X		6.01	120.3	4 3/4	X		61.98	1,239.6
1 3/4	X		8.19	163.7	5	X	X	68.58	1,371.7
2	X		10.69	213.8	5 1/2	X		82.79	1,655.8
2 1/4	X		13.74	274.4	5 3/4	X		91.64	1,832.9
2 1/2	X		17.13	342.5	6	X	X	99.64	1,992.7
2 3/4	X		20.91	418.2	6 1/2	X	X	116.62	2,332.5
3	X		24.81	496.3	7	X	X	134.95	2,699.0
3 1/4	X		28.90	577.9	7 1/2	X		154.61	3,092.2
3 1/2	X		33.46	669.1	8	X	X	175.61	3,512.1
3 5/8		X	36.15	723.0	8 1/2		X	198.01	3,960.1
3 3/4	X		38.65	772.9	9	X	X	221.68	4,433.6
4	X	X	43.90	877.9	9 1/2		X	246.69	4,933.8
4 1/4	X		49.48	989.6	10	X	X	273.12	5,462.4
4 1/2	X		55.40	1,107.9	17 1/2	X		842.12	16,842.4

SEE PAGE A•21 FOR TOLERANCES

NOTE 1: Hot Rolled sizes are stocked through 3" diameter.
NOTE 2: Rough Turned Oversize bars are over 3" diameter.

5160 ALLOY SPRING STEEL

AISI/SAE 5160 As Rolled — Chrome Alloy

PACIFIC 5160 CHROME ALLOY SPRING STEEL is stocked in round edge flat bars. This grade is used where good wear properties are needed as well as for leaf springs. It is sometimes used in the as rolled condition but requires heat treating to achieve uniform hardness and a proper spring temper.

TYPICAL APPLICATIONS:

Chopping Blades	Scrapers	Tracks
Froes	Springs	Wear Surfaces

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S	Cr
.56/.64	.75/1.00	.035 max	.040 max	.70/.90

PROCESSING TEMPERATURES: Typical

Forge: 2200°F max Normalize: 1550/1650°F Anneal: 1450/1550°F
Harden: 1475/1550°F Temper: 800/1000°F

SEE PAGE H•27-28 FOR HEAT TREATING INFORMATION

5160 ALLOY STEEL ROUND EDGE FLATS

CONDITION	COLOR CODE
As Rolled	Orchid

STOCK SIZES

SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
.214 x 2	1.44	28.76	.360 x 1 3/4	2.09	41.82
x 2 1/4	1.62	32.40	x 2	2.40	47.95
.262 x 1 3/4	1.53	30.65	x 2 1/2	3.01	60.20
x 2	1.76	35.10	x 3	3.62	72.45
x 2 1/4	1.98	39.56	x 3 1/2	4.24	84.70
x 2 1/2	2.20	44.02	x 4	4.85	96.95
x 3	2.65	52.94	3/8 x 2 1/4	2.81	56.28
.291 x 2 1/4	2.19	43.87	.401 x 3	4.03	80.57
x 2 1/2	2.44	48.82	7/16 x 2 1/4	3.27	65.44
5/16 x 1 1/2	1.56	31.11	x 3 1/2	5.13	102.66
x 1 3/4	1.82	36.42	x 4	5.88	117.55
x 2 1/4	2.35	47.06	.447 x 2 1/2	3.72	74.43
x 3 1/2	3.68	73.65	x 3	4.48	89.64
x 4	4.21	84.28	.499 x 2 1/2	4.14	82.88
.323 x 2	2.16	43.12	x 3	4.99	99.86
x 2 1/2	2.71	54.11	x 4	6.69	133.82
x 3	3.26	65.10	5/8 x 4	8.35	166.97
			.788 x 4	10.47	209.47

SEE PAGE A•22 FOR TOLERANCES

8620/8620H ALLOY STEEL

AISI/SAE 8620/8620H — As Rolled, Carburizing Quality

PACIFIC 8620 is a triple alloyed nickel-chrome-moly steel. It has become the standard alloy grade for carburizing because of its balanced case-core hardenability, availability and moderate cost. Pacific 8620H is rough turned oversize in sizes exceeding 3" diameter. These sizes are also calcium treated, vacuum degassed and ultrasonic tested for optimum machinability, cleanliness and soundness. This grade is often used in the as received condition where moderate strength with good weldability is required. In sizes up to 2" diameter it can be quenched and tempered to the 100,000 psi yield strength range. Flat and square bars are sawed from plate.

TYPICAL APPLICATIONS:

Axles	Gauges	Ratchets
Bearings	Gears	Rollers
Bushings	Gear Shafts	Rolls
Cams	Jigs	Spindles
Crankshafts	Molds	Thrust Washers
Dies	Pins	Wear Plates

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits

	C	Mn	P	S	Ni	Cr	Mo
8620	.18/.23	.70/.90	.035 max	.040 max	.40/.70	.40/.60	.15/.25
8620H	.17/.23	.60/.95	.035 max	.040 max	.35/.75	.35/.65	.15/.25
8620Plate	.17/.23	.60/.90	.035 max	.040 max	.40/.70	.35/.60	.15/.25

***TYPICAL PROPERTIES:** Approximate—not for specification

Diameter	Tensile, psi	Yield, psi	Elong.	Hardness	Machinability
1"	87,000	52,000	26%	183HB	65%
2"	82,000	51,000	27%	179HB	65%
4"	80,000	50,000	28%	163HB	65%

*As-Rolled — See page H•5 for heat treated properties.

PROCESSING TEMPERATURES: Typical

Forge: 2250°F max Normalize: 1650/1750°F Carburize: 1650/1750°F

Harden: 1550/1700°F Temper: 300/450°F

SEE PAGE H•5 FOR HEAT TREATING INFORMATION

8620/8620H ALLOY STEEL ROUNDS

SHAPE	CONDITION	COLOR CODE
Rounds	As Rolled	Orchid with Orange Cross
Flats	As Rolled	Orchid with Orange Stripe

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
7/8	2.05	40.9	5 3/4	91.64	1,832.9
1 1/2	6.01	120.3	6	99.64	1,992.7
1 5/8	7.06	141.2	6 1/4	108.0	2,159.3
1 3/4	8.19	163.7	6 1/2	116.6	2,332.5
1 7/8	9.40	187.9	6 3/4	125.6	2,512.4
2	10.69	213.8	7	135.0	2,699.0
2 1/8	12.25	245.0	7 1/2	154.6	3,092.2
2 1/4	13.74	274.4	7 3/4	164.9	3,298.8
2 1/2	16.91	338.3	8	175.6	3,512.1
2 3/4	20.91	418.2	8 1/4	186.6	3,732.1
3	24.81	496.3	8 1/2	198.0	3,960.1
3 1/4	28.90	577.9	9	221.7	4,433.6
3 1/2	33.46	669.1	9 1/2	246.7	4,933.8
3 3/4	38.65	772.9	10	273.1	5,462.4
4	43.90	877.9	11	324.4	6,486.6
4 1/4	49.48	989.6	12	401.1	8,021.9
4 1/2	55.40	1,107.9	13	469.3	9,385.1
4 3/4	61.98	1,239.6	14	542.8	10,855.2
5	68.58	1,371.7	15	621.6	12,432.2
5 1/4	75.52	1,510.4	16	705.8	14,116.1
5 1/2	82.79	1,655.8	18	890.2	17,804.6

SEE PAGE A•21 FOR TOLERANCES

8620 ALLOY FLATS & SQUARES — are sawed from plate.
See HOT ROLLED PLATE section for stock sizes on page A•19.

NOTE 1: Hot Rolled rounds are stocked through 3" diameter.
NOTE 2: Rough Turned Oversize rounds are stocked in diameters over 3".
NOTE 3: Press Forged bars are stocked in sizes over 11" diameter.

HOT ROLLED PLATE

Carbon & Alloy Steel

PACIFIC Hot Rolled Steel Plate stock is available as either full plates or SE®-Bars (Saw Edge). PACIFIC introduced plate sawing to the Northwest in the 1970's and continues to lead the industry. Standard carbon and alloy steel plus quenched & tempered structural steel is made to square and flat bar sizes without a detrimental heat affected edge. This saves time and costs associated with stress relieving bars which have been flame cut. Standard SE®-Bar widths are offered in 1/4" increments through 3" wide, 1/2" increments over 3" through 6" wide and 1" increments over 6" through 12" wide; available in cut pieces to full bars. Custom widths are available to 25" wide in full bars only (approximately 12 ft.).

1045 Plate is a medium carbon grade with the capability of through hardening in thin sections. It responds well to flame or induction hardening. Condition is as rolled.

4140 Plate is a medium carbon alloy grade which responds well to through hardening when oil quenched. It can also be flame or induction hardened. Condition is either annealed or normalized and tempered to 229 HB maximum.

8620 Plate is a low carbon alloy grade used primarily for carburized and hardened applications. Condition is as rolled.

A514 is a structural ASTM grade. It is a low carbon alloy grade which has been mill heat treated. Condition is quenched and tempered to 100,000 psi minimum in thickness through 2 1/2 inches (90,000 psi minimum, over 2 1/2" through 6").

GRADE	COLOR CODE
1045	Yellow
4140	Orchid
8620	Half Orchid & Half Orange
A514	Red

STOCK SIZES													
GRADE		THICKNESS (INCHES)											
		3/8	1/2	3/4	1	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/2	3	4	5
CARBON & ALLOY	1045		X	X	X	X		X	**	X				
	4140	X	X	X	X	X		X	X	X	X	X	X	X
	8620		X	X	X	X		X		X	X	X	X	
	A514		X	X	X	X	X	X	X	X				

** 1 3/4" 1045 is resulfurized for free machining — color code is half yellow and half white.

HOT ROLLED MANUFACTURING TOLERANCES

Carbon and Alloy Plate / SE®-Bars

PERMISSIBLE VARIATIONS IN THICKNESS WHEN ORDERED TO THICKNESS

RECTANGULAR PLATES
CARBON, HIGH STRENGTH LOW ALLOY, AND ALLOY STEEL

SPECIFIED THICKNESS, IN.	TOLERANCE OVER SPECIFIED THICKNESS FOR WIDTHS GIVEN, IN.								
	48 and under	Over 48 to 60, excl.	60 to 72, excl.	72 to 84, excl.	84 to 96, excl.	96 to 108, excl.	108 to 120, excl.	120 to 132, excl.	132 to 144, excl.
To 1/4, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04
1/4 to 5/16, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04
5/16 to 3/8, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04
3/8 to 7/16, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05
7/16 to 1/2, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05
1/2 to 5/8, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05
5/8 to 3/4, excl.	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05
3/4 to 1, excl.	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06
1 to 2, excl.	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.10	0.10
2 to 3, excl.	0.09	0.09	0.09	0.10	0.10	0.11	0.12	0.13	0.14
3 to 4, excl.	0.11	0.11	0.11	0.11	0.11	0.13	0.14	0.14	0.14
4 to 6, excl.	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6 to 10, excl.	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
10 to 12, excl.	0.29	0.29	0.33	0.33	0.33	0.33	0.33	0.33	0.33
12 to 15, excl.	0.29	0.29	0.35	0.35	0.35	0.35	0.35	0.35	0.35

Note 1. Permissible variation under specified thickness, 0.01 in.

Note 2. Thickness to be measured at 3/8 to 3/4 in. from the longitudinal edge.

Note 3. For thickness measured at any location other than that specified in Note 2, the permissible maximum over-tolerance shall be increased by 75 per cent.

Note 4. Width of the plate from which SE®-Bars are cut determines thickness tolerances. Typical width is 96 in.

WIDTH TOLERANCES for SE®-BARS

Tolerances Are Determined by Equipment Used for Production

STANDARD TOLERANCE	– 0.000"	/	+ 0.125"
SPECIAL TOLERANCE	– 0.000"	/	+ 0.063"

Note: Even though tolerances are on the plus side, clean-up is not guaranteed at nominal width.

HOT ROLLED MANUFACTURING TOLERANCES

Carbon and Alloy Steel Bars, ASTM A29

PERMISSIBLE VARIATIONS IN CROSS SECTION FOR HOT-WROUGHT ROUND, SQUARE, AND ROUND-CORNERED SQUARE BARS OF STEEL

SPECIFIED SIZE, IN.	AISI PERMISSIBLE VARIATION FROM SPECIFIED SIZE, IN. Over	Under	OUT-OF-ROUND OR OUT-OF-SQUARE, IN.[A]	PM & TS CO. ROUGH TURNED, OVERSIZED ROUNDS Oversize Tolerance
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	0.029/0.047
Over 3 1/2 to 4 1/2, incl.	1/16	0	0.046	0.042/0.063
Over 4 1/2 to 5 1/2, incl.	5/64	0	0.058	0.053/0.078
Over 5 1/2 to 6 1/2, incl.	1/8	0	0.070	0.093/0.118
Over 6 1/2 to 8 1/4, incl.	5/32	0	0.085	0.093/0.118
Over 8 1/4 to 9 1/2, incl.	3/16	0	0.100	0.093/0.121
Over 9 1/2 to 10, incl.	1/4	0	0.120	0.093/0.124
Over 10 to 11, incl.	—	—	—	0.093/0.124
11 Ni-Grades (8620 & 4340)	—	—	—	0.000/0.031

[A] Out-of-round is the difference between the maximum and minimum 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 between opposite faces.

PERMISSIBLE VARIATIONS IN CROSS SECTION FOR HOT-WROUGHT HEXAGONAL BARS OF STEEL

SPECIFIED SIZES BETWEEN OPPOSITE SIDES, IN.	PERMISSIBLE VARIATIONS FROM SPECIFIED SIZE, IN. Over	Under	OUT-OF-HEXAGON (CARBON STEEL AND ALLOY STEEL) OR OUT-OF-OCTAGON (ALLOY STEEL), IN.[A]
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 2, 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
Over 3 1/2 to 4 1/16, incl.	5/64	1/64	5/64

[A] Out-of-hexagon or out-of-octagon is the greatest difference between any two dimensions at the same cross section between opposite faces.

HOT ROLLED MANUFACTURING TOLERANCES

Carbon and Alloy Steel Bars, ASTM A29

PERMISSIBLE VARIATIONS IN THICKNESS AND WIDTH FOR HOT-WROUGHT SQUARE EDGE AND ROUND EDGE FLAT BARS[B]

SPECIFIED WIDTH, IN.	PERMISSIBLE VARIATIONS IN THICKNESS, FOR THICKNESS GIVEN, OVER AND UNDER, IN.							PERMISSIBLE VARIATIONS IN WIDTH, IN.	
	0.203 to 0.230, excl.	0.230 to 1/4, excl.	1/4 to 1/2, incl.	Over 1/2 to 1, incl.	Over 1 to 2, incl.	Over 2 to 3, incl.	Over 3	OVER	UNDER
To 1, incl.	0.007	0.007	0.008	0.010	—	—	—	1/64	1/64
Over 1 to 2, incl.	0.007	0.007	0.012	0.015	1/32	—	—	1/32	1/32
Over 2 to 4, incl.	0.008	0.008	0.015	0.020	1/32	3/64	3/64	1/16	1/32
Over 4 to 6, incl.	0.009	0.009	0.015	0.020	1/32	3/64	3/64	3/32	1/16
Over 6 to 8, incl.	[A]	0.015	0.016	0.025	1/32	3/64	1/16	1/8	3/32

[A] Flats over 6 to 8 in., incl. in width, are not available as hot-wrought steel bars in thickness under 0.230 in.

[B] When a square is held against a face and an edge of a square edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.

PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR HOT-WROUGHT BARS AND BAR SIZE SECTIONS OF STEEL[A, B]

Standard tolerances	1/4 in. in any 5 ft.	or	(1/4 in. x length in ft.)/5
Special tolerances	1/8 in. in any 5 ft.	or	(1/8 in. x length in ft.)/5

[A] Because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation or controlled cooling has been performed.

[B] Because saw edge bars are cut from plate, these tolerances do not apply. Plate has both flatness and waviness tolerances which must be considered.

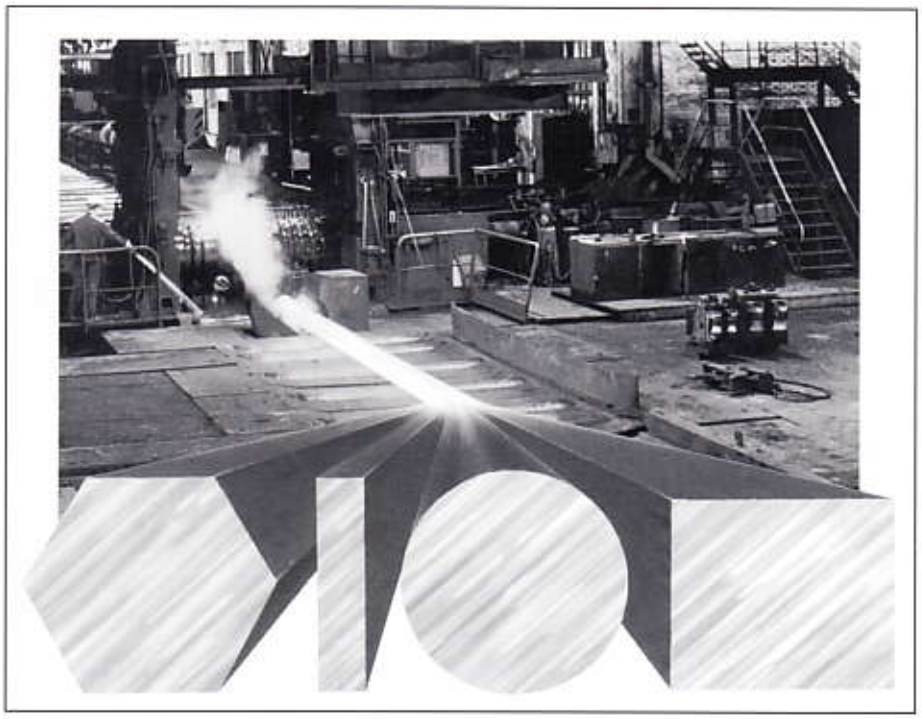
RECOMMENDED MINIMUM MACHINING ALLOWANCE PER SIDE, PER CENT OF SPECIFIED SIZE

REGULAR QUALITY ALLOY AND SPECIAL QUALITY CARBON STEEL BARS

	Non-Resulfurized		Resulfurized	
	2" & UNDER	OVER 2"	2" & UNDER	OVER 2"
CENTERLESS TURNED OR GROUND	2.6%	1.6%	3.4%	2.4%

Note 1. Based on bars with special straightness tolerance.

Note 2. Bars turned on centers. Since this operation is dependent upon length and straightness consideration, each item should be negotiated between consumer and supplier.



SECTION INDEX
COLD FINISHED CARBON & ALLOY STEEL

CARBON STEEL BARS

ALLOY STEEL BARS

STAINLESS STEEL BARS

1018 COLD FINISHED BARS

AISI/SAE 1018 — Low Carbon

PACIFIC 1018 cold finished rounds are stocked in the cold drawn condition through 4" diameter. The turned and polished condition is stocked in popular bearing sizes from $1^{15}/_{16}$" through 6" diameters. 1018 is a low carbon steel which can be readily machined and welded. It can be heat treated by carburizing and case hardening but will not furnace or flame harden because of its low carbon content. Flats and squares are cold drawn to shape and size.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S
.15/.20	.60/.90	.040 max	.050 max

TYPICAL PROPERTIES: Approximate—not for specification

	Tensile, psi	Yield, psi	Elong.	Hardness	Mach.
Cold Drawn	64,000	54,000	15%	126HB	66%
*Turned & Polished	58,000	32,000	25%	116HB	66%

*Hot finished properties (no cold working).

PROCESSING TEMPERATURES: Typical

Forge: 2300°F max Normalize: 1625/1725°F Case Harden: 1500/1700°F

1018 COLD DRAWN ROUNDS

CONDITION	COLOR CODE
Cold Drawn	Orange

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
$^3/_{16}$	0.09	1.88	$1\ ^1/_{16}$	3.02	60.35
$^1/_4$	0.17	3.34	$1\ ^1/_8$	3.38	67.66
$^5/_{16}$	0.26	5.22	$1\ ^3/_{16}$	3.77	75.38
$^3/_8$	0.38	7.52	$1\ ^1/_4$	4.18	83.53
$^7/_{16}$	0.51	10.23	$1\ ^5/_{16}$	4.60	92.09
$^1/_2$	0.67	13.36	$1\ ^3/_8$	5.05	101.1
$^9/_{16}$	0.85	16.91	$1\ ^7/_{16}$	5.52	110.5
$^5/_8$	1.04	20.88	$1\ ^1/_2$	6.01	120.3
$^{11}/_{16}$	1.26	25.27	$1\ ^9/_{16}$	6.53	130.5
$^3/_4$	1.50	30.07	$1\ ^5/_8$	7.06	141.2
$^{13}/_{16}$	1.76	35.29	$1\ ^{11}/_{16}$	7.61	152.2
$^7/_8$	2.05	40.93	$1\ ^3/_4$	8.19	163.7
$^{15}/_{16}$	2.35	46.98	$1\ ^7/_8$	9.40	187.9
1	2.67	53.46	$1\ ^{15}/_{16}$	10.03	200.7

SEE PAGE B•22 FOR TOLERANCES

1018 COLD DRAWN and TURNED & POLISHED SHAFTING

CONDITION	COLOR CODE
Cold Drawn	Orange
Turned & Polished	Orange with Black Stripe

STOCK SIZES (Continued)

DIAMETER (INCHES)	CONDITION	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	DIAMETER (INCHES)	CONDITION	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
1 15/16	CD, T&P	10.03	200.7	3 1/8	CD	26.10	522.0
2	CD	10.69	213.8	3 1/4	CD	28.23	564.6
2 1/8	CD	12.07	241.4	3 7/16	CD, T&P	31.58	631.7
2 3/16	CD, T&P	12.79	255.8	3 1/2	CD	32.74	654.9
2 1/4	CD	13.53	270.6	3 3/4	CD	37.59	751.7
2 3/8	CD	15.08	301.5	3 15/16	CD, T&P	41.44	828.8
2 7/16	CD, T&P	15.88	317.6	4	CD	42.77	855.3
2 1/2	CD	16.71	334.1	4 7/16	T&P	52.63	1,052.7
2 5/8	CD	18.42	368.4	4 1/2	T&P	54.13	1,082.5
2 11/16	CD	19.31	386.1	4 15/16	T&P	65.16	1,303.2
2 3/4	CD	20.21	404.3	5	T&P	66.82	1,336.4
2 7/8	CD	22.09	441.9	5 7/16	T&P	79.03	1,580.5
2 15/16	CD, T&P	23.06	461.3	5 15/16	T&P	94.23	1,884.6
3	CD, T&P	24.06	481.1	6	T&P	96.22	1,924.5

1018 COLD DRAWN SQUARES — Key Stock

CONDITION	COLOR CODE
Cold Drawn	Orange

STOCK SIZES

SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
1/8	0.05	0.64	1 3/16	4.80	57.59
3/16	0.12	1.44	1 1/4	5.32	63.81
1/4	0.21	2.55	1 3/8	6.43	77.21
5/16	0.33	3.99	1 1/2	7.66	91.89
3/8	0.48	5.74	1 5/8	8.99	107.8
7/16	0.65	7.82	1 3/4	10.42	125.1
1/2	0.85	10.21	1 7/8	11.96	143.6
9/16	1.08	12.92	2	13.61	163.4
5/8	1.33	15.95	2 1/4	17.23	206.7
3/4	1.91	22.97	2 1/2	21.27	255.2
7/8	2.61	31.27	2 3/4	25.74	308.8
15/16	2.99	35.89	3	30.63	367.6
1	3.40	40.84	3 1/2	41.69	500.3
1 1/8	4.31	51.69	4	54.45	653.4

SEE PAGE B•22 FOR TOLERANCES
SEE PAGE B•26 FOR STD. KEY SIZES

1018 COLD DRAWN FLATS

CONDITION	COLOR CODE
Cold Drawn	Orange

STOCK SIZES

SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
1/8 X 1/4	0.11	1.28	1/4 X 7/8	0.74	8.93
3/8	0.16	1.91	1	0.85	10.21
1/2	0.21	2.55	1 1/4	1.06	12.76
5/8	0.27	3.19	1 1/2	1.28	15.31
3/4	0.32	3.83	1 3/4	1.49	17.87
7/8	0.37	4.47	2	1.70	20.42
1	0.43	5.10	2 1/4	1.91	22.97
1 1/4	0.53	6.38	2 1/2	2.13	25.52
1 1/2	0.64	7.66	2 3/4	2.34	28.08
1 3/4	0.74	8.93	3	2.55	30.63
2	0.85	10.21	3 1/2	2.98	35.73
2 1/2	1.06	12.76	4	3.40	40.84
3	1.28	15.31	5	4.25	51.05
3 1/2	1.49	17.87	6	5.10	61.26
4	1.70	20.42	8	6.81	81.68
5	2.13	25.52	10	8.51	102.10
6	2.55	30.63	12	10.21	122.52
3/16 X 1/4	0.16	1.91	5/16 X 3/8	0.40	4.79
3/8	0.24	2.87	1/2	0.53	6.38
1/2	0.32	3.83	5/8	0.66	7.98
5/8	0.40	4.79	3/4	0.80	9.57
3/4	0.48	5.74	1	1.06	12.76
7/8	0.56	6.70	1 1/4	1.33	15.95
1	0.64	7.66	1 1/2	1.60	19.14
1 1/4	0.80	9.57	2	2.13	25.52
1 1/2	0.96	11.49	2 1/2	2.66	31.91
1 3/4	1.12	13.40	3	3.19	38.29
2	1.28	15.31	3 1/2	3.72	44.67
2 1/4	1.44	17.23	4	4.25	51.05
2 1/2	1.60	19.14	5	5.32	63.81
3	1.91	22.97	6	6.38	76.57
3 1/2	2.23	26.80	3/8 X 1/2	0.64	7.66
4	2.55	30.63	5/8	0.80	9.57
5	3.19	38.29	3/4	0.96	11.49
6	3.83	45.94	7/8	1.12	13.40
1/4 X 5/16	0.27	3.19	1	1.28	15.31
3/8	0.32	3.83	1 3/16	1.52	18.19
1/2	0.43	5.10	1 1/4	1.60	19.14
5/8	0.53	6.38	1 1/2	1.91	22.97
3/4	0.64	7.66	1 3/4	2.23	26.80

Continued on next page

SEE PAGE B•22 FOR TOLERANCES

1018 COLD DRAWN FLATS — Continued

STOCK SIZES					
SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
3/8 X 2	2.55	30.63	5/8 X 1 3/4	3.72	44.67
2 1/4	2.87	34.46	2	4.25	51.05
2 1/2	3.19	38.29	2 1/4	4.79	57.43
3	3.83	45.94	2 1/2	5.32	63.81
3 1/2	4.47	53.60	3	6.38	76.57
3 3/4	4.79	57.43	3 1/2	7.44	89.33
4	5.10	61.26	3 3/4	7.98	95.72
5	6.38	76.57	4	8.51	102.10
6	7.66	91.89	4 1/2	9.57	114.86
7	8.93	107.20	5	10.64	127.62
8	10.21	122.52	5 1/2	11.70	140.38
10	12.76	153.14	6	12.76	153.14
12	15.31	183.77	8	17.02	204.19
7/16 X 1/2	0.74	8.93	10	21.27	255.24
3/4	1.12	13.40	12	25.52	306.29
1	1.49	17.87	3/4 X 7/8	2.00	24.04
1 1/2	2.23	26.80	1	2.55	30.63
2	2.98	35.73	1 1/8	2.87	34.46
1/2 X 5/8	1.06	12.76	1 1/4	3.19	38.29
3/4	1.28	15.31	1 1/2	3.83	45.94
7/8	1.49	17.87	1 3/4	4.47	53.60
1	1.70	20.42	2	5.10	61.26
1 1/4	2.13	25.52	2 1/4	5.74	68.91
1 1/2	2.55	30.63	2 1/2	6.38	76.57
1 3/4	2.98	35.73	2 3/4	7.02	84.23
2	3.40	40.84	3	7.66	91.89
2 1/4	3.83	45.94	3 1/2	8.93	107.20
2 1/2	4.25	51.05	4	10.21	122.52
2 3/4	4.68	56.15	4 1/2	11.49	137.83
3	5.10	61.26	5	12.76	153.14
3 1/2	5.96	71.47	6	15.31	183.77
4	6.81	81.68	7	17.87	214.40
4 1/2	7.66	91.89	8	20.42	245.03
5	8.51	102.10	10	25.52	306.29
6	10.21	122.52	12	30.63	367.55
8	13.61	163.35	7/8 X 1	2.98	35.73
10	17.02	204.19	1 1/4	3.72	44.67
12	20.42	245.03	1 1/2	4.47	53.60
5/8 X 3/4	1.60	19.14	1 3/4	5.21	62.53
7/8	1.86	22.33	2	5.96	71.47
1	2.13	25.52	2 1/2	7.44	89.33
1 1/4	2.66	31.91	3	8.93	107.20
1 1/2	3.19	38.29	3 1/2	10.42	125.07

Continued on next page

SEE PAGE B•22 FOR TOLERANCES

1018 COLD DRAWN FLATS — Continued

STOCK SIZES					
SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
7/8 X 4	11.91	142.93	1 1/2 X 2 1/2	12.76	153.14
5	14.89	178.67	2 3/4	14.04	168.46
5 1/2	16.38	196.53	3	15.31	183.77
1 X 1 1/8	3.83	45.94	3 1/2	17.87	214.40
1 1/4	4.25	51.05	4	20.42	245.03
1 3/8	4.68	56.15	4 1/2	22.97	275.66
1 1/2	5.10	61.26	5	25.52	306.29
1 3/4	5.96	71.47	6	30.63	367.55
2	6.81	81.68	8	40.84	490.06
2 1/2	8.51	102.10	10	51.05	612.58
3	10.21	122.52	12	61.26	735.09
3 1/2	11.91	142.93	1 3/4 X 2	11.91	142.93
4	13.61	163.35	2 1/2	14.89	178.67
4 1/2	15.31	183.77	3	17.87	214.40
5	17.02	204.19	3 1/2	20.84	250.14
5 1/2	18.72	224.61	3 3/4	22.33	268.00
6	20.42	245.03	4	23.82	285.87
8	27.23	326.71	4 1/2	26.80	321.60
10	34.03	408.38	5	29.78	357.34
12	40.84	490.06	6	35.73	428.80
1 1/8 X 2	7.66	91.89	2 X 2 1/2	17.02	204.19
3	11.49	137.83	2 3/4	18.72	224.61
1 1/4 X 1 1/2	6.38	76.57	3	20.42	245.03
1 3/4	7.44	89.33	3 1/2	23.82	285.87
2	8.51	102.10	3 3/4	25.52	306.29
2 1/4	9.57	114.86	4	27.23	326.71
2 1/2	10.64	127.62	4 1/2	30.63	367.55
3	12.76	153.14	5	34.03	408.38
3 3/4	15.95	191.43	5 1/2	37.44	449.22
4	17.02	204.19	6	40.84	490.06
4 1/2	19.14	229.72	8	54.45	653.41
5	21.27	255.24	12	81.68	980.12
5 1/2	23.40	280.76	2 1/2 X 3	25.52	306.29
6	25.52	306.29	3 1/2	29.78	357.34
8	34.03	408.38	4	34.03	408.38
12	51.05	612.58	3 X 6	61.26	735.09
1 1/2 X 1 3/4	8.93	107.20			
2	10.21	122.52			
2 1/4	11.49	137.83			

SEE PAGE B•22 FOR TOLERANCES

12L14 COLD FINISHED SCREW STOCK

AISI/SAE 12L14

PACIFIC 12L14 is a leaded, resulfurized and rephosphorized grade with the highest machinability rating of standard AISI/SAE grades. It is particularly adaptable to automatic screw machines and produces an excellent surface finish. Welding is not recommended because of the high sulfur content. It can be case hardened with light to moderate case depths.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits,%

C	Mn	P	S	Pb
.15 max	.85/1.15	.04/.09	.26/.35	.15/.35

TYPICAL PROPERTIES: Approximate—not for specification

	Tensile, psi	Yield, psi	Elong.	Hardness	Mach.
C.D	78,000	60,000	10%	163HB	160%
*T & P	57,000	34,000	20%	121HB	

*Hot finished properties (no cold working).

PROCESSING TEMPERATURES: Typical
Forging, Normalizing & Annealing: not normally required
Light Case Hardening: 1500/1700°F

12L14 COLD FINISHED ROUNDS

CONDITION	COLOR CODE
Cold Drawn	Green
Turned & Polished	Green

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
5/32	0.07	0.78	15/16	2.35	28.19
3/16	0.09	1.13	1	2.67	32.07
7/32	0.13	1.53	1 1/16	3.02	36.21
1/4	0.17	2.00	1 1/8	3.38	40.59
9/32	0.21	2.54	1 3/16	3.77	45.23
5/16	0.26	3.13	1 1/4	4.18	50.12
21/64	0.29	3.45	1 5/16	4.60	55.25
11/32	0.32	3.79	1 3/8	5.05	60.64
23/64	0.34	4.14	1 7/16	5.52	66.28
3/8	0.38	4.51	1 1/2	6.01	72.17
13/32	0.44	5.29	1 5/8	7.06	84.70
7/16	0.51	6.14	1 11/16	7.61	91.34
15/32	0.59	7.05	1 3/4	8.19	98.23
1/2	0.67	8.02	1 7/8	9.40	112.8
9/16	0.85	10.15	2	10.69	128.3
5/8	1.04	12.53	2 1/16	11.37	136.4
11/16	1.26	15.16	2 1/8	12.07	144.8
3/4	1.50	18.04	2 1/4	13.53	162.4
25/32	1.63	19.58	2 3/8	15.08	180.9
13/16	1.76	21.17	2 7/16	15.88	190.6
7/8	2.05	24.56	2 1/2	16.71	200.5

Continued on next page

SEE PAGE B•22 FOR TOLERANCES

12L14 COLD FINISHED ROUNDS — Continued

CONDITION	COLOR CODE
Cold Drawn	Green
Turned & Polished	Green

STOCK SIZES (Continued)

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
2 1/2	16.71	200.5	3 3/4	37.59	451.1
2 5/8	18.42	221.0	3 7/8	40.13	481.6
2 3/4	20.21	242.5	4	42.77	513.2
2 7/8	22.01	265.1	4 1/2	54.13	649.5
3	24.06	288.7	4 3/4	60.31	723.7
3 1/8	26.10	313.2	5	66.82	801.9
3 1/4	28.23	388.8	5 1/2	80.85	970.3
3 3/8	30.45	365.4	* 6	96.22	1,154.7
3 1/2	32.74	392.9	* 6 1/2	112.93	1,355.1
3 5/8	35.12	421.5	* 7	130.97	1,571.7

*Turned and Polished (not cold drawn).

12L14 COLD DRAWN HEXAGONS

CONDITION	COLOR CODE
Cold Drawn	Green

STOCK SIZES

SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
1/4	0.18	2.21	1 1/8	3.73	44.76
5/16	0.29	3.45	1 1/4	4.61	55.26
3/8	0.41	4.97	1 5/16	5.01	60.92
7/16	0.56	6.77	1 3/8	5.57	66.86
1/2	0.74	8.84	1 7/16	6.09	73.08
9/16	0.93	11.19	1 1/2	6.63	79.57
5/8	1.15	13.81	1 5/8	7.78	93.39
11/16	1.39	16.72	1 11/16	8.39	100.7
3/4	1.66	19.89	1 3/4	9.03	108.3
13/16	1.95	23.35	1 7/8	10.36	124.3
7/8	2.26	27.08	2	11.79	141.5
15/16	2.59	31.08	2 1/4	14.92	179.0
1	2.95	35.37	2 1/2	18.42	221.0
1 1/16	3.33	39.92	2 3/4	22.29	267.5
1 1/8	3.73	44.76	3	26.52	318.3

SEE PAGE B•22 FOR TOLERANCES

SUPER 1200® LEAD FREE SCREW STOCK

AISI 1215 Controlled Chemistry

SUPER 1200® is manufactured by LaSalle Steel Company to restricted chemistry within the standard AISI range. New SUPER 1200® is virtually equivalent to 12L14 in machining speed without any machining additives such as lead, bismuth, selenium, etc. Each lot of product is subjected to machinability testing and has certified mechanical properties. SUPER 1200® has low nitrogen content to facilitate cold forming; it can be case hardened and it can be brazed. As with all highly resulfurized steels, welding is not recommended.

CHEMICAL COMPOSITION: Typical, %

C	S	P	Mn	Si
.07	.32	.05	.95	<.01

TYPICAL PROPERTIES: Approximate—not for specification

Tensile, psi	Yield, psi	Elong.	Hardness	Machinability
70/90,000	60/80,000	15/20%	137/183 HB	195%

PROCESSING TEMPERATURES: Typical

Forging, Normalizing & Annealing not normally required.

Light Case Hardening: 1500/1700°F

SUPER 1200® COLD DRAWN ROUNDS

CONDITION	COLOR CODE
Cold Drawn	Turquoise

STOCK SIZES
A limited number of sizes are available at time of printing. Please call to check current stock and availability.

1215Bi NON-LEADED SCREW STOCK

AISI/SAE 1215 Modified with Bismuth Added

PACIFIC 1215Bi offers premium screw stock quality bars without lead additions. 1215Bi gives even faster machinability than 12L14 through controlled chemistry and the addition of element 83, bismuth. Different mills produce slightly different analyses of this grade. Trade names used are 83®-420 by LaSalle Steel and Multicut® Bizš by Republic Steel. As with all 1200 series steels, welding is not recommended.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

	C	Mn	P	S	Bi
1215 (for reference)	.09 max	.75/1.05	.04/.09	.26/35	—
83®-420	.09 max	.85/1.15	.04/.09	.26/35	"added"
Multicut®-Bizš	.06/.09	.95/1.20	.04/.09	.04 min	.10 mean

TYPICAL PROPERTIES: Approximate—not for specification

Tensile, psi	Yield, psi	Elong.	Hardness	Machinability
78,000	60,000	10%	163HB	200%+

PROCESSING TEMPERATURES: Typical

Forging, Normalizing & Annealing: not normally required

Light Case Hardening: 1500/1700°F

1215Bi COLD DRAWN ROUNDS

CONDITION	COLOR CODE
Cold Drawn	Pink

STOCK SIZES
At printing a limited number of sizes were stocked in rounds and hexagons. Please call to check current stock and availability.

1045 COLD FINISHED BARS

AISI/SAE 1045 — Medium Carbon

PACIFIC 1045 cold finished bars are medium carbon steel and have strengths above 1018 but below the heat treated alloy grades. 1045 can be heat treated and is often induction hardened for surface strength and wear resistance. PACIFIC 1045 Cold Finished Bars are offered in three quality conditions:

TURNED & POLISHED offers medium carbon strength at lowest cost. Manufacturing tolerances are the widest for this condition. It is stocked in popular shafting sizes from $1^{15}/_{16}$" through $6^{7}/_{16}$" diameters.

ARROW-TEN® PRECISION SHAFTING is ground and polished to insure tight diameter tolerances and 16 rms maximum surface finish. ARROW-TEN® has been successfully used in many higher rpm, medium load applications such as shafts, spindles and arbors.

RING GAGE QUALITY bars offer the qualities of ARROW-TEN® with the added benefit of having been individually ring gaged. This is to insure that bearings will slip over the entire length of the bar with minimal effort.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S
.43/.50	.60/.90	.040 max	.050 max

TYPICAL PROPERTIES: Approximate—not for specification

	Tensile, psi	Yield, psi	Elong.	Hardness	Mach.
*Cold Drawn	91,000	77,000	12%	179HB	56%
*Turned & Polished	82,000	45,000	16%	163HB	56%

*Turned & Polished bars usually have hot rolled bar mechanical properties. Ground and polished bars have either cold drawn **or** hot rolled properties.

PROCESSING TEMPERATURES: Typical

Forge: 2275°F max Normalize: 1550/1650°F

Harden: 1525/1600°F

SEE PAGE H•7-10 FOR HEAT TREATING INFORMATION

REQUEST OUR PRODUCT BROCHURE ON COLD FINISHED ALLOY & CARBON STEEL BARS.

1045 COLD FINISHED ROUNDS

CONDITION	COLOR CODE
Turned & Polished	Yellow with Green Stripe
ARROW-TEN® G & P	Green wtih Yellow Stripe
Ring Gage Quality	Silver with Red Stipe

STOCK SIZES

DIAMETER (INCHES)	CONDITION			WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
	T&P	G&P	RGQ		
1/2		X		0.67	13.36
5/8		X		1.04	20.88
3/4		X		1.50	30.07
7/8		X		2.05	40.93
1		X	X	2.67	53.46
1 1/8		X		3.38	67.66
1 3/16		X	X	3.77	75.38
1 1/4		X		4.18	83.53
1 3/8		X		5.05	101.1
1 7/16		X	X	5.52	110.5
1 1/2		X	X	6.01	120.3
1 5/8		X		7.06	141.2
1 11/16		X	X	7.61	152.2
1 3/4		X		8.19	163.7
1 15/16	X	X	X	10.03	200.7
2		X		10.69	213.8
2 3/16	X	X	X	12.79	255.8
2 1/4		X		13.53	270.6
2 7/16	X	X	X	15.88	317.6
2 1/2		X		16.71	334.1
2 11/16		X	X	19.31	386.1
2 3/4		X		20.21	404.3
2 15/16	X	X	X	23.06	461.3
3		X		24.06	481.1
3 1/4		X		28.23	564.6
3 7/16	X	X	X	31.58	631.7
3 1/2		X		32.74	654.9
3 3/4		X		37.59	751.7
3 15/16	X	X	X	41.44	828.8
4		X		42.77	855.3
4 7/16	X	X		52.63	1,052.7
4 1/2		X		54.13	1,082.5
4 15/16	X	X		65.16	1,303.2
5		X		66.82	1,336.4
5 7/16	X	X		79.03	1,580.5
5 1/2		X		80.85	1,617.1
5 15/16	X			94.23	1,884.6
6 7/16	X			110.77	2,215.4

SEE PAGE B•22 & 24 FOR TOLERANCES

STRESSPROOF® & FATIGUE-PROOF® BARS

AISI/SAE 1144 High Strength & Free Machining Medium Carbon

STRESSPROOF® is made by a patented process which consists of drawing the bar through a special die under heavy draft, then stress relieving it. This severe cold working combined with the stress relieving results in a high strength bar with good stability and exceptional machinability. STRESSPROOF® can often replace heat treated alloy steel for machined parts requiring hardness in the range 23-30 HRC. It can be induction hardened but should be watched for quench cracks because of the high sulfur and manganese content. Welding is not recommended. STRESSPROOF® exceeds ASTM A311, Class B.

FATIGUE-PROOF® is an even higher strength grade made by various combinations of mechanical working and thermal treatments. This high strength bar can eliminate heat treating in the 32-36 HRC range plus the secondary operations associated with heat treating, i.e., cleaning, straightening, remachining and inspection. All this, in combination with free machining, works to reduce end costs. FATIGUE-PROOF® can be induction hardened using the same precautions as with STRESSPROOF®. Welding is not recommended.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S	Si
.40/.48	1.35/1.65	.040 max	.24/.33	.15/.30

MECHANICAL PROPERTIES:

	Tensile, psi	Yield, psi	Elong.	Hardness	Mach.
Stressproof®	130,000 (mean)	100,000 min	12% (mean)	—	83%
Fatigue-Proof®	140,000 (mean)	125,000 min	10% (mean)	*280HB min	80%

*In the event of disagreement between hardness and tensile strength, the tensile strength shall govern.

THREAD ROLLING STOCK

ASTM A311, Class B, Grade 1144

PACIFIC Thread Rolling Stock meets AISI/SAE 1144 chemistry range. It is stocked in decimal sizes for rolling nominal fractional size threads. See page B•14 for stock sizes.

MECHANICAL PROPERTIES:

Diameter, in.	Tensile, psi	Yield, psi	Elong.	Red. of Area
thru 7/8	115,000 min	100,000 min	8% min	25% min
>7/8 thru 1 1/4	115,000 min	100,000 min	8% min	25% min
>1 1/4 thru 2	115,000 min	100,000 min	8% min	25% min
>2 thru 3	115,000 min	100,000 min	8% min	20% min
>3 thru 4 1/2	115,000 min	100,000 min	7% min	20% min

STRESSPROOF® & FATIGUE-PROOF® ROUND BARS

GRADE	CONDITION	COLOR CODE
Stressproof®	Cold Drawn	Copper
Stressproof®	Ground & Polished	Copper with White Dot
Fatigue Proof®	Cold Drawn	Blue

STOCK SIZES

DIAMETER (INCHES)	CONDITION			WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
	STRESSPROOF		FATIGUE-PROOF		
	CD	G&P	CD Only		
1/4	X		X	0.17	3.34
5/16	X		X	0.26	5.22
3/8	X	X	X	0.38	7.52
7/16	X			0.51	10.23
1/2	X	X	X	0.67	13.36
9/16	X		X	0.85	16.91
5/8	X	X	X	1.04	20.88
11/16	X	X		1.26	25.27
3/4	X	X	X	1.50	30.07
13/16	X	X		1.76	35.29
7/8	X	X	X	2.05	40.93
15/16	X	X		2.35	46.96
1	X	X	X	2.67	53.46
1 1/16	X			3.02	60.35
1 1/8	X	X	X	3.38	67.66
1 3/16	X	X		3.77	75.38
1 1/4	X	X	X	4.18	83.53
1 5/16	X	X		4.60	92.09
1 3/8	X	X	X	5.05	101.1
1 7/16	X	X		5.52	110.5
1 1/2	X	X	X	6.01	120.3
1 9/16	X	X		6.53	130.5
1 5/8	X	X		7.06	141.2
1 11/16	X	X		7.61	152.2
1 3/4	X	X	X	8.19	163.7
1 7/8	X			9.40	187.9
1 15/16	X	X		10.03	200.7
2	X	X		10.69	213.8
2 1/16	X			11.37	227.4
2 1/8	X	X		12.07	241.4
2 3/16	X	X		12.79	255.8
2 1/4	X	X		13.53	270.6
2 5/16	X			14.29	285.9
2 3/8	X	X		15.08	301.5
2 7/16	X	X		15.88	317.6
2 1/2	X	X		16.71	334.1
2 9/16	X			17.55	351.0
2 5/8	X	X		18.42	368.4
2 11/16		X		19.31	386.1
2 3/4	X	X		20.21	404.3
2 7/8	X			22.09	441.9
2 15/16	X	X		23.06	461.3
3	X			24.06	481.1
3 1/4	X	X		28.23	544.6

FATIGUE-PROOF is stocked in 12' bars
Multiply 20' bar wt. by 0.6 for 12' wt.

Stressproof® sizes continued on next page

SEE PAGE B•22 & 24 FOR TOLERANCES

STRESSPROOF® ROUND BARS — Continued

CONDITION	COLOR CODE
Cold Drawn Ground & Polished	Copper Copper with White Dot

STOCK SIZES (Continued)

DIAMETER (INCHES)	CONDITION		WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
	CD	G&P		
3 3/8	X		30.45	608.9
3 7/16		X	31.58	631.7
3 1/2	X	X	32.74	654.9
3 5/8	X		35.12	702.5
3 3/4	X		37.59	751.7
3 15/16		X	41.44	828.8
4	X	X	42.77	855.3
4 7/16		X	52.63	1,052.7
4 1/2	X		54.13	1,082.5

STRESSPROOF® COLD DRAWN HEXAGONS

CONDITION	COLOR CODE
Cold Drawn	Copper

STOCK SIZES

SIZE (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
1/2	0.74	8.84
9/16	0.93	11.19
3/4	1.66	19.89
7/8	2.26	27.01
1	2.95	35.37
1 1/8	3.73	44.76
1 1/4	4.61	55.26
1 1/2	6.63	79.57
1 3/4	9.03	108.31
2	11.79	141.46

ASTM A 311—CLASS B THREAD ROLLING STOCK
AISI/SAE 1144

CONDITION	COLOR CODE
Cold Drawn	Silver

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
0.346	0.32	6.40
0.465	0.58	11.56
0.707	1.34	26.72
0.951	2.42	48.35
1.068	3.05	60.97
1.193	3.80	76.08

SEE PAGE B•22 & 24 FOR TOLERANCES

4130 ANNEALED or NORMALIZED, COLD DRAWN

AISI/SAE 4130

PACIFIC 4130 is a chromium-molybdenum low alloy steel with lower carbon than the more popular 4140. Because of lower carbon content it has better weldability but lower hardenability (response to hardening). Maximum achievable hardness by furnace hardening is approximately 52 HRC. 4130 can be hardened by either water or oil quenching. PACIFIC 4130 is furnished in either the annealed or the normalized condition depending upon mill availability.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S	Cr	Mo
.28/.33	.40/.60	.035 max	.040 max	.80/1.10	.15/.25

TYPICAL PROPERTIES: Approximate—not for specification

Tensile, psi	Yield, psi	Elong.	Hardness	Machinability
95,000	80,000	18%	179HB	70%

PROCESSING TEMPERATURES: Typical

Forge: 2200°F max Normalize: 1600/1700°F Anneal: 1525/1575°F

Water Harden: 1550/1600°F Oil Harden: 1575/1625°F Temper: 400/1300°F

SEE PAGE H•19-20 FOR HEAT TREATING INFORMATION

4130 COLD DRAWN ROUNDS

CONDITION	COLOR CODE
Annealed	Blue with Red Dot
Normalized	Blue with White Cross

STOCK SIZES				
DIAMETER (INCHES)	CONDITION		WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
	Anneal.	Norm.		
1/2	X		0.67	8.02
5/8	X		1.04	12.53
3/4	X		1.50	18.04
7/8		X	2.05	24.56
1		X	2.67	32.07
1 1/2		X	6.01	72.17
Ask for availability on sizes not listed				

SEE PAGE B•23 FOR TOLERANCES

ACRALLOY® PRECISION SHAFTING
AISI/SAE 4140/4142

PACIFIC ACRALLOY® has satisfied the high strength precision shafting requirements of the Pacific Northwest for decades. Acralloy® is heat treated by quenching and tempering for high strength. It is then specially straightened, stress relieved and drawn or turned, then ground and polished to 16 maximum rms. Acralloy® has good toughness as well as high strength and is the choice for many heavy duty shafting applications. It can be welded if properly preheated (see article on welding, page I•43). Acralloy® can also be surface hardened by induction heat treating and by nitriding.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S	Cr	Mo
.38/.45	.75/1.00	.035 max	.040 max	.80/1.10	.15/.25

TYPICAL PROPERTIES: Approximate—not for specification

Tensile, psi	Yield, psi	Elong.	Hardness	Machinability
120,000	100,000	20%	255HB	55%

ACRALLOY® PRECISION ROUNDS

CONDITION	COLOR CODE
Ground & Polished	Half Blue & Half Orchid

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
1/2	0.67	13.36	2	10.69	213.8
5/8	1.04	20.88	2 1/8	12.07	241.4
11/16	1.26	25.27	2 3/16	12.79	255.8
3/4	1.50	30.07	2 1/4	13.53	270.6
13/16	1.76	35.29	2 7/16	15.88	317.6
7/8	2.05	40.93	2 1/2	16.71	334.1
15/16	2.35	46.98	2 11/16	19.31	386.1
1	2.67	53.46	2 3/4	20.21	404.3
1 1/16	3.02	60.35	2 15/16	23.06	461.3
1 1/8	3.38	67.66	3	24.06	481.1
1 3/16	3.77	75.38	3 3/16	27.16	543.1
1 1/4	4.18	83.53	3 1/4	28.23	564.6
1 3/8	5.05	101.1	3 7/16	31.58	631.7
1 7/16	5.52	110.5	3 1/2	32.74	654.9
1 1/2	6.01	120.3	3 3/4	37.59	751.7
1 5/8	7.06	141.2	3 15/16	41.44	828.8
1 11/16	7.61	152.2	4	42.77	855.3
1 3/4	8.19	163.7	4 1/4	48.28	965.6
1 13/16	8.78	175.6	4 7/16	52.63	1,052.7
1 7/8	9.40	187.9	4 1/2	54.13	1,082.5
1 15/16	10.03	200.7	4 15/16	65.16	1,303.2
2	10.69	213.8	5	66.82	1,336.4

SEE PAGE B•24 FOR TOLERANCES

"e.t.d." 150® ALLOY SHAFTING

AISI/SAE Medium Carbon 4100 Series

"e.t.d." 150® is a high strength alloy steel with improved machinability. LaSalle Steel manufactures "e.t.d." 150® from medium carbon 4100 series alloy steel modified with one machinability additive such as selenium, sulfur, or tellurium. The high strength is developed by elevated temperature drawing below the critical temperature range. Mechanical properties are exceptionally uniform throughout the cross section of each bar. "e.t.d." 150® is often used to replace material being heat treated to the 32/38 HRC range. It can be roll threaded, knurled or plated and is suitable for induction hardening. Welding is generally not recommended.

CHEMICAL COMPOSITION: Heat Analysis (typical), %

C	Mn	Cr	Mo	Other
.40	.70/1.10	.80/1.20	.15/.25	See Note

Note: "e.t.d." 150® contains additives to improve machinability. These may be Te, Se, S or others.

TYPICAL PROPERTIES:

Tensile, psi	Yield, psi	Elong.	Hardness	Machinability
150,000 min	130,000 min	10% mean	*302HB min	75%

*If disagreement between hardness and tensile strength, tensile strength shall govern.

"e.t.d." 150® ALLOY ROUNDS

CONDITION	COLOR CODE
Cold Drawn	Yellow
Ground & Polished	Yellow with White Dot

STOCK SIZES

DIAMETER (INCHES)	CONDITION		WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
	CD	G&P		
1/2	X		0.67	8.02
5/8	X		1.04	12.53
3/4	X		1.50	18.04
7/8	X		2.05	24.56
1	X	X	2.67	32.07
1 1/8	X		3.38	40.59
1 3/16	X		3.77	45.23
1 1/4	X		4.18	50.12
1 3/8	X	X	5.05	60.64
1 1/2	X		6.01	72.17
1 3/4	X		8.19	98.23
1 7/8	X		9.40	112.76
2	X		10.69	128.30
2 1/4	X		13.53	162.38
2 1/2	X		16.71	200.47
2 3/4	X		20.21	242.56
3	X		24.06	288.67
3 1/4	X		28.23	338.79

SEE PAGE B•23-24 FOR TOLERANCES

41L40 ANNEALED, COLD DRAWN (LEADED)

AISI/SAE 41L40

PACIFIC 41L40 is the free machining version of MOLY-KROME®. The addition of a small amount of lead to the chemistry plus cold drawing increases the average machinability rating to 86%. This leaded grade can be heat treated the same as a standard 4140 to achieve similar hardness and strength. Impact toughness is somewhat lower for the leaded grade for hardnesses exceeding 35 HRC. 41L40 works well in screw machines. It is sometimes used in the as received condition but is normally heat treated prior to use.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S	Cr	Mo	Pb
.38/.43	.75/1.00	.035 max	.040 max	.80/1.10	.15/.25	.15/.35

TYPICAL PROPERTIES: Approximate—not for specification

Tensile, psi	Yield, psi	Elong.	Hardness	Machinability
105,000	85,000	15%	187HB	86%

41L40 ANNEALED, CD ROUNDS

CONDITION	COLOR CODE
Cold Drawn	Orchid

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
1/4	0.17	2.00	1 1/16	3.02	36.21
5/16	0.26	3.13	1 1/8	3.38	40.59
3/8	0.38	4.51	1 3/16	3.77	45.23
7/16	0.51	6.14	1 1/4	4.18	50.12
1/2	0.67	8.02	1 3/8	5.05	60.64
9/16	0.85	10.15	1 7/16	5.52	66.28
5/8	1.04	12.53	1 1/2	6.01	72.17
11/16	1.26	15.16	1 9/16	6.53	78.31
3/4	1.50	18.04	1 5/8	7.06	84.70
13/16	1.76	21.17	1 3/4	8.19	98.23
7/8	2.05	24.56	2	10.69	128.3
15/16	2.35	28.19	2 1/8	12.07	148.84
1	2.67	32.07	2 3/4	20.21	242.56

SEE PAGE B•23 FOR TOLERANCES

86L20 COLD DRAWN (LEADED)

AISI/SAE 86L20

PACIFIC 86L20 is cold drawn in the as rolled condition. The addition of lead gives free machining characteristics to this carburizing grade of alloy steel. Heat treatment is carried out just as it would be for the standard grade to achieve similar results for hardness and case depth. Even though 86L20 is considered a carburizing grade, it sometimes is used in the as received (natural) condition.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S	Ni	Cr	Mo	Pb
.18/.23	.70/.90	.035 max	.040 max	.40/.70	.40/.60	.15/.25	.15/.35

TYPICAL PROPERTIES: Approximate—not for specification

Tensile, psi	Yield, psi	Elong.	Hardness	Machinability
95,000	80,000	15%	179HB	86%

86L20 CD ROUNDS

CONDITION	COLOR CODE
Cold Drawn	Orchid with Orange Stripe

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
1/4	0.17	2.00	1 3/4	8.19	98.23
3/8	0.38	4.51	1 7/8	9.40	112.76
1/2	0.67	8.02	2	10.69	128.30
5/8	1.04	12.53	2 1/4	13.53	162.38
3/4	1.50	18.04	2 3/8	15.08	180.92
7/8	2.05	24.56	2 1/2	16.71	200.47
1	2.67	32.07	2 3/4	20.21	242.56
1 1/16	3.02	36.21	2 7/8	22.09	265.11
1 1/8	3.38	40.59	3	24.06	288.67
1 3/16	3.77	45.23	3 1/4	28.23	338.79
1 1/4	4.18	50.12	3 3/8	40.45	365.35
1 3/8	5.05	60.64	3 1/2	32.74	392.91
1 1/2	6.01	72.17	3 3/4	37.59	451.05
1 5/8	7.06	84.70	4	42.77	513.19

SEE PAGE B•23 FOR TOLERANCES

TYPE 303 FREE MACHINING STAINLESS STEEL

AISI 303 (UNS 30300)

PACIFIC 303 stainless steel is the free machining version of austenitic (non-magnetic) stainless steel. Being an 18% chromium - 8% nickel grade, it is resistant to atmospheric corrosion, foodstuffs, most organic chemicals and a wide variety of inorganic chemicals. As with other 18-8 type stainless grades, sensitization to intergranular corrosion can occur if type 303 is heated between 800°F and 1650°F or if cooled slowly through this temperature range. Passivation is suggested where maximum corrosion resistance is required. Welding is not recommended because of the high sulfur content. 300 series stainless steels are not hardenable by heat treatment. Smaller diameters are usually stocked with a cold drawn surface condition. Diameters 3/4" and larger usually have a smooth turned surface finish. Unlike carbon and low alloy cold finished bars, stainless diameter tolerances are both plus and minus from nominal size.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S	Si	Cr	Ni
.15 max	2.00 max	.20 max	.15 min	1.00 max	17.00/19.00	8.00/10.00

TYPICAL PROPERTIES: Approximate—not for specification

Condition	Tensile, psi	Yield, psi	Elong.	Hardness	Mach.
Annealed	75,000	35,000	50%	131HB	78%
Cold Drawn	100,000	60,000	30%	179HB	78%

303 STAINLESS ROUNDS

CONDITION	COLOR CODE
Annealed, cold drawn	Red
Annealed, smooth turned	Red

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
1/4	0.17	2.00
5/16	0.26	3.13
3/8	0.38	4.51
1/2	0.67	8.02
5/8	1.04	12.53
3/4	1.50	18.04
7/8	2.05	24.56
1	2.67	32.07
1 1/8	3.38	40.59
1 3/16	3.77	45.23
1 1/4	4.18	50.12
1 3/8	5.05	60.64
1 7/16	5.52	66.28
1 1/2	6.01	72.17
1 5/8	7.06	84.70
1 3/4	8.19	98.23
1 15/16	10.03	120.4
2	10.69	128.3
2 1/4	13.53	162.4
2 1/2	16.71	200.5
3	24.06	288.7

SEE PAGE B•25 FOR TOLERANCES

17-4 PH HIGH STRENGTH STAINLESS STEEL

AISI TYPE 630 (UNS S17400)

PACIFIC 17-4 PH stainless steel is a precipitation hardening grade offering high strength with corrosion resistance similar to type 304 in most environments. It is stocked centerless ground and polished in condition H1075. Condition H1075 has been aged (precipitation hardened) at 1075°F for strengthening without sacrificing the machinability of the solution annealed condition. 17-4 PH is readily welded and selection of filler metal depends on properties requirements of the welded joint.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S	Si	Cr	Ni	Cu	Cb+Ta
.07 max	1.00 max	.040 max	.003 max	1.00 max	15.00/17.50	3.00/5.00	3.00/5.00	.15/.35

TYPICAL PROPERTIES: Approximate—not for specification

Condition	Tensile, psi	Yield, psi	Elong.	Hardness	Mach.
H1075	145,000	125,000	13%	311/375HB	45%

17-4 PH STAINLESS ROUNDS

CONDITION	COLOR CODE
H1075, Ground & Polished	Light Blue

STOCK SIZES		
DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)
3/4	1.50	30.07
1	2.67	53.46
1 1/4	4.18	83.53
1 3/8	5.05	101.1
1 1/2	6.01	120.3
1 3/4	8.19	163.7
2	10.69	213.8
2 1/2	16.71	334.1
3	24.06	481.1
3 1/2	32.74	654.9
4	42.77	855.3
ASK FOR AVAILABILITY ON OTHER SIZES AND CONDITIONS OF 17-4 PH		

DIAMETER TOLERANCES (INCHES)	
SIZE RANGE	MINUS / PLUS
thru 1 3/8	.004 / .001
1 1/2 thru 3 1/2	.0045 / .0015
4	.003 / .003

COLD FINISHED MANUFACTURING TOLERANCES

Carbon Bars, ASTM A29

CARBON STEEL BARS				
COLD DRAWN or TURNED & POLISHED				
SIZE RANGE, Inches	Maximum of Carbon Range 0.28% or Less	Maximum of Carbon Range over 0.28 to 0.55% incl.	Maximum of Carbon Range to 0.55% Incl. Stress Relieved or Annealed After Cold Finishing	Maximum of Carbon Range over 0.55% and All Grades Quenched & Tempered or Normalized & Tempered Before Cold Finishing
ROUNDS — Cold Drawn or Turned & Polished	*ALL TOLERANCES ARE IN INCH AND ARE MINUS*			
To 1½ incl.	.002	.003	.004	.005
Over 1½ to 2½ incl.	.003	.004	.005	.006
Over 2½ to 4 incl.	.004	.005	.006	.007
Over 4 to 6 incl.	.005	.006	.007	.008
Over 6 to 8 incl.	.006	.007	.008	.009
Over 8 to 9 incl.	.007	.008	.009	.010
Over 9	.008	.009	.010	.011
HEXAGONS — Cold Drawn				
To ¾ incl.	.002	.003	.004	.006
Over ¾ to 1½ incl.	.003	.004	.005	.007
Over 1½ to 2½ incl.	.004	.005	.006	.008
Over 2½ to 3⅛ incl.	.005	.006	.007	.009
SQUARES — Cold Drawn				
To ¾ incl.	.002	.004	.005	.007
Over ¾ to 1½ incl.	.003	.005	.006	.008
Over 1½ to 2½ incl.	.004	.006	.007	.009
Over 2½ to 4 incl.	.006	.008	.009	.011
FLATS — Cold Drawn				
WIDTH IN INCHES				
To ¾ incl.	.003	.004	.006	.008
Over ¾ to 1½ incl.	.004	.005	.008	.010
Over 1½ to 3 incl.	.005	.006	.010	.012
Over 3 to 4 incl.	.006	.008	.011	.016
Over 4 to 6 incl.	.008	.010	.012	.020
Over 6	.013	.015	—	—

This table includes tolerances for bars that have been annealed, spheroidize annealed, normalized and tempered or quenched and tempered before cold finishing. This table does not include tolerances for bars that are spheroidize annealed, normalized, normalized and tempered or quenched and tempered after cold finishing.

Note 1. Width governs the tolerances for both width and thickness of flats. For example, when the maximum of carbon range is 0.28 per cent or less, for a flat 2 in. wide and 1 in. thick, the width tolerance is 0.005 in. and the thickness tolerance is the same, namely, 0.005 in.

Note 2. For sizes larger than those shown, the producer should be consulted regarding size tolerances.

COLD FINISHED MANUFACTURING TOLERANCES

Alloy Bars, ASTM A29

ALLOY STEEL BARS				
COLD DRAWN or TURNED & POLISHED				
SIZE RANGE, Inches	Maximum of Carbon Range 0.28% or Less	Maximum of Carbon Range over 0.28 to 0.55% incl.	Maximum of Carbon Range to 0.55% Incl. Stress Relieved or Annealed After Cold Finishing	Maximum of Carbon Range over 0.55% With or Without Stress Relieving or Annealing After Cold Finishing and All Grades Quenched & Tempered or Normalized & Tempered Before Cold Finishing
ROUNDS — Cold Drawn or Turned & Polished	*ALL TOLERANCES ARE IN INCH AND ARE MINUS*			
To 1 1/2 incl.	.003	.004	.005	.006
Over 1 1/2 to 2 1/2 incl.	.004	.005	.006	.007
Over 2 1/2 to 4 incl.	.005	.006	.007	.008
Over 4 to 6 incl.	.006	.007	.008	.009
Over 6 to 8 incl.	.007	.008	.009	.010
Over 8 to 9 incl.	.008	.009	.010	.011
Over 9	.009	.010	.011	.012
HEXAGONS — Cold Drawn				
To 3/4 incl.	.003	.004	.005	.007
Over 3/4 to 1 1/2 incl.	.004	.005	.006	.008
Over 1 1/2 to 2 1/2 incl.	.005	.006	.007	.009
Over 2 1/2 to 3 1/8 incl.	.006	.007	.008	.010
Over 3 1/8 to 4 incl.	.006	—	—	—
SQUARES — Cold Drawn				
To 3/4 incl.	.003	.005	.006	.008
Over 3/4 to 1 1/2 incl.	.004	.006	.007	.009
Over 1 1/2 to 2 1/2 incl.	.005	.007	.008	.010
Over 2 1/2 to 3 1/8 incl.	.007	.009	.010	.012
Over 4 to 5 incl.	.011	—	—	—
FLATS — Cold Drawn				
WIDTH IN INCHES				
To 3/4 incl.	.004	.005	.007	.009
Over 3/4 to 1 1/2 incl.	.005	.006	.009	.011
Over 1 1/2 to 3 incl.	.006	.007	.011	.013
Over 3 to 4 incl.	.007	.009	.012	.017
Over 4 to 6 incl.	.009	.011	.013	.021
Over 6	.014	—	—	—

This table includes tolerances for bars that have been annealed, spheroidize annealed, normalized, normalized and tempered or quenched and tempered before cold finishing. This table does not include tolerances for bars that are spheroidize annealed, normalized, normalized and tempered or quenched and tempered after cold finishing.

Note 1. The tolerances for flats apply to thickness as well as width for both cold drawn and rolled flats.

Note 2. Width governs the tolerances for both width and thickness of flats. For example: when the maximum of carbon range is 0.28 per cent or less, for a flat 2 in. wide and 1 in. thick, the width tolerance is 0.006 in. and the thickness tolerance is the same, namely, 0.006 in.

Note 3. The size of a hexagon or square is the distance between opposite sides.

COLD FINISHED MANUFACTURING TOLERANCES

Carbon and Alloy Bars, ASTM A29

DRAWN OR TURNED; GROUND & POLISHED	
SIZE RANGE INCHES	TOLERANCE ARE MINUS ONLY INCHES
thru 1 1/2	0.001
over 1 1/2 thru 2 1/2	0.0015
over 2 1/2 thru 3	0.002
over 3 thru 4	0.003
over 4 thru 6	0.004*
over 6	0.005*

* For non-resulfurized steels (max. S limit under 0.08%) or for steels thermally treated, the tolerance is increased by 0.001 inch.

RECOMMENDED STOCK REMOVAL — COLD DRAWN BARS
0.001 in. per 1/16 in. of cross section, or 0.010 in.; whichever is greater (increase by 50% for resulfurized grades)

STRAIGHTNESS TOLERANCES — COLD FINISHED BARS					
		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 Over 0.28% and All Grades Thermally Treated	
SIZE, INCHES	LENGTH, FEET	Rounds	Squares, Hexagons and Octagons	Rounds	Squares, Hexagons and 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

[A] The foregoing tolerances are based on the following method of measuring straightness: Departure from straightness is measured by placing the bar on a level table so that the arc or departure from straightness is horizontal, and the depth of the arc is measured with a feeler gage and a straightedge.

[B] It should be recognized that straightness is a perishable quality and may be altered by mishandling. The preservation of straightness in cold-finished bars requires the utmost care in subsequent handling.

MANUFACTURING TOLERANCES

Stainless Steel Bars, ASTM A484

COLD FINISHED ROUND BARS

SPECIFIED SIZE, in. (mm)	SIZE TOLERANCES, in. (mm) [a, b]			
	OVER		UNDER	
Over 0.050 to 5/16 (1.27 to 7.94), excl.	0.001	(0.03)	0.001	(0.03)
5/16 to 1/2 (7.94 to 12.7), excl.	0.0015	(0.04)	0.0015	(0.04)
1/2 to 1 (12.7 to 25.4), excl.	0.002	(0.05)	0.002	(0.05)
1 to 1 1/2 (25.4 to 38.1), excl.	0.0025	(0.06)	0.0025	(0.06)
1 1/2 to 4 (38.1 to 101.6), excl.[c]	0.003	(0.08)	0.003	(0.08)

[a] Size tolerances are over and under as shown in the above table. Also, rounds can be produced to tolerances all over and nothing under, all under and nothing over or any combination of over and under, if the total spread in size tolerance for a specified size is not less than the total spread shown in the table.
[b] When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.
[c] Cold finished bars over 4 in (101.6 mm) in diameter are produced; size tolerances for such bars are not included herein.

HOT ROLLED ROUND & SQUARE BARS

SPECIFIED SIZE, in. (mm)	SIZE TOLERANCES, in. (mm)				OUT-OF-ROUND OR OUT-OF-SQUARE SECTION[b], in. (mm)	
	OVER		UNDER			
7/32 to 5/16 (5.56 to 7.9), incl. [c, d]	[e]		[e]		[e]	
Over 5/16 to 7/16 (7.94 to 11.11), incl. [c, d]	0.006	(0.15)	0.006	(0.15)	0.009	(0.23)
Over 7/16 to 5/8 (11.11 to 15.88), incl. [c, d]	0.007	(0.18)	0.007	(0.18)	0.010	(0.25)
Over 5/8 to 7/8 (15.88 to 22.22), incl.	0.008	(0.20)	0.008	(0.20)	0.012	(0.30)
Over 7/8 to 1 (22.22 to 25.4), incl.	0.009	(0.23)	0.009	(0.23)	0.013	(0.33)
Over 1 to 1 1/8 (25.4 to 26.8), incl.	0.010	(0.25)	0.010	(0.25)	0.015	(0.38)
Over 1 1/8 to 1 1/4 (26.8 to 31.8), incl.	0.011	(0.28)	0.011	(0.28)	0.016	(0.41)
Over 1 1/4 to 1 3/8 (31.8 to 34.9), incl.	0.012	(0.30)	0.012	(0.30)	0.018	(0.46)
Over 1 3/8 to 1 1/2 (34.9 to 38.1), incl.	0.014	(0.36)	0.014	(0.36)	0.021	(0.53)
Over 1 1/2 to 2 (38.1 to 50.8), incl.	1/64	(0.40)	1/64	(0.40)	0.023	(0.58)
Over 2 to 2 1/2 (50.8 to 63.5), incl.	1/32	(0.79)	0		0.023	(0.58)
Over 2 1/2 to 3 1/2 (63.5 to 88.9), incl.	3/64	(1.19)	0		0.035	(0.89)
Over 3 1/2 to 4 1/2 (88.9 to 114.3), incl.	1/16	(1.59)	0		0.046	(1.17)
Over 4 1/2 to 5 1/2 (114.3 to 139.7), incl.	5/64	(1.98)	0		0.058	(1.47)
Over 5 1/2 to 6 1/2 (139.7 to 165.1), incl.	1/8	(3.18)	0		0.070	(1.78)
Over 6 1/2 to 8 (165.1 to 203), incl.	5/32	(3.97)	0		0.085	(2.16)

[a] Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same cross section.
[b] Out-of-square section is the difference in the two dimensions at the same cross section of a square bar, each dimension being the distance between opposite faces.
[c] Size tolerances for rounds in the size range of 1/4 to 5/16 in (6.35 to 7.94 mm), incl., and for rounds in the size range of 1/4 in (6.35 mm) to approximately 5/8 in (15.88 mm) which are produced on rod mills in coils, are not shown.
[d] Variations in size of coiled product made on rod mills are greater than size tolerances for product made on bar mills.
[e] Squares in this size are not produced as hot rolled product.

KEY SIZE vs. SHAFT DIAMETER

KEY SIZE VERSUS SHAFT DIAMETER (USAS B17.1-1967)						
NOMINAL SHAFT DIAMETER*		NOMINAL KEY SIZE*			NOMINAL KEYSEAT DEPTH*	
OVER	TO (INCL.)	WIDTH, *W*	HEIGHT, *H*		*H / 2*	
			SQUARE	RECTANGULAR	SQUARE	RECTANGULAR
5/16	7/16	3/32	3/32	....	3/64	....
7/16	9/16	1/8	1/8	3/32	1/16	3/64
9/16	7/8	3/16	3/16	1/8	3/32	1/16
7/8	1 1/4	1/4	1/4	3/16	1/8	3/32
1 1/4	1 3/8	5/16	5/16	1/4	5/32	1/8
1 3/8	1 3/4	3/8	3/8	1/4	3/16	1/8
1 3/4	2 1/4	1/2	1/2	3/8	1/4	3/16
2 1/4	2 3/4	5/8	5/8	7/16	5/16	7/32
2 3/4	3 1/4	3/4	3/4	1/2	3/8	1/4
3 1/4	3 3/4	7/8	7/8	5/8	7/16	5/16
3 3/4	4 1/2	1	1	3/4	1/2	3/8
4 1/2	5 1/2	1 1/4	1 1/4	7/8	5/8	7/16
5 1/2	6 1/2	1 1/2	1 1/2	1	3/4	1/2
6 1/2	7 1/2	1 3/4	1 3/4	1 1/2**	7/8	3/4
7 1/2	9	2	2	1 1/2	1	3/4
9	11	2 1/2	2 1/2	1 3/4	1 1/4	7/8

NOTE: Square keys are preferred for shaft sizes through 6 1/2" diameter; rectangular keys for larger diameters.

* All dimensions in inches

** Some key standards show 1 1/4"; preferred height is 1 1/2"

TOLERANCES FOR 1018 KEY STOCK ARE SHOWN ON PAGE B•22

SPECIAL SHAPES

Special shapes other than flats, squares, rounds and hexagons can be cold drawn from many grades. Examples are half-rounds, dove-tails, c-sections, etc. Special cold drawn shapes can virtually eliminate machining by being drawn to exact shape and size. Talk to your PACIFIC representative for details.

SECTION INDEX
SPRING STEEL

HOT ROLLED

COLD FINISHED

TOLERANCES

SPRING STEEL SHEETS

AISI/SAE 1075/1095

PACIFIC's Spring Steel Sheets are stocked in the hot rolled (unannealed) condition with approximate hardness 25/35 HRC. Typical uses are shims, springs, scrapers, blades, knives and other applications where thin spring steel or carbon tool steel is required. If forming is required, it will usually have to be done hot. Spring temper will require heat treating. Hardening is usually done by quenching in water or oil from approximately 1450°F and tempering (drawing) at 400/900°F to required hardness. Stock widths are 18" to 36".

STOCK SIZES

THICKNESS (INCHES)	WEIGHT PER SQ. FT. (POUNDS)	EST. WT. PER 2' X 6' SHEET (POUNDS)
0.032	1.31	15.68
0.050	2.04	24.50
0.062	2.53	30.38
0.072	2.94	35.28
0.091	3.72	44.60
0.125	5.10	61.25

COLD ROLLED ANNEALED SPRING STEEL

AISI/SAE 1050, 1075 & 1095

PACIFIC Cold Rolled Spring Steel is available on short notice from mill depot stock for those jobs requiring maximum formability; spheroidize annealing gives maximum softness in each carbon range. Availability is in either coil or straightened cut lengths. The lowest carbon range (1050) gives maximum formability and the highest carbon range (1095) gives maximum strength and hardness. Heat treatment will be required for spring temper.

MILL STOCK SIZES

Thickness in Inches	AISI - SAE Analyses Available	Wt. Per Sq. Ft. Lbs.	Thickness in Inches	AISI - SAE Analyses Available	Wt. Per Sq. Ft. Lbs.	Thickness in Inches	AISI - SAE Analyses Available	Wt. Per Sq. Ft. Lbs.
.003	1095	.1224	.025	1050-1075-1095	1.0200	.065	1050-1075-1095	2.6520
.004	1095	.1632	.028	1050-1075-1095	1.1424	.072	1050-1075-1095	2.9370
.005	1095	.2040	.030	1050-1075-1095	1.2240	.075	1075	3.0600
.006	1095	.2448	.032	1050-1075-1095	1.3056	.078	1050-1075-1095	3.1824
.007	1095	.2856	.035	1050-1075-1095	1.4280	.083	1050-1075-1095	3.3864
.008	1075-1095	.3264	.037	1050-1075-1095	1.5096	.093	1050-1075-1095	3.7944
.009	1095	.3672	.040	1050-1075-1095	1.6320	.095	1050-1075-1095	3.8760
.010	1050-1075-1095	.4080	.042	1050-1075-1095	1.7136	.100	1075	4.0900
.012	1050-1075-1095	.4896	.045	1050-1075-1095	1.8360	.109	1050-1075-1095	4.4472
.013	1075	.5304	.047	1050-1075-1095	1.9176	.120	1050-1075-1095	5.0000
.014	1050-1075-1095	.5712	.050	1050-1075-1095	2.0400	.125	1050-1075-1095	5.1000
.015	1050-1075-1095	.6120	.055	1050-1075	2.2440	.134	1050-1075-1095	5.4672
.016	1050-1075-1095	.6525	.058	1050-1075-1095	2.3640	.156	1050-1075-1095	6.3648
.018	1050-1075-1095	.7344	.060	1050-1075-1095	2.4480	.187	1050-1075-1095	7.6296
.020	1050-1075-1095	.8160	.062	1050-1075-1095	2.5290	.250	1075	10.7000
.022	1050-1075-1095	.8976						

NOTE: 0.003" through 0.009" available in coils only to 12" maximum width.
0.010" through 0.250" available in coils or sheared lengths to 48" maximum width.

BLUE TEMPERED & POLISHED SPRING STEEL

AISI/SAE 1095

PACIFIC Blue Tempered & Polished Spring Steel is prehardened and tempered to a standard range of 48/51 HRC, polished and blued with a smooth finished (#1) edge. 1095 carbon steel is the standard grade for this product with some sizes available in 1075. It is available in thicknesses from 0.002" through 0.062" and widths (dependent on thickness) from 1/8" through 6". Originally known as "clock spring" steel, blue tempered & polished spring steel finds wide use in any equipment or machinery requiring coiled or straight length springs; also used for prehardened shims, blades, etc. Limited forming to large radii is possible. Stock sizes listed below include both warehouse stock and sizes readily available from mill stock.

BLUE TEMPERED & POLISHED FLATS

STOCK SIZES

SIZE (INCHES)	WT. PER 100' (LBS)	SIZE (INCHES)	WT. PER 100' (LBS)	SIZE (INCHES)	WT. PER 100' (LBS)
1/8 X .010	.425	5/16 X .008	.851	1/2 X .008	1.361
.015	.638	.010	1.064	.010	1.702
.018	.766	.012	1.276	.012	2.042
.020	.851	.015	1.595	.015	2.552
.022	.936	.018	1.914	.016	2.723
.025	1.064	.020	2.127	.018	3.063
.028	1.191	.022	2.340	.020	3.403
.032	1.361	.025	2.659	.022	3.744
.035	1.489	.028	2.978	.025	4.254
.042	1.787	.032	3.403	.028	4.764
.050	2.127	.035	3.722	.032	5.445
.062	2.637	.042	4.467	.035	5.956
		.050	5.318	.042	7.147
3/16 X .003	0.191	.062	6.594	.050	8.508
.008	0.510			.062	10.550
.010	0.638	3/8 X .004	.510	.094	15.995
.012	0.766	.005	.638	.125	21.270
.015	0.957	.006	.766		
.018	1.149	.007	.893	9/16 X .008	1.531
.020	1.276	.008	1.021	.025	4.786
.025	1.595	.010	1.276		
.028	1.787	.012	1.531	5/8 X .008	1.702
.032	2.042	.015	1.914	.010	2.127
.035	2.233	.018	2.297	.012	2.552
.042	2.680	.020	2.552	.015	3.191
.050	3.191	.022	2.808	.018	3.829
.062	3.956	.025	3.191	.020	4.254
		.028	3.573	.022	4.679
1/4 X .004	.340	.032	4.084	.025	5.318
.005	.425	.035	4.467	.028	5.956
.006	.510	.042	5.360	.032	6.806
.007	.596	.050	6.381	.035	7.445
.008	.681	.062	7.912	.042	8.933
.010	.851			.050	10.653
.012	1.021	7/16 X .010	1.489	.062	13.187
.015	1.276	.012	1.787	.094	19.994
.018	1.531	.015	2.233		
.020	1.702	.025	3.722	3/4 X .004	1.021
.022	1.872	.032	4.764	.005	1.276
.025	2.127	.042	6.235	.006	1.531
.028	2.382	.062	9.231	.007	1.787
.032	2.723			.008	2.042
.035	2.978	1/2 X .004	.681	.010	2.552
.042	3.573	.005	.851	.012	3.063
.050	4.254	.006	1.021	.015	3.829
.062	5.275	.007	1.191	.018	4.594

Continued on next page

BLUE TEMPERED & POLISHED FLATS — Continued

STOCK SIZES					
SIZE (INCHES)	WT. PER 100' (LBS)	SIZE (INCHES)	WT. PER 100' (LBS)	SIZE (INCHES)	WT. PER 100' (LBS)
3/4 X .020	5.105	1 1/4 X .012	5.105	2 1/4 X .006	4.594
.022	5.615	.015	6.381	.010	7.657
.025	6.381	.022	9.359		
.028	7.147	.025	10.635	2 1/2 X .005	4.254
.032	8.168	.032	13.613	.006	5.105
.035	8.933	.042	17.867	.008	6.806
.042	10.720	.050	21.270	.010	8.508
.050	12.762	.062	26.375	.018	15.314
.062	15.825	.094	39.988	.032	27.226
.094	23.993	.125	53.175	.062	52.750
.125	31.905			.094	79.975
		1 1/2 X .005	2.552		
7/8 X .010	2.978	.006	3.063	3 X .002	2.042
.015	4.467	.007	3.573	.003	3.063
.018	5.360	.008	4.084	.004	4.084
.020	5.956	.010	5.105	.005	5.105
.022	6.551	.015	7.657	.006	6.126
.025	7.445	.018	9.189	.007	7.147
.028	8.338	.020	10.210	.008	8.168
.032	9.529	.022	11.231	.010	10.210
.050	14.889	.025	12.762	.012	12.252
.062	18.462	.032	16.335	.015	15.314
.094	27.991	.035	17.867	.018	18.377
.125	37.223	.042	21.440	.020	20.419
		.050	25.524	.022	22.461
1 X .004	1.361	.062	31.650	.025	25.524
.005	1.702	.125	63.810	.028	28.587
.006	2.042			.032	32.671
.007	2.382	1 3/4 X .006	3.573	.035	35.734
.008	2.723	.008	4.764	.042	42.880
.010	3.403	.010	5.956	.050	51.048
.012	4.084	.015	8.933	.062	63.300
.015	5.105	.030	17.867	.094	95.970
.018	6.126				
.020	6.806	2 X .004	2.723	3 1/2 X .018	21.440
.022	7.487	.005	3.403		
.025	8.508	.006	4.084	4 X .005	6.806
.028	9.529	.008	5.445	.008	10.890
.032	10.890	.010	6.806	.009	12.252
.035	11.911	.012	8.168	.010	13.613
.042	14.293	.015	10.210	.012	16.335
.050	17.016	.018	12.252	.015	20.419
.062	21.100	.020	13.613	.018	24.503
.094	31.990	.022	14.974	.020	27.226
.125	42.540	.025	17.016	.022	29.948
		.028	19.058	.025	34.032
1 1/8 X .032	12.252	.032	21.780	.028	38.116
		.035	23.822	.032	43.561
1 1/4 X .010	4.254	.042	28.587	.035	47.645
		.050	34.032		
		.062	42.200		
		.094	63.980		

Continued on next page

BLUE TEMPERED & POLISHED FLATS — Continued

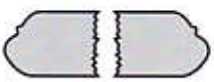
STOCK SIZES					
SIZE (INCHES)	WT. PER 100' (LBS)	SIZE (INCHES)	WT. PER 100' (LBS)	SIZE (INCHES)	WT. PER 100' (LBS)
4 X .042	57.174	6 X .012	24.503	8 1/4 X .007	19.653
.050	68.064	.013	26.545		
.062	84.399	.014	28.587	12 X 0.12	49.006
.094	127.960	.015	30.629		
		.016	32.671	12 3/8 X .010	42.115
5 X .004	6.806	.018	36.755	.012	50.538
.094	159.950	.020	40.838	.015	63.172
		.022	44.922	.018	75.806
6 X .004	8.168	.025	51.048	.020	84.229
.005	10.210	.030	61.258	.025	105.287
.006	12.252	.032	65.341	.032	134.767
.007	14.293	.035	71.467	.035	147.401
.008	16.335	.042	85.761	.062	261.111
.009	18.377	.050	102.096		
.010	20.419	.062	126.599	12 3/4 X .030	130.172

SPRING STEEL EDGES — ILLUSTRATION

NO. 1 EDGE
(SQUARE)
Broken Radial Corners

NO. 1 EDGE*
(ROUND)
Radius approximately equal to 1/2 thickness

NO. 2 EDGE
Natural mill edge



NO. 3 EDGE
(SLIT)
Approximately square

NO. 4 EDGE
(ROUND)
Rounded corners — may be flat with slitting fracture visible across the edge

NO. 5 EDGE
Approximately square
(No. 3 edge de-burred)

NO. 6 EDGE
(SQUARE)
Radial corners — may have slitting fracture visible across the edge

*Standard edge for blue tempered & polished

SPRING STEEL TOLERANCES
COLD ROLLED TEMPERED FLATS

STANDARD THICKNESS TOLERANCE INCLUDING CROWN

SPECIFIED THICKNESS (INCHES)	TOLERANCE FROM SPECIFIED THICKNESS (Plus or minus for indicated width — inches)				
	½" and Under	Over ½" and Less than 1"	1" to Under 3"	3" to 6"	Over 6" to 9"
.084 to .099	.002	.002	.003	.003	.0035
.069 to .083	.002	.002	.003	.003	.0035
.050 to .068	.0015	.002	.0025	.003	.003
.040 to .049	.0015	.002	.0025	.0025	.003
.035 to .039	.0015	.002	.0025	.0025	.003
.032 to .034	.0015	.0015	.002	.002	.003
.029 to .031	.0015	.0015	.0015	.002	.003
.026 to .028	.001	.0015	.0015	.002	.0025
.023 to .025	.001	.001	.0015	.002	.002
.020 to .022	.001	.001	.0015	.002	.002
.017 to .019	.001	.001	.001	.0015	.002
.014 to .016	.001	.001	.001	.0015	.002
.012 to .013	.001	.001	.001	.001	.0015
.010 to .011	.001	.001	.001	.001	.0015
.008 to .009	.00075	.00075	.00075	.00075	.001
.005 to .007	.0005	.0005	.0005	.00075	—
.002 to .004	.0005	.0005	.0005	.0005	—

Measured ⅜ inches in from edge on 1 inch or wider; and on narrower than 1 inch at any place between the edges.

STANDARD WIDTH TOLERANCE

SPECIFIED THICKNESS (INCHES)	TOLERANCE FROM SPECIFIED WIDTH (Plus or minus for indicated width — inches)					
	Under ½"	½" to Under 1"	1" to Under 1½"	1½" to Under 3"	3" thru 6"	Over 6" to 9"
.249 to .161	—	.016	.016	.016	.016	.020
.160 to .100	.010	.010	.010	.010	.010	.016
.099 to .069	.008	.008	.008	.008	.008	.010
.068 to .017	.005	.005	.005	.005	.005	.005
.016 to thinner	.005	.005	.005	.005	.005	.005

Above width tolerances apply to round edge or rotary slitting. Width tolerance for square shearing plus or minus .015".

SPRING STEEL TOLERANCES

ANNEALED and HARD ROLLED FLATS

STANDARD THICKNESS TOLERANCE

SPECIFIED THICKNESS (INCHES)	TOLERANCE FROM SPECIFIED THICKNESS (Plus or minus for indicated width — inches)						
	Under 1"	1" and Less Than 3"	3" to 6" Incl.	Over 6" to 9" Incl.	Over 9" to 12" Incl.	Over 12" to 16" Incl.	Over 16" to 20" Incl.
.249 to .161	.0025	.0035	.004	.004	.0045	.0045	.005
.160 to .100	.002	.002	.003	.003	.003	.0035	.0045
.099 to .069	.002	.002	.0025	.003	.003	.0035	.0035
.068 to .050	.002	.002	.0025	.0025	.0025	.003	.003
.049 to .040	.002	.002	.0025	.0025	.0025	.0025	.0025
.039 to .035	.002	.002	.002	.002	.002	.002	.002
.034 to .032	.0015	.0015	.002	.002	.002	.002	.002
.031 to .029	.0015	.0015	.0015	.002	.002	.002	.002
.028 to .026	.001	.0015	.0015	.002	.002	.002	.002
.025 to .023	.001	.001	.001	.0015	.0015	.002	.002
.022 to .020	.001	.001	.001	.0015	.0015	.0015	.0015
.019 to .017	.00075	.00075	.00075	.001	.001	.0015	.0015
.016 to .015	.00075	.00075	.00075	.001	.001	.0015	.0015
.014 to .013	.00075	.00075	.00075	.001	.001	.0015	.0015
.012	.00075	.00075	.00075	.001	.001	.001	.001
.011	.00075	.00075	.00075	.001	.001	.001	.001
.010 to .009	.00075	.00075	.00075	.001	.001	.001	.001
.008 to .007	.00075	.00075	.00075				
.006 and under	.00050	.00050	.00050				

Measured 3/8 inches in from edge on 1 inch or wider; and on narrower than 1 inch at any place between the edges.

STANDARD WIDTH TOLERANCE

SPECIFIED THICKNESS (INCHES)	TOLERANCE FROM SPECIFIED WIDTH (Plus or minus for indicated width — inches)								
	Under 1/2" to 3/16" Incl.	Under 1" to 1/2" Incl.	Under 1 1/2" to 1" Incl.	Under 3" to 1 1/2" Incl.	3" to 6" Incl.	Over 6" to 9" Incl.	Over 9" to 12" Incl.	Over 12" to 16" Incl.	Over 16" to 20" Incl.
0.249 to 0.161	—	0.016	0.016	0.016	0.016	0.020	0.020	0.031	0.031
0.160 to 0.100	0.010	0.010	0.010	0.010	0.010	0.016	0.016	0.020	0.020
0.099 to 0.069	0.008	0.008	0.008	0.008	0.008	0.010	0.010	0.016	0.016
0.068 to 0.017	0.005	0.005	0.005	0.005	0.005	0.005	0.010	0.016	0.016
0.016 or thinner	0.005	0.005	0.005	0.005	0.005	0.005	0.010	0.016	0.016

SECTION INDEX
FLUID POWER & SPECIALTY PRODUCTS

FLUID POWER PRODUCTS

SPECIALTY PRODUCTS

CHROME PLATED BAR

AISI 1045/50, Stressproof® and Acralloy®

PACIFIC Chrome Plated Bar is typically used for hydraulic cylinder rods. It is stocked in two basic conditions; **CPO®** (Chrome Plated Only) and **IHCP®** (Induction Hardened and Chrome Plated). The primary difference is that IHCP® bars are induction hardened to give a hard case on the surface for support to the chrome plating; this minimizes surface damage to the chrome from abrasion and/or impact.

Also, AISI 1045/50 CPO® and IHCP® are both available in standard and high strength properties. Thickness of chrome plating is designated as either Standard (0.0005" min.) or Heavy (0.001" min.).

CPO® bars are also stocked in Acralloy® and Stressproof® grades. Acralloy® offers the strength and toughness of a quenched and tempered alloy steel; Stressproof® gives high strength with free machining characteristics. Types and grades of PACIFIC Chrome Plated Bar are listed below:

S-CPO®: Standard Chrome Plated Only ..... AISI 1045/50 & Stressproof®
H-CPO®: Heavy Chrome Plated Only ..... AISI 1045/50 & Acralloy®
IHCP®: Induction Hardened & Chrome Plated ..... AISI 1045/50

S-CPO® HS: High Strength-SCPO ..... AISI 1045/50
IHCP® HS: High Strength-IHCP ..... AISI 1045/50

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

Grade	C	Mn	P	S	Cr	Mo
AISI 1045/50	.43/.55	.60/.90	.040 max	.050 max	—	—
Stressproof®	.40/.48	1.35/1.65	.040 max	.24/.33	—	—
Acralloy®	.38/.45	.75/1.00	.035 max	.040 max	.80/1.00	.15/.25

TYPICAL PROPERTIES: Approximate—not for specification

Grade	Tensile, psi	Yield, psi	Elong.	Hardness	Mach.
* AISI 1045/50	90,000	75,000	10%	179HB	56%
** AISI 1045/50 HS	115,000	100,000	9%	235HB	56%
** Stressproof®	115,000	100,000	8%	241HB	83%
Acralloy®	120,000	100,000	20%	255HB	55%

* Cold drawn properties apply through 4½" diameter; larger diameters have hot rolled properties, i.e., 50,000 psi approximate yield strength.
** ASTM A311, Class B

CHROME PLATING PROPERTIES: CPO® and IHCP®

	Thickness	Hardness	Surface Finish
Standard	.0005" min	69HRC min	16RMS max
Heavy	.001" min	69HRC min	16RMS max

INDUCTION HARDENED PROPERTIES: IHCP®

Surface Hardness	Effective Case Depth (to 50HRC)
50HRC min	.050" min

TOLERANCES: In decimals of an inch — provide for undersize variation only †

Diameter	Tolerance
to 1½"	.001"
1½" to 2½"	.0015"
2½" thru 3"	.002"
over 3" thru 4"	.003"
over 4"	.005"

† H-CPO® tolerances can be oversize to the nominal diameter. Ask your PACIFIC representative on specific items

REMEMBER PACIFIC 17-4PH FOR HIGH STRENGTH STAINLESS CYLINDER RODS — SEE PAGE B•21

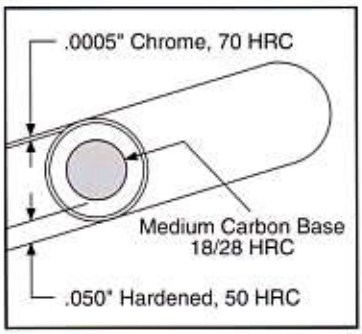
MACHINING IHCP®

Setup and machining parameters

THE MATERIAL

IHCP® is an induction hardened and chrome plated, medium carbon steel. The induction hardened layer is a minimum of .050" deep with a minimum hardness of 50 HRC. The chrome plate is a minimum of .0005" thick with a hardness of approximately 70 HRC. The medium carbon steel base is approximately .45% carbon with a hardness of approximately 18 to 28 HRC.

The machining of IHCP® will include cutting of all of the above conditions. The most critical operation will be the removal of the chrome plate and the induction hardened layer which will necessitate the use of somewhat unique tooling.

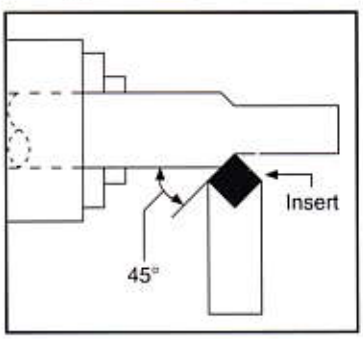


THE SETUP

Maximum rigidity is a must. Tool overhang must be kept to a minimum and the machine must be in good tight condition. Since the chrome is of such high hardness, the cutting insert must be oriented to a 45° side cutting edge angle (S.C.E.A.) to minimize the notch effect.

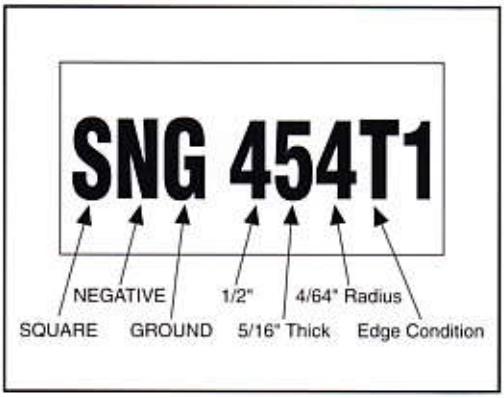
- The area to be machined should be as close as possible to the chuck.
- The use of a steadyrest is not recommended unless a live center in the tailstock is also incorporated in the setup.

The speed:	280/320 surface feet per minute (SFM)
The feed:	.003/.005" per revolution
The depth of cut:	1/8"
Coolant:	none
Horsepower:	approximately 7



THE TOOLING

The first turn operation is performed on material that is very hard. Consequently a very hard and abrasion resistant cutting tool must be used. Hot pressed ceramics fill this need. The style and size of this insert is described as follows:



These hot pressed ceramic inserts are available through major tooling suppliers.

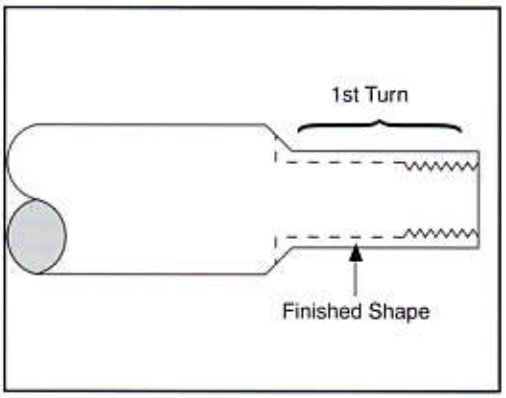
THE RESULTS

During the cutting an intense amount of heat will be generated. This is normal. The chips will be dark red in color and some sparking may occur. At no time should coolant be applied as thermal shock will definitely destroy the ceramic insert.

Do not allow the insert to dwell or rub as work hardening will occur.

The high hardness of the chrome will cause a notch to form at the depth of cut line (⅛" D.O.C.) on the ceramic insert. However, many cuts can be made before the notch causes the insert to fail.

After the hardened and chromed layer is removed, conventional carbide tooling with coolant is used to finish machine the part.



1045/50 CHROME PLATED ROUNDS

CONDITION	COLOR CODE
S-CPO®	Green with Black Stripe
S-CPO® HS	Half Green & Half Black
H-CPO®	Green with Red Stripe
IHCP®	Half White & Half Black
IHCP® HS	Half White & Half Black

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	CONDITION				
			S-CPO®	S-CPO® HS	H-CPO®	IHCP®	IHCP® HS
1/2	0.67	13.36	X				
5/8	1.04	20.88	X				
3/4	1.50	30.07	X				X
7/8	2.05	40.93	X				X
1	2.67	53.46	X		X		X
1 1/8	3.38	67.66	X				X
1 1/4	4.18	83.53	X				X
1 3/8	5.05	101.1	X				X
1 1/2	6.01	120.3	X				X
1 3/4	8.19	163.7	X		X		X
2	10.69	213.8	X				X
2 1/4	13.53	270.6	X				X
2 1/2	16.71	334.1	X	X	X		X
2 3/4	20.21	404.3	X	X			X
3	24.06	481.1	X	X	X		X
3 1/4	28.23	564.6					X
3 1/2	32.74	654.9	X	X			X
3 3/4	37.59	751.7					X
4	42.77	855.3	X	X	X		X
4 7/16	52.63	1,052.7		X			
4 1/2	54.13	1,082.5	X	X	X		X
5	66.82	1,336.4	X			X	
5 1/2	80.85	1,617.1				X	

ACRALLOY® & STRESSPROOF® CHROME PLATED ROUNDS

GRADE	COLOR CODE
Acralloy® H-CPO®	Half Orchid & Half Red
Stressproof® S-CPO®	Half Copper & Half Black

STOCK SIZES

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 20' BAR (LBS.)	GRADE	
			Acralloy® H-CPO®	Stressproof® S-CPO®
3/4	1.50	30.07		X
1	2.67	53.46	X	X
1 1/4	4.18	83.53	X	X
1 3/8	5.05	101.1	X	X
1 1/2	6.01	120.3	X	X
1 3/4	8.19	163.7	X	X
2	10.69	213.8	X	X
2 1/2	16.71	334.1	X	

OTHER SIZES AVAILABLE ON SHORT NOTICE

CHROME PLATED ID TUBING

Air Cylinder Tubing

PACIFIC Honed & Chromed ID tubing is used primarily for air cylinder barrels. However, it is used wherever thin walls and the corrosion protection of chromium plating are beneficial. 1026 DOM is the raw stock for this product. Steel tubing has higher strength than aluminum air cylinder tubing. Standard chrome thickness is 0.0003/0.0005 inch and finish is 10/20 rms.

CHROME PLATED ID TUBING

STOCK SIZES			
OD (INCHES)	ID (INCHES)	REF. WALL (INCHES)	WT. PER FT. (LBS.)
1.740	1.500/1.503	0.120	2.08
2.240	2.000/2.003	0.120	2.72
2.740	2.500/2.503	0.120	3.36
3.240	3.000/3.003	0.120	4.00
3.490	3.250/3.253	0.120	4.32
3.750	3.500/3.503	0.125	4.84
4.236	4.000/4.003	0.118	5.20
5.235	5.000/5.003	0.118	6.46
6.250	6.000/6.003	0.125	8.19
7.438	7.000/7.004	0.219	16.90
8.450	8.000/8.005	0.225	19.79
10.450	10.000/10.005	0.225	24.60
12.450	12.000/12.010	0.225	29.41
14.450	14.000/14.012	0.225	34.22

SAVE PLATING COSTS. USE PACIFIC CHROME PLATED BARS — See page D•1.

CAST IRON — Continuous Cast Bars

GRAY and DUCTILE CAST IRON

PACIFIC CAST IRON is stocked in both gray and ductile (nodular) grades. Both types machine well plus exhibit good compressive properties and excellent damping characteristics. Continuous casting virtually eliminates typical casting problems of porosity, surface flaws and shrinkage. Both gray and ductile iron can be considered for replacing steel, aluminum and bronze in many applications. Benefits are better machinability and lower costs. Gray iron is classified by its tensile strength (class 40 is nominally 40,000 psi). Ductile iron is classified by its nominal strengths and ductility (grade 60-45-12 is nominally 60,000 psi tensile strength, 45,000 psi yield strength and 12% elongation). Both class 40 gray iron and 80-55-06 ductile iron can be hardened by furnace heat treating and by flame or induction hardening. As cast bars have machining allowance to clean to nominal size.

TYPICAL APPLICATIONS

Bearings	Gibs	Plungers	Seals
Bushings	Glands	Pulleys	Sheaves
Collars	Glass Molds	Quills	Sleeves
Dies	Guides	Rolls	Spools
Eccentrics	Liners	Rotors	Valves
Gears	Pistons	Seal Rings	Ways

CHEMICAL COMPOSITION: Typical—not for specification, %

	C	Mn	Si
Gray Iron	2.9/3.7	0.5/0.8	1.6/2.7
Ductile Iron	3.6/3.9	0.1/0.4	2.3/2.8

Other elements added as required to produce microstructure and mechanical properties.

TYPICAL BRINELL HARDNESS

SIZE (inches)	GRAY CLASS 40	DUCTILE (65-45-12)	DUCTILE (80-55-06)
1½ — 2	207/269	153/220	217/262
2 — 3	197/262	153/220	217/262
3 — 6	197/262	143/220	207/255
6 — 10	183/262	131/220	207/255
10 — 20	183/262	131/220	187/255

PROCESSING TEMPERATURES: Typical

Harden: 1575/1675°F, quench in agitated oil
Anneal: 1500/1650°F and furnace cool
Temper: 375/1200°F
Stress Relieve: 1050/1100°F

REQUEST OUR PRODUCT BROCHURE ON CONTINUOUS CAST IRON.

CAST IRON ROUNDS

AS CAST

GRADE	COLOR CODE
Class 40; Gray	Green
65-45-12; Ductile	Yellow
80-55-06; Ductile	Light Blue

STOCK SIZES

DIAMETER (INCHES)	AVE. STOCK ALLOW. (INCHES)	WT. PER FT. (POUNDS)	WT. PER 6' BAR (POUNDS)	GRADE		
				Class 40	65-45-12	80-55-06
1 1/2	.085	6.156	36.9	X	X	X
1 3/4	.085	8.251	49.5	X		X
2	.085	10.653	63.9	X	X	X
2 1/2	.110	16.693	100.2	X	X	X
2 3/4	.110	20.044	120.3	X	X	X
3	.110	23.701	142.2	X	X	X
3 1/4	.125	27.912	167.5	X	X	
3 1/2	.125	32.200	193.2	X	X	X
3 5/8	.125	34.459	206.8	X		
3 3/4	.125	36.795	220.8		X	
4	.125	41.696	250.2	X	X	X
4 1/4	.140	44.574	267.4	X	X	
4 1/2	.140	52.757	316.5	X	X	X
4 3/4	.140	58.595	351.6	X	X	X
5	.140	64.740	388.4	X	X	
5 1/2	.155	78.363	470.2	X	X	X
5 3/4	.155	85.445	512.7	X		
6	.155	92.833	557.0	X	X	X
6 1/2	.170	109.017	654.1		X	X
7	.170	125.975	755.8	X	X	X
7 1/2	.190	144.910	869.5	X		
8	.190	164.366	986.2	X	X	X
8 1/4	.216	175.631	1,053.8	X		
9	.216	208.127	1,248.8		X	X
10	.254	257.651	1,545.9	X	X	X
11	.400	318.459	1,910.8		X	
11 1/2	.582	357.703	2,146.2	X	X	
12	.582	387.921	2,327.5		X	X
12 1/2	.582	419.366	2,516.2	X		
14	.582	521.049	3,126.3	X		
15	.582	594.964	3,569.8	X		
18	.762	862.587	5,175.5	X		
20	.762	1,056.289	6,337.7	X		

MILL DEPOT STOCK AVAILABILITY:

- Hollow Bar (Trepanned Rounds)
- As Cast Squares and Rectangles
- Centerless Ground Rounds
- Custom Shapes

ZINCALOY® BAR STOCK

ZA®-12 Zinc-Aluminum Alloy

PACIFIC ZA®-12 is continuous cast by Zincaloy® Inc. in 11' random length solid and hollow bars; solid bars are available in rounds and flats. ZA®-12 has proved through use to be an upgrade for 660 bronze in most bushing (plain bearing) applications—especially heavy load, low RPM situations. It has also been successfully used to replace hardened steel bushings in many applications. Besides bearing applications, ZA®-12 has been used for lead screw nuts, gears, kiln cart wheels, wear strips, hydraulic cylinder components and trolley wheels. Zincaloy® bar stock offers many performance benefits:

- **GOOD MECHANICAL PROPERTIES**—strength approximately equal to medium carbon steel.
- **LOW COEFFICIENT OF FRICTION**—equal to and sometimes lower than 660 bronze.
- **LIGHT WEIGHT**—32% lighter than 660 bronze.
- **ANTI-SEIZING PROPERTIES**—unlikely to gall if lubricant failure occurs.
- **EXCELLENT MACHINABILITY**—rated 14% higher than 660 bronze.
- **LEAD FREE**—no special precautions for chip disposal.
- **RESILIENCE**—protects bearing housings from deformation due to pounding.
- **LONGER BEARING LIFE**

PROPERTIES COMPARISON

PROPERTY	ZA®-12	BEARING BRONZE (660)	ALUMINUM BRONZE (954)
Ultimate Tensile Strength (ksi)	65	35	85
Yield Strength (ksi)	50	20	32
Elongation (%)	2	10	12
Hardness (Brinell)	130	60	170
Density (lb/in^3)	0.218	0.322	0.269
Melting Range (°F)	710-810	1570-1790	1880-1900
Electrical Conductivity (% IACS)	28	12	13
Thermal Conductivity (btu/h·ft·°F)	67	34	34
Coef. of Thermal Expansion (µin/in.°F)	13	10	9
Machinability (% of Free Cutting Brass)	80	70	60

CHEMISTRY, % — ASTM B791

Al	Cu	Mg	Zn
10.5/11.5	0.5/1.2	0.015/0.030	Balance

ZINCALOY® BAR STOCK

ZA®-12 Zinc-Aluminum Alloy

TOLERANCES

DIAMETER			ROUNDNESS		STRAIGHTNESS	CONCENTRICITY
SIZE	TOLERANCE			Maximum Out Of		
O.D. (in.)	O.D. (in.)	I.D. (in.)	O.D. (in.)	Roundness (in.)	Solid & Hollow Bar	Hollow Bar
¾—2 incl.	± 0.010	+0.012 −0.033	thru 4	0.010	Less than .050 inch deviation in any 12 inches. Maximum curvature (depth of arc) less than ½ inch in any 10 ft. length.	The outside periphery is concentric with the bore within a maximum variation of 4% of the nominal wall thickness for all sizes of stock.
over 2 to 4 excl.	± 0.015	+0.012 −0.033				
4 to 5 incl.	± 0.025	+0.012 −0.033	over 4	0.015		
over 5	± 0.025	+0.032 −0.064				

MACHINING ALLOWANCE: Listed sizes are nominal and do not include ⅛" machining allowance on all dimensions.

P-V BEARING DATA

V (ft/min)	P (psi)		PV	
	660 BRONZE	ZA®-12	660 BRONZE	ZA®-12
<10	3,800	5,000	19,000	25,000
10	3,700	4,200	37,000	42,000
15	3,200	3,000	48,000	45,000
20	2,800	2,100	56,000	42,000

ZA®-12 also has higher P values at speeds greater than V=45

$$V = \frac{\pi d\,(RPM)}{12}$$

$$P = \frac{W}{d\,L}$$

V = Shaft surface speed; $\frac{ft}{min}$

P = bearing stress; $\frac{lb}{in^2}$

d = bearing ID; inches

L = bearing length; inches

W = total bearing load; pounds

RPM = shaft rotation; $\frac{revolutions}{min}$

DESIGN GUIDELINES

Shaft Clearance, in	(0.0025) x shaft dia.
Bearing Length, in	(0.4 to 1.5) x shaft dia.
Min. Bearing Thickness, in	(0.045) x shaft dia. + 0.020
Max Bearing Stress, psi	4500
Max. Operating Temp., °F	250

ZINCALOY® BAR STOCK

ZA®-12 Zinc-Aluminum Alloy

CONDITION	COLOR CODE
Round Bar	Blue
Flat Bar	Blue
Hollow Bar	Blue

ZINCALOY® SOLID BAR

STOCK SIZES					
DIAMETER[1] (INCHES)	WT. PER FT. (LBS.)	DIAMETER[1] (INCHES)	WT. PER FT. (LBS.)	DIAMETER[1] (INCHES)	WT. PER FT. (LBS.)
5/8	1.16	2 5/8	15.54	4 3/4	48.33
3/4	1.57	2 3/4 [2]	16.98	4 7/8	51.37
7/8	2.05	2 7/8	18.49	5	53.97
1	2.60	3	20.06	5 1/4	59.36
1 1/8	3.21	3 1/8	21.70	5 3/8	62.15
1 3/8	4.62	3 1/4	23.40	5 1/2	65.01
1 1/2	5.43	3 1/2	27.00	5 7/8	73.97
1 5/8	6.29	3 3/4	30.85	6	77.08
1 7/8	8.22	3 7/8	32.87	6 3/8	86.81
2	9.28	4	34.96	6 7/8 [2]	100.68
2 1/8	10.40	4 1/4	39.33	7 [2]	104.30
2 3/8	12.84	4 3/8	41.61	7 3/4 [2]	127.42
2 1/2	14.16	4 1/2	43.95	8 [2]	135.64

[1] Approximately 1/8" machining allowance guarantees ability to finish at the nominal diameter.

[2] Mill depot stock size.

ZINCALOY® FLAT BAR

MILL STOCK SIZES[2]					
THICKNESS[1] (INCHES)	WIDTH[1] (INCHES)	WT. PER FT. (LBS.)	THICKNESS[1] (INCHES)	WIDTH[1] (INCHES)	WT. PER FT. (LBS.)
3/8	2 7/8	3.92	1 3/8	7 7/8	31.39
5/8	1 1/8	2.45	1 7/8	3 7/8	20.93
7/8	6 7/8	18.31	2 3/8	3 1/4	22.07
1	3	9.20	2 7/8	3 7/8	31.39
1 3/8	4 1/2	18.15			

[1] Approximately 1/8" machining allowance on thickness and width guarantees ability to finish at nominal dimensions.

[2] Available from mill stock only—special sizes and shapes also available with minimum orders.

ZINCALOY® HOLLOW BAR

STOCK SIZES					
ID[1] (INCHES)	OD[1] (INCHES)	WT. PER FT. (LBS.)	ID[1] (INCHES)	OD[1] (INCHES)	WT. PER FT. (LBS.)
1	1 3/4 [2]	5.65	2	3	12.84
	2	7.70		3 1/4	16.18
	2 1/4 [2]	10.02		3 1/2	19.78
	2 1/2	12.58		3 3/4 [2]	23.63
	2 3/4 [2]	15.41		4	27.74
	3	18.49		4 1/4 [2]	32.10
	3 1/4 [2]	21.83		4 1/2 [2]	36.73
	3 1/2 [2]	25.43		4 3/4 [2]	41.61
	3 3/4 [2]	29.28		5 [2]	46.74
	4 [2]	33.39	2 1/4	2 3/4	7.70
1 1/4	2 [2]	6.68		3	10.79
	2 1/4 [2]	8.99		3 1/4 [2]	14.13
	2 1/2 [2]	11.56		3 1/2	17.72
	2 3/4 [2]	14.38		3 3/4 [2]	21.57
	3 [2]	17.46		4 [2]	25.68
	3 1/4 [2]	20.80		4 1/4 [2]	30.05
	3 1/2 [2]	24.40		4 1/2 [2]	34.67
	3 3/4 [2]	28.25		4 3/4 [2]	39.55
	4 [2]	32.36		5 [2]	44.69
	4 1/4 [2]	36.73		5 1/4 [2]	50.08
1 1/2	2 1/4	7.70	2 1/2	3 1/4	11.81
	2 1/2	10.27		3 1/2 [2]	15.41
	2 3/4 [2]	13.10		3 3/4 [2]	19.26
	3	16.18		4	23.37
	3 1/4	19.52		4 1/4 [2]	27.74
	3 1/2	23.11		4 1/2	32.36
	3 3/4 [2]	26.97		4 3/4 [2]	37.24
	4 [2]	31.08		5 [2]	42.38
	4 1/4 [2]	35.44		5 1/4 [2]	47.77
	4 1/2 [2]	40.06		5 1/2 [2]	53.42
1 3/4	2 1/4 [2]	6.16	2 3/4	3 1/2	12.84
	2 1/2	8.73		3 3/4	16.69
	2 3/4 [2]	11.56		4	20.80
	3	14.64		4 1/4	25.17
	3 1/4 [2]	17.98		4 1/2 [2]	29.79
	3 1/2	21.57		4 3/4 [2]	34.67
	3 3/4 [2]	25.43		5 [2]	39.81
	4 [2]	29.53		5 1/4 [2]	45.20
	4 1/4 [2]	33.90		5 1/2 [2]	50.85
	4 1/2 [2]	38.52		5 3/4 [2]	56.76
	4 3/4 [2]	43.40	3	3 3/4	13.87
2	2 1/2	6.93		4	17.98
	2 3/4 [2]	9.76		4 1/4	22.34

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ZINCALOY® HOLLOW BAR — Continued

STOCK SIZES					
ID[1] (INCHES)	OD[1] (INCHES)	WT. PER FT. (LBS.)	ID[1] (INCHES)	OD[1] (INCHES)	WT. PER FT. (LBS.)
3	4 1/2	26.97	3 3/4	5 1/2 [2]	38.01
	4 3/4 [2]	31.85		5 3/4 [2]	43.92
	5	36.98		6 [2]	50.08
	5 1/4 [2]	42.38		6 1/2 [2]	63.18
	5 1/2 [2]	48.03	4	4 3/4	17.98
	5 3/4 [2]	53.93		5	23.11
	6 [2]	60.10		5 1/4 [2]	28.51
3 1/4	4	14.90		5 1/2 [2]	34.16
	4 1/4 [2]	19.26		5 3/4 [2]	40.06
	4 1/2 [2]	23.88		6	46.23
	4 3/4 [2]	28.76		6 1/2 [2]	59.33
	5	33.90	4 1/2	5 1/4	20.03
	5 1/4 [2]	39.29		5 1/2	26.68
	5 1/2 [2]	44.94		5 3/4 [2]	31.59
	5 3/4 [2]	50.85		6	37.75
	6 [2]	57.02		6 1/2 [2]	50.85
3 1/2	4 1/4	15.92	5	6	28.25
	4 1/2	20.55		6 1/2 [2]	41.35
	4 3/4 [2]	25.43		7 [2]	55.47
	5	30.56		7 3/4 [2]	78.59
	5 1/4 [2]	35.96	5 1/2	6 1/2 [2]	30.82
	5 1/2	41.61		7 [2]	44.94
	5 3/4 [2]	47.51		7 3/4 [2]	68.06
	6 [2]	53.68	6	7 [2]	33.39
	6 1/2 [2]	66.77		7 3/4 [2]	56.50
3 3/4	4 1/2 [2]	16.95		8 [2]	64.72
	4 3/4 [2]	21.83	6 1/2	7 3/4 [2]	43.92
	5 [2]	26.97		8 [2]	52.14
	5 1/4 [2]	32.36			

[1] Approximately 1/8" machining allowance guarantees ability to finish at nominal dimensions.

[2] Mill depot stock size.

ZINCALOY® BARS ARE STOCKED IN 11 FT. RANDOM LENGTHS (± 2 FT.)

SECTION INDEX
STEEL TUBING

DOM WELDED MECHANICAL TUBING

ASTM A513, Type 5

PACIFIC Drawn Over Mandrel (DOM) Tubing is made by electric resistance welding and then cold drawing over a mandrel. This gives the closest tolerances and concentricity available in tubing. **DOM Mechanical Tubing** is used as raw stock for honed ID hydraulic cylinder barrels and for other mechanical applications requiring accurate dimensional tolerances. It is normally stress relieved after cold drawing. **Honed ID DOM** is prehoned to exact ID tolerances for standard cylinder sizes. Honed and **Chromed ID DOM** is intended primarily for use as air cylinder barrels. DOM is most commonly stocked in the AISI 1026 grade; other grades of both carbon and alloy DOM are available in certain sizes. Regular DOM is usually specified by OD and wall thickness. Honed DOM is usually specified by OD and exact ID, i.e., 4"OD X 3.497"/3.500"HID (Honed ID). Custom sizes can be produced and are available in both regular and honed conditions of either carbon or alloy grades.

GRADE 1026 CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S
.22/.26	.60/.90	.035 max	.035 max

TYPICAL PROPERTIES: Approximate—not for specification

Grade / Condition	Tensile	Yield	Elongation
1018 DOM S/R	70,000	60,000	15%
1026 DOM S/R	85,000	75,000	15%
4130 DOM S/R	95,000	85,000	10%

PROCESSING TEMPERATURES: Typical

Forge: 2300°F max Normalize: 1600/1700°F Carburize: 1500/1700°F

DOM MECHANICAL TUBING

CONDITION	COLOR CODE
Cold Drawn	Green

STOCK SIZES

OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)	OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)
3/8	0.049	0.277	0.171	1/2	0.095	0.310	0.411
	0.120	0.135	0.327		0.120	0.260	0.488
7/16	0.028	0.382	0.123	5/8	0.049	0.527	0.302
	0.120	0.198	0.407		0.065	0.495	0.389
					0.095	0.435	0.538
1/2	0.035	0.430	0.174		0.120	0.385	0.648
	0.049	0.402	0.236		3/16	1/4	0.877
	0.065	0.370	0.302				

Continued on next page

DOM MECHANICAL TUBING — Continued

STOCK SIZES							
OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)	OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)
3/4	0.049	0.652	0.367	1 5/16	0.058	1.197	0.778
	0.065	0.620	0.476		5/32	1	1.932
	0.095	0.560	0.665				
	0.120	0.510	0.808	1 3/8	.065	1.245	0.910
	5/32	7/16	0.991		.120	1.135	1.610
	3/16	3/8	1.128		3/16	1	2.381
	1/4	1/4	1.336		1/4	7/8	3.007
					5/16	3/4	3.550
0.760	0.255	0.250	1.377		3/8	5/8	4.009
7/8	.065	0.745	0.563	1 7/16	0.120	1.198	1.690
	.095	0.685	0.792				
	.120	0.635	0.969	1 1/2	0.065	1.370	0.997
	5/32	9/16	1.201		0.095	1.310	1.427
	3/16	1/2	1.378		1/8	1 1/4	1.838
	1/4	3/8	1.671		5/32	1 3/16	2.245
					3/16	1 1/8	2.631
1	0.065	0.870	0.650		7/32	1 1/16	2.997
	0.095	0.810	0.919		1/4	1	3.341
	0.120	0.760	1.129		5/16	7/8	3.968
	5/32	11/16	1.410		3/8	3/4	4.510
	3/16	5/8	1.629				
	1/4	1/2	2.005	1 5/8	0.065	1.495	1.084
	5/16	3/8	2.297		0.120	1.385	1.931
					3/16	1 1/4	2.882
1 1/8	0.049	1.027	0.564		7/32	1 3/16	3.289
	0.065	0.995	0.737		1/4	1 1/8	3.675
	0.095	0.935	1.046		5/16	1	4.385
	0.120	0.885	1.289		3/8	7/8	5.012
	3/16	3/4	1.879				
	1/4	5/8	2.339	1 3/4	0.065	1.620	1.171
					0.095	1.560	1.681
1 3/16	3/16	13/16	2.005		1/8	1 1/2	2.172
					0.134	1.482	2.315
1 1/4	0.065	1.120	0.824		5/32	1 7/16	2.662
	0.095	1.060	1.173		3/16	1 3/8	3.132
	1/8	1	1.503		1/4	1 1/4	4.009
	5/32	15/16	1.827		5/16	1 1/8	4.803
	3/16	7/8	2.130		3/8	1	5.513
	7/32	13/16	2.412				
	1/4	3/4	2.673				
	3/8	1/2	3.508				

Continued on next page

DOM MECHANICAL TUBING — Continued

STOCK SIZES							
OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)	OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)
1 7/8	0.065	1.745	1.258	2 1/2	0.117	2.266	2.981
	0.095	1.685	1.808		0.120	2.226	3.053
	0.120	1.635	2.252		3/16	2 1/8	4.636
	3/16	1 1/2	3.383		1/4	2	6.014
	1/4	1 3/8	4.343		.260	1.980	6.227
	5/16	1 1/4	5.220		5/16	1 7/8	7.309
	3/8	1 1/8	6.014		3/8	1 3/4	8.520
2	0.065	1.870	1.345	2 5/8	3/16	2 1/4	4.886
	1/8	1 3/4	2.506		1/4	2 1/8	6.348
	5/32	1 11/16	3.080		5/16	2	7.726
	3/16	1 5/8	3.633		3/8	1 7/8	9.021
	7/32	1 9/16	4.166		1/2	1 5/8	11.360
	0.242	1.516	4.549				
	1/4	1 1/2	4.678	2 3/4	1/8	2 1/2	3.508
	5/16	1 3/8	5.638		0.134	2.482	3.748
	3/8	1 1/4	6.515		3/16	2 3/8	5.137
					1/4	2 1/4	6.682
2 1/8	0.065	1.195	1.432		5/16	2 1/8	8.144
	0.120	1.885	2.572		3/8	2	9.522
	3/16	1 3/4	3.844		1/2	1 3/4	12.028
	1/4	1 5/8	5.012				
	5/16	1 1/2	6.056	2 7/8	3/16	2 1/2	5.387
	3/8	1 3/8	7.016		1/4	2 3/8	7.016
					5/16	2 1/4	8.562
2 1/4	0.120	2.010	2.733		3/8	2 1/8	10.023
	0.134	1.982	3.032				
	3/16	1 7/8	4.135	3	.095	2.810	2.951
	1/4	1 3/4	5.346		.120	2.760	3.695
	5/16	1 5/8	6.473		3/16	2 5/8	5.638
	3/8	1 1/2	7.517		.260	2.480	7.617
					5/16	2 3/8	8.979
2 3/8	0.065	2.245	1.605		3/8	2 1/4	10.574
	1/8	2 1/8	3.007		7/16	2 1/8	11.986
	3/16	2	4.385		1/2	2	13.364
	1/4	1 7/8	5.680				
	3/8	1 5/8	8.019	3 1/8	3/16	2 3/4	5.889

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DOM MECHANICAL TUBING — Continued

STOCK SIZES							
OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)	OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)
3 1/4	0.120	3.010	4.016		5/16	3 3/8	12.320
	1/4	2 3/4	8.019		.380	3.240	14.707
	5/16	2 5/8	9.814		1/2	3	18.710
	3/8	2 1/2	11.527		5/8	2 3/4	22.552
	7/16	2 3/8	13.156				
	1/2	2 1/4	14.701	4.090	0.180	3.730	7.525
	5/8	2	17.541				
				4 1/4	0.095	4.060	4.220
3 3/8	3/16	3	6.390		1/8	4	5.513
	1/4	2 7/8	8.353		0.134	3.982	5.897
	5/16	2 3/4	10.232		0.188	3.874	8.165
					1/4	3 3/4	10.691
3 1/2	0.120	3.260	4.336		5/16	3 5/8	13.156
	0.134	3.232	4.822		3/8	3 1/2	15.536
	3/16	3 1/8	6.640		1/2	3 1/4	20.047
	1/4	3	8.687				
	0.260	2.980	9.006	4 3/8	0.198	3.979	8.842
	5/16	2 7/8	10.650				
	3/8	2 3/4	12.529	4 1/2	1/8	4 1/4	5.847
	1/2	2 1/2	16.037		0.134	4.232	6.255
					1/4	4	11.360
3 5/8	5/16	3	11.067		0.260	3.980	11.786
	3/8	2 7/8	13.030		5/16	3 7/8	13.991
					3/8	3 3/4	16.538
3 3/4	0.120	3.510	4.657		1/2	3 1/2	21.383
	1/4	3 1/4	9.355		5/8	3 1/4	25.893
	0.260	3.230	9.701				
	5/16	3 1/8	11.485	4 3/4	0.120	4.510	5.940
	3/8	3	13.531		1/4	4 1/4	12.028
	7/16	2 7/8	15.494		5/16	4 1/8	14.826
	1/2	2 3/4	17.374		3/8	4	17.541
	5/8	2 1/2	20.882		.385	3.980	17.967
					1/2	3 3/4	22.719
3 7/8	3/16	3 1/2	7.392				
				5	3/16	4 5/8	9.647
4	0.120	3.760	4.978		1/4	4 1/2	12.696
	0.134	3.732	5.539		.260	4.480	13.176
	3/16	3 5/8	7.643		3/8	4 1/4	18.543
	1/4	3 1/2	10.023		1/2	4	24.056
	.260	3.480	10.396		5/8	3 3/4	29.234

Continued on next page

DOM MECHANICAL TUBING — Continued

STOCK SIZES							
OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)	OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)
5 1/4	0.134	4.982	7.329	7	1/4	6 1/2	18.042
	1/4	4 3/4	13.364		3/8	6 1/4	26.562
	3/8	4 1/2	19.545		0.506	5.988	35.132
	0.385	4.480	20.025				
	1/2	4 1/4	25.392	7 1/4	5/8	6	44.269
	0.632	3.986	31.204				
				7 1/2	1/4	7	19.378
5 1/2	1/4	5	14.033		3/8	6 3/4	28.566
	0.260	4.980	14.566		1/2	6 1/2	37.420
	3/8	4 3/4	20.548				
	1/2	4 1/2	26.729	7 3/4	3/8	7	29.569
	5/8	4 1/4	32.576		0.385	6.980	30.316
					1/2	6 3/4	38.757
5 3/4	1/4	5 1/4	14.701				
	3/8	5	21.550	7.835	0.440	6.955	34.788
	0.385	4.980	22.083				
	1/2	4 3/4	28.065	8	1/4	7 1/2	20.715
	0.641	4.468	35.013		3/8	7 1/4	30.571
					0.505	6.990	40.467
6	3/16	5 5/8	11.652				
	1/4	5 1/2	15.369	8 1/4	1/4	7 3/4	21.383
	0.260	5.480	15.956		0.630	6.990	51.325
	3/8	5 1/4	22.552				
	1/2	5	29.402	8 1/2	1/4	8	22.051
	5/8	4 3/4	35.917		3/8	7 3/4	32.576
					1/2	7 1/2	42.766
6 1/4	0.380	5.490	23.848				
	1/2	5 1/4	30.738	9	0.510	7.980	46.293
6 1/2	1/4	6	16.705	9 1/2	1/2	8 1/2	48.112
	0.260	5.980	17.346				
	3/8	5 3/4	24.557	10	0.505	8.990	51.265
	1/2	5 1/2	32.074				
				10 1/4	1/2	9 1/4	52.121
6 5/8	0.308	6.009	20.802				
				11	1/2	10	56.130
6 3/4	0.380	5.990	25.880				
	0.390	5.970	26.519	12	3/8	11 1/4	46.608
	1/2	5 3/4	33.411		1/2	11	61.476
					0.531	10.938	65.111

HONED ID DOM

CONDITION	COLOR CODE
Cold Finished	Red

STOCK SIZES

OD		ID (INCHES)	WT. PER FT. (POUNDS)	OD		ID (INCHES)	WT. PER FT. (POUNDS)
2 1/2	X	1.997/2.000	6.014	6 1/4	X	5.497/5.000	37.587
						5.525/5.028	36.837
2 5/8	X	2.265/2.268	4.669				
				6 1/2	X	5.997/6.000	16.705
3	X	2.497/2.500	7.350				
		2.525/2.528	6.974	6 5/8	X	6.040/6.045	19.642
3 1/2	X	2.997/3.000	8.687	6 3/4	X	5.996/6.000	25.559
		3.015/3.020	8.365			6.000/6.004	25.431
		3.025/3.028	8.236			6.025/6.028	24.659
3 3/4	X	3.247/3.250	9.355	7	X	5.997/6.000	34.747
						6.025/6.028	33.847
4	X	3.497/3.500	10.023				
		3.520/3.525	9.554	7 1/4	X	6.025/6.028	43.369
		3.525/3.528	9.497				
				7 3/4	X	6.997/7.000	29.569
4 1/4	X	3.525/3.528	19.907			7.000/7.005	29.381
						7.025/7.028	28.519
4 1/2	X	3.025/3.028	29.619				
		3.997/4.000	11.360	7.835	X	7.000/7.005	32.922
		4.000/4.004	11.274				
		4.020/4.025	10.823	8	X	7.025/7.028	39.043
		4.025/4.028	10.759				
				8 3/4	X	7.500/7.505	54.092
4 3/4	X	3.997/4.000	17.541				
		4.025/4.028	16.940	9	X	8.025/8.028	44.239
5	X	4.275/4.278	17.905	10	X	9.025/9.028	49.435
		4.497/4.500	12.696			9.050/9.055	48.130
5 1/4	X	4.500/4.504	19.449	11	X	10.055/10.060	52.913
		4.525/4.528	18.870				
				12	X	11.000/11.006	61.123
5 1/2	X	4.275/4.278	31.937				
		4.997/5.000	14.033				
		5.020/5.025	13.363				
5 3/4	X	4.997/5.000	21.550				
		5.025/5.028	20.880				
6	X	5.497/5.500	15.369				

SEAMLESS MECHANICAL STEEL TUBING
ASTM A519

PACIFIC Seamless Tubing is stocked in both hot and cold finished conditions and typically in heavier wall thicknesses than DOM tubing. Hot finished seamless tubing has lower mechanical properties and less precise tolerances than cold finished tubing. Cold drawing increases strength by cold working the steel which improves machinability and surface finish. A certain amount of eccentricity between ID and OD of all seamless tubing must be expected because of the way it is manufactured, i.e., piercing a hot billet of steel with a mandrel. Be sure to consider eccentricity when calculating machining allowances. PACIFIC seamless tubing is usually stocked in the AISI/SAE 1026 grade. Other grades of both carbon and alloy seamless mechanical tubing are available in certain sizes—ask your PACIFIC representative for availability. Size of seamless tubing is usually specified by OD and wall thickness.

AISI/SAE 1026 CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

C	Mn	P	S
.22/.26	.60/.90	.040 max	.050 max

TYPICAL PROPERTIES: Approximate—not for specification

Grade / Condition		Tensile, psi	Yield, psi	Elongation
1018	HF	60,000	35,000	30%
1018	CF	80,000	65,000	15%
1026	HF	70,000	45,000	25%
1026	CF	85,000	75,000	15%
4130	CD	100,000	85,000	12%
4130	CD-Norm	90,000	60,000	25%
4140	HF-Ann	85,000	60,000	20%

SEAMLESS MECHANICAL TUBING — COLD DRAWN

CONDITION	COLOR CODE
Cold Drawn	Black

STOCK SIZES

OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)	OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)
1 3/8	0.095	1.185	1.300	2	0.028	1.944	0.590
1 1/2	1/2	1/2	5.346		7/16	1 1/4	7.309
1 3/4	1/2	3/4	6.682		1/2	1	8.019
1 7/8	1/2	7/8	7.350		5/8	3/4	9.188
				2 1/4	7/16	1 3/8	8.478
					1/2	1 1/4	9.355
					5/8	1	10.859

Continued on next page

SEAMLESS MECHANICAL TUBING — COLD DRAWN — Continued

STOCK SIZES							
OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)	OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)
2 3/8	1/2	1 3/8	10.023	4 1/4	3/4	2 3/4	28.065
					1	2 1/4	34.747
2 1/2	1/2	1 1/2	10.691				
	5/8	1 1/4	12.529	4 1/2	3/4	3	30.070
	3/4	1	14.033		7/8	2 3/4	33.912
					1	2 1/2	37.420
2 3/4	1/2	1 3/4	12.028		1 1/4	2	43.434
	5/8	1 1/2	14.200				
	3/4	1 1/4	16.037	4 3/4	3/4	3 1/4	32.074
					1	2 3/4	40.093
2 7/8	1/2	1 7/8	12.696				
				5	3/4	3 1/2	34.079
3	5/8	1 3/4	15.870		7/8	3 1/4	38.590
	3/4	1 1/2	18.042		1	3	42.766
	7/8	1 1/4	19.879		1 1/4	2 1/2	50.116
	1	1	21.383		1.271	2.458	50.673
3 1/4	3/16	2 7/8	6.139	5 1/4	1	3 1/4	45.439
	5/8	2	17.541				
	3/4	1 3/4	20.047	5 1/2	3/4	4	38.088
	1	1 1/4	24.056		7/8	3 3/4	43.267
					1	3 1/2	48.112
3 1/2	5/8	2 1/4	19.211		1 1/4	3	56.798
	3/4	2	22.051				
	1	1 1/2	26.729	5 3/4	1	3 3/4	50.784
3 5/8	5/8	2 3/8	20.047	6	3/4	4 1/2	42.098
	3/4	2 1/4	23.053		7/8	4 1/4	47.945
					1	4	53.457
3 3/4	3/4	2 1/4	24.056		1 1/4	3 1/2	63.481
	1	1 3/4	29.402				
				6 1/2	3/4	5	46.107
4	3/4	2 1/2	26.060		1	4 1/2	58.803
	7/8	2 1/4	29.234		1 1/4	4	70.163
	1	2	32.074				
	1 1/8	1 3/4	34.580	7	3/4	5 1/2	50.116
	1 1/4	1 1/2	36.752		1	5	64.149

Continued on next page

SEAMLESS MECHANICAL TUBING — COLD DRAWN — Continued

STOCK SIZES							
OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)	OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)
7 1/2	3/4	6	54.126	9 1/2	3/4	8	70.163
	1	5 1/2	69.495				
				10	3/4	8 1/2	74.172
8	3/4	6 1/2	58.135				
	1	6	74.840	11	1	9	106.915
8 1/2	3/4	7	62.144	11 1/2	0.780	9.940	89.398
	1	6 1/2	80.186				
9	3/4	7 1/2	66.153				
	1	7	85.532				

SEAMLESS MECHANICAL TUBING — HOT FINISHED

CONDITION	COLOR CODE
Hot Finished	Black

STOCK SIZES							
OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)	OD	WALL (INCHES)	ID	WT. PER FT. (POUNDS)
5	1 1/2	2	56.130	6 1/2	1 1/2	3 1/2	80.186
5 1/2	1 1/2	2 1/2	64.149	8 1/2	1 1/2	5 1/2	112.260
6	1 1/2	3	72.167	10	1 1/4	7 1/2	116.938
6 1/4	1 1/4	3 3/4	66.822				
Call for Mill Stock Availability on Non-Stock Sizes							

AS-WELDED MECHANICAL TUBING

ASTM A513, Types 1 and 2

PACIFIC As-Welded Mechanical Tubing is used for light wall applications where internal pressure is not applied and the higher strength, tighter tolerance 1026 DOM is not required. It is usually available in either 1010 or 1020 grade; the higher carbon 1020 is often used for drive line applications. Finish is hot rolled for wall thickness over 0.065"; wall thickness 0.065" and less can be cold rolled. Flash is controlled to 0.010" in sizes over 1 1/8" diameter.

CHEMICAL COMPOSITION: Heat Analysis—ranges and limits, %

Grade	C	Mn	P	S
1010	0.08/0.13	0.30/0.60	0.035 max	0.035 max
1020	0.17/0.23	0.30/0.60	0.035 max	0.035 max

TYPICAL PROPERTIES: Approximate—not for specification

Grade	Tensile, psi	Yield, psi	Elong.	Hardness
1010	45,000	32,000	15%	55 HRB
1020	52,000	38,000	12%	62 HRB

AS-WELDED MECHANICAL TUBING

GRADE	COLOR CODE
1010	Black
1020	White

STOCK SIZES

OD	WALL (INCHES)	ID	WT. PER FT. (LBS.)	GRADE	
				1010	1020
5/8	0.049	0.527	0.302	X	
5/8	0.060	0.505	0.362	X	
2	0.095	1.810	1.935		X
2	0.120	1.760	2.412	X	X
2 3/4	0.120	2.510	3.374		X
3	0.065	2.870	2.040	X	
4	0.083	3.834	3.476		X

Call for Mill Stock Availability on Non-Stock Sizes

DOM MANUFACTURING TOLERANCES

Cold Drawn Tubing

DIAMETER TOLERANCES for DOM TUBING

OD SIZE RANGE Inches (mm)	OD, Inches (mm) OVER	OD, Inches (mm) UNDER	ID, Inches (mm) OVER	ID, Inches (mm) UNDER
0.625- 1.699 (15.82- 43.16)	.005 (.13)	.000	.000	.005 (.13)
1.700- 2.099 (43.17- 53.32)	.006 (.15)	.000	.000	.006 (.15)
2.100- 2.499 (53.33- 63.48)	.007 (.18)	.000	.000	.007 (.18)
2.500- 2.899 (63.49- 73.64)	.008 (.20)	.000	.000	.008 (.20)
2.900- 3.299 (73.65- 83.80)	.009 (.23)	.000	.000	.009 (.23)
3.300- 3.699 (83.81- 93.96)	.010 (.25)	.000	.000	.010 (.25)
3.700- 4.099 (93.97-104.12)	.011 (.28)	.000	.000	.011 (.28)
4.100- 4.499 (104.13-114.28)	.012 (.30)	.000	.000	.012 (.30)
4.500- 4.899 (114.29-124.44)	.013 (.33)	.000	.000	.013 (.33)
4.900- 5.299 (124.45-134.60)	.014 (.36)	.000	.000	.014 (.36)
5.300- 5.549 (134.61-140.95)	.015 (.38)	.000	.000	.015 (.38)
5.550- 5.999 (140.96-152.38)	.009 (.23)	.009 (.23)	.009 (.23)	.009 (.23)
6.000- 6.499 (152.39-165.08)	.010 (.25)	.010 (.25)	.010 (.25)	.010 (.25)
6.500- 6.999 (165.09-177.78)	.012 (.30)	.012 (.30)	.012 (.30)	.012 (.30)
7.000- 7.499 (177.79-190.48)	.013 (.33)	.013 (.33)	.013 (.33)	.013 (.33)
7.500- 7.999 (190.49-203.18)	.015 (.38)	.015 (.38)	.015 (.38)	.015 (.38)
8.000- 8.499 (203.19-215.88)	.016 (.41)	.016 (.41)	.016 (.41)	.016 (.41)
8.500- 8.999 (215.89-228.58)	.017 (.43)	.017 (.43)	.017 (.43)	.017 (.43)
9.000- 9.499 (228.59-241.28)	.019 (.48)	.019 (.48)	.019 (.48)	.019 (.48)
9.500- 9.999 (241.29-253.98)	.020 (.51)	.020 (.51)	.020 (.51)	.020 (.51)
10.000-10.999 (253.99-279.38)	.022 (.56)	.022 (.56)	.022 (.56)	.022 (.56)
11.000-11.999 (279.39-304.80)	.025 (.64)	.025 (.64)	.025 (.64)	.025 (.64)
12.000-12.999 (304.81-330.18)	.027 (.69)	.027 (.69)	.027 (.69)	.027 (.69)
13.000-13.999 (330.19-355.58)	.029 (.74)	.029 (.74)	.029 (.74)	.029 (.74)
14.000-15.000 (355.59-381.00)	.030 (.76)	.030 (.76)	.030 (.76)	.030 (.76)

OVALITY TOLERANCES for DOM TUBING

Ovality shall be within the above O.D. tolerances, except when the wall thickness is less than 3% of the outside diameter, then ovality shall be within those below.

O.D. Inches	Additional Ovality Tolerance Inch (mm)	O.D. Inches	Additional Ovality Tolerance Inch (mm)
Up to 2.000 (50.80)	.010 (.25)	9.001-10.000 (228.61-254.00)	.050 (1.27)
2.001-3.000 (50.81-76.20)	.015 (.38)	10.001-11.000 (254.01-279.40)	.055 (1.40)
3.001-4.000 (76.21-101.60)	.020 (.51)	11.001-12.000 (279.41-304.80)	.060 (1.52)
4.001-5.000 (101.61-127.00)	.025 (.64)	12.001-13.000 (304.81-330.20)	.065 (1.65)
5.001-6.000 (127.01-152.40)	.030 (.76)	13.001-14.000 (330.21-355.60)	.070 (1.78)
6.001-7.000 (152.41-177.80)	.035 (.89)	14.001-15.000 (355.61-381.00)	.075 (1.91)
7.001-8.000 (177.81-203.20)	.040 (1.02)		
8.001-9.000 (203.21-228.60)	.045 (1.14)		

DOM MANUFACTURING TOLERANCES

Cold Drawn Tubing

WALL THICKNESS TOLERANCES for DOM TUBING

WALL THICKNESS (INCHES)	OUTSIDE DIAMETER (INCHES)				WALL THICKNESS (MILLIMETERS)	OUTSIDE DIAMETER (MILLIMETERS)			
	.375 to .875	Over .875 to 1.875	Over 1.875 to 3.750	Over 3.750 to 15.000		9.53 to 22.23	Over 22.23 to 47.63	Over 47.63 to 96.25	Over 96.25 to 381.00
.065	+.002	+.002	+.002	+.004	1.65	+.05	+.05	+.05	+.10
	−.002	−.003	−.003	−.004		−.05	−.08	−.08	−.10
.083	+.002	+.002	+.003	+.004	2.11	+.05	+.05	+.08	+.10
	−.002	−.003	−.003	−.005		−.05	−.08	−.08	−.13
.095	+.002	+.002	+.003	+.004	2.41	+.05	+.05	+.08	+.10
	−.002	−.003	−.003	−.005		−.05	−.08	−.08	−.13
.109	+.002	+.002	+.003	+.005	2.77	+.05	+.05	+.08	+.13
	−.003	−.004	−.003	−.005		−.08	−.10	−.08	−.13
.120	+.003	+.002	+.003	+.005	3.05	+.08	+.05	+.08	+.13
	−.003	−.004	−.003	−.005		−.08	−.10	−.08	−.13
.134	+.002	+.002	+.003	+.005	3.40	+.05	+.05	+.08	+.13
	−.004	−.004	−.003	−.005		−.10	−.10	−.08	−.13
.148	+.002	+.002	+.003	+.005	3.76	+.05	+.05	+.08	+.13
	−.004	−.004	−.003	−.005		−.10	−.10	−.08	−.13
.165	+.003	+.003	+.003	+.005	4.19	+.08	+.08	+.08	+.13
	−.004	−.004	−.004	−.006		−.10	−.10	−.10	−.15
.180	+.004	+.004	+.003	+.006	4.57	+.10	+.10	+.08	+.15
	−.004	−.004	−.005	−.006		−.10	−.10	−.13	−.15
.203	+.004	+.004	+.004	+.006	5.16	+.10	+.10	+.10	+.15
	−.005	−.005	−.005	−.007		−.13	−.13	−.13	−.18
.220	+.004	+.004	+.004	+.007	5.69	+.10	+.10	+.10	+.18
	−.006	−.006	−.006	−.007		−.15	−.15	−.15	−.18
.238	+.005	+.005	+.005	+.007	6.05	+.13	+.13	+.13	+.18
	−.006	−.006	−.006	−.007		−.15	−.15	−.15	−.18
.259		+.005	+.005	+.007	6.58		+.13	+.13	+.18
		−.006	−.006	−.007			−.15	−.15	−.18
.284		+.005	+.005	+.007	7.21		+.13	+.13	+.18
		−.006	−.006	−.007			−.15	−.15	−.18
.300		+.006	+.006	+.008	7.62		+.15	+.15	+.20
		−.006	−.006	−.008			−.15	−.15	−.20
.320		+.007	+.007	+.008	8.13		+.18	+.18	+.20
		−.007	−.007	−.008			−.18	−.18	−.20
.344		+.008	+.008	+.009	8.74		+.20	+.20	+.23
		−.008	−.008	−.009			−.20	−.20	−.23
.375			+.009	+.009	9.53			+.23	+.23
			−.009	−.009				−.23	−.23
.400			+.010	+.010	10.16			+.25	+.25
			−.010	−.010				−.25	−.25
.438			+.011	+.011	11.13			+.28	+.28
			−.011	−.011				−.28	−.28
.480			+.012	+.012	12.19			+.30	+.30
			−.012	−.012				−.30	−.30
.531			+.013	+.013	13.49			+.33	+.33
			−.013	−.013				−.33	−.33
.563			+.013	+.013	14.30			+.33	+.33
			−.013	−.013				−.33	−.33
.580			+.014	+.014	14.73			+.36	+.36
			−.014	−.014				−.36	−.36
.600			+.015	+.015	15.24			+.38	+.38
			−.015	−.015				−.38	−.38
.625			+.016	+.016	15.88			+.41	+.41
			−.016	−.016				−.41	−.41
.650			+.017	+.017	16.51			+.43	+.43
			−.017	−.017				−.43	−.43

DOM MANUFACTURING TOLERANCES

Cold Drawn Tubing

MINIMUM HONING ALLOWANCES for DOM TUBING

OD INCHES (mm)	WALL THICKNESS, INCHES (mm)						
	UP TO .125 (3.18)	.125 (3.18) to .187 (4.75)	Over .187 (4.75) to .250 (6.35)	Over .250 (6.35) to .375 (9.53)	Over .375 (9.53) to .500 (12.70)	Over .500 (12.70) to .625 (15.88)	OVER .625 (15.88)
Up to—3.000	.006	.007	.008	.009	.010	—	—
(76.20)	(.15)	(.18)	(.20)	(.23)	(.25)	—	—
3.001—4.000	.007	.008	.009	.010	.011	.012	.014
(76.21—101.60)	(.18)	(.20)	(.23)	(.25)	(.28)	(.30)	(.36)
4.001—6.000	.008	.009	.010	.011	.012	0.13	.015
(101.61—152.40)	(.20)	(.23)	(.25)	(.28)	(.30)	(.33)	(.38)
6.001—8.000	.008	.009	.010	.011	.013	.014	.16
(152.41—203.20)	(.20)	(.23)	(.25)	(.28)	(.33)	(.36)	(.41)
8.001—10.500			.011	.012	.013	.015	.017
(203.21—266.70)			(.28)	(.30)	(.33)	(.38)	(.43)
10.501—12.500				.013	.014	.015	.018
(266.71—317.50)				(.33)	(.36)	(.38)	(.46)
12.501—14.000				.017	.019	.021	.023
(317.51—355.60)				(.43)	(.48)	(.53)	(.58)
14.001—15.000				.019	.021	.023	.025
(355.61—381)				(.48)	(.53)	(.58)	(.64)

MINIMUM MACHINING ALLOWANCES for DOM TUBING

OD INCHES (mm)	WALL THICKNESS, INCHES (mm)						
	UP TO .125 (3.18)	.125 (3.18) to .187 (4.75)	Over .187 (4.75) to .250 (6.35)	Over .250 (6.35) to .375 (9.53)	Over .375 (9.53) to .500 (12.70)	Over .500 (12.70) to .625 (15.88)	OVER .625 (15.88)
Up to—3.000	.012	.014	.017	.020	.021	.025	—
(76.20)	(.30)	(.36)	(.43)	(.51)	(.53)	(.64)	—
3.001—4.000	.014	.017	.020	.021	.025	.028	.030
(76.21—101.60)	(.36)	(.43)	(.51)	(.53)	(.64)	(.71)	(.76)
4.001—6.000	.020	.021	.025	.028	.030	.032	.035
(101.61—152.40)	(.51)	(.53)	(.64)	(.71)	(.76)	(.81)	(.89)
6.001—8.000		.025	.028	.030	.032	.035	.039
(152.41—203.20)		(.64)	(.71)	(.76)	(.81)	(.89)	(.99)
8.001—10.500				.034	.035	.039	.042
(203.21—266.70)				(.86)	(.89)	(.99)	(1.07)
10.501—12.500				.037	.039	.042	.044
(266.71—317.50)				(.94)	(.99)	(1.07)	(1.12)
12.501—14.000				.039	.042	.045	.048
(317.51—355.60)				(.99)	(1.07)	(1.14)	(1.22)
14.001—15.000				.043	.045	.048	.050
(355.61—381.00)				(1.09)	(1.14)	(1.22)	(1.27)

Camber: For every 12 inch (304.80mm) or fraction thereof over 12 inch, add .010 inch (.25mm) for camber.

DOM MANUFACTURING TOLERANCES

Cold Drawn Tubing

MINIMUM CENTERLESS GRINDING ALLOWANCE for DOM							
OD INCHES (mm)	WALL THICKNESS, INCHES (mm)						
	UP TO .125 (3.18)	.125 (3.18) to .187 (4.75)	Over .187 (4.75) to .250 (6.35)	Over .250 (6.35) to .375 (9.53)	Over .375 (9.53) to .500 (12.70)	Over .500 (12.70) to .625 (15.88)	OVER .625 (15.88)
Up to—3.000	.008	.010	.011	.014	.017	.018	—
(76.20)	(.20)	(.25)	(.28)	(.36)	(.43)	(.46)	—
3.001—4.000	.011	.013	.014	.015	.017	.018	.020
(76.21—101.60)	(.28)	(.33)	(.36)	(.38)	(.43)	(.46)	(.51)
4.001—6.000	.013	.014	.015	.017	.018	.020	.021
(101.61—152.40)	(.33)	(.36)	(.38)	(.43)	(.46)	(.51)	(.53)
6.001—8.000		.015	.017	.018	.020	.021	.022
(152.41—203.20)		(.38)	(.43)	(.46)	(.51)	(.53)	(.56)
8.001—10.500			.018	.019	.020	.022	.024
(203.21—266.70)			(.46)	(.48)	(.51)	(.56)	(.61)
10.501—12.500				.021	.022	.024	.026
(266.71—317.50)				(.53)	(.56)	(.61)	(.66)
12.501—14.000				.022	.024	.026	.028
(317.51—355.60)				(.56)	(.61)	(.66)	(.71)
14.001—15.000				.024	.026	.030	.032
(355.61—381.00)				(.61)	(.66)	(.76)	(.81)

SEAMLESS MANUFACTURING TOLERANCES

ASTM A519 — Cold Finished

OUTSIDE AND INSIDE DIAMETER TOLERANCES FOR ROUND COLD-WORKED TUBING

Outside Diameter Size Range, in.	Wall Thickness As Percent of Outside Diameter	Thermal Treatment after Final Cold Work Producing Size*							
		None, or not exceeding 1100°F Nominal Temperature				Heated Above 1100°F Nominal Temperature Without Accelerated Cooling			
		OD, in.		ID, in.		OD, in.		ID, in.	
		Over	Under	Over	Under	Over	Under	Over	Under
Up to 0.499	all	0.004	0.000	—	—	0.005	0.002	—	—
0.500 - 1.699	all	0.005	0.000	0.000	0.005	0.007	0.002	0.002	0.007
1.700 - 2.099	all	0.006	0.000	0.000	0.006	0.006	0.005	0.005	0.006
2.100 - 2.499	all	0.007	0.000	0.000	0.007	0.008	0.005	0.005	0.008
2.500 - 2.899	all	0.008	0.000	0.000	0.008	0.009	0.005	0.005	0.009
2.900 - 3.299	all	0.009	0.000	0.000	0.009	0.011	0.005	0.005	0.011
3.300 - 3.699	all	0.010	0.000	0.000	0.010	0.013	0.005	0.005	0.013
3.700 - 4.099	all	0.011	0.000	0.000	0.011	0.013	0.007	0.010	0.010
4.100 - 4.499	all	0.012	0.000	0.000	0.012	0.014	0.007	0.011	0.011
4.500 - 4.899	all	0.013	0.000	0.000	0.013	0.016	0.007	0.012	0.012
4.900 - 5.200	all	0.014	0.000	0.000	0.014	0.018	0.007	0.013	0.013
5.300 - 5.549	all	0.015	0.000	0.000	0.015	0.020	0.007	0.014	0.014
5.550 - 5.559	under 6	0.010	0.010	0.010	0.010	0.018	0.018	0.018	0.018
	6 to 7½	0.009	0.009	0.009	0.009	0.016	0.016	0.016	0.016
	over 7½	0.018	0.000	0.009	0.009	0.017	0.015	0.016	0.016
6.000 - 6.499	under 6	0.013	0.013	0.013	0.013	0.023	0.023	0.023	0.023
	6 to 7½	0.010	0.010	0.010	0.010	0.018	0.018	0.018	0.018
	over 7½	0.020	0.000	0.010	0.010	0.020	0.015	0.018	0.018
6.500 - 6.999	under 6	0.015	0.015	0.015	0.015	0.027	0.027	0.027	0.027
	6 to 7½	0.012	0.012	0.012	0.012	0.021	0.021	0.021	0.021
	over 7½	0.023	0.000	0.012	0.012	0.026	0.015	0.021	0.021
7.000 - 7.499	under 6	0.018	0.018	0.018	0.018	0.032	0.032	0.032	0.032
	6 to 7½	0.013	0.013	0.013	0.013	0.023	0.023	0.023	0.023
	over 7½	0.026	0.000	0.013	0.013	0.031	0.015	0.023	0.023
7.500 - 7.999	under 6	0.020	0.020	0.020	0.020	0.035	0.035	0.035	0.035
	6 to 7½	0.015	0.015	0.015	0.015	0.026	0.026	0.026	0.026
	over 7½	0.029	0.000	0.015	0.015	0.036	0.015	0.026	0.026
8.000 - 8.499	under 6	0.023	0.023	0.023	0.023	0.041	0.041	0.041	0.041
	6 to 7½	0.016	0.016	0.016	0.016	0.028	0.028	0.028	0.028
	over 7½	0.031	0.000	0.015	0.016	0.033	0.022	0.028	0.028
8.500 - 8.999	under 6	0.025	0.025	0.025	0.025	0.044	0.044	0.044	0.044
	6 to 7½	0.017	0.017	0.017	0.017	0.030	0.030	0.030	0.030
	over 7½	0.034	0.000	0.015	0.019	0.038	0.022	0.030	0.030
9.000 - 9.499	under 6	0.028	0.028	0.028	0.028	0.045	0.045	0.049	0.049
	6 to 7½	0.019	0.019	0.019	0.019	0.033	0.033	0.033	0.033
	over 7½	0.037	0.000	0.015	0.022	0.043	0.022	0.033	0.033
9.500 - 9.999	under 6	0.030	0.030	0.030	0.030	0.045	0.045	0.053	0.053
	6 to 7½	0.020	0.020	0.020	0.020	0.035	0.035	0.035	0.035
	over 7½	0.040	0.000	0.015	0.025	0.048	0.022	0.035	0.035
10.000 - 10.999	under 6	0.034	0.034	0.034	0.034	0.045	0.045	0.060	0.060
	6 to 7½	0.022	0.022	0.022	0.022	0.039	0.039	0.039	0.039
	over 7½	0.044	0.000	0.015	0.029	0.055	0.022	0.039	0.039
11.000 - 12.000	under 6	0.035	0.035	0.035	0.035	0.050	0.050	0.065	0.065
	6 to 7½	0.025	0.025	0.025	0.025	0.045	0.045	0.045	0.045
	over 7½	0.045	0.000	0.015	0.035	0.060	0.022	0.045	0.045

*See the next page for quenched and tempered tolerances

SEAMLESS MANUFACTURING TOLERANCES

ASTM A519 — Cold Finished

OUTSIDE AND INSIDE DIAMETER TOLERANCES FOR ROUND COLD-WORKED TUBING — CONTINUED

Outside Diameter Size Range, in.	Wall Thickness As Percent of Outside Diameter	Thermal Treatment after Final Cold Work			
		Quenched and Tempered			
		OD, in.		ID, in.	
		Over	Under	Over	Under
Up to 0.499	all	0.010	0.010	0.010	0.010
0.500 - 1.699	all	0.015	0.015	0.015	0.015
1.700 - 2.099	all	0.020	0.020	0.020	0.020
2.100 - 2.499	all	0.023	0.023	0.023	0.023
2.500 - 2.899	all	0.025	0.025	0.025	0.025
2.900 - 3.299	all	0.028	0.028	0.028	0.028
3.300 - 3.699	all	0.030	0.030	0.030	0.030
3.700 - 4.099	all	0.033	0.033	0.033	0.033
4.100 - 4.499	all	0.036	0.036	0.036	0.036
4.500 - 4.899	all	0.038	0.038	0.038	0.038
4.900 - 5.299	all	0.041	0.041	0.041	0.041
5.300 - 5.549	all	0.044	0.044	0.044	0.044

WALL THICKNESS TOLERANCES FOR ROUND COLD-WORKED TUBING

Wall Thickness Range as % of Outside Diameter	Wall Thickness Tolerance Over and Under Nominal %	
	Up to 1.499 in., ID	1.500 in., and Over
25 and Under	10.0	7.5
Over 25	12.5	10.0

STRAIGHTNESS TOLERANCES

OD Size Range (inches)	Maximum Curvature per Foot (inches)
Thru 5	0.010
Over 5 to 8	0.015
Over 8	0.020

SEAMLESS MANUFACTURING TOLERANCES

ASTM A519 — Hot Finished

OUTSIDE DIAMETER TOLERANCES FOR ROUND HOT-FINISHED TUBING[A,B,C]

Outside Diameter Size Range, in. (mm)	Outside Diameter Tolerance, in. (mm) Over	Under
Up to 2.999 (76.17)	0.020 (0.51)	0.020 (0.51)
3.000 - 4.499 (76.20 - 114.27)	0.025 (0.64)	0.025 (0.64)
4.500 - 5.999 (114.30 - 152.37)	0.031 (0.79)	0.031 (0.79)
6.000 - 7.499 (152.40 - 190.47)	0.037 (0.94)	0.037 (0.94)
7.500 - 8.999 (190.50 - 228.57)	0.045 (1.14)	0.045 (1.14)
9.000 - 10.750 (228.60 - 273.05)	0.050 (1.27)	0.050 (1.27)

[A] Diameter tolerances are not applicable to normalized and tempered or quenched and tempered conditions.

[B] The common range of sizes of hot finished tubes is 1½ in. (38.1 mm) to 10¾ in. (273.0 mm) outside diameter with wall thickness at least 3 % or more of outside diameter, but not less than 0.095 in. (2.41 mm).

[C] Larger sizes are available; consult manufacturer for sizes and tolerances.

WALL THICKNESS TOLERANCES FOR ROUND HOT-FINISHED TUBING

Wall Thickness Range as Percent of Outside Diameter	Wall Thickness Tolerance,[A] percent Over and Under Nominal		
	Outside Diameter 2.999 in. (76.19 mm) and smaller	Outside Diameter 3.000 in. (76.20 mm) to 5.999 in. (152.37 mm)	Outside Diameter 6.000 in. (152.40 mm) to 10.750 in. (273.05 mm)
Under 15	12.5	10.0	10.0
15 and over	10.0	7.5	10.0

[A] Wall thickness tolerances may not be applicable to walls 0.199 in. (5.05 mm) and less; consult manufacturer for wall tolerances on such tube sizes.

STRAIGHTNESS: Cold Finished tolerances apply (see page E•16)

REQUEST OUR PRODUCT BROCHURE ON STEEL TUBING.

NOMINAL PIPE SIZES

Dimensions and Weights

NPS Designator	Outside Diamter, in. (mm)	Wall Thickness, in. (mm)	Nominal Weight per ft (m), Plain End, lb (kg)	Weight Class	Schedule No.
1/8	0.405 (10.3)	0.068 (1.73)	0.24 (0.37)	STD	40
		0.095 (2.41)	0.31 (0.47)	XS	80
1/4	0.540 (13.7)	0.088 (2.24)	0.42 (0.63)	STD	40
		0.119 (3.02)	0.54 (0.80)	XS	80
3/8	0.675 (17.1)	0.091 (2.31)	0.57 (0.84)	STD	40
		0.126 (3.20)	0.74 (1.10)	XS	80
1/2	0.840 (21.3)	0.109 (2.77)	0.85 (1.27)	STD	40
		0.147 (3.73)	1.09 (1.62)	XS	80
		0.188 (4.78)	1.31 (1.95)	. . .	160
		0.294 (7.47)	1.71 (2.55)	XXS	. . .
3/4	1.050 (26.7)	0.113 (2.87)	1.13 (1.69)	STD	40
		0.154 (3.91)	1.47 (2.20)	XS	80
		0.219 (5.56)	1.94 (2.90)	. . .	160
		0.308 (7.82)	2.44 (3.64)	XXS	. . .
1	1.315 (33.4)	0.133 (3.38)	1.68 (2.50)	STD	40
		0.179 (4.55)	2.17 (3.24)	XS	80
		0.250 (6.35)	2.84 (4.24)	. . .	160
		0.358 (9.09)	3.66 (5.45)	XXS	. . .
1 1/4	1.660 (42.2)	0.140 (3.56)	2.27 (3.39)	STD	40
		0.191 (4.85)	3.00 (4.47)	XS	80
		0.250 (6.35)	3.76 (5.61)	. . .	160
		0.382 (9.70)	5.21 (7.77)	XXS	. . .
1 1/2	1.900 (48.3)	0.145 (3.68)	2.72 (4.05)	STD	40
		0.200 (5.08)	3.63 (5.41)	XS	80
		0.281 (7.14)	4.86 (7.25)	. . .	160
		0.400 (10.16)	6.41 (9.56)	XXS	. . .
2	2.375 (60.3)	0.154 (3.91)	3.65 (5.44)	STD	40
		0.218 (5.54)	5.02 (7.48)	XS	80
		0.344 (8.74)	7.46 (11.1)	. . .	160
		0.436 (11.07)	9.03 (13.44)	XXS	. . .
2 1/2	2.875 (73.0)	0.203 (5.16)	5.79 (8.63)	STD	40
		0.276 (7.01)	7.66 (11.41)	XS	80
		0.375 (9.52)	10.01 (14.90)	. . .	160
		0.552 (14.02)	13.70 (20.39)	XXS	. . .

Continued on next page

NOMINAL PIPE SIZES — Continued

NPS Designator	Outside Diamter, in. (mm)	Wall Thickness, in. (mm)	Nominal Weight per ft (m), Plain End, lb (kg)	Weight Class	Schedule No.
3	3.500 (89.9)	0.216 (5.49)	7.58 (11.29)	STD	40
		0.300 (7.62)	10.25 (15.27)	XS	80
		0.438 (11.13)	14.32 (21.35)	. . .	160
		0.600 (15.24)	18.58 (27.68)	XXS	. . .
3½	4.000 (101.6)	0.226 (5.74)	9.11 (13.57)	STD	40
		0.250 (6.35)	10.01 (14.92)	. . .	. . .
		0.281 (7.14)	11.16 (16.63)	. . .	. . .
		0.318 (8.08)	12.51 (18.63)	XS	80
4	4.500 (114.3)	0.237 (6.02)	10.79 (16.07)	STD	40
		0.337 (8.56)	14.98 (22.32)	XS	80
		0.531 (13.49)	22.51 (33.54)	. . .	160
		0.674 (17.12)	27.54 (41.03)	XXS	. . .
5	5.563 (141.3)	0.258 (6.55)	14.62 (21.77)	STD	40
		0.375 (9.52)	20.78 (30.94)	XS	80
		0.625 (15.88)	32.96 (49.11)	. . .	160
		0.750 (19.05)	38.55 (57.43)	XXS	. . .
6	6.625 (168.3)	0.280 (7.11)	18.97 (28.26)	STD	40
		0.432 (10.97)	28.57 (42.56)	XS	80
		0.719 (18.26)	45.35 (67.56)	. . .	160
		0.864 (21.95)	53.16 (79.22)	XXS	. . .
8	8.625 (219.1)	0.322 (8.18)	28.55 (42.55)	STD	40
		0.500 (12.70)	43.39 (64.64)	XS	80
		0.875 (22.22)	72.42 (107.88)	XXS	. . .
		0.906 (23.01)	74.69 (111.27)	. . .	160
10	10.750 (273.0)	0.365 (9.27)	40.48 (60.29)	STD	40
		0.500 (12.70)	54.74 (81.52)	XS	60
		0.594 (15.09)	64.43 (95.97)		80
		1.000 (25.40)	104.13 (155.09)	XXS	120
		1.125 (28.57)	115.65 (172.21)	. . .	160
12	12.750 (323.8)	0.375 (9.52)	49.56 (73.78)	STD	. . .
		0.406 (10.31)	53.52 (79.70)	. . .	40
		0.500 (12.70)	65.42 (97.43)	XS	. . .
		0.688 (17.48)	88.63 (132.04)	. . .	80
		1.000 (25.40)	125.49 (186.91)	XXS	120
		1.312 (33.32)	160.27 (238.68)	. . .	160

Continued on next page

NOMINAL PIPE SIZES — Continued

NPS Designator	Outside Diamter, in. (mm)	Wall Thickness, in. (mm)	Nominal Weight per ft (m), Plain End, lb (kg)	Weight Class	Schedule No.
14	14.000 (355.6)	0.375 (9.52)	54.57 (81.25)	STD	. . .
		0.438 (11.13)	63.44 (94.55)	. . .	40
		0.500 (12.70)	72.09 (107.39)	XS	. . .
		0.750 (19.05)	106.13 (158.10)	. . .	80
		1.406 (35.71)	189.11 (281.70)	. . .	160
16	16.000 (406.4)	0.375 (9.52)	62.58 (93.17)	STD	30
		0.500 (12.70)	82.77 (123.30)	XS	40
		0.844 (21.44)	136.62 (203.53)	. . .	80
		1.594 (40.49)	245.25 (365.35)	. . .	160
18	18.000 (457.2)	0.375 (9.52)	70.59 (105.10)	STD	. . .
		0.500 (12.70)	93.45 (139.20)	XS	. . .
		0.562 (14.27)	104.67 (155.87)	. . .	40
		0.938 (23.83)	170.92 (254.67)	. . .	80
		1.781 (45.24)	308.50 (459.59)	. . .	180
		0.375 (9.52)	78.60 (117.02)	STD	20
		0.500 (12.70)	104.13 (155.12)	XS	30
		0.594 (15.09)	123.11 (183.42)	. . .	40
		1.031 (26.19)	208.87 (311.17)	. . .	80
		1.969 (50.01)	379.10 (564.81)	. . .	160
24	24.000 (609.6)	0.375 (9.52)	94.62 (140.88)	STD	20
		0.500 (12.70)	125.49 (186.94)	XS	. . .
		0.688 (17.48)	171.29 (255.24)	. . .	40
		1.219 (30.96)	296.58 (441.78)	. . .	80
		2.344 (59.54)	542.14 (807.63)	. . .	160
26	26.000 (660.4)	0.375 (9.52)	102.63 (152.80)	STD	. . .
		0.500 (12.70)	136.17 (202.85)	XS	20

WE WOULD APPRECIATE RECEIVING YOUR INQUIRIES FOR TUBING NOT SHOWN IN THIS SECTION.

BURSTING PRESSURE for STEEL TUBING

Theoretical Values Based on Barlow's Formula

CALCULATED BURSTING PRESSURE (PSI) for Each 10,000 PSI of Steel Tubing Tensile Strength								
OD (INCHES)	WALL (INCHES)							
	.035 (20 ga.)	.049 (18 ga.)	.065 (16 ga.)	.095 (13 ga.)	.120 (11 ga.)	5/32	3/16	7/32
1/2	1400	1960	2600	3800	4800	6240	7480	••••
5/8	1120	1568	2080	3040	3840	4992	5984	7008
3/4	933	1307	1733	2533	3200	4160	4987	5840
7/8	800	1120	1486	2171	2743	3566	4274	5006
1	700	980	1300	1900	2400	3120	3740	4380
1 1/8	622	871	1156	1689	2133	2773	3324	3893
1 1/4	560	784	1040	1520	1920	2496	2992	3504
1 3/8	509	713	945	1382	1745	2269	2720	3185
1 1/2	467	653	867	1267	1600	2080	2493	2920
1 3/4	400	560	743	1086	1371	1783	2137	2503
2	350	490	650	950	1200	1560	1870	2190
2 1/4	311	436	578	844	1067	1387	1662	1947
2 1/2	280	392	520	760	960	1248	1496	1752
2 3/4	255	356	473	691	873	1135	1360	1593
3	••••	327	433	633	800	1040	1247	1460
3 1/4	••••	302	400	585	738	960	1151	1348
3 1/2	••••	280	371	543	686	891	1069	1251
3 3/4	••••	261	347	507	640	832	997	1168
4	••••	245	325	475	600	780	935	1095
4 1/4	••••	••••	306	447	565	734	880	1031
4 1/2	••••	••••	289	412	533	693	831	973
4 3/4	••••	••••	274	400	505	657	787	922
5	••••	••••	260	380	480	624	748	876
5 1/2	••••	••••	••••	345	436	567	680	796
6	••••	••••	••••	317	400	520	623	730
6 1/2	••••	••••	••••	••••	369	480	575	674
7	••••	••••	••••	••••	••••	446	534	626
7 1/2	••••	••••	••••	••••	••••	416	499	584
8	••••	••••	••••	••••	••••	••••	468	548
8 1/2	••••	••••	••••	••••	••••	••••	••••	515

NOTE: The tables give approximate bursting pressures as calculated from Barlow's Formula, $P=2 \cdot S \cdot t/D$; where

P = Bursting Pressure, PSI
S = Tensile Strength, PSI
t = Wall Thickness, inches
D = Outside diameter, inches

All of the calculated values are for tubing with a tensile strength of 10,000 PSI. Therefore a tube made of steel with a tensile strength of 50,000 PSI would theoretically burst at five times the tabular value. This information is given for estimating purposes only. **Mechanical tubing is not guaranteed to meet a minimum bursting pressure.**

BURSTING PRESSURE for STEEL TUBING — Continued
Theoretical Values Based on Barlow's Formula

CALCULATED BURSTING PRESSURE (PSI) for Each 10,000 PSI of Steel Tubing Tensile Strength								
OD (INCHES)	WALL (INCHES)							
	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1
1/2	.....	.....	.....	.....	.....	.....	.....	.....
5/8	.....	.....	.....	.....	.....	.....	.....	.....
3/4	6667	.....	.....	.....	.....	.....	.....	.....
7/8	5714	7154	.....	.....	.....	.....	.....	.....
1	5000	6260	7500	.....	.....	.....	.....	.....
1 1/8	4444	5564	6667	.....	.....	.....	.....	.....
1 1/4	4000	5008	6000	8000	.....	.....	.....	.....
1 3/8	3636	4553	5455	7273	.....	.....	.....	.....
1 1/2	3333	4173	5000	6667	8333	.....	.....	.....
1 3/4	2857	3577	4286	5714	7143	.....	.....	.....
2	2500	3130	3750	5000	6250	7500	.....	.....
2 1/4	2222	2782	3333	4444	5556	6667	.....	.....
2 1/2	2000	2504	3000	4000	5000	6000	7000	.....
2 3/4	1818	2276	2727	3636	4545	5455	6364	7273
3	1667	2087	2500	3333	4167	5000	5833	6667
3 1/4	1538	1926	2308	3077	3846	4615	5385	6154
3 1/2	1429	1789	2143	2857	3571	4286	5000	5714
3 3/4	1333	1669	2000	2667	3333	4000	4667	5333
4	1250	1565	1875	2500	3125	3750	4375	5000
4 1/4	1176	1473	1765	2353	2941	3529	4118	4706
4 1/2	1111	1391	1667	2222	2778	3333	3889	4444
4 3/4	1053	1318	1579	2105	2632	3158	3684	4211
5	1000	1252	1500	2000	2500	3000	3500	4000
5 1/2	909	1138	1364	1818	2273	2727	3182	3636
6	833	1043	1250	1667	2083	2500	2917	3333
6 1/2	769	963	1154	1538	1923	2308	2692	3077
7	714	894	1071	1429	1786	2143	2500	2857
7 1/2	667	835	1000	1333	1667	2000	2333	2667
8	625	783	938	1250	1563	1875	2188	2500
8 1/2	588	736	882	1176	1471	1765	2059	2353
9	556	696	833	1111	1389	1667	1944	2222
9 1/2	526	659	789	1053	1316	1579	1842	2105
10	500	626	750	1000	1250	1500	1750	2000
10 1/2	476	596	714	952	1190	1429	1667	1905

SECTION INDEX
TOOL STEEL

IDENTIFICATION AND TYPE CLASSIFICATION OF TOOL STEELS

The system used by AISI and SAE for classifying the types of tool steels includes such basic principles as method of quenching, specific application, special characteristics, etc. The different types have been grouped into eight major headings as listed below. Each commonly accepted group of tool steels under the eight headings has been assigned a letter symbol:

COLD WORK DIE STEELS
- **O** Oil Hardening Types
- **A** Medium Alloy Air Hardening Types
- **D** High Chromium High Carbon Types

SHOCK RESISTING TOOL STEELS
- **S**

HOT WORK TOOL STEELS
- **H**

WATER HARDENING TOOL STEELS
- **W**

MOLD STEELS
- **P**

SPECIAL PURPOSE TOOL STEELS
- **L**

STANDARD HIGH SPEED TOOL STEELS
- **M** Molybdenum Types
- **T** Tungsten Types

INTERMEDIATE HIGH SPEED TOOL STEELS
- **M**50-**M**59 Molybdenum Types

Each grade of tool steel is identified by its group letter and a number to signify the exact type, for instance, A2, O1, H13, etc. The common grades of PACIFIC Tool Steel are described on the following pages with typical applications and heat treatments. For grades which are not listed ask your PACIFIC representative about information on availability and application.

APPROXIMATE MACHINABILITY OF ANNEALED TOOL STEELS

Type	Rating, %	Type	Rating, %
O6	125	A2 thru A9	45 to 60
W1 thru W5	100 *	H21 thru H42	45 to 55 †
A10	90	T1	40 to 50
P6	80	M2	40 to 50
P20, P21	65 to 80	T4	35 to 40
L2, L6	65 to 75	M3 (Class 1)	35 to 40
S1 thru S7	60 to 70	D2 thru D7, A7	30 to 40
H10 thru H19	60 to 70 †	T15	25 to 30
O1, O2, O7	45 to 60	M15	25 to 30

* Equivalent to approximately 30% machinability of B1112
† For hardness range 150 to 200 HB

A SIMPLE APPROACH TO THE SELECTION OF TOOL STEELS

When considering the selection of a grade of tool steel, there are four areas which should be considered:

1. *What will the tool or die be used for?*
2. *How will the tool or die be manufactured?*
3. *How many parts will the tool or die make?*
4. *Is the tool steel being considered available?*

The end use of the tool or die usually determines which of the material properties are most important. The properties normally considered are wear resistance and toughness; hot hardness is also considered when high temperatures are involved. Generally, as the carbon content increases in alloy tool steels, wear resistance also increases, but toughness usually decreases. With this in mind one can use the carbon content of the tool steel as a simple first approach to selection; higher carbon for better wear and lower carbon when toughness is more important. A table on the next page lists alloy tool steels by ascending carbon content for your convenience.

How the tool is to be manufactured (machined, heat treated, etc.) will lead to consideration of the steel's machinability and stability in heat treatment. Machinability is somewhat analogous to wear resistance and in general is a function of carbon content. Stability in heat treatment is dependent mostly on how slowly the part is cooled during the hardening operation. Therefore, the air hardening grades usually have the lowest distortion during heat treatment.

How many parts the tool or die will produce will help determine what level of wear resistance is required for die life. For instance, when blanking mild steel sheet, 01 might be chosen for dies producing 1000 or less parts, while A2 could be used to produce up to 100,000 parts and D2 might produce up to 1,000,000 parts — again, increasing the carbon (and alloy) content increases the wear resistance.

Once the material with optimum properties is selected, it is time to contact PACIFIC MACHINERY & TOOL STEEL CO. to determine if that grade and shape is available. Chances are that the item is in stock and can be cut and shipped immediately. Some grades and sizes will not be available, even by special order, because mills no longer produce them. In these cases PACIFIC MACHINERY & TOOL STEEL CO. can offer alternate grades.

In summary—determine the relative importance of wear resistance and toughness, then consult the following chart listing alloy tool steels by ascending carbon content. Use the higher carbon grades when wear resistance is most important, the lower carbon grades for the most toughness and stay in the middle when toughness and wear resistance must be combined.

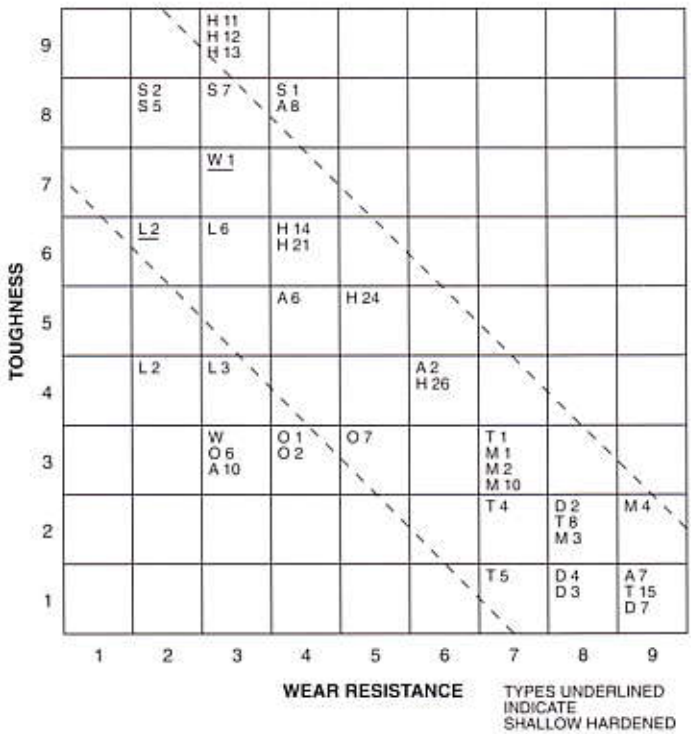
ALLOY TOOL STEEL PROPERTIES
BY INCREASING CARBON CONTENT

GRADE	% Carbon	Wear Resistance	Toughness	Hot Hardness	Machinability	Max. Ann. Hardness**
H13	.38	3	9	6	8	235
S7	.50	3	8	5	8	223
A8	.55	4	8	4	8	241
A6	.70	4	5	4	6	248
O1	.92	4	3	3	8	212
A2	1.00	6	4	5	8	235
D2	1.50	8	2	6	3	255
A7	2.42	9	1	6	1	269
A10*	1.37	3	3	3	8	269
O6*	1.40	3	3	2	9	229

* These graphitic grades are listed separately because of their special nature as free machining grades

** Brinell

ALLOY TOOL STEEL PROPERTIES
TOUGHNESS vs. WEAR RESISTANCE



WELDING OF TOOL STEELS

(Reprinted from METALS HANDBOOK, 9th Ed., with permission of the publisher, ASM International, Metals Park, Ohio)

Conditions for welding. Tool steels are preferably welded in the annealed condition, but often this is impractical as well as costly to the extent that any gain made possible by the use of weld repair would be nullified by the cost of annealing.

Tools and dies in the quenched and tempered condition can often be repaired by welding, but in such a case the preheating and postheating treatments for the base metal must not exceed the original tempering temperature. In some applications, therefore, the microstructure of the base metal, in addition to composition, influences the choice of filler metal.

Most of the rules that apply to the welding of alloy steels apply also to the welding of tool steels, but as the alloy content or carbon content, or both, increase, the importance of adhering to these rules also increases. The following guidelines apply to the arc welding of all grades of tool steel:

- Always use the smallest diameter electrode that will do the job.
- Prepare the surface by machining or grinding. A crack should be gouged out to a U-shape, never to V-shape, because sharp angles will promote cracking.
- Grind or machine away all of the existing cracks, and provide at least $^{1}/_{16}$ in. of excess metal for finish grinding.
- Make sure that all electrodes and base metal surfaces are clean and dry before welding. Absolute freedom from oil and grease is essential.
- Insofar as possible, position the work so that weld beads are laid slightly uphill. This aids joint penetration.
- Never weld any tool steel that is at room temperature; the recommended preheating temperature must be adhered to.
- Keep heat input to the minimum; use minimum arc voltage and amperage, and reduce amperage for secondary and finishing passes.

Selection of Filler Metal. The factors that must be considered in the selection of an electrode for arc welding of tool steel include (1) composition of the base metal, (2) heat treated condition of the base metal (annealed or hardened), and (3) service requirements of the welded area — whether the weld is located at a critical working surface such as a cutting edge or in an area of high wear. Typical electrode compositions (deposit analyses) are presented in the footnotes under Table A. The selections listed in this table are based on the assumption that the welded area is a working surface of the tool and, therefore, must have approximately the same hardness, or be capable of achieving the same hardness, as the base metal. Selection of an electrode is often simplified when this requirement does not have to be met.

When welding annealed tools, the composition of the deposited weld metal should approximate that of the base metal, so that the weld and base metal will respond similarly to heat treatment and will develop the same hardness after heat treatment.

TABLE A Conditions for Arc Welding of Tool Steels

Steel (AISI type)	Type of tool steel electrode(a)	Annealed base metal: Annealing temperature, °F	Annealed base metal: Preheat and postheat temperature, °F	Annealed base metal: Hardening temperature, °F	Annealed base metal: Quenching medium	Annealed base metal: Tempering temperature, °F	Annealed base metal: Resulting hardness, HRC	Hardened base metal: Preheat and postheat temperature, °F	Hardened base metal: C Hardness (b), HRC
W1, W2	Water hardening(c)	1375-1425	250-450	1375-1475	Water	300-650	54-65	250-450	56-62
S1	Hot work(d)	1475	300-500	1750	Oil	300-500	54-57	300-500	52-56
S5	Hot work(d)	1450	300-500	1625	Oil	500 min	55-59	300-500	52-56
S7	Hot work(d)	1500-1550	300-500	1725	Air(e)	400-425(f)	56-58	300-500	52-56
O1	Oil hardening(g)	1450	300-400	1475	Oil	300-450	61-63	300-400	56-62
O6	Oil hardening(g)	1425-1450	300-400	1450-1500	Oil	300-450	61-63	300-400	56-62
A2	Air hardening(h)	1650	300-500	1775	Air	350-400(f)	60-61	300-400	56-58
A4	Air hardening(h)	1425	300-500	1550	Air	350-400(f)	60-61	300-400	60-62
D2	Air hardening(h)	1650	700-900	1850	Air	900-925(f)	58-60	700-900	58-60
H11, H12, H13	Hot work(d)	1600(j)	900-1200	1850	Air	1000-1150(f)	40-50	700-1000	46-54
M1, M2, M10	High speed(k)	1550(j)	950-1100	(m)	Salt(e)	1000-1050(f)	65-66	950-1050	60-63

(a) Nominal compositions of weld deposits are footnoted by type. The compositions of proprietary electrodes vary. (b) As-deposited after postheat. (c) Deposit: 0.95% C, 0.20% Si, 0.30% Mn, 0.20% V. (d) Deposit: 0.33% C, 1.00% Si, 0.40% Mn, 5.00% Cr, 1.35% Mo, 1.25% W. (e) Oil may also be used. (f) Double temper recommended. (g) Deposit: 0.92% C, 0.30% Si, 1.28% Mn, 0.50% Cr, 0.50 W. (h) Deposit: 0.95% C, 0.30% Si, 0.40% Mn, 5.25% Cr, 1.10% Mo, 0.25% V. (j) For H12 and M2 steels, anneal at 1625°F. (k) Proprietary compositions. (m) 2240°F for M1, 2260°F for M2, 2215°F for M10.

Selection of electrodes for welding hardened tools requires more consideration than for welding annealed tools. If the weld metal is to be deposited at a functional area of the tool (such as a cutting edge), it is necessary to select a filler metal that will harden as it cools. Under these conditions, the composition of the deposited weld metal may be entirely different from that of the base metal.

Another technique that is often used in repair welding of hardened tools when the weld will be in a working area is to begin the weld with an electrode that deposits weld metal that hardens only slightly or not at all on cooling — for example, a stainless steel or a low-hydrogen low-alloy steel electrode. A major portion of the weld is made with one of these electrodes, but approximately $^{3}/_{16}$ in. of weld depth is left for completing the weld with an electrode that deposits approximately the same composition as the base metal. This final layer may need to be thicker than $^{3}/_{16}$ in., depending on the stresses to which it will be subjected. However, this procedure should not be used if the welded tool will be quenched and tempered, because cracking may occur.

When high hardness is not required in the welded area, the most common practice is to make the entire weld with a low-alloy, stainless steel, or nickel-based alloy electrode.

Preheat and Interpass Temperatures. Regardless of composition or condition (annealed or hardened), tools should never be welded without preheating. Preheating temperature varies with tool steel composition. Sometimes, a steel of a given composition is preheated at different temperatures depending on whether it is in the annealed or the hardened condition. Preheating temperatures commonly used for various grades of tool steel in both annealed and hardened conditions are given in Table A. As shown in Table A, preheating temperatures range from 250°F for the water-hardening tool steels (W grades) to 1200°F for annealed hot work steels (H grades). When a temperature range, as opposed to a specific temperature, is shown (for instance, 250 to 450°F for W1 and W2), the lower temperature of the range is used for thin sections and the higher temperature for thick sections and massive tools. The minimum preheating temperature should always be maintained as the interpass temperature during welding.

Postweld Heat Treating. When welding annealed material, best practice is to allow the weldment to cool to about 150°F, and then to heat it within the appropriate temperature range (see Table A). When dealing with hardened base metal, the postheating temperature must not exceed the original tempering temperature if the hardness of the tool is to be retained. Common practice is to heat at 25 to 50°F below the original tempering temperature.

AISI W1 WATER HARDENING
CARBON TOOL STEEL

PACIFIC W1 is a carbon tool steel with chemistry equivalent to 1095 carbon spring steel. W1 is most commonly available as drill rod — in fractional, letter and number sizes. It hardens with a hard case and a soft core (except for thin sections which through harden). Use is limited to parts having fairly uniform sections with minimal stress raisers to minimize quench cracking.

TYPICAL APPLICATIONS

Bushings	Drawing Punches	Lathe Centers
Center Punches	Embossing Dies	Pipe Cutters
Collets	Forming Rolls	Reamers
Crimping Dies	Forming Tools	Stamping Dies

CHEMICAL ANALYSIS: Typical, %

C	Mn	P	S
0.95	0.25	0.030 max	0.030 max

THERMAL PROCESSING: Guidelines — Use Good Judgement

FORGING: Heat to 1800/1950°F, do not forge below 1500°F.

ANNEALING: Heat to 1400/1450°F and hold 20 minutes to 2½ hours depending on maximum section thickness. Cool at a maximum rate of 50°F per hour to 1000°F, after which controlled cooling is not necessary. Typical annealed hardness is 156/201 HB.

NORMALIZING: Heat to 1600°F and hold for 15 minutes to 1 hour depending on part size and cool in still air.

STRESS RELIEVING: Heat to 1200/1250°F and hold 1 hour per inch of cross section (minimum 1 hour) and cool in air.

HARDENING: Heat slowly to 1425/1475°F and hold for 10 to 30 minutes before quenching in agitated water or brine. Expected as quenched hardness is 65/68 HRC.

TEMPERING (Drawing): Temper immediately at 350°F to about 650°F for about 1 hour at temperature. Approximate tempered hardness will be 50/64 HRC:

Tempering Temperature, °F	Approximate Hardness, HRC	Tempering Temperature, °F	Approximate Hardness, HRC
350	63/65	800	45/48
400	62/64	900	40/43
500	58/61	1000	34/38
600	55/57	1100	28/31
700	49/52	1200	22/25

AISI O1 OIL HARDENING
COLD WORK TOOL STEEL

PACIFIC O1 is a general purpose, relatively nondeforming grade which hardens from low temperatures (smaller tools and dies can be heated with a torch). When greater stability in heat treatment and/or wear resistance is required, consider PACIFIC A2. If machinability is of prime importance, consider Graph-Mo® (O6).

TYPICAL APPLICATIONS

Blanking Dies	Gages	Punches
Cams	Knives	Shear Blades
Coining Dies	Machine Parts	Stamps
Drawing Dies	Machine Ways	Straight Edges
Forming Dies	Plastic Molds	Trim Dies

CHEMICAL ANALYSIS: Typical, %

C	Mn	Cr	W
0.90	1.00	0.50	0.50

THERMAL PROCESSING: Guidelines — Use Good Judgement

FORGING: Heat to 1800/1950°F, do not forge below 1550°F.

ANNEALING: Heat to 1400/1450°F and hold 1 to 4 hours depending on part size, cool at a maximum rate of 40°F per hour to 1000°F (cooling rate below 1000°F is not critical). Typical annealed hardness is 183/212 HB.

STRESS RELIEVING: Heat to 1200/1250°F for 1 hour minimum at temperature and cool in air.

HARDENING: Preheat at 1200°F. Austenitize at 1450/1500°F for 10 to 30 minutes. Quench in oil to an expected hardness of 63/65 HRC.

TEMPERING (Drawing): Temper at 350/500°F for an hour at temperature to approximate hardness of 62 to 57 HRC. Usually, when greater toughness is required than can be obtained by tempering above 500°F, it is customary to use a shock resisting tool steel such as PACIFIC S7:

Tempering Temperature, °F	Approximate Hardness, HRC	Tempering Temperature, °F	Approximate Hardness, HRC
300	63/65	600	55/57
350	62/64	700	51/53
400	61/63	800	48/40
450	60/62	900	44/47
500	58/60	1000	40/44

AISI O1 ROUNDS

CONDITION	COLOR CODE
Annealed and Decarb Free	Silver

STOCK SIZES*					
DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
1/4	0.17	2.00	1 5/8	7.06	84.70
5/16	0.26	3.13	2	10.69	128.3
3/8	0.38	4.51	2 1/4	13.53	162.4
7/16	0.51	6.14	2 1/2	16.71	200.5
1/2	0.67	8.02	3	24.06	288.7
5/8	1.04	12.53	3 1/2	32.74	392.9
3/4	1.50	18.04	4	42.77	513.2
7/8	2.05	24.56	4 1/2	54.13	649.5
1	2.67	32.07	6	96.22	1,154.7
1 1/8	3.38	40.59	8	171.1	2,052.8
1 1/4	4.18	50.12	12	384.2	4,618.7
1 1/2	6.01	72.17			

*Intermediate and larger sizes are quickly available from mill depot stock.

AISI O1 PLATE & SE®-BARS

CONDITION	COLOR CODE
Annealed and Decarb Free	Silver

STOCK SIZES

Standard sizes of bars are stocked in the plate thicknesses listed below. Standard widths are in 1/4" increments through 3" wide, 1/2" increments over 3" through 6" wide, and 1" increments over 6" through 12" wide. Non-standard widths are available on order (in full bar lengths) in any width to 25" maximum.

THICKNESS (INCHES)	WEIGHT PER SQUARE FOOT (LBS.)
1/2	20.42
5/8	25.52
3/4	30.63
1	40.84
1 1/4	51.05
1 1/2	61.26

SEE PAGE F•24 FOR TOLERANCES

AISI O6 OIL HARDENING-GRAPHITIC
COLD WORK TOOL STEEL

PACIFIC O6 has the highest machinability rating of any standard grade of tool steel. Free graphite in the microstructure gives unique machining characteristics; it also allows lubricant retention which gives non-seizing properties. O6 can usually be substituted for O1 in any application where machinability is a prime consideration.

TYPICAL APPLICATIONS

Bushings	Forming Dies	Small Tools
Cams	Gages	Spinning Tools
Deep Draw Dies	Machine Ways	Trim Dies
Draw Punches	Sizing Dies	Wear Plates

CHEMICAL ANALYSIS: Typical, %

C	Si	Mn	Mo
1.45	1.00	0.80	0.25

THERMAL PROCESSING: Guidelines — Use Good Judgement

FORGING: Heat to 1800/1950°F, do not forge below 1500°F.

ANNEALING: Heat to 1410/1450°F and hold for 1 to 4 hours depending on part size, cool at a maximum rate of 20°F per hour to 1000°F (cooling rate below 1000°F is not critical). Typical annealed hardness is 183/217 HB.

STRESS RELIEVING: Heat to 1200/1250°F for 1 hour minimum at temperature and cool in air.

HARDENING: Heat slowly to austenitize at 1410/1450°F (preheat complex and/or large tools to 1200°F); soak 10 to 30 minutes and quench in oil. Typical as quenched hardness is 63/65 HRC.

TEMPERING (Drawing): Temper at 350/600°F for 1 hour minimum at temperature to an approximate corresponding hardness of 63 to 58 HRC:

Tempering Temperature, °F	Approximate Hardness, HRC	Tempering Temperature, °F	Approximate Hardness, HRC
300	61/63	800	48/52
400	60/62	900	45/49
500	58/60	1000	38/42
600	56/59	1100	32/38
700	52/54	1200	22/30

AISI O6 ROUNDS

CONDITION	COLOR CODE
Annealed and Decarb Free	Silver with Black Stripe

STOCK SIZES*					
DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
3/8	0.38	4.51	2	10.69	128.3
13/32	0.44	5.29	2 1/8	12.07	144.8
1/2	0.67	8.02	2 1/4	13.53	162.4
9/16	0.85	10.15	2 1/2	16.71	200.5
5/8	1.04	12.53	2 3/4	20.21	242.5
3/4	1.50	18.04	3	24.06	288.7
13/16	1.76	21.17	3 1/4	28.23	388.8
7/8	2.05	24.56	3 1/2	32.74	292.9
1	2.67	32.07	3 3/4	37.59	451.1
1 1/8	3.38	40.59	4	42.77	513.2
1 1/4	4.18	50.12	4 1/4	48.28	579.3
1 3/8	5.05	60.64	4 1/2	54.13	649.5
1 1/2	6.01	72.17	5	66.82	801.9
1 5/8	7.06	84.70	6	96.22	1,154.9
1 3/4	8.19	98.23	7	130.97	1,571.7
1 7/8	9.40	128.3	8	171.06	2,052.8

*Intermediate and larger sizes are readily available from mill depot stock.

AISI O6 PLATE & SE®–BARS

CONDITION	COLOR CODE
Annealed and Decarb Free	Silver with Black Stripe

STOCK SIZES*

Standard sizes of bars are stocked in the plate thicknesses listed below. Standard widths are in 1/4" increments through 3" wide, 1/2" increments over 3" through 6" wide, and 1" increments over 6" through 12" wide. Non-standard widths are available on order (in full bar lengths) in any width to 25" maximum.

THICKNESS (INCHES)	WEIGHT PER SQUARE FOOT (LBS.)
1/2	20.42
5/8	25.52
3/4	30.63

*Flats and squares to 4" thicknesses are readily available from mill depot stock.

SEE PAGE F•24 FOR TOLERANCES

AISI A2 AIR HARDENING
COLD WORK TOOL STEEL

PACIFIC A2 is our most popular grade of cold work tool steel. It has better wear resistance and toughness than O1 plus the dimensional stability offered by air hardening qualities. Where even better wear is required (with a corresponding decrease in toughness) consider D2. Where more toughness is needed consider A6 or S7. If machinability is of prime importance, consider Graph-Air® (A10).

TYPICAL APPLICATIONS

Blanking Dies	Forming Rolls	Plastic Molds
Coining Dies	Gages	Punches
Cold Forming Tools	Knives	Shear Blades
Drawing Dies	Lamination Dies	Slitters
Embossing Dies	Mandrels	Trim Dies

CHEMICAL ANALYSIS: Typical, %

C	Mn	Cr	Mo	V
1.00	0.60	5.00	1.00	0.25

THERMAL PROCESSING: Guidelines — Use Good Judgement

FORGING: Preheat to 1200/1250°F before raising to forging heat of 1850/2000°F, do not forge below 1650°F. Cool slowly to avoid cooling cracks; anneal after forging.

ANNEALING: Heat slowly to 1550/1600°F and soak prior to cooling at a maximum rate of 40°F per hour to 1000°F (cooling rate below 1000°F is not critical). Typical annealed hardness is 201/235 HB.

STRESS RELIEVING: Heat to 1200/1250°F and hold 1 hour minimum at temperature. Cool in air.

HARDENING: Preheat at 1450°F. Austenitize at 1725/1775°F for 20 minutes for small tools to 45 minutes for large tools. Air cool as evenly as possible; as quenched hardness is usually 62/65 HRC. Temper immediately.

TEMPERING (Drawing): Temper at 350/1000°F immediately after the tool has cooled to 120/150°F. Double tempering is suggested. Allow the tool to cool to room temperature before the final temper:

Tempering Temperature, °F	Approximate Hardness, HRC	Tempering Temperature, °F	Approximate Hardness, HRC
AQ	63/65	700	57/59
350	61/63	800	57/59
400	60/62	900	57/59
450	55/61	1000	56/58
500	58/60	1100	49/52
600	57/59	1200	42/45

AISI A2 ROUNDS

CONDITION	COLOR CODE
Annealed and Decarb Free	White with Red Stripe

STOCK SIZES*					
DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
5/16	0.26	3.13	2 1/4	13.53	162.4
3/8	0.38	4.51	2 3/8	15.08	180.9
7/16	0.51	6.14	2 1/2	16.71	200.5
1/2	0.67	8.02	2 3/4	20.21	242.5
5/8	1.04	12.53	3	24.06	288.7
3/4	1.50	18.04	3 1/4	28.23	388.8
13/16	1.76	21.17	3 1/2	32.74	392.9
7/8	2.05	24.56	3 3/4	37.59	451.1
1	2.67	32.07	4	42.77	513.2
1 1/8	3.38	40.59	4 1/2	54.13	649.5
1 1/4	4.18	50.12	5	66.82	801.9
1 3/8	5.05	60.64	6	96.22	1,154.9
1 1/2	6.01	72.17	6 1/4	104.41	1,252.9
1 5/8	7.06	84.70	7	130.97	1,571.7
1 3/4	8.19	98.23	8	171.06	2,052.8
1 7/8	9.40	112.8	10	267.29	3,207.4
2	10.69	128.3			

*Intermediate and larger sizes are readily available from mill depot stock.

AISI A2 PLATE & SE®–BARS

CONDITION	COLOR CODE
Annealed and Decarb Free	White with Red Stripe

STOCK SIZES*			
Standard sizes of bars are stocked in the plate thicknesses listed below. Standard widths are in 1/4" increments through 3" wide, 1/2" increments over 3" through 6" wide, and 1" increments over 6" through 12" wide. Non-standard widths are available on order (in full bar lengths) in any width to 25" maximum.			
THICKNESS (INCHES)	WT. PER FT.[2] (LBS.)	THICKNESS (INCHES)	WT. PER FT.[2] (LBS.)
1/4	10.21	1 1/4	51.05
3/8	15.31	1 1/2	61.26
1/2	20.42	1 3/4	71.47
5/8	25.52	2	81.68
3/4	30.63	2 1/2	102.10
7/8	35.73	3	122.52
1	40.84	4	163.35

*Greater thickness flats and squares are readily available from mill depot stock.

SEE PAGE F•24 FOR TOLERANCES

AISI A6 AIR HARDENING
COLD WORK TOOL STEEL

PACIFIC A6 can be hardened from relatively low temperatures which results in low residual stress and reduced chances for distortion. A6 has lower carbon content than A2 and is alloyed primarily with manganese instead of chromium. Therefore, A6 is tougher but has lower wear and temper resistance.

TYPICAL APPLICATIONS

Bending Dies	Forming Dies	Plastic Molds
Blanking Dies	Gages	Punches
Cams	Mandrels	Rolls
Coining Dies	Master Hubs	Shear Blades
Drill Plates	Notching Dies	Stripper Plates

CHEMICAL ANALYSIS: Typical, %

C	Mn	Mo	Cr
0.70	2.00	1.25	1.00

THERMAL PROCESSING: Guidelines — Use Good Judgement

FORGING: Heat slowly to 1900/2050°F, do not forge below 1600°F.

ANNEALING: Heat slowly to 1350/1375°F, then cool at a maximum rate of 25°F per hour to 1000°F (faster cooling rates can be used below 1000°F). Typical annealed hardness is 217/248 HB.

STRESS RELIEVING: Heat to 1250/1300°F and hold for 1 hour minimum at temperature; cool in air.

HARDENING: Preheat at 1200°F. Austenitize at 1525/1600°F for 20 minutes (for small tools) to 45 minutes (for large tools). Air cool to harden; typical as quenched hardness is 59/63 HRC.

TEMPERING (Drawing): Temper immediately after the tool has cooled to 120/150°F. Typical tempering range is 300/800°F. Double tempering is suggested (cool to room temperature after the first temper):

Tempering Temperature, °F	Approximate Hardness, HRC	Tempering Temperature, °F	Approximate Hardness, HRC
AQ	61/62	600	55/56
200	61/62	700	54/55
300	60/61	800	52/53
400	58/59	900	50/51
500	56/57	1000	48/49

AISI A6 ROUNDS

CONDITION	COLOR CODE
Annealed and Decarb Free	White with Green Stripe

STOCK SIZES*					
DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
1/2	0.67	8.02	1 1/2	6.01	72.17
5/8	1.04	12.53	1 3/4	8.19	98.23
3/4	1.50	18.04	2	10.69	128.3
7/8	2.05	24.56	2 1/4	13.53	162.4
1	2.67	32.07	2 1/2	16.71	200.5
1 1/4	4.18	50.12	3	24.06	288.7

*Intermediate and larger sizes are readily available from mill depot stock.

AISI A6 PLATE & SE®-BARS

CONDITION	COLOR CODE
Annealed and Decarb Free	White with Green Stripe

STOCK SIZES*

Standard sizes of bars are stocked in the plate thicknesses listed below. Standard widths are in 1/4" increments through 3" wide, 1/2" increments over 3" through 6" wide, and 1" increments over 6" through 12" wide. Non-standard widths are available on order (in full bar lengths) in any width to 25" maximum.

THICKNESS (INCHES)	WT. PER FT.² (LBS.)	THICKNESS (INCHES)	WT. PER FT.² (LBS.)
1/2	20.42	1 1/2	61.26
3/4	30.63	1 3/4	71.47
1	40.84	2	81.68
1 1/4	51.05	2 1/2	102.10

*Greater thickness flats and squares are readily available from mill depot stock.

SEE PAGE F•24 FOR TOLERANCES

AISI A10 AIR HARDENING
COLD WORK TOOL STEEL

PACIFIC A10 contains graphite particles distributed throughout the microstructure which gives it excellent machinability and good anti-seizing characteristics. Because of hardening from low temperature (1450/1500°F), its size change and distortion characteristics are both very low. A10 is perhaps the most stable of all tool steels through heat treatment.

TYPICAL APPLICATIONS

Arbors	Circuit Board Dies	Guides
Bending Dies	Coining Dies	Lamination Dies
Bushings	Forming Dies	Plastic Molds
Cams	Gages	Wear Surfaces

CHEMICAL ANALYSIS: Typical, %

C	Mn	Si	Mo	Ni
1.35	1.80	1.25	1.50	1.80

THERMAL PROCESSING: Guidelines — Use Good Judgement

FORGING: Preheat at 1200/1250°F before raising to 1800/1925°F forging temperature. Do not forge below 1600°F.

ANNEALING: Heat slowly and uniformly to 1410/1460°F and soak before cooling at a maximum rate of 15°F per hour to 950°F (cooling rate below 950°F is not critical). Typical annealed hardness is 235/269 HB.

STRESS RELIEVING: Heat to 1200/1250°F and hold 1 hour minimum at temperature; cool in air.

HARDENING: Preheat at 1200/1250°F before raising to an austenitizing temperature of 1450/1500°F; hold at temperature 30 to 60 minutes. Cool in air (to 80/90°F for maximum hardness); typical as quenched hardness is 62/64 HRC.

TEMPERING (Drawing): Temper immediately at 350/800°F to an approximate hardness range of 62 to 55 HRC. Double tempering is suggested with cooling to room temperature between tempers:

Tempering Temperature, °F	Approximate Hardness, HRC	Tempering Temperature, °F	Approximate Hardness, HRC
300	61	800	55
400	60	900	53
500	59	1000	48
600	58	1100	41
700	57	1200	36

AISI A10 ROUNDS

CONDITION	COLOR CODE
Annealed and Decarb Free	Silver with Blue Stripe

STOCK SIZES*					
DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
1/2	0.67	8.02	2 1/4	13.53	162.4
5/8	1.04	12.53	2 1/2	16.71	200.5
3/4	1.50	18.04	2 3/4	20.21	242.5
7/8	2.05	24.56	3	24.06	288.7
1	2.67	32.07	3 1/2	32.74	392.9
1 1/4	4.18	50.12	3 3/4	37.59	451.1
1 1/2	6.01	72.17	4	42.77	513.2
1 3/4	8.19	98.23	6	96.22	1,154.9
2	10.69	128.3			

*Intermediate and larger sizes are readily available from mill depot stock.

AISI A10 PLATE & SE®-BARS

CONDITION	COLOR CODE
Annealed and Decarb Free	Silver with Blue Stripe

STOCK SIZES*

Standard sizes of bars are stocked in the plate thicknesses listed below. Standard widths are in 1/4" increments through 3" wide, 1/2" increments over 3" through 6" wide, and 1" increments over 6" through 12" wide. Non-standard widths are available on order (in full bar lengths) in any width to 25" maximum.

THICKNESS (INCHES)	WT. PER FT.² (LBS.)	THICKNESS (INCHES)	WT. PER FT.² (LBS.)
1/2	20.42	1 1/2	61.26
5/8	25.52	2	81.68
3/4	30.63	2 1/2	102.10
1	40.84	3	122.52
1 1/4	51.05		

*Flats and squares to 4" thickness are readily available from mill depot stock.

SEE PAGE F•24 FOR TOLERANCES

AISI D2 HIGH CARBON HIGH CHROME
COLD WORK TOOL STEEL

PACIFIC D2 is the most wear resistant of the commonly available grades of tool steel. It is deep hardening and has very low size change during heat treatment. Because of its inherent wear resistance, D2 has a low machinability rating when compared to other standard alloy tool steel grades. The high chromium content gives it mild corrosion resistance in the hardened condition.

TYPICAL APPLICATIONS

Blanking Dies	Broaches	Slitter Knives
Burnishing Tools	Edging & Forming Dies	Swaging Dies
Coining Dies	Gages	Thread Rolling Dies
Cutlery	Punches	Trimming Dies
	Shear Blades	Wear Plates

CHEMICAL ANALYSIS: Typical, %

C	Cr	Mo	V
1.50	12.00	1.0	1.00

THERMAL PROCESSING: Guidelines — Use Good Judgement

FORGING: Preheat to 1200/1300°F before raising to forging heat of 1850/2000°F. Stop forging at 1700°F. Cool slowly after forging.

ANNEALING: Heat slowly to 1600/1650°F and hold at temperature 1½ to 6 hours depending on part size. Cool at a maximum rate of 40°F per hour to 1000°F (cooling rate below 1000°F is not critical). Typical annealed hardness is 217/255 HB.

STRESS RELIEVING: Heat to 1250/1300°F for 1 hour minimum at temperature and cool in air.

HARDENING: Preheat at 1500°F before raising to an austenitizing temperature of 1825/1875°F; soak 15 to 45 minutes at temperature before cooling in air to harden.

TEMPERING (Drawing): Temper immediately after the tool has cooled to 120/150°F. Double tempering is suggested (after cooling to room temperature from the first temper):

Tempering Temperature, °F	Approximate Hardness, HRC	Tempering Temperature, °F	Approximate Hardness, HRC
AQ	62/64	800	57/59
400	59/61	900	57/59
500	59/61	1000	56/58
600	58/60	1100	48/55
700	57/59	1200	40/45

AISI D2 ROUNDS

CONDITION	COLOR CODE
Annealed and Decarb Free	White

STOCK SIZES*					
DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
3/8	0.38	4.51	2	10.69	128.3
1/2	0.67	8.02	2 1/8	12.07	144.8
5/8	1.04	12.53	2 1/4	13.53	162.4
3/4	1.50	18.04	2 1/2	16.71	200.5
7/8	2.05	24.56	2 3/4	20.21	242.5
1	2.67	32.07	3	24.06	288.7
1 1/8	3.38	40.59	4	42.77	513.2
1 1/4	4.18	50.12	4 1/2	54.13	649.5
1 3/8	5.05	60.64	5	66.82	801.9
1 1/2	6.01	72.17	5 1/2	80.85	970.3
1 5/8	7.06	84.70	6	96.22	1,154.9
1 3/4	8.19	98.23	8	171.06	2,052.8
1 7/8	9.40	112.8			

*Intermediate and larger sizes are readily available from mill depot stock.

AISI D2 PLATE & SE®-BARS

CONDITION	COLOR CODE
Annealed and Decarb Free	White

STOCK SIZES*

Standard sizes of bars are stocked in the plate thicknesses listed below. Standard widths are in 1/4" increments through 3" wide, 1/2" increments over 3" through 6" wide, and 1" increments over 6" through 12" wide. Non-standard widths are available on order (in full bar lengths) in any width to 25" maximum.

THICKNESS (INCHES)	WT. PER FT.² (LBS.)	THICKNESS (INCHES)	WT. PER FT.² (LBS.)
3/8	15.31	1 1/4	51.05
1/2	20.42	1 1/2	61.26
5/8	25.52	2	81.68
3/4	30.63	2 1/2	102.10
1	40.84		

*Greater thickness flats and squares are readily available from mill depot stock.

SEE PAGE F•24 FOR TOLERANCES

AISI S7 AIR HARDENING
SHOCK RESISTING TOOL STEEL

PACIFIC S7 has exceptional impact properties plus the highest hardenability of the shock resisting grades of tool steel. It also possesses good softening resistance at high temperatures which gives it hot work capabilities. Because of its unusual combination of properties, S7 is suitable for a wide range of tool and die applications. It is used for hot and cold shock applications, medium hot-work dies and medium-run cold work tools and dies.

TYPICAL APPLICATIONS

Bending Dies	Gripper Dies	Pipe Cutters
Chisels	Hot Header Dies	Plastic Molds
Die Casting Dies	Mandrels	Punches
Drift Pins	Moil Points	Rivet Sets

CHEMICAL ANALYSIS: Typical, %

C	Mn	Cr	Mo
0.50	0.60	3.25	1.40

THERMAL PROCESSING: Guidelines — Use Good Judgement

FORGING: Heat to 1950/2050°F, do not forge below 1700°F.

ANNEALING: Heat to 1500/1550°F and hold 1 to 4 hours depending on part size. Cool at a maximum rate of 25°F per hour to 950°F (cooling rate below 950°F is not critical). Typical annealed hardness is 187/223 HB.

STRESS RELIEVING: Heat to 1200/1250°F for 1 hour minimum at temperature and cool in air.

HARDENING: Preheat at 1200/1300°F. Austenitize at 1700/1750°F for 15 to 45 minutes and cool in air to harden (larger sections may have to be oil quenched for maximum hardness). Typical as quenched hardness is 60/61 HRC.

TEMPERING (Drawing): Temper at 400/1150°F to an expected hardness of 57/45 HRC; 400/500°F is typical for cold working applications and 900/1000°F for hot working:

Tempering Temperature, °F	Approximate Hardness, HRC	Tempering Temperature, °F	Approximate Hardness, HRC
AQ	59/61	800	52/54
400	57/59	900	51/53
500	55/57	1000	50/52
600	54/56	1100	49/51
700	53/55	1200	37/39

TOUGHNESS: Resistance to fracture by impact at high hardness is often the reason for using S7. Results from Bethlehem, Crucible and Latrobe steel companies using unnotched, C-notched and V-notched Charpy impact tests show the same. There is a toughness peak reached by tempering in the range of 450/600°F with resulting hardnesses 55/57 HRC. Even higher toughness can be achieved by tempering above 1000°F. However, hardness will drop to approximately 50 HRC and lower as tempering temperature increases.

AISI S7 ROUNDS

CONDITION	COLOR CODE
Annealed and Decarb Free	Yellow with Blue Stripe

STOCK SIZES*

DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
3/8	0.38	4.51	1 7/8	9.40	112.8
7/16	0.51	6.14	2	10.69	128.3
1/2	0.67	8.02	2 1/4	13.53	162.4
5/8	1.04	12.53	2 1/2	16.71	200.5
3/4	1.50	18.04	2 3/4	20.21	242.5
7/8	2.05	24.56	3	24.06	288.7
1	2.67	32.07	3 1/4	28.23	388.8
1 1/8	3.38	40.59	3 1/2	32.74	392.9
1 1/4	4.18	50.12	3 3/4	37.59	451.1
1 3/8	5.05	60.64	4	42.77	513.2
1 1/2	6.01	72.17	4 1/2	54.13	649.5
1 5/8	7.06	84.70	5	66.82	801.9
1 3/4	8.19	98.23	8	171.06	2,052.8

*Intermediate and larger sizes are readily available from mill depot stock.

AISI S7 PLATE & SE®-BARS

CONDITION	COLOR CODE
Annealed and Decarb Free	Yellow with Blue Stripe

STOCK SIZES*

Standard sizes of bars are stocked in the plate thicknesses listed below. Standard widths are in 1/4" increments through 3" wide, 1/2" increments over 3" through 6" wide, and 1" increments over 6" through 12" wide. Non-standard widths are available on order (in full bar lengths) in any width to 25" maximum.

THICKNESS (INCHES)	WT. PER FT.² (LBS.)	THICKNESS (INCHES)	WT. PER FT.² (LBS.)
1/2	20.42	1 1/4	51.05
5/8	25.52	1 1/2	61.26
3/4	30.63	2	81.68
7/8	35.73	3	122.52
1	40.84		

*Greater thickness flats and squares are readily available from mill depot stock.

SEE PAGE F•24 FOR TOLERANCES

AISI H13 AIR HARDENING
HOT WORK TOOL STEEL

PACIFIC H13 is deep hardening with very high toughness and excellent resistance to heat checking. Although primarily used for hot work applications, it can be used in cold work applications where extra toughness is required (but sacrifice in wear resistance can be tolerated). H13 exhibits low distortion in heat treating and has good machinability.

TYPICAL APPLICATIONS

Cores	Forging Dies	Hot Shears
Die Casting Dies	Gripper Dies	Hot Swaging Dies
Dummy Blocks	Header Dies	Mandrels
Extrusion Dies	Hot Punches	Piercing Tools

CHEMICAL ANALYSIS: Typical, %

C	Si	Mo	Cr	V
0.35	1.00	1.50	5.00	1.00

THERMAL PROCESSING: Guidelines — Use Good Judgement

FORGING: Preheat at 1300/1350°F prior to raising to forging temperature of 1950/2100°F. Do not forge below 1650°F; cool slowly.

ANNEALING: Heat slowly to 1550/1650°F and hold at temperature 1 to 4 hours depending on part size. Cool at a maximum rate of 50°F per hour to 1000°F (cooling rate below 1000°F is not critical). Typical annealed hardness is 192/229 HB.

STRESS RELIEVING: Heat to 1200/1250°F and hold at temperature 1 hour minimum; cool in air.

HARDENING: Preheat at 1400/1500°F before austenitizing at 1825/1900°F for 15 to 40 minutes; cool in air to harden. Typical as quenched hardness is 51/54 HRC.

TEMPERING (Drawing): Temper immediately, typically 1 hour minimum at 1000/1200°F to an expected hardness of 53/38 HRC. Double tempering is suggested with cooling to room temperature after the first temper:

Tempering Temperature, °F	Approximate Hardness, HRC	Tempering Temperature, °F	Approximate Hardness, HRC
AQ	52/54	1000	51/54
800	51/53	1100	48/51
900	51/53	1200	36/40

AISI H13 ROUNDS

CONDITION	COLOR CODE
Annealed and Decarb Free	Black with Yellow Stripe

STOCK SIZES*					
DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)	DIAMETER (INCHES)	WT. PER FT. (LBS.)	WT. PER 12' BAR (LBS.)
3/8	0.38	4.51	2	10.69	128.3
1/2	0.67	8.02	2 1/4	13.53	162.4
5/8	1.04	12.53	2 1/2	16.71	200.5
3/4	1.50	18.04	2 3/4	20.21	242.5
7/8	2.05	24.56	3	24.06	288.7
1	2.67	32.04	3 1/2	32.74	392.9
1 1/8	3.38	40.59	3 5/8	35.12	421.5
1 1/4	4.18	50.12	3 3/4	37.59	451.1
1 1/2	6.01	72.17	4	42.77	513.2
1 5/8	7.06	84.70	5	66.82	801.9
1 3/4	8.19	98.23			

*Intermediate and larger sizes are readily available from mill depot stock.

AISI H13 PLATE & SE®-BARS

CONDITION	COLOR CODE
Annealed and Decarb Free	Black with Yellow Stripe

STOCK SIZES*			
Standard sizes of bars are stocked in the plate thicknesses listed below. Standard widths are in 1/4" increments through 3" wide, 1/2" increments over 3" through 6" wide, and 1" increments over 6" through 12" wide. Non-standard widths are available on order (in full bar lengths) in any width to 25" maximum.			
THICKNESS (INCHES)	WT. PER FT.[2] (LBS.)	THICKNESS (INCHES)	WT. PER FT.[2] (LBS.)
3/4	30.63	1 1/2	61.26
1	40.84	2	81.68
1 1/4	51.05		

*Greater thickness flats and squares are readily available from mill depot stock.

SEE PAGE F•24 FOR TOLERANCES

TOOL STEEL TOLERANCES

Industry Standards

MACHINED OVERSIZE FLAT & SQUARE BARS

For close tolerances and improved surface finish, bars with machined surfaces in standard bar lengths are available in the more popular tool steel grades. The bars are free of surface imperfections and decarburization. They may be furnished as individually rolled or forged bars machined on all four sides or as bars cut from machined plate. These bars are furnished oversize to allow for finishing after heat treatment. The producer should be consulted for limitations on surface finish.

THICKNESS TOLERANCES

SPECIFIED THICKNESS, in. (mm)	OVERSIZE, in. (mm)	THICKNESS TOLERANCE ON OVERSIZED DIMENSION,[a] in. (mm)	
		MINUS	PLUS
1/2 to 4 incl. (12.7 to 101.6)	0.015 (0.38)	0.000	0.020 (0.51)
Over 4 to 6 incl.[b] (101.6 to 152.4)	0.062 (1.59)	0.000	0.031 (0.79)

WIDTH TOLERANCES

SPECIFIED THICKNESS, in. (mm)	OVERSIZE, in. (mm)	INDIVIDUALLY ROLLED AND MACHINED BARS		BARS CUT FROM MACHINED PLATE	
		TOLERANCE ON OVERSIZED DIMENSION in. (mm)		TOLERANCE ON OVERSIZED DIMENSION in. (mm)	
		MINUS	PLUS	MINUS	PLUS
1/2 to 4 incl. (12.7 to 101.6)	0.015 (0.38)	0.000	0.020 (0.51)	0.000	0.062 (1.59)
Over 4 to 6 incl.[b] (101.6 to 152.4)	0.062 (1.59)	0.000	0.031 (0.79)	0.000	0.062 (1.59)

[a] On either individually rolled and machined bars or bars cut from machined plate.
[b] For oversize and tolerances on larger sizes, refer to producer.

STRAIGHTNESS TOLERANCES

1/16 in. in any 5 ft, but may not exceed

$$\frac{1}{16}\text{ in.} \times \frac{\text{no. of feet in length}}{5}$$

$$\left(\begin{array}{c}\text{1.59 mm in any 1.52 m, but may not exceed} \\ 1.59\text{ mm} \times \dfrac{\text{no. of meters in length}}{1.52\text{ m}}\end{array}\right)$$

The foregoing formula applies also to bars under 5 ft (1.52 m) in length.

DECARB FREE OVERSIZE ROUND BARS

Round bars are rough ground or turned to produce surfaces free of imperfections and decarburization. Enough stock is left on the diameter to finish at nominal size after final heat treatment and machining. Each manufacturer establishes their own oversize tolerance range; tolerance ranges are similar to those listed above for flats and squares.

SECTION INDEX
DRILL ROD & PRECISION FLAT GROUND STOCK

DRILL ROD

FLAT GROUND STOCK

DRILL ROD

PACIFIC Drill Rod is stocked in W1, O1, A2 and S7 tool steel grades; other tool steel grades are available on order. Standard length for drill rod is 3 feet. Twelve-foot lengths are also available in some sizes and grades. Drill rod is furnished in the annealed condition and will require heat treatment if high hardness is required. See the Tool Steel Section for heat treatment procedures of the individual grades. The tight tolerances and fine surface finish of drill rod make it an economical product when these qualities are required. Rounds, except for small sizes, are centerless ground and polished. All squares and hexagons are cold drawn to accurate dimensional size and shape. Sizes for rounds are listed by fraction, Stub's Steel Wire Gage numbers and by Morse Twist Drill Gage letters. To prevent confusion one should specify the exact decimal diameter when ordering drill rod rounds — drill size numbers are *not* equal in diameter to drill rod size numbers.

SIZE TOLERANCES			
ROUNDS—Polished or Ground		SQUARES & HEXAGONS—Cold Drawn	
DIAMETER (INCHES)	TOLERANCE (INCHES)	SIZE (INCHES)	TOLERANCE (INCHES)
to 0.124	± 0.0003	to 1/4	± 0.0005
0.125 to 0.500	± 0.0005	1/4 to 3/4	± 0.001
0.500 thru 2.000	± 0.001	3/4 thru 1	± 0.0015

PRECISION FLAT GROUND STOCK

PACIFIC Precision Flat Ground Stock can reduce manufacturing costs for tools, dies, jigs and fixtures. It has exact dimensions, square corners, flat and parallel sides, a smooth finish and a uniform, stress free structure. PACIFIC Precision Flat Ground Stock is most commonly available in the O1 tool steel grade; also stocked are O6 (free machining graphitic tool steel), A2 (air hardening tool steel) and low carbon grades. Other tool steel grades are available on short notice from mill stock. Stock lengths for the tool steel grades are 18" and 36"; for low carbon it is 24". Stock sizes are standard tolerance (nominal thickness) but oversize tolerance is available in the tool steel grades. Precision Flat Ground Stock is annealed to give the best machinability. Heat treatment information is located in the Tool Steel Section for hardening the tool steel grades; low carbon requires carburizing for hardening.

TOLERANCES	
DIMENSION	TOLERANCE
Length	+0.250" / –0.000
Width*	+0.005" / –0.000
Thickness* thru 1 1/4" over 1 1/4"	 +0.001" / –0.001" +0.002" / –0.002"
Squareness	+0.003" per inch thickness
Finish	35 RMS maximum
* Tolerance for oversize ground stock is +0.010" to 0.015" for both width and thickness dimensions.	

WATER HARDENING DRILL ROD

AISI W1 Rounds

STOCK SIZES					
SIZE (INCHES)	DECIMAL EQUIVALENT (INCHES)	WEIGHT** 3-FOOT PIECE	SIZE (INCHES)	DECIMAL EQUIVALENT (INCHES)	WEIGHT** 3-FOOT PIECE
1/32	.0313	.0078			
1/16	.0625	.0313	16	.175	.245
52	.063	.0320	15	.178	.254
51	.066	.0349	14	.180	.260
50	.069	.0381	13	.182	.265
49	.072	.0415	12	.185	.274
48	.075	.0451	3/16	.1875	.282
47	.077	.0479	11	.188	.283
5/64	.0781	.0489	10	.191	.292
46	.079	.0500	9	.194	.302
45	.081	.0526	8	.197	.311
44	.085	.0578	7	.199	.317
43	.088	.0620	6	.201	.324
42	.092	.0678	13/64	.2031	.331
3/32	.0937	.0704	5	.204	.333
41	.095	.0723	4	.207	.343
40	.097	.0754	3	.212	.360
39	.099	.0785	7/32	.2187	.383
38	.101	.0817	2	.219	.384
37	.103	.0850	1	.227	.413
36	.106	.0900	A	.234	.439
35	.108	.0934	15/64	.2343	.440
7/64	.1093	.0958	B	.238	.454
34	.110	.0969	C	.242	.469
33	.112	.100	D	.246	.485
32	.115	.106	1/4	.250	.501
31	.120	.115	F	.257	.527
1/8	.125	.125	G	.261	.546
30	.127	.129	17/64	.2656	.565
29	.134	.144	H	.266	.567
28	.139	.155	I	.272	.593
9/64	.1406	.158	J	.277	.615
27	.143	.164	K	.281	.632
26	.146	.171	9/32	.2812	.634
25	.148	.175	L	.290	.674
24	.151	.183	M	.295	.697
23	.153	.188	19/64	.2968	.706
22	.155	.192	N	.302	.731
5/32	.1562	.196	5/16	.3125	.782
21	.157	.197	O	.316	.800
20	.161	.208	P	.323	.836
19	.164	.215	21/64	.3281	.863
18	.168	.226	Q	.332	.883
11/64	.1718	.237	R	.339	.921
17	.172	.238	11/32	.3437	.947

** All sizes available from mill depot stock in 12' lengths.

Continued on next page

WATER HARDENING DRILL ROD — Continued

STOCK SIZES					
SIZE (INCHES)	DECIMAL EQUIVALENT (INCHES)	WEIGHT** 3-FOOT PIECE	SIZE (INCHES)	DECIMAL EQUIVALENT (INCHES)	WEIGHT** 3-FOOT PIECE
S	.348	.970	15/16	.9375	7.041
T	.358	1.027	61/64	.9531	7.278
23/64	.3593	1.035	31/32	.9681	7.518
U	.368	1.085	63/64	.9843	7.763
3/8	.375	1.127	1	1.000	8.011
V	.377	1.139	1 1/64 *	1.0156	8.259
W	.386	1.194	1 1/32	1.0312	8.514
25/64	.3906	1.222	1 3/64 *	1.0468	8.774
X	.397	1.263	1 1/16 *	1.0625	9.044
Y	.404	1.308	1 5/64 *	1.0781	9.306
13/32	.4062	1.332	1 3/32 *	1.0937	9.578
Z	.413	1.366	1 7/64 *	1.1093	9.853
27/64	.4218	1.426	1 1/8	1.125	10.139
7/16	.4375	1.533	1 9/64 *	1.1406	10.412
29/64	.4531	1.645	1 5/32 *	1.1562	10.764
15/32	.4687	1.760	1 11/64 *	1.1718	10.994
31/64	.4843	1.880	1 3/16	1.1875	11.297
1/2	.500	2.003	1 13/64 *	1.2031	11.590
33/64	.5156	2.130	1 7/32 *	1.2187	11.892
17/32	.5312	2.261	1 15/64 *	1.2343	12.198
35/64	.5468	2.396	1 1/4	1.250	12.518
9/16	.5625	2.535	1 17/64 *	1.2656	12.849
37/64	.5781	2.678	1 9/32 *	1.2812	13.143
19/32	.5937	2.824	1 19/64 *	1.2968	13.464
39/64	.6093	2.975	1 5/16	1.3125	13.801
5/8	.625	3.129	1 21/64 *	1.3281	14.123
41/64	.6406	3.288	1 11/32 *	1.2437	14.457
21/32	.6562	3.450	1 23/64 *	1.3593	14.795
43/64	.6718	3.616	1 3/8	1.375	15.146
11/16	.6875	3.787	1 25/64 *	1.3906	15.484
45/64	.7031	3.961	1 13/32 *	1.4062	15.833
23/32	.7187	4.139	1 27/64 *	1.4218	16.186
47/64	.7343	4.321	1 7/16	1.4375	16.554
3/4	.750	4.506	1 29/64 *	1.4531	16.907
49/64	.7656	4.696	1 15/32 *	1.4687	17.272
25/32	.7812	4.890	1 31/64 *	1.4843	17.641
51/64	.7968	5.087	1 1/2	1.500	18.025
13/16	.8125	5.289	1 9/16 *	1.5625	18.548
53/64	.8281	5.494	1 5/8 *	1.625	21.143
27/32	.8437	5.703	1 11/16 *	1.6875	22.800
55/64	.8593	5.917	1 3/4	1.750	24.534
7/8	.875	6.134	1 13/16 *	1.8125	26.300
57/64	.8906	6.355	1 7/8 *	1.875	28.150
29/32	.9602	6.580	1 15/16	1.9375	30.060
59/64	.9218	6.808	2	2.000	32.088

* Mill depot stock availability ** All sizes available from mill depot stock in 12' lengths.

WATER HARDENING DRILL ROD

AISI W1 Squares & Hexagons

STOCK SIZES			
SQUARES		HEXAGONS	
SIZE (INCHES)	WEIGHT 3-FOOT PIECE	SIZE (INCHES)	WEIGHT 3-FOOT PIECE
1/8	.1590	1/8	.1381
3/16	.3600	3/16	.3108
1/4	.6360	1/4	.5526
5/16	.9960	5/16	.8634
3/8	1.434	3/8	1.243
7/16	1.952	7/16	1.692
1/2	2.550	1/2	2.210
5/8	3.980	7/8	6.769
3/4	5.740	1	8.842
7/8	7.810		
1	10.200		
SQUARES AVAILABLE IN 12' LENGTH FROM MILL DEPOT STOCK			

WATER HARDENING DRILL ROD

AISI W1 Flats — Available on Order

MILL STOCK SIZES			
SIZE (INCHES)	WEIGHT 3-FOOT PIECE	SIZE (INCHES)	WEIGHT 3-FOOT PIECE
1/16 x 1/8	.0798	5/32 x 3/8	.5976
1/16 x 3/16	.1194	5/32 x 1/2	.7968
1/16 x 1/4	.1593	3/16 x 1/4	.4782
3/32 x 1/8	.1194	3/16 x 5/16	.5976
3/32 x 3/16	.1774	3/16 x 3/8	.7173
3/32 x 1/4	.2391	3/16 x 1/2	.9564
3/32 x 5/16	.2988	3/16 x 5/8	.9960
3/32 x 3/8	.3585	3/16 x 3/4	1.4340
1/8 x 3/16	.2391	1/4 x 5/16	.7968
1/8 x 1/4	.3189	1/4 x 3/8	.9564
1/8 x 5/16	.3984	1/4 x 1/2	1.2750
1/8 x 3/8	.4782	1/4 x 3/4	1.9125
1/8 x 1/2	.6370	1/2 x 5/8	3.1890
1/8 x 3/4	.9564	1/2 x 3/4	3.8250
5/32 x 1/4	.3984	1/2 x 1	5.1000
STOCKED IN 3' AND 12' LENGTHS			

OIL HARDENING DRILL ROD

AISI O1 Rounds

STOCK SIZES					
SIZE (INCHES)	DECIMAL EQUIVALENT (INCHES)	WEIGHT** 3-FOOT PIECE	SIZE (INCHES)	DECIMAL EQUIVALENT (INCHES)	WEIGHT** 3-FOOT PIECE
1/16	.0625	.0313	16 *	.175	.245
52 *	.063	.0320	15 *	.178	.254
51 *	.066	.0349	14 *	.180	.260
50 *	.069	.0381	13 *	.182	.265
49 *	.072	.0415	12 *	.185	.274
48 *	.075	.0451	3/16	.1875	.282
47 *	.077	.0479	11 *	.188	.283
5/64 *	.0781	.0489	10 *	.191	.292
46 *	.079	.0500	9 *	.194	.302
45 *	.081	.0526	8 *	.197	.311
44 *	.085	.0578	7 *	.199	.317
43 *	.088	.0620	6 *	.201	.324
42 *	.092	.0678	13/64 *	.2031	.331
3/32	.0937	.0704	5 *	.204	.333
41 *	.095	.0723	4 *	.207	.343
40 *	.097	.0754	3 *	.212	.360
39 *	.099	.0785	7/32	.2187	.383
38 *	.101	.0817	2 *	.219	.384
37 *	.103	.0850	1 *	.227	.413
36 *	.106	.0900	A *	.234	.439
35 *	.108	.0934	15/64 *	.2343	.440
7/64	.1093	.0958	B *	.238	.454
34 *	.110	.0969	C *	.242	.469
33 *	.112	.100	D *	.246	.485
32 *	.115	.106	1/4	.250	.501
31 *	.120	.115	F *	.257	.527
1/8	.125	.125	G *	.261	.546
30 *	.127	.129	17/64 *	.2656	.565
29 *	.134	.144	H *	.266	.567
28 *	.139	.155	I *	.272	.593
9/64	.1406	.158	J *	.277	.615
27 *	.143	.164	K *	.281	.632
26 *	.146	.171	9/32	.2812	.634
25 *	.148	.175	L *	.290	.674
24 *	.151	.183	M *	.295	.697
23 *	.153	.188	19/64 *	.2968	.706
22 *	.155	.192	N *	.302	.731
5/32	.1562	.196	5/16	.3125	.782
21 *	.157	.197	O *	.316	.800
20 *	.161	.208	P *	.323	.836
19 *	.164	.215	21/64 *	.3281	.863
18 *	.168	.226	Q *	.332	.883
11/64	.1718	.237	R *	.339	.921
17 *	.172	.238	11/32	.3437	.947

* Mill depot stock availability ** All sizes available from mill depot stock in 12' lengths.

Continued on next page

OIL HARDENING DRILL ROD — Continued

STOCK SIZES					
SIZE (INCHES)	DECIMAL EQUIVALENT (INCHES)	WEIGHT** 3-FOOT PIECE	SIZE (INCHES)	DECIMAL EQUIVALENT (INCHES)	WEIGHT** 3-FOOT PIECE
S *	.348	.970	15/16	.9375	7.041
T *	.358	1.027	61/64 *	.9531	7.278
23/64 *	.3593	1.035	31/32	.9681	7.518
U *	.368	1.085	63/64	.9843	7.763
3/8	.375	1.127	1	1.000	8.011
V *	.377	1.139	1 1/64 *	1.0156	8.259
W *	.386	1.194	1 1/32 *	1.0312	8.514
25/64 *	.3906	1.222	1 3/64 *	1.0468	8.774
X *	.397	1.263	1 1/16	1.0625	9.044
Y *	.404	1.308	1 5/64 *	1.0781	9.306
13/32	.4062	1.332	1 3/32 *	1.0937	9.578
Z *	.413	1.366	1 7/64 *	1.1093	9.853
27/64 *	.4218	1.426	1 1/8	1.125	10.139
7/16	.4375	1.533	1 9/64 *	1.1406	10.412
29/64 *	.4531	1.645	1 5/32 *	1.1562	10.764
15/32	.4687	1.760	1 11/64 *	1.1718	10.994
31/64	.4843	1.880	1 3/16 *	1.1875	11.297
1/2	.500	2.003	1 13/64 *	1.2031	11.590
33/64 *	.5156	2.130	1 7/32 *	1.2187	11.892
17/32	.5312	2.261	1 15/64 *	1.2343	12.198
35/64 *	.5468	2.396	1 1/4	1.250	12.518
9/16	.5625	2.535	1 17/64 *	1.2656	12.849
37/64	.5781	2.678	1 9/32 *	1.2812	13.143
19/32	.5937	2.824	1 19/64 *	1.2968	13.464
39/64 *	.6093	2.975	1 5/16 *	1.3125	13.801
5/8	.625	3.129	1 21/64 *	1.3281	14.123
41/64 *	.6406	3.288	1 11/32 *	1.3437	14.457
21/32	.6562	3.450	1 23/64 *	1.3593	14.795
43/64 *	.6718	3.616	1 3/8	1.375	15.146
11/16	.6875	3.787	1 25/64 *	1.3906	15.484
45/64	.7031	3.961	1 13/32 *	1.4062	15.833
23/32	.7187	4.139	1 27/64 *	1.4218	16.186
47/64 *	.7343	4.321	1 7/16 *	1.4375	16.554
3/4	.750	4.506	1 29/64 *	1.4531	16.907
49/64 *	.7656	4.696	1 15/32 *	1.4687	17.272
25/32	.7812	4.890	1 31/64 *	1.4843	17.641
51/64 *	.7968	5.087	1 1/2	1.500	18.025
13/16	.8125	5.289	1 9/16 *	1.5625	18.548
53/64	.8281	5.494	1 5/8 *	1.625	21.143
27/32	.8473	5.703	1 11/16 *	1.6875	22.800
55/64 *	.8593	5.917	1 3/4	1.750	24.534
7/8	.875	6.134	1 13/16 *	1.8125	26.300
57/64 *	.8906	6.355	1 7/8 *	1.875	28.150
29/32	.9602	6.580	1 15/16 *	1.9375	30.060
59/64 *	.9218	6.808	2	2.000	32.088

* Mill depot stock availability ** All sizes available from mill depot stock in 12' lengths.

AIR HARDENING DRILL ROD

AISI S7 & A2

STOCK SIZES					
S7			A2		
SIZE	DECIMAL EQUIVALENT (INCHES)	WEIGHT 3-FOOT PIECE	SIZE*	DECIMAL EQUIVALENT (INCHES)	WEIGHT 3-FOOT PIECE
5/64	.0781	.0489	1/16	.0625	.0313
3/32	.0937	.0704	1/8	.1250	.1250
7/64	.1093	.0958	3/16	.1875	.2820
3mm	.1181	.1118	1/4	.2500	.5010
1/8	.1250	.1250	5/16	.3125	.7820
3/16	.1875	.2820	3/8	.3750	1.1270
1/4	.2500	.5010	7/16	.4375	1.5330
9/32	.2812	.6320	1/2	.5000	2.0030
5/16	.3125	.7820	5/8	.6250	3.1290
11/32	.3437	.9470	3/4	.7500	4.5060
3/8	.3750	1.1270	7/8	.8750	6.1340
13/32	.4062	1.3220	1	1.0000	8.0110
7/16	.4375	1.5330			
15/32	.4687	1.7600			
1/2	.5000	2.0030			
9/16	.5625	2.5350			
5/8	.6250	3.1290			
11/16	.6875	3.7870			
3/4	.7500	4.5060			
13/16	.8125	5.2890			
7/8	.8750	6.1340			
15/16	.9375	7.0410			
1	1.0000	8.0110			
1 1/4	1.2500	12.518			
1 1/2	1.5000	18.025			

*A full range of sizes is available from mill depot stock in both 3-foot and 12-foot lengths. Size increments are: 1/64" from 1/8" through 1/2" diameter and 1/32" from 17/32" through 3/4" diameter. Additional availability is in sizes 13/16", 7/8", 1", 1 1/16", 1 1/8", 1 1/4", 1 3/8", 1 1/2", 1 3/4" and 2".

PRECISION FLAT GROUND STOCK

AISI O1, Oil Hardening — Annealed

STOCK SIZES
FLATS & SQUARES — 18" LENGTHS

SIZE (INCHES)	WT. PER PC. (POUNDS)
1/64 x 1/2	.04
3/4	.06
1	.08
1 1/4	.10
1 1/2	.12
2	.16
2 1/2	.20
3	.24
4	.32
1/32 x 1/2	.08
3/4	.12
1	.16
1 1/4	.20
1 1/2	.24
2	.32
2 1/2	.40
3	.48
4	.64
6	.96
3/64 x 1/2	.12
3/4	.18
1	.24
1 1/4	.30
1 1/2	.36
2	.48
2 1/2	.60
3	.72
3 1/2	.84
4	.96
6	1.44

SIZE (INCHES)	WT. PER PC. (POUNDS)
1/16 x 1/4	.08
3/8	.12
1/2	.16
5/8	.20
3/4	.24
1	.32
1 1/4	.40
1 1/2	.48
1 3/4	.56
2	.64
2 1/2	.80
3	.96
3 1/2	1.12
4	1.27
5	1.59
6	1.91
8	2.55
10	3.19
5/64 x 1/2	.20
3/4	.30
1	.40
1 1/4	.50
1 1/2	.60
2	.80
2 1/2	1.00
3	1.20
4	1.60
6	2.40
3/32 x 1/2	.24
3/4	.36
1	.48
1 1/4	.60
1 1/2	.72
1 3/4	.84
2	.96
2 1/2	1.20
3	1.43
4	1.91
5	2.39
6	2.87
8	3.83
10	4.79

SIZE (INCHES)	WT. PER PC. (POUNDS)
7/64 x 1/2	.28
3/4	.40
1	.56
1 1/4	.70
1 1/2	.84
2	1.12
3	1.68
4	2.23
1/8 x 1/8	.09
1/4	.16
3/8	.23
1/2	.32
5/8	.41
3/4	.48
1	.64
1 1/4	.80
1 1/2	.96
1 3/4	1.12
2	1.27
2 1/2	1.60
3	1.91
3 1/2	2.24
4	2.55
4 1/2	2.87
5	3.19
6	3.82
7	4.47
8	5.11
10	6.38
12	7.66
14	8.93
9/64 x 9/64	.10
1/2	.12
3/4	.54
1	.72
1 1/2	1.08
2	1.44
3	2.16
4	2.87

Continued on next page

PRECISION FLAT GROUND STOCK — Continued

STOCK SIZES
FLATS & SQUARES — 18" LENGTHS

SIZE (INCHES)	WT. PER PC. (POUNDS)
7/16 x 7/16	.98
1/2	1.12
3/4	1.68
1	2.23
1 1/4	2.79
1 1/2	3.35
2	4.46
2 1/2	5.58
3	6.70
4	8.93
6	13.39
1/2 x 1/2	1.28
5/8	1.60
3/4	1.91
1	2.55
1 1/4	3.19
1 1/2	3.82
1 3/4	4.46
2	5.10
2 1/2	6.37
3	7.65
3 1/2	8.93
4	10.20
4 1/2	11.48
5	12.75
6	15.30
7	17.85
8	20.40
10	25.50
12	30.60
14	35.70
9/16 x 9/16	1.62
3/4	2.15
1	2.87
1 1/4	3.59
1 1/2	4.31
2	5.74
5/8 x 5/8	1.99
3/4	2.39
1	3.19
1 1/4	3.98
1 1/2	4.78
2	6.37
2 1/2	7.97
3	9.56
3 1/2	11.16
4	12.75
5	15.94
6	19.12
7	22.32
8	25.57
10	31.88
12	38.25
3/4 x 3/4	2.87
1	3.82
1 1/4	4.78
1 1/2	5.73
1 3/4	6.68
2	7.65
2 1/2	9.56
3	11.47
3 1/2	13.39
4	15.30
4 1/2	17.22
5	19.13
6	22.95
8	30.60
10	38.25
12	45.90
7/8 x 7/8	3.90
1	4.46
1 1/4	5.58
1 1/2	6.69
2	8.92
2 1/2	11.15
3	13.39
3 1/2	15.63
4	17.85
6	26.78
1 x 1	5.10
1 1/4	6.38
1 1/2	7.65
1 3/4	8.93
2	10.20
2 1/2	12.75
3	15.30
3 1/2	17.85
4	20.40
4 1/2	22.95
5	25.50
6	30.60
8	40.80
10	51.00
12	61.20
1 1/8 x 1 1/8	6.46
1 1/2	8.61
2	11.49
3	17.23
4	22.97
6	34.46
1 1/4 x 1 1/4	7.97
1 1/2	9.56
2	12.75
2 1/2	15.94
3	19.13
4	25.50
5	31.88
6	38.25
8	51.00
10	63.75
1 1/2 x 1 1/2	11.48
2	15.30
2 1/2	16.26
3	17.22
3 1/2	18.18
4	19.13
5	22.95
6	26.78
8	30.60
10	38.25

Continued on next page

PRECISION FLAT GROUND STOCK — Continued

STOCK SIZES
FLATS & SQUARES — 18" LENGTHS

SIZE (INCHES)	WT. PER PC. (POUNDS)
2 x 2	20.40
3	30.60
4	40.80
6	61.20
5/32 x 5/32	.13
1/2	.40
3/4	.60
1	.80
1 1/4	1.00
1 1/2	1.19
1 3/4	1.40
2	1.59
2 1/2	1.99
3	2.39
3 1/2	2.79
4	3.19
5	3.99
6	4.78
8	6.38
3/16 x 3/16	.18
1/4	.24
3/8	.36
1/2	.48
5/8	.60
3/4	.72
1	.96
1 1/4	1.20
1 1/2	1.43
1 3/4	1.68
2	1.91
2 1/2	2.39
3	2.87
3 1/2	3.35
4	3.82
5	4.78
6	5.74
8	7.65
10	9.56
12	11.49
7/32 x 7/32	.25
1/2	.56
3/4	.84
7/32 x 1	1.12
1 1/4	1.40
1 1/2	1.68
2	2.23
2 1/2	2.79
3	3.35
4	4.46
6	6.70
8	8.93
1/4 x 1/4	.32
3/8	.48
1/2	.64
5/8	.80
3/4	.96
1	1.27
1 1/4	1.59
1 1/2	1.91
1 3/4	2.23
2	2.55
2 1/2	3.19
3	3.82
3 1/2	4.46
4	5.10
4 1/2	5.74
5	6.37
5 1/2	7.02
6	7.65
7	8.92
8	10.20
10	12.75
12	15.30
14	17.85
9/32 x 9/32	.41
1/2	.72
3/4	1.08
1	1.44
1 1/4	1.80
1 1/2	2.15
2	2.88
2 1/2	3.60
3	4.30
4	5.76
6	8.60
5/16 x 5/16	.50
3/8	.60
1/2	.80
5/8	1.00
3/4	1.20
1	1.59
1 1/4	1.99
1 1/2	2.39
1 3/4	2.79
2	3.19
2 1/2	3.98
3	4.78
3 1/2	5.58
4	6.37
4 1/2	7.18
5	7.97
6	9.56
7	11.15
8	12.75
10	15.94
12	19.13
3/8 x 3/8	.72
1/2	.96
5/8	1.20
3/4	1.43
1	1.91
1 1/4	2.39
1 1/2	2.87
1 3/4	3.35
2	3.82
2 1/2	4.78
3	5.74
3 1/2	6.69
4	7.65
4 1/2	8.61
5	9.56
5 1/2	10.52
6	11.47
7	13.39
8	15.30
10	19.12
12	22.95

PRECISION FLAT GROUND STOCK

Low Carbon — 24" Lengths

Selected sizes in warehouse stock. Full range of sizes from 1/16" x 1/2" through 2" x 2" available from mill depot stock.

PRECISION FLAT GROUND STOCK

AISI O6 Graphitic, Free Machining — Annealed

Selected sizes of 18" lengths in warehouse stock. Full range of sizes from 3/32" x 1/2" through 1 1/2" x 6" available from mill depot stock in both 18" and 36" lengths.

PRECISION FLAT GROUND STOCK

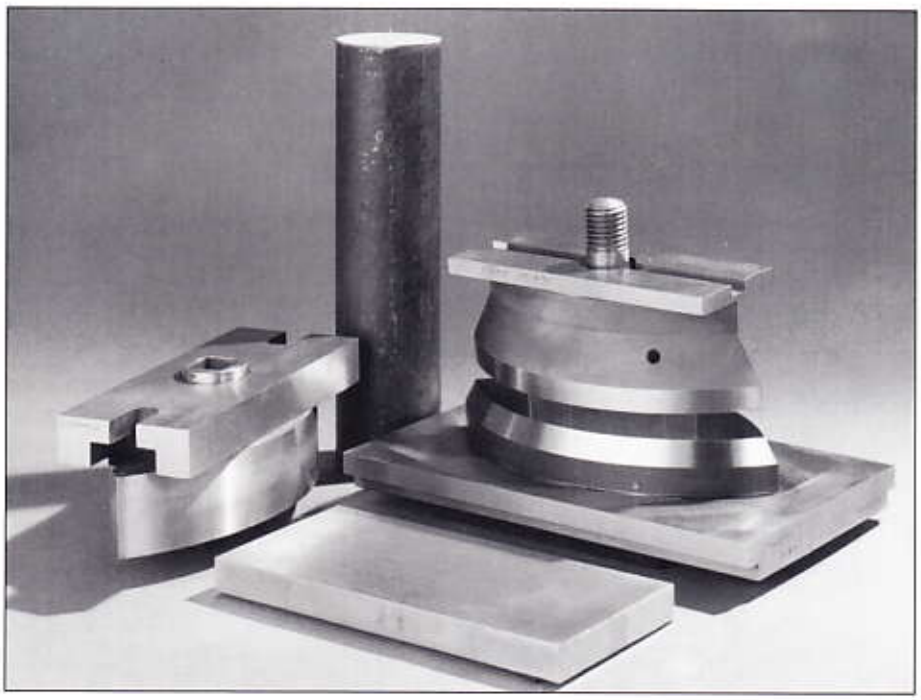
Air Hardening — Annealed

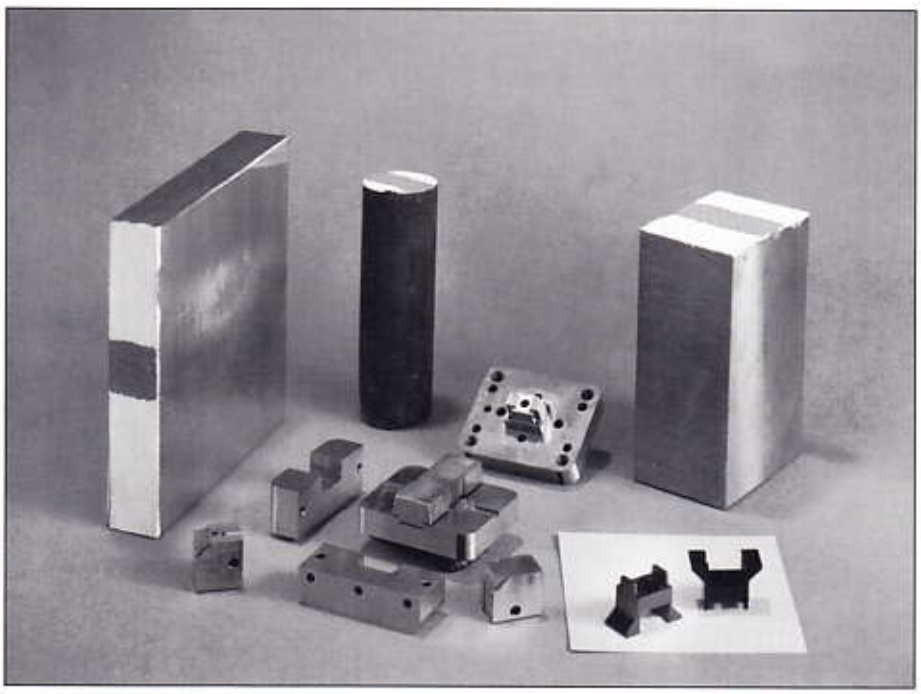
AISI A2: Selected sizes of 36" lengths in warehouse stock. Full range of sizes from 1/16" x 1/2" through 2" x 14" available from mill depot stock in both 18" and 36" lengths; oversize tolerances also available.

AISI A6: Full range of sizes from 1/16" x 1/2" through 2" x 6" available from mill depot stock in both 18" and 36" lengths; oversize tolerances also available.

AISI D2: Full range of sizes from 1/8" x 1/2" through 2" x 8" available from mill depot stock in both 18" and 36" lengths; oversize tolerances also available.

AISI S7: Full range of size—in oversize tolerances only—from 1/8" x 1/2" through 1/2" x 6" available from mill depot stock in both 18" and 36" lengths.





SECTION INDEX
HEAT TREATING

ACCESSORIES

CARBON & ALLOY STEEL PROPERTIES ..... H•2

HEAT TREATING ACCESSORIES

Surface Protection & Hardness Testers

TICRONIC® STAINLESS FOIL WRAP is used to protect the surface of air hardening tool steels. It can be used to 2100°F maximum and prevents scale and decarburization without the use of costly prepared atmospheres. Ticronic® foil is used by making an envelope and placing the tool or die inside; extra time is allowed in the furnace for complete heating of the part. When the package is removed from the furnace, the foil can be removed for better air circulation to insure complete hardening. Ticronic® foil is available in 50 ft. rolls 0.002" thick by 24" wide.

PBC (Phoenix Brand Compound) prevents scale and decarburization on steels requiring heat treatment at temperatures below 1650°F; it works equally well for hardening and annealing. The manufacturer states that PBC powder must be applied dry to clean pieces of steel; free of oil, dirt and water. Apply by heating the part to about 500°F and coating with PBC powder. After coating parts with PBC powder heat treat as normal; oil quenching or annealing will usually require boiling in water to remove the PBC coating. Water quenched parts will usually come clean upon quenching. PBC is available in 5 lb. cans.

HARDNESS TESTERS are available for both Rockwell and Brinell scales in either bench or portable models. Equivalent Rockwell C Scale portable hardness tester kits are kept in stock. These testers make a small indentation with a carbide tipped punch; equivalent Rockwell C hardness is read directly in a hand held microscope.

REQUEST OUR HEAT & TEMPER COLOR CHART.

HEAT TREATED PROPERTIES

Carbon and Alloy Steels

The mechanical properties of a number of common carbon and alloy steels are given on the following pages. The data were obtained by testing *single heats* of the compositions indicated, and may be used as a guide in selecting grades for specific applications. However, it should be kept in mind that every grade of steel is furnished to a range of composition, and that the resultant heat-to-heat variations in the percentages of individual elements present in any grade can cause significant differences in the properties obtainable by thermal treatment. Similarly, section size and thermal treatment parameters markedly influence the properties which can be developed in any particular part. Hence, the *mechanical properties given in this section should not be considered as maximum, minimum, or average values* for a particular application of the grades involved.

Charts shown are compiled from information furnished through the courtesy of Bethlehem Steel Company:

1018*

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Grain Size
Grade	.185	.675	.017	.027	.185	
Ladle	.15/.20	.60/.90	.040 Max	.040 Max	—	6-8

Critical Points, °F: Ac_1 1375 Ac_3 1545 Ar_3 1475 Ar_1 1345

SINGLE QUENCH AND TEMPER

Carburized at 1675°F for 8 hours; pot-cooled; reheated to 1425°F; water-quenched; tempered at 350°F

1-in. Round Treated Case Depth .047 in. Case Hardness HRC 62

MASS EFFECT

Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1600°F, furnace-cooled 30°F per hour to 1295°F, cooled in air.)					
1	59,125	46,750	35.0	67.5	124
Normalized (Heated to 1700°F, cooled in air.)					
½	66,900	50,500	37.2	69.7	135
1	65,750	49,500	35.5	68.5	132
2	64,500	46,250	35.8	67.9	127
4	63,250	43,500	35.2	68.9	124
Blank-Carburized at 1675°F for 8 hours; reheated to 1425°F; quenched in water; tempered at 350°F.					
½	120,500	67,500	14.3	28.6	240
1	82,250	48,500	27.8	63.2	167
2	76,500	46,000	31.0	70.0	147
4	70,750	40,750	31.5	70.6	135

As-quenched Hardness (water)

Size Round	Surface	½ Radius	Center
½	HRC 38.5	HRC 26.5	HRC 25
1	HRC 25.5	HRB 93.5	HRB 91.5
2	HRB 96.6	HRB 84.5	HRB 82.5
4	HRB 95.5	HRB 79	HRB 77.5

*All results listed are averaged from original results for 1015 and 1022 grades.

4320

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Grade	.17/.22	.45/.65	—	—	.20/.35	1.65/2.00	.40/.60	.20/.30	
Ladle	.20	.59	.021	.018	.25	1.77	.47	.23	6-8

MASS EFFECT

Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1560°F, furnace-cooled 30°F per hour to 790°F, cooled in air.)					
1	84,000	61,625	29.0	58.4	163
Normalized (Heated to 1640°F, cooled in air.)					
½	121,500	74,375	23.9	54.3	248
1	115,000	67,250	20.8	50.7	235
2	102,500	58,750	23.3	59.2	212
4	102,000	57,000	22.3	54.7	201
Blank-Carburized at 1700°F for 8 hours; reheated to 1500°F; quenched in oil; tempered at **300**°F.					
½	212,000	163,250	11.8	45.5	415
1	152,500	107,250	17.0	51.0	302
2	132,500	86,000	22.5	56.4	255
4	119,750	75,250	24.0	57.1	248
Blank-Carburized at 1700°F for 8 hours; reheated to 1500°F; quenched in oil; tempered at **450**°F.					
½	187,500	149,500	13.9	52.8	388
1	148,750	105,000	17.8	55.2	285
2	129,750	85,000	20.8	63.8	255
4	118,000	75,000	22.5	51.9	241

As-quenched Hardness (oil)

Size Round	Surface	½ Radius	Center
½	HRC 44.5	HRC 44.5	HRC 44.5
1	HRC 39	HRC 37	HRC 36
2	HRC 35	HRC 30	HRC 27
4	HRC 25	HRC 24	HRC 24

8620

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Grade	.18/.23	.70/.90	—	—	.20/.35	.40/.70	.40/.60	.15/.25	90% 7-8
Ladle	.23	.81	.025	.016	.28	.56	.43	.19	10% 4

MASS EFFECT

Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1600°F, furnace-cooled 30°F per hour to 1150°F, cooled in air.)					
1	77,750	55,875	31.3	62.1	149
Normalized (Heated to 1675°F, cooled in air.)					
½	96,500	54,250	26.3	62.5	197
1	91,750	51,750	26.3	59.7	183
2	87,250	51,500	27.8	62.1	179
4	81,750	51,500	28.5	62.3	163
Blank-Carburized at 1700°F for 8 hours; reheated to 1550°F; quenched in oil; tempered at **300**°F.					
½	199,500	157,000	13.2	49.4	388
1	126,750	83,750	20.8	52.7	255
2	117,250	73,000	23.0	57.8	235
4	98,500	57,750	24.3	57.6	207
Blank-Carburized at 1700°F for 8 hours; reheated to 1550°F; quenched in oil; tempered at **450**°F.					
½	178,500	139,500	14.6	53.9	352
1	124,250	80,750	19.5	54.2	248
2	114,500	72,250	22.0	59.0	229
4	98,000	55,500	25.5	57.8	201

As-quenched Hardness (oil)

Size Round	Surface	½ Radius	Center
½	HRC 43	HRC 43	HRC 43
1	HRC 29	HRC 27	HRC 25
2	HRC 23	HRC 22	HRB 97
4	HRC 22	HRB 95	HRB 93

E9310

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Grade	.08/.13	.45/.65	—	—	.20/.35	3.00/3.50	1.00/1.40	.08/.15	80% 5
Ladle	.09	.57	.012	.010	.32	3.11	1.23	.13	20% 2-4

MASS EFFECT

Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1550°F, furnace-cooled 30°F per hour to 760°F, cooled in air.)					
1	119,000	63,750	17.3	42.1	241
Normalized (Heated to 1630°F, cooled in air.)					
½	133,000	87,750	20.0	63.7	285
1	131,500	82,750	18.8	58.1	269
2	131,250	82,000	19.5	60.5	262
4	125,250	81,750	19.5	61.7	255
Blank-Carburized at 1700°F for 8 hours; reheated to 1450°F; quenched in oil; tempered at **300**°F.					
½	178,750	143,000	15.7	58.9	363
1	159,000	122,750	15.5	57.5	321
2	145,250	108,000	18.5	66.7	293
4	136,000	94,750	19.0	62.3	277
Blank-Carburized at 1700°F for 8 hours; reheated to 1450°F; quenched in oil; tempered at **450**°F.					
½	178,250	141,500	15.0	60.3	363
1	157,500	123,000	16.0	61.7	321
2	143,500	105,500	17.8	68.1	293
4	131,500	96,500	20.5	67.0	269

As-quenched Hardness (oil)

Size Round	Surface	½ Radius	Center
½	HRC 40	HRC 40	HRC 38
1	HRC 40	HRC 38	HRC 37
2	HRC 38	HRC 35	HRC 32
4	HRC 31	HRC 30	HRC 29

1045 WATER-QUENCHED*

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Grain Size
Grade	.43/.50	.60/.90	.040 Max	.050 Max	—	
Ladle	.465	.70	.016	.033	.17	5-7

Critical Points, °F: Ac_1 1340 Ac_3 1430 Ar_3 1335 Ar_1 1250

MASS EFFECT

Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Water-quenched from 1537°F, tempered at **1000**°F.					
1/2	121,500	90,250	21.9	58.0	246
1	119,500	83,375	21.6	59.3	239
2	115,500	76,750	22.7	60.0	231
4	110,750	71,000	23.1	57.7	225
Water-quenched from 1537°F, tempered at **1100**°F.					
1/2	110,000	79,500	24.0	65.5	227
1	109,000	74,750	24.2	62.4	224
2	106,000	73,250	26.0	65.1	216
4	103,250	63,500	25.3	59.4	210
Water-quenched from 1537°F, tempered at **1200**°F.					
1/2	103,000	77,500	26.2	63.3	215
1	101,250	72,250	25.3	64.5	213
2	98,250	68,500	26.7	65.0	203
4	94,750	58,500	27.7	64.0	193

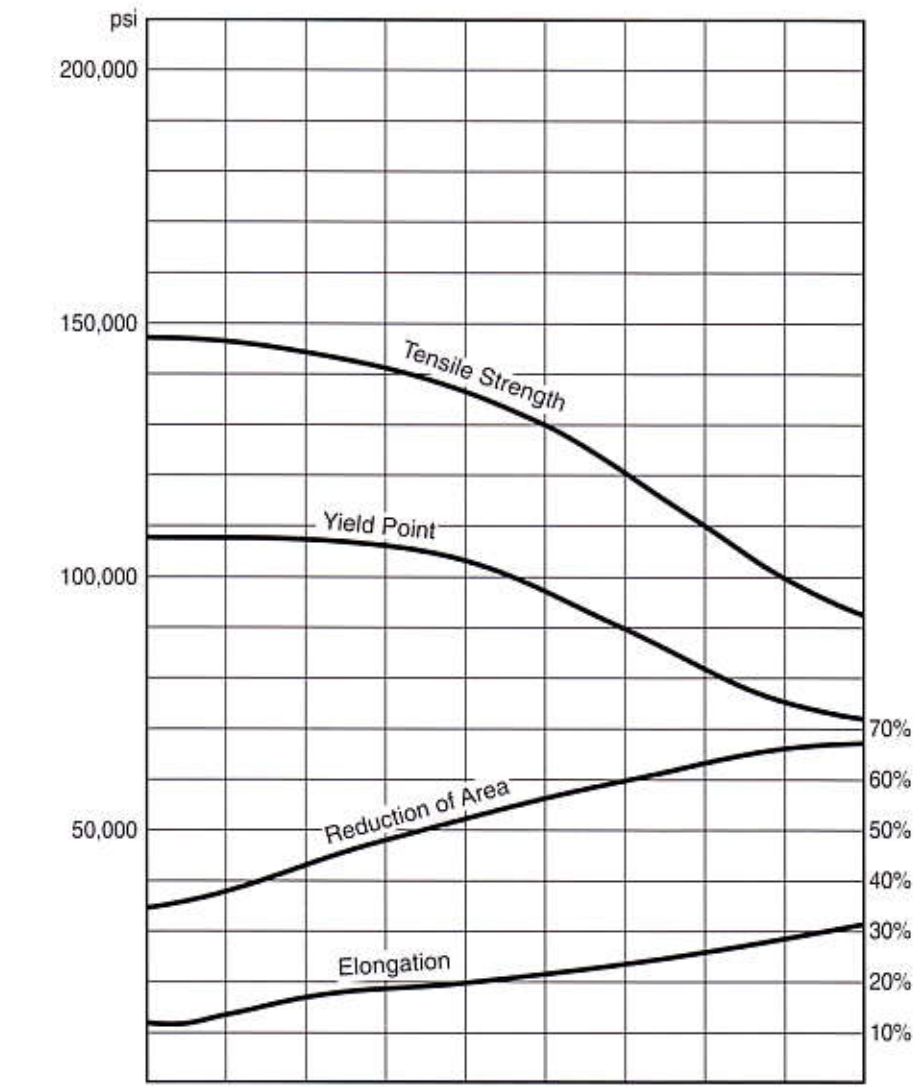
As-quenched Hardness (water)

Size Round	Surface	1/2 Radius	Center
1/2	HRC 59	HRC 56	HRC 55
1	HRC 55	HRC 28	HRC 25
2	HRC 50	HRC 25	HRC 21
4	HRC 26	HRC 22	HRC 18

*All results listed are averaged from original results for 1040 and 1050 grades.

WATER-QUENCHED 1045*

Treatment: Normalized at 1650 F; reheated to 1537°F; quenched in water.
1-in. Round Treated; .505-in. Round Tested. As-quenched HB 567.



*All results listed are averaged from original results for 1040 and 1050 grades.

1045 OIL-QUENCHED*

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Grain Size
Grade	.43/.50	.60/.90	.040 Max	.050 Max	—	
Ladle	.465	.70	.016	.033	.17	5-7

Critical Points, °F: Ac_1 1340 Ac_3 1430 Ar_3 1335 Ar_1 1250

MASS EFFECT

Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1450°F, furnace-cooled 20°F per hour to 1200°F, cooled in air.)					
1	83,750	52,000	26.9	48.5	168
Normalized (Heated to 1650°F, cooled in air.)					
½	99,750	60,500	25.7	50.8	203
1	97,000	58,000	24.0	47.1	193
2	95,250	55,500	24.0	46.0	189
4	91,750	52,500	24.3	46.7	184
Oil-quenched from 1567°F, tempered at **1000**°F.					
½	118,500	80,000	23.8	57.4	239
1	109,750	72,000	23.3	57.2	222
2	107,250	67,250	23.3	55.5	217
4	101,500	63,250	23.3	54.1	210
Oil-quenched from 1567°F, tempered at **1100**°F.					
½	111,250	69,250	24.9	61.6	227
1	102,750	67,250	25.8	60.5	205
2	99,250	63,500	25.5	59.0	198
4	91,750	55,500	27.6	58.0	189
Oil-quenched from 1567°F, tempered at **1200**°F.					
½	108,500	73,500	25.8	61.7	223
1	99,500	65,250	26.7	62.5	197
2	97,250	61,250	27.0	61.0	195
4	89,750	54,250	28.2	59.5	181

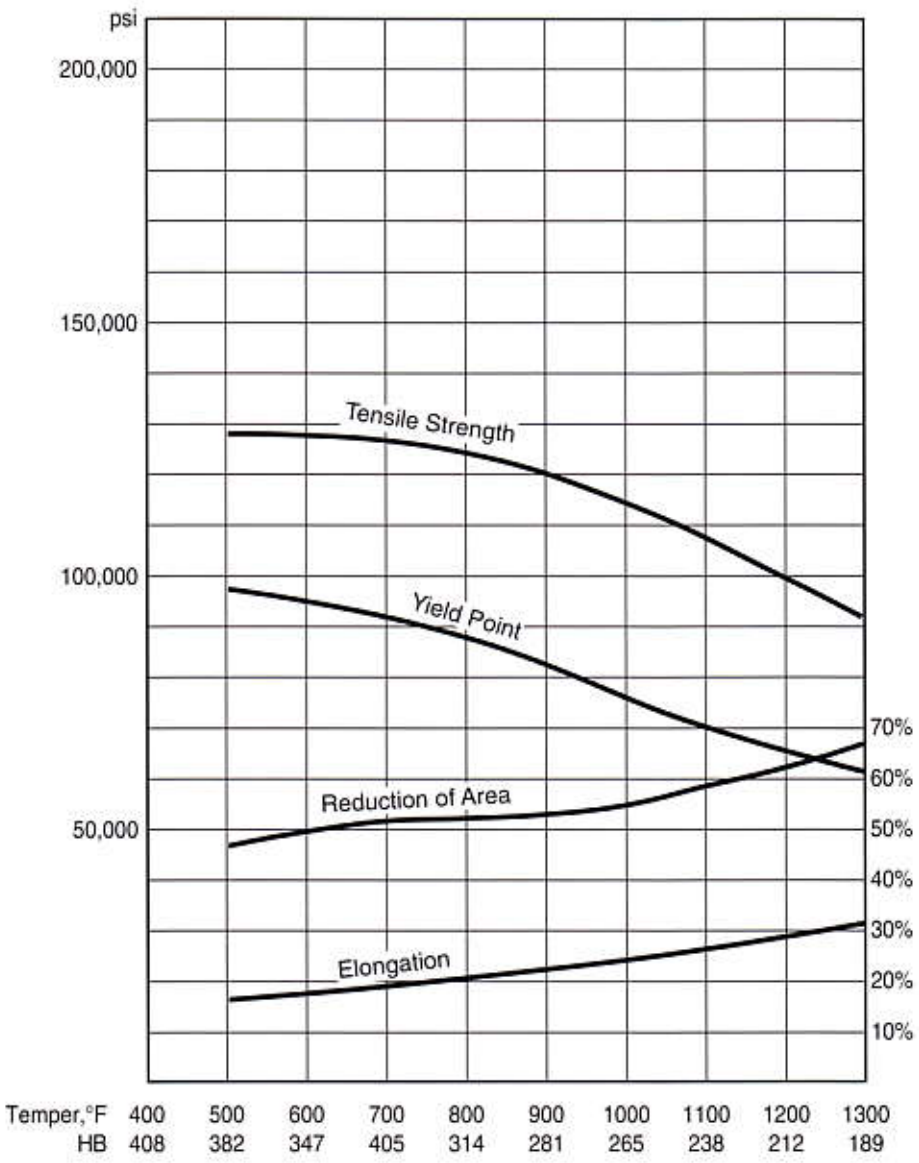
As-quenched Hardness (oil)

Size Round	Surface	½ Radius	Center
½	HRC 43	HRC 30	HRC 28
1	HRC 28	HRC 26	HRC 22
2	HRC 20	HRB 97	HRB 95
4	HRB 95	HRB 93	HRB 90

*All results listed are averaged from original results for 1040 and 1050.

OIL-QUENCHED 1045*

Treatment: Normalized at 1650 F; reheated to 1567°F; quenched in oil.
1-in. Round Treated; .505-in. Round Tested. As-quenched HB 295.



*All results listed are averaged from original results for 1040 and 1050 grades.

1060 OIL-QUENCHED

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Grain Size
Grade	.55/.65	.60/.90	.040 Max	.050 Max	—	90% 5-7
Ladle	.60	.66	.016	.046	.17	10% 1-3

Critical Points, °F: Ac_1 1355 Ac_3 1400 Ar_3 1300 Ar_1 1250

MASS EFFECT

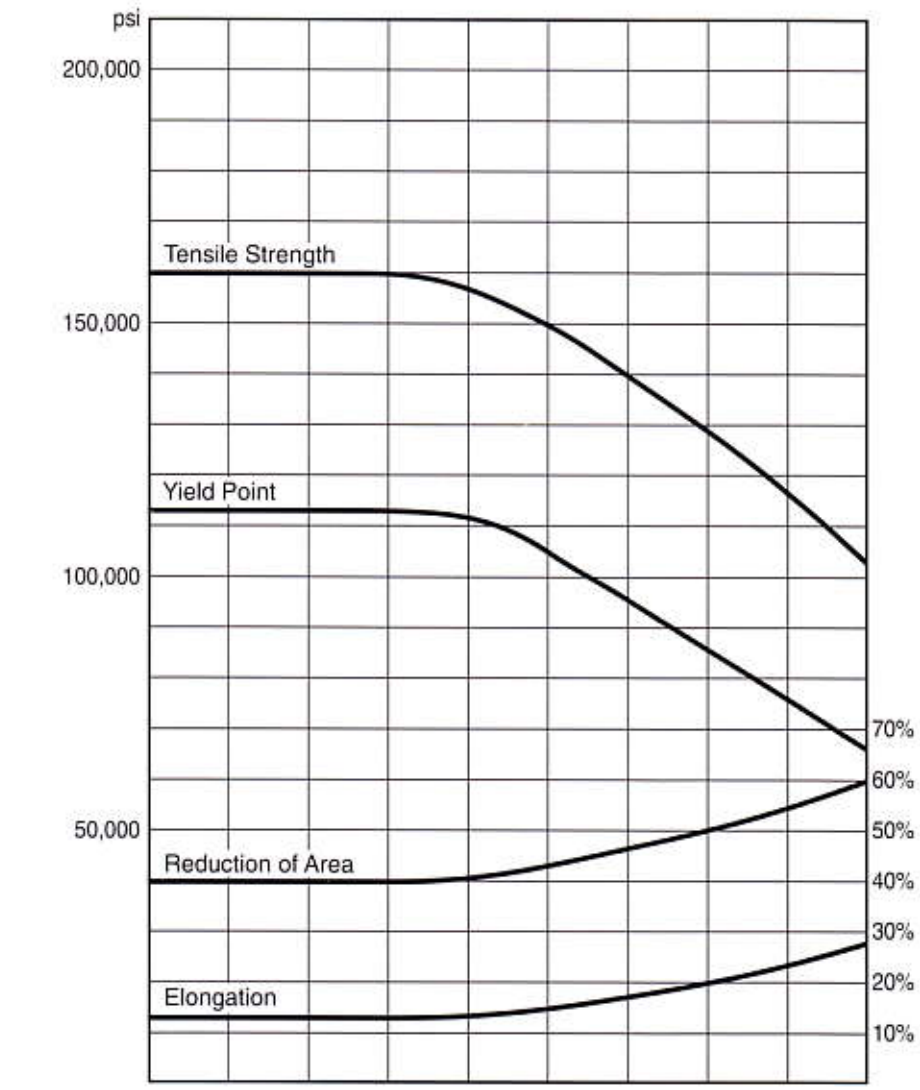
Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1450°F, furnace-cooled 20°F per hour to 1200°F, cooled in air.)					
1	90,750	54,000	22.5	38.2	179
Normalized (Heated to 1650°F, cooled in air.)					
½	113,000	62,000	20.4	40.6	229
1	112,500	61,000	18.0	37.2	229
2	110,000	57,500	17.7	34.0	223
4	108,250	51,250	18.0	31.3	223
Oil-quenched from 1550°F, tempered at **900**°F.					
½	149,000	98,250	15.1	46.0	302
1	145,500	93,000	16.2	44.0	293
2	142,750	89,500	16.5	46.2	285
4	134,750	75,250	18.2	44.8	269
Oil-quenched from 1550°F, tempered at **1000**°F.					
½	139,500	92,000	19.6	52.1	277
1	136,500	85,750	17.7	48.0	269
2	133,000	79,250	18.5	50.3	262
4	124,500	66,250	20.0	48.0	248
Oil-quenched from 1550°F, tempered at **1100**°F.					
½	131,500	82,500	20.7	53.5	262
1	127,750	79,000	20.0	51.7	255
2	125,250	76,500	20.2	53.3	248
4	118,750	62,000	21.5	49.4	241

As-quenched Hardness (oil)

Size Round	Surface	½ Radius	Center
½	HRC 59	HRC 37	HRC 35
1	HRC 34	HRC 32	HRC 30
2	HRC 30.5	HRC 27.5	HRC 25
4	HRC 29	HRC 26	HRC 24

OIL-QUENCHED 1060

Treatment: Normalized at 1650°F; reheated to 1550°F; quenched in oil.
1-in. Round Treated; .505-in. Round Tested. As-quenched HB 321.



Temper,°F	400	500	600	700	800	900	1000	1100	1200	1300
HB	321	321	321	321	311	302	277	248	229	212

1080 OIL-QUENCHED

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Grain Size
Grade	.75/.88	.60/.90	.040 Max	.050 Max	—	
Ladle	.85	.76	.012	.027	.13	80% 5-7 20% 1-4

Critical Points,°F: Ac_1 1350 Ac_3 1370 Ar_3 1280 Ar_1 1250

MASS EFFECT

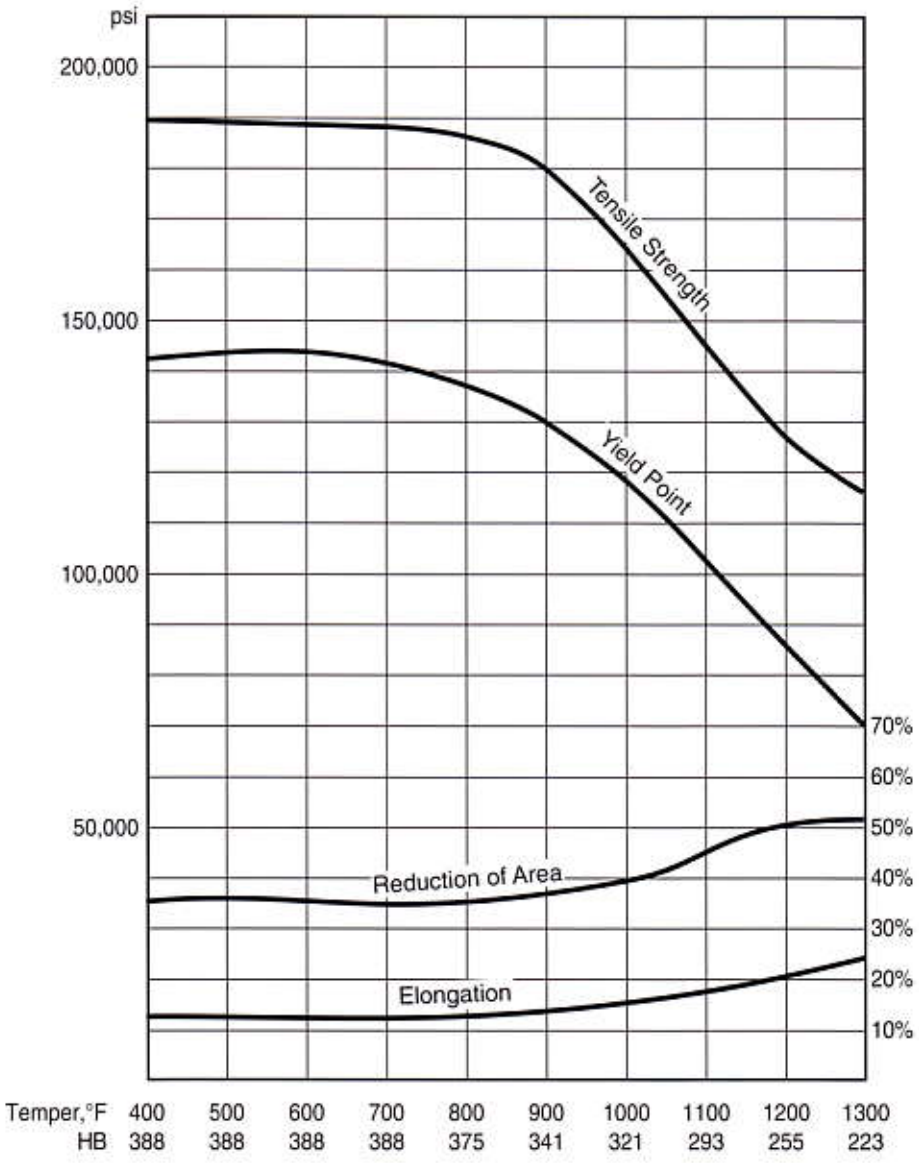
Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1450°F, furnace-cooled 20°F per hour to 1200°F, cooled in air.)					
1	89,250	54,500	24.7	45.0	174
Normalized (Heated to 1650°F, cooled in air.)					
½	150,500	80,500	12.4	27.7	293
1	146,500	76,000	11.0	20.6	293
2	141,000	70,000	10.7	17.0	285
4	134,750	64,000	10.7	15.5	269
Oil-quenched from 1500°F, tempered at **900**°F.					
½	184,000	125,500	12.1	34.4	363
1	181,500	112,500	13.0	35.8	352
2	180,000	110,000	12.7	37.3	352
4	171,250	104,000	11.7	28.6	341
Oil-quenched from 1500°F, tempered at **1000**°F.					
½	169,000	121,500	15.0	38.6	341
1	166,000	103,500	15.0	37.6	331
2	163,500	102,625	15.2	38.0	321
4	157,000	89,750	11.5	24.4	311
Oil-quenched from 1500°F, tempered at **1100**°F.					
½	152,000	107,000	17.0	43.6	302
1	150,000	97,000	16.5	40.3	302
2	140,250	87,500	17.7	42.2	277
4	134,500	75,000	15.7	33.1	269

As-quenched Hardness (oil)

Size Round	Surface	½ Radius	Center
½	HRC 60	HRC 43	HRC 40
1	HRC 45	HRC 42	HRC 39
2	HRC 43	HRC 40	HRC 37
4	HRC 39	HRC 37	HRC 32

OIL-QUENCHED 1080

Treatment: Normalized at 1650°F; reheated to 1500°F; quenched in oil.
1-in. Round Treated; .505-in. Round Tested. As-quenched HB 388.



1095 WATER-QUENCHED

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Grain Size
Grade	.90/1.03	.30/.50	.040 Max	.050 Max	—	50% 5-7 50% 1-4
Ladle	.96	.40	.012	.029	.20	

Critical Points, °F: Ac_1 1350 Ac_3 1365 Ar_3 1320 Ar_1 1265

MASS EFFECT

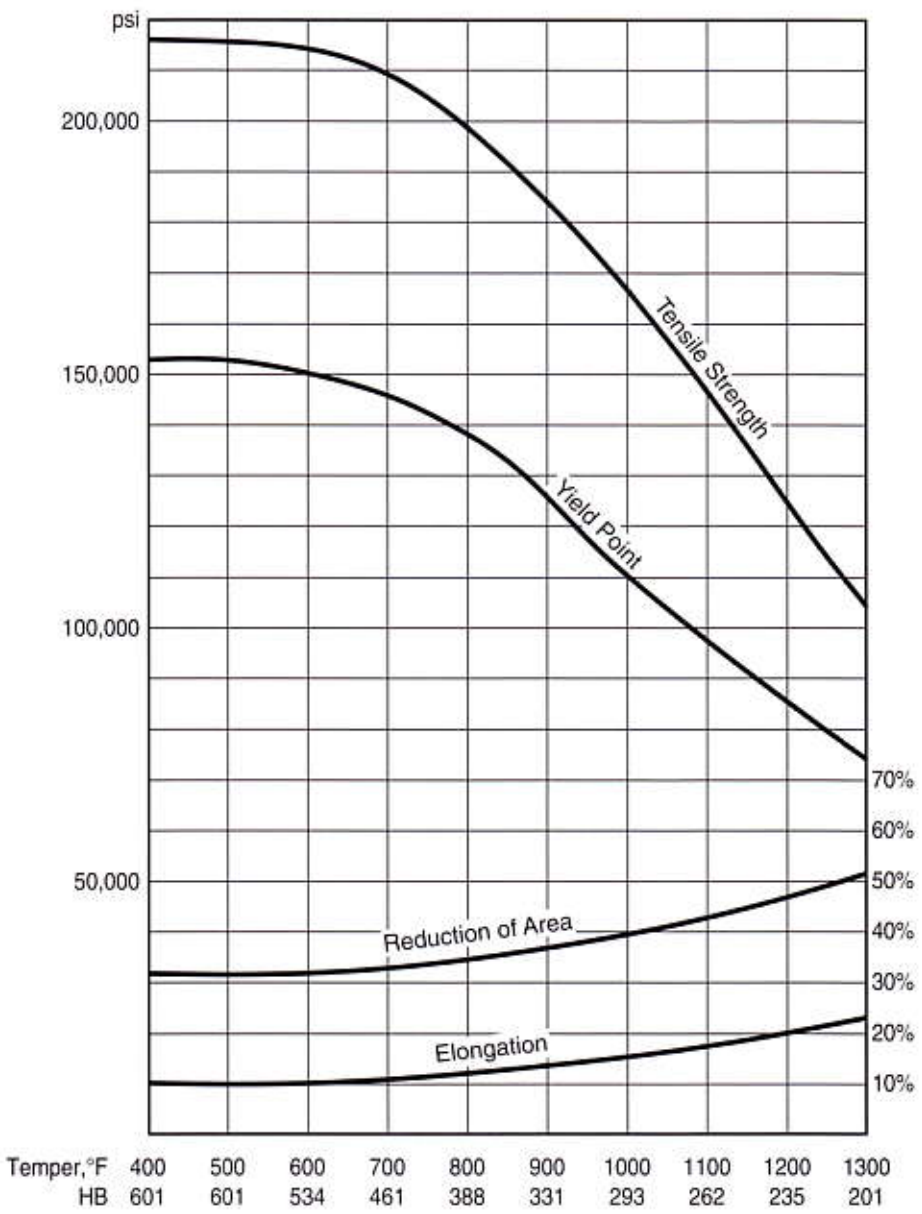
Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Water-quenched from 1450°F, tempered at **900**°F.					
½	191,500	135,500	12.3	31.7	375
1	182,000	121,000	13.0	37.3	363
2	179,750	113,000	12.7	33.8	352
4	167,250	94,500	12.5	31.4	331
Water-quenched from 1450°F, tempered at **1000**°F.					
½	172,000	111,000	12.4	44.1	321
1	165,000	102,500	16.0	41.4	311
2	154,750	98,500	15.7	39.1	302
4	150,000	81,000	15.7	35.3	285
Water-quenched from 1450°F, tempered at **1100**°F.					
½	144,000	99,000	17.2	44.9	293
1	143,000	96,500	16.7	43.7	293
2	140,000	90,000	17.5	43.6	285
4	131,250	78,000	18.7	41.1	262

As-quenched Hardness (water)

Size Round	Surface	½ Radius	Center
½	HRC 65	HRC 55	HRC 48
1	HRC 64	HRC 46	HRC 44
2	HRC 63	HRC 43	HRC 40
4	HRC 63	HRC 38	HRC 30

WATER-QUENCHED 1095

Treatment: Normalized at 1650°F; reheated to 1450°F; quenched in water.
1-in. Round Treated; .505-in. Round Tested. As-quenched HB 601.



1095 OIL-QUENCHED

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Grain Size
Grade	.90/1.03	.30/.50	.040 Max	.050 Max	—	50% 5-7 50% 1-4
Ladle	.96	.40	.012	.029	.20	

Critical Points, °F: Ac_1 1350 Ac_3 1365 Ar_3 1320 Ar_1 1265

MASS EFFECT

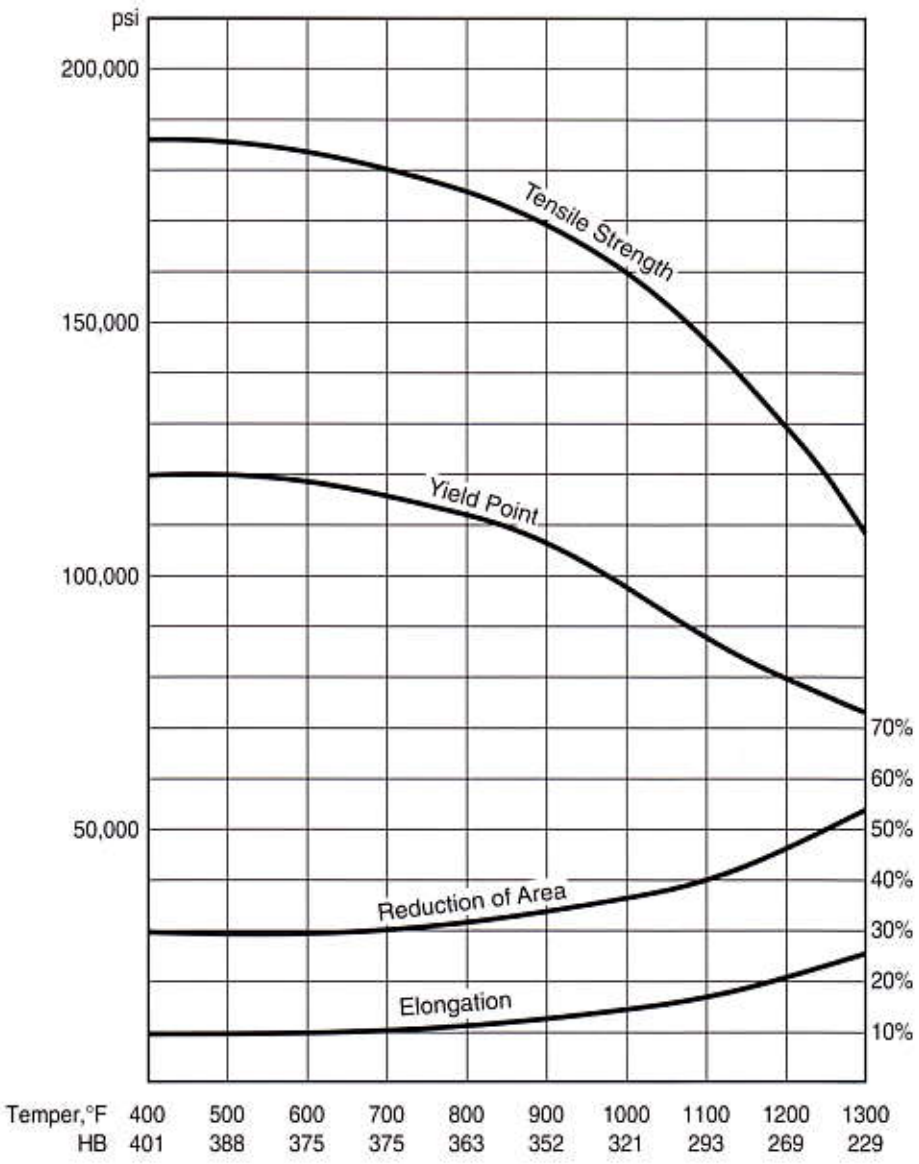
Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1450°F, furnace-cooled 20°F per hour to 1215°F, cooled in air.)					
1	95,250	55,000	13.0	20.6	192
Normalized (Heated to 1650°F, cooled in air.)					
½	151,000	80,500	12.3	27.7	302
1	147,000	72,500	9.5	13.5	293
2	132,500	58,000	9.2	13.4	269
4	128,250	57,250	10.0	13.9	255
Oil-quenched from 1475°F, tempered at **900**°F.					
½	184,000	116,000	12.8	35.5	363
1	175,750	102,250	10.0	23.4	352
2	167,750	98,250	12.0	29.8	331
4	165,000	93,000	12.2	17.3	331
Oil-quenched from 1475°F, tempered at **1000**°F.					
½	166,500	101,500	15.7	40.0	331
1	159,750	95,250	13.2	32.4	321
2	151,000	92,500	13.7	31.4	311
4	148,000	80,000	11.7	22.1	302
Oil-quenched from 1475°F, tempered at **1100**°F.					
½	142,000	87,000	17.4	42.8	293
1	139,750	79,000	17.2	38.8	277
2	134,500	77,250	18.7	43.4	269
4	130,000	65,750	17.2	34.4	262

As-quenched Hardness (oil)

Size Round	Surface	½ Radius	Center
½	HRC 60	HRC 44	HRC 41
1	HRC 46	HRC 42	HRC 40
2	HRC 43	HRC 40	HRC 37
4	HRC 40	HRC 37	HRC 30

OIL-QUENCHED 1095

Treatment: Normalized at 1650°F; reheated to 1475°F; quenched in oil.
1-in. Round Treated; .505-in. Round Tested. As-quenched HB 401.



4130 WATER-QUENCHED

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Grade	.28/.33	.40/.60	—	—	.20/.35	—	.80/1.10	.15/.25	
Ladle	.30	.48	.015	.015	.20	.12	.91	.20	6-8

MASS EFFECT

Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1585°F, furnace-cooled 20°F per hour to 1255°F, cooled in air.)					
1	81,250	52,250	28.2	55.6	156
Normalized (Heated to 1600°F, cooled in air.)					
½	106,500	67,000	25.1	59.6	217
1	97,000	63,250	25.5	59.5	197
2	89,000	61,750	28.2	65.4	167
4	88,750	57,750	27.0	61.2	163
Water-quenched from 1575°F, tempered at **900**°F.					
½	166,500	161,000	16.4	61.0	331
1	161,000	137,500	14.7	54.4	321
2	132,750	110,250	19.0	63.3	269
4	121,500	95,000	20.5	63.6	241
Water-quenched from 1575°F, tempered at **1000**°F.					
½	151,000	142,500	18.1	63.9	302
1	144,500	129,500	18.5	61.8	293
2	121,750	98,750	21.2	66.3	241
4	116,000	91,500	21.5	63.5	235
Water-quenched from 1575°F, tempered at **1100**°F.					
½	133,000	122,500	20.7	69.0	269
1	128,000	113,250	21.2	67.5	262
2	114,500	91,500	21.7	67.7	229
4	101,500	77,500	24.5	69.2	197

As-quenched Hardness (water)

Size Round	Surface	½ Radius	Center
½	HRC 51	HRC 50	HRC 50
1	HRC 51	HRC 50	HRC 44
2	HRC 47	HRC 32	HRC 31
4	HRC 45.5	HRC 25	HRC 24.5

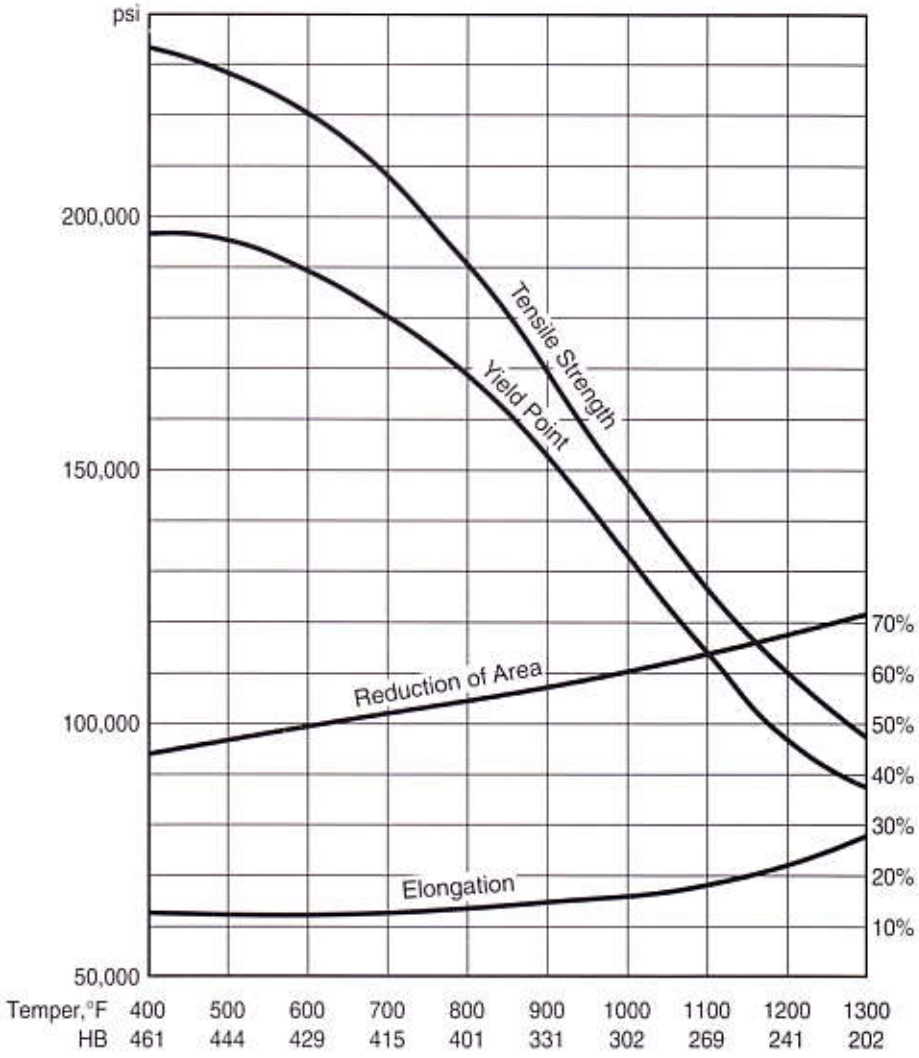
WATER-QUENCHED 4130

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Ladle	.30	.48	.015	.015	.20	.12	.91	.20	6-8

Critical Points, °F: Ac_1 1400 Ac_3 1510 Ar_3 1400 Ar_1 1305

Treatment: Normalized at 1600°F; reheated to 1575°F; quenched in water. .530-in. Round Treated; .505-in. Round Tested. As-quenched HB 495.



4140 OIL-QUENCHED

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Grade	.38/.43	.75/1.00	—	—	.20/.35	—	.80/1.10	.15/.25	
Ladle	.40	.83	.012	.009	.26	.11	.94	.21	7-8

MASS EFFECT

Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1500°F, furnace-cooled 20°F per hour to 1230°F, cooled in air.)					
1	95,000	60,500	25.7	56.9	197
Normalized (Heated to 1600°F, cooled in air.)					
½	148,500	98,500	17.8	48.2	302
1	148,000	95,000	17.7	46.8	302
2	140,750	91,750	16.5	48.1	285
4	117,500	69,500	22.2	57.4	241
Oil-quenched from 1550°F, tempered at **1000**°F.					
½	171,500	161,000	15.4	55.7	341
1	156,000	143,250	15.5	56.9	311
2	139,750	115,750	17.5	59.8	285
4	127,750	99,250	19.2	60.4	277
Oil-quenched from 1550°F, tempered at **1100**°F.					
½	157,500	148,750	18.1	59.4	321
1	140,250	135,000	19.5	62.3	285
2	127,500	102,750	21.7	65.0	262
4	116,750	87,000	21.5	62.1	235
Oil-quenched from 1550°F, tempered at **1200**°F.					
½	136,500	128,750	19.9	62.3	277
1	132,750	122,500	21.0	65.0	269
2	121,500	98,250	23.2	65.8	241
4	112,500	83,500	23.2	64.9	229

As-quenched Hardness (oil)

Size Round	Surface	½ Radius	Center
½	HRC 57	HRC 56	HRC 55
1	HRC 55	HRC 55	HRC 50
2	HRC 49	HRC 43	HRC 38
4	HRC 36	HRC 34.5	HRC 34

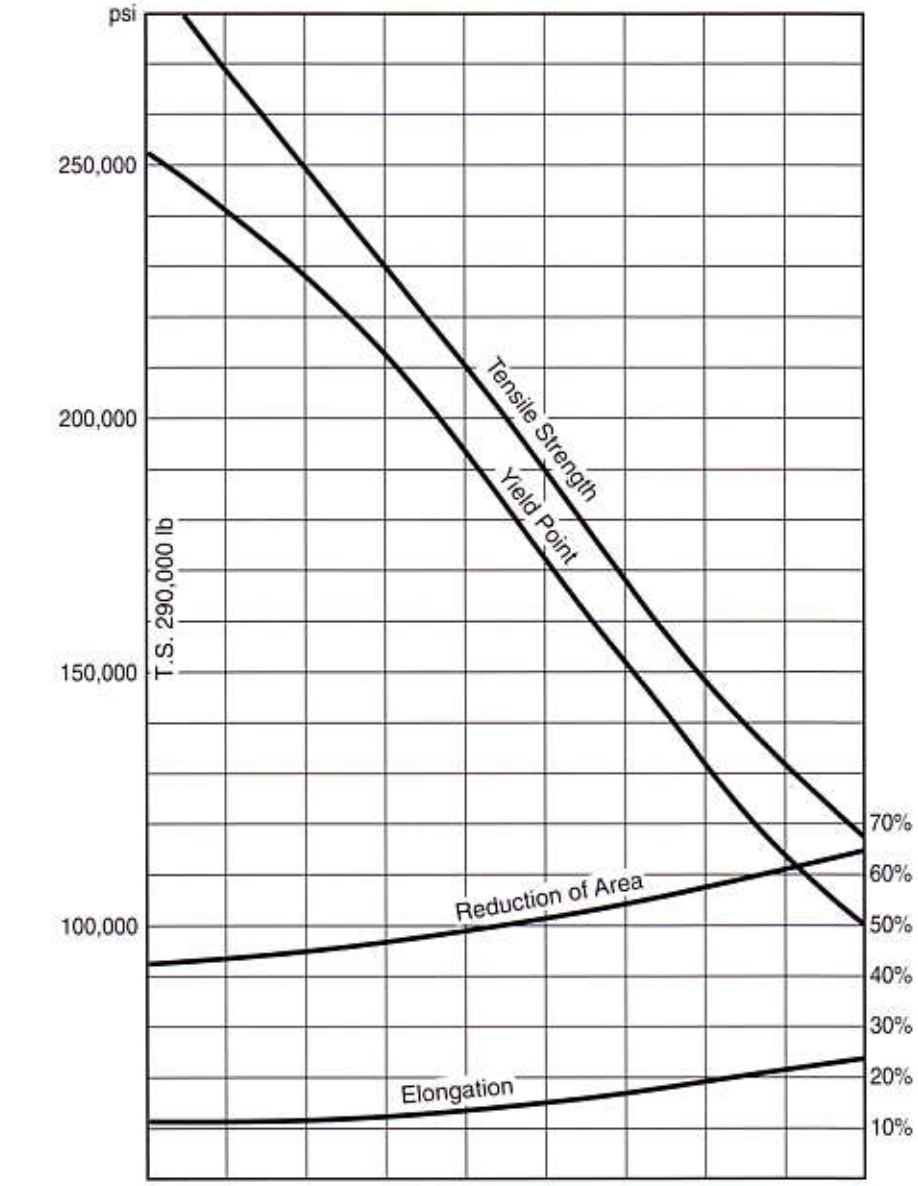
OIL-QUENCHED 4140

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Ladle	.41	.85	.024	.031	.20	.12	1.01	.24	6-8

Critical Points, °F: Ac_1 1395 Ac_3 1450 Ar_3 1330 Ar_1 1280

Treatment: Normalized at 1600°F; reheated to 1550°F; quenched in agitated oil.
.530-in. Round Treated; .505-in. Round Tested. As-quenched HB 601.



Temper, °F	400	500	600	700	800	900	1000	1100	1200	1300
HB	578	534	495	461	429	388	341	311	277	235

4150 OIL-QUENCHED

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Grade	.48/.53	.75/1.00	—	—	.20/.35	—	.80/1.10	.15/.25	
Ladle	.51	.89	.018	.017	.27	.12	.87	.18	95% 7-8 5% 5

MASS EFFECT

Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1525°F, furnace-cooled 20°F per hour to 1190°F, cooled in air.)					
1	105,750	55,000	20.2	40.2	197
Normalized (Heated to 1600°F, cooled in air.)					
½	194,000	129,500	10.0	24.8	375
1	167,500	106,500	11.7	30.8	321
2	158,750	104,000	13.5	40.6	311
4	146,000	91,750	19.5	56.5	293
Oil-quenched from 1525°F, tempered at **1000**°F.					
½	189,500	176,250	13.5	47.2	375
1	175,250	159,500	14.0	46.5	352
2	168,750	151,000	15.5	51.0	341
4	158,750	127,750	15.0	46.7	311
Oil-quenched from 1525°F, tempered at **1100**°F.					
½	170,000	155,500	14.6	45.5	341
1	165,500	150,000	15.7	51.1	331
2	150,250	131,500	18.7	56.4	302
4	132,500	93,250	20.0	57.5	269
Oil-quenched from 1525°F, tempered at **1200**°F.					
½	148,000	137,250	17.4	53.3	302
1	141,000	127,500	18.7	55.7	285
2	134,750	118,250	20.5	60.0	269
4	124,000	91,000	21.5	61.4	255

As-quenched Hardness (oil)

Size Round	Surface	½ Radius	Center
½	HRC 64	HRC 64	HRC 63
1	HRC 62	HRC 62	HRC 62
2	HRC 58	HRC 57	HRC 56
4	HRC 47	HRC 43	HRC 42

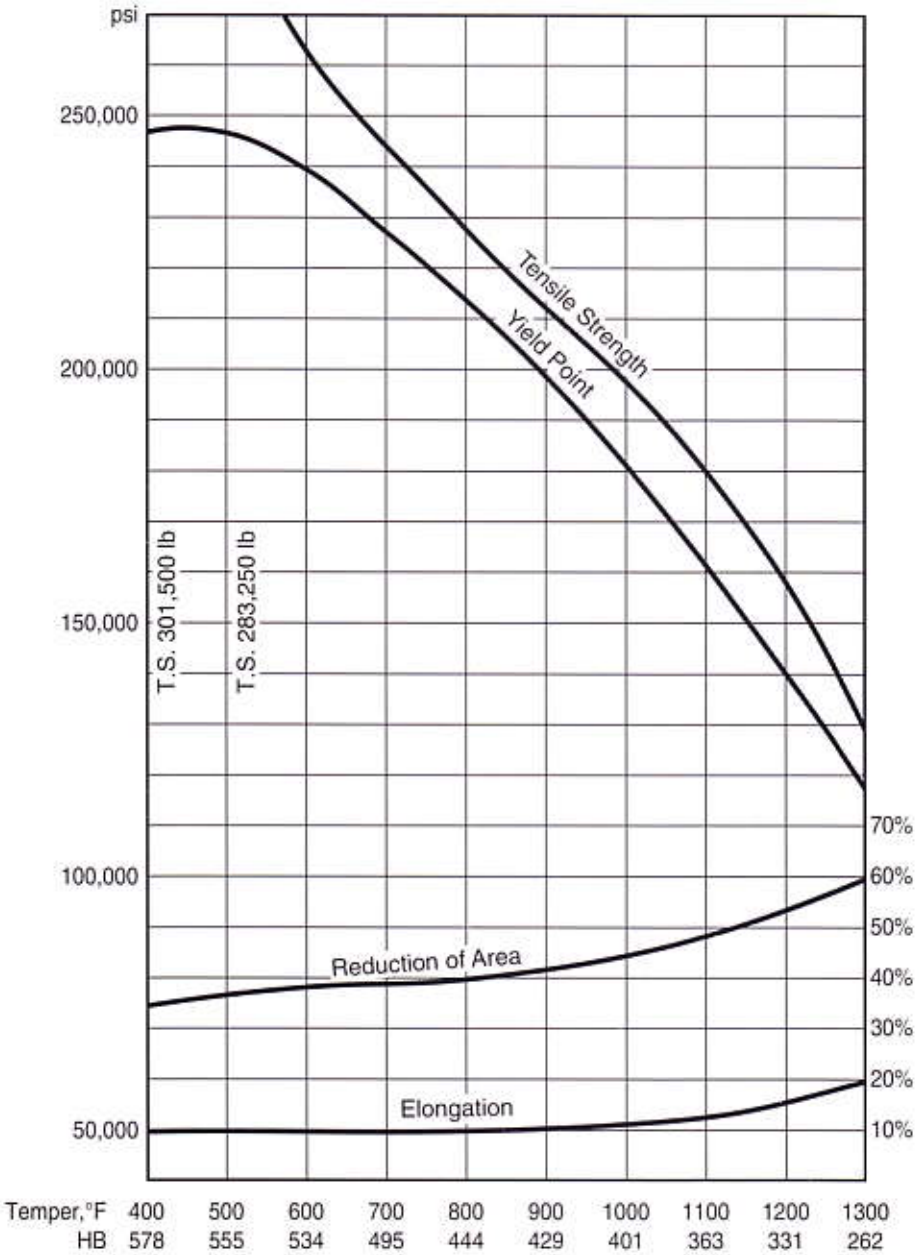
OIL-QUENCHED 4150

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Ladle	.50	.76	.015	.012	.21	.20	.95	.21	90% 7-8

Critical Points,°F: Ac_1 1390 Ac_3 1450 Ar_3 1290 Ar_1 1245

Treatment: Normalized at 1600°F; reheated to 1525°F; quenched in oil.
.530-in. Round Treated; .505-in. Round Tested. As-quenched HB 656.



4340 OIL-QUENCHED

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Grade	.38/.43	.60/.80	—	—	.20/.35	1.65/2.00	.70/.90	.20/.30	
Ladle	.40	.68	.020	.013	.28	1.87	.74	.25	7-8

MASS EFFECT

Size Round in.	Tensile Strength psi	Yield Point psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1490°F, furnace-cooled 20°F per hour to 670°F, cooled in air.)					
1	108,000	68,500	22.0	49.9	217
Normalized (Heated to 1600°F, cooled in air.)					
½	209,500	141,000	12.1	35.3	388
1	185,500	125,000	12.2	36.3	363
2	176,750	114,500	13.5	37.3	341
4	161,000	103,000	13.2	36.0	321
Oil-quenched from 1475°F, tempered at **1000**°F.					
½	182,000	169,000	13.7	45.0	363
1	175,000	166,000	14.2	45.9	352
2	170,000	159,500	16.0	54.8	341
4	164,750	145,250	15.5	53.4	331
Oil-quenched from 1475°F, tempered at **1100**°F.					
½	165,750	162,000	17.1	57.0	331
1	164,750	159,000	16.5	54.1	331
2	147,250	139,250	19.0	60.4	293
4	133,750	114,500	19.7	60.7	269
Oil-quenched from 1475°F, tempered at **1200**°F.					
½	145,000	135,500	20.0	59.3	285
1	139,000	128,000	20.0	59.7	277
2	134,750	121,000	20.5	62.5	269
4	124,000	105,750	21.7	63.0	255

As-quenched Hardness (oil)

Size Round	Surface	½ Radius	Center
½	HRC 58	HRC 58	HRC 56
1	HRC 57	HRC 57	HRC 56
2	HRC 56	HRC 55	HRC 54
4	HRC 53	HRC 49	HRC 47

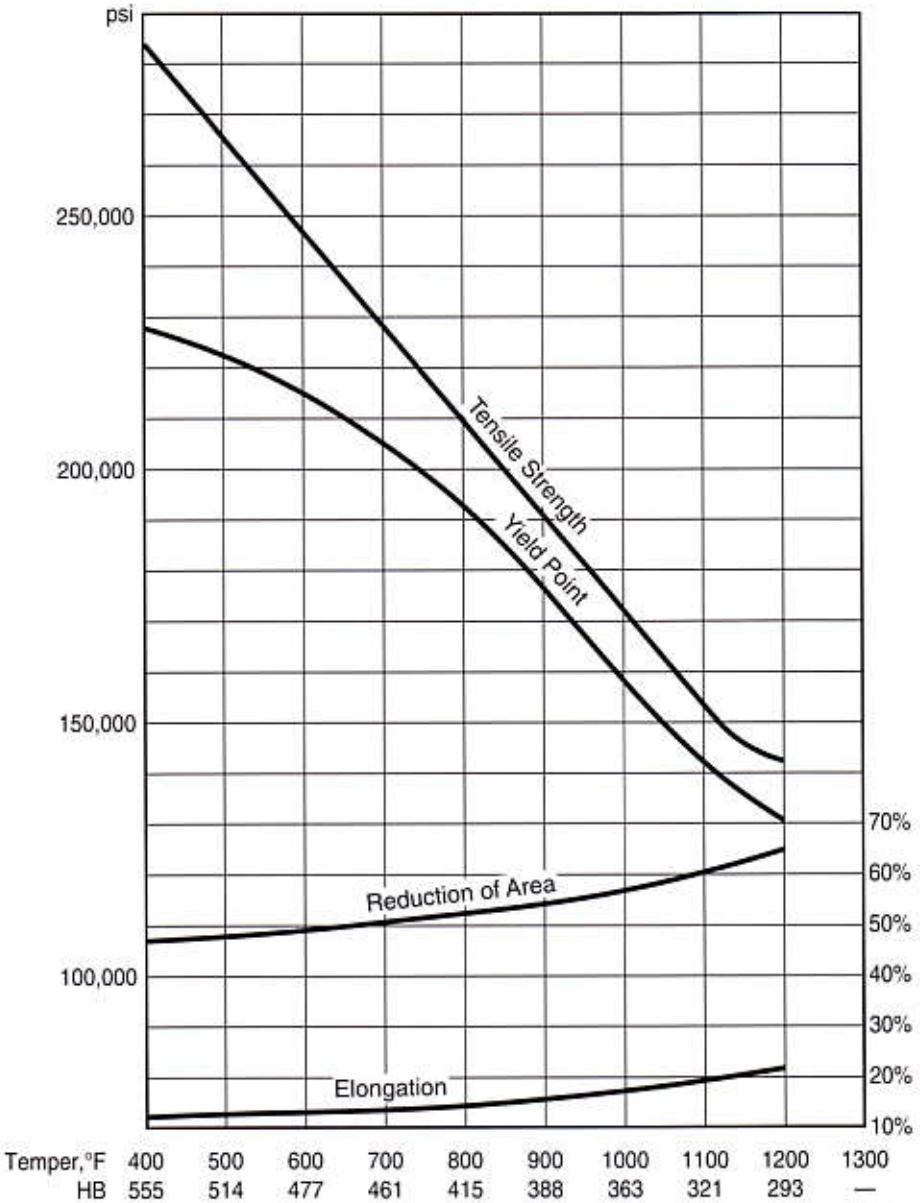
OIL-QUENCHED 4340

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Ladle	.41	.67	.023	.018	.26	1.77	.78	.26	6-8

Critical Points, °F: Ac_1 1350 Ac_3 1415 Ar_3 890 Ar_1 720

Treatment: Normalized at 1600°F; reheated to 1475°F; quenched in agitated oil. .530-in. Round Treated; .505-in. Round Tested. As-quenched HB 601.



5160 OIL-QUENCHED

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Grade	.56/.64	.75/1.00	—	—	.20/.35	—	.70/.90	—	
Ladle	.62	.84	.010	.034	.24	.04	.74	.01	6-8

MASS EFFECT

Size Round in.	Tensile Strength psi	Yield Strength (.2% Offset) psi	Elongation % 2 in.	Reduction of Area, %	Hardness HB
Annealed (Heated to 1495°F, furnace-cooled 20°F per hour to 900°F, cooled in air.)					
1	104,750	40,000	17.2	30.6	197
Normalized (Heated to 1575°F, cooled in air.)					
½	149,000	93,750	18.2	50.7	285
1	138,750	77,000	17.5	44.8	269
2	133,750	73,500	16.0	39.0	262
4	133,500	70,250	14.8	34.2	255
Oil-quenched from 1525°F, tempered at **1000**°F.					
½	170,500	155,250	14.2	45.1	341
1	165,500	145,500	14.5	45.7	341
2	154,250	102,250	17.8	51.2	293
4	140,500	101,750	18.5	52.0	285
Oil-quenched from 1525°F, tempered at **1100**°F.					
½	152,250	134,000	16.6	50.6	302
1	145,250	126,000	18.0	53.6	302
2	135,250	91,750	20.0	54.6	277
4	129,250	89,250	21.2	57.0	262
Oil-quenched from 1525°F, tempered at **1200**°F.					
½	133,000	115,250	19.8	55.5	269
1	128,750	110,750	20.7	55.6	262
2	113,250	84,000	21.8	57.5	248
4	120,500	77,750	22.8	60.8	241

As-quenched Hardness (oil)

Size Round	Surface	½ Radius	Center
½	HRC 63	HRC 62	HRC 62
1	HRC 62	HRC 61	HRC 60
2	HRC 53	HRC 46	HRC 43
4	HRC 40	HRC 32	HRC 29

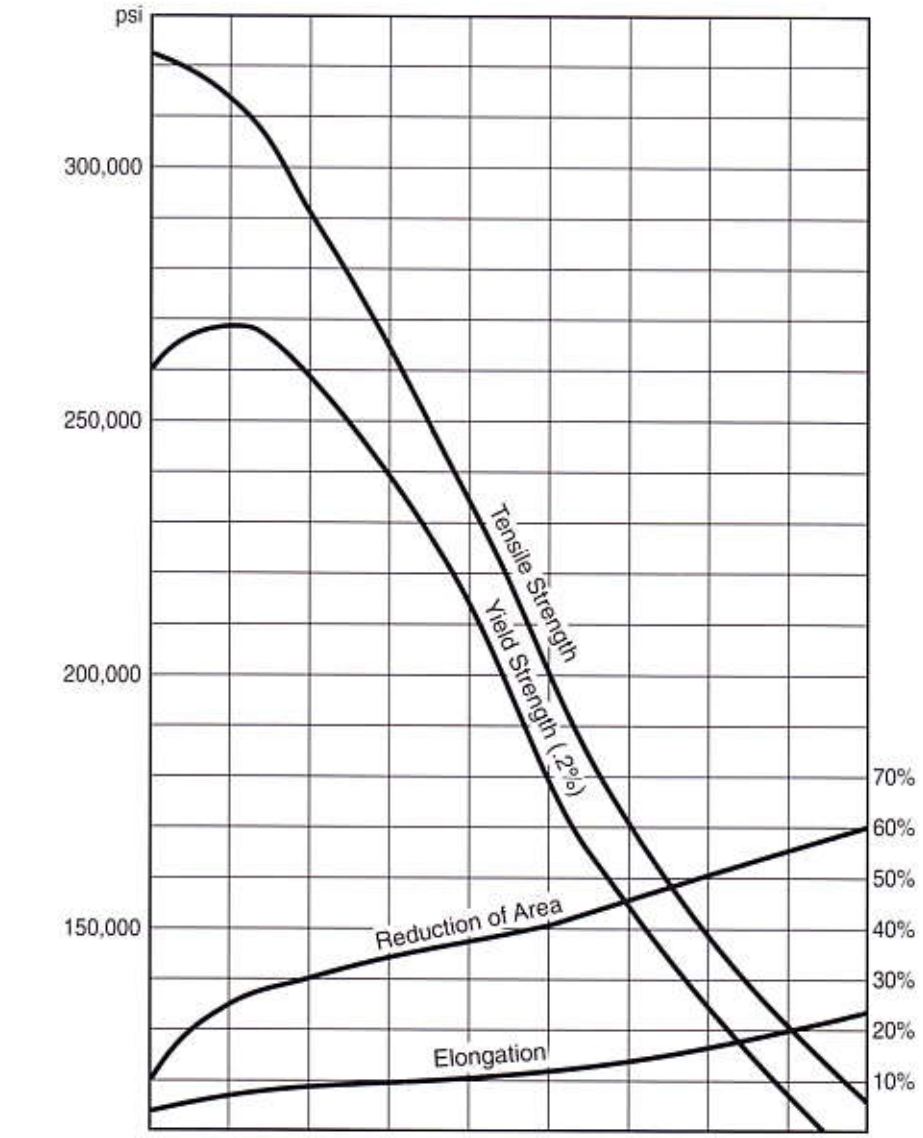
OIL-QUENCHED 5160

SINGLE HEAT RESULTS

	C	Mn	P	S	Si	Ni	Cr	Mo	Grain Size
Ladle	.62	.84	.010	.034	.24	.04	.74	.01	6-8

Critical Points, °F: Ac_1 1380 Ac_3 1420 Ar_3 1310 Ar_1 1280

Treatment: Normalized at 1575°F; reheated to 1525°F; quenched in oil.
.530-in. Round Treated; .505-in. Round Tested. As-quenched HB 682.

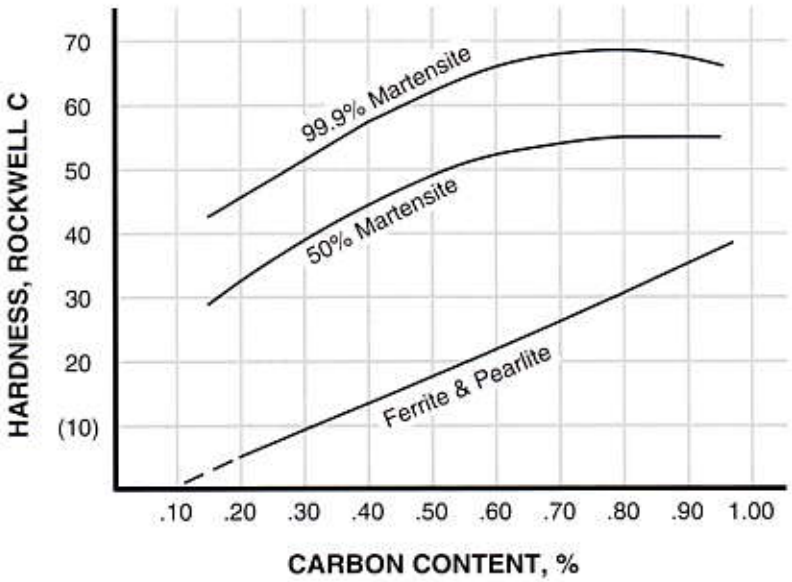


Temper, °F	400	500	600	700	800	900	1000	1100	1200	1300
HB	627	601	555	514	461	388	341	302	269	229

HARDENABILITY vs. HARDNESS

When considering heat treatment of steel it is important to understand the difference between ***hardness*** and ***hardenability***. Hardness is a measure of resistance to surface deformation or penetration. Hardenability is a measure of the distribution of and ease of obtaining hardness to a given depth.

Maximum hardness obtainable in steel is determined by the steel's carbon content. The maximum hardness can be achieved by heating the steel above its critical temperature to obtain austenite and then quenching (cooling rapidly) to obtain a microstructure of 100% martensite.



A steel which transforms rapidly to martensite has high hardenability. A lower hardenability steel transforms more slowly to martensite and requires faster cooling to achieve obtainable hardness. In general, alloy steels have greater hardenability than do carbon steels.

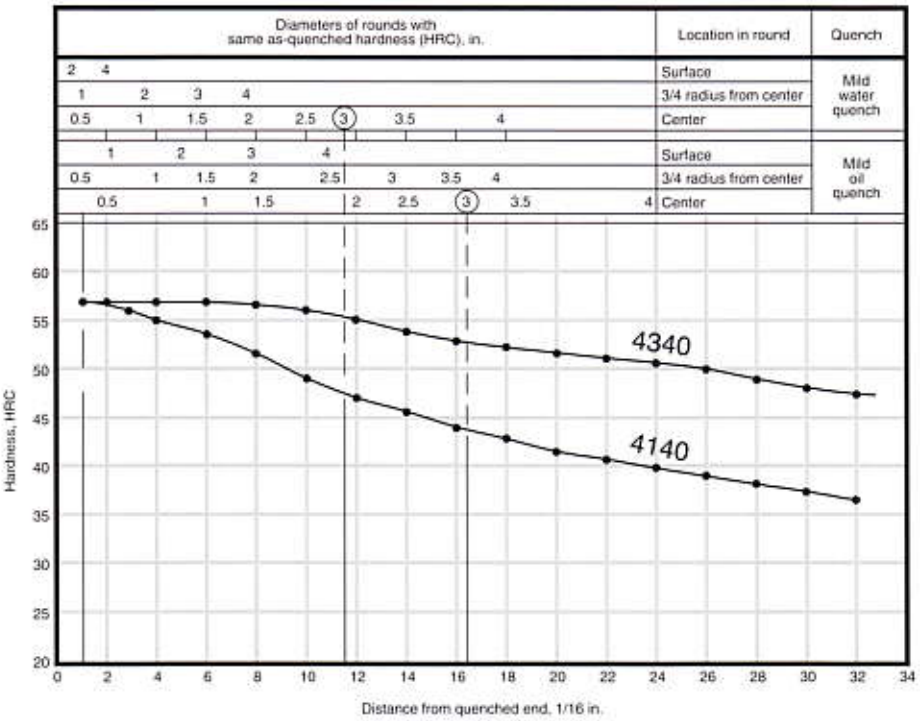
The Jominy end-quench test is a standard hardenability test for carbon and low alloy steels. A round bar of standard size is heated to austenite and then end-quenched with a stream of water at specified temperature and flow rate. Rockwell C hardness is measured every $^1/_{16}$" along the surface of the bar beginning from the quenched end. The hardness results are then plotted against distance on a hardenability chart. Each $^1/_{16}$" is defined as one Jominy distance; J-1 is $^1/_{16}$", J-2 is $^1/_8$", J-3 is $^3/_{16}$", etc.

HARDENABILITY vs. HARDNESS — Continued

Hardness measured on the end-quench bar is determined by cooling rate at each point along the bar. Since these cooling rates are known quantities, hardenability curves can be used to predict the hardness in parts where the cooling rates are known. The best example is round bars—standard hardenability charts list the diameters of round bars at equivalent cooling rate positions for both water and oil quenching media.

The following hardenability chart shows mid-range hardenability curves for two 0.40% carbon content steels. If we wish to predict the as-quenched hardness at the core of a 3" diameter round bar, we simply draw a line from the 3" center location to intersect with the hardenability curve; this gives the hardness value. For a mild water quench we see the 3" diameter center position (circled) is between J-11 and J-12, equal to 55 HRC for 4340 and 48 HRC for 4140. For a mild oil quench the 3" diameter center position (circled) is between J-16 and J-17, equal to 53 HRC for 4340 and 44 HRC for 4140.

End-quench hardenability limits for standard carbon and alloy H-steels appear on the following pages. These values can be used to predict as-quenched hardness ranges for these grades in the same method as above.



H-steels are specified by both chemical composition and hardenability limits. Chemical composition limits for H-steels are slightly modified from the same grade when specified by chemical composition only. As an example, the composition limits of carbon for 4140 is 0.38/0.43% but it is 0.37/0.44% for 4140H. Technically, the following end quench hardenability information applies only to H-steels. However, it is also useful for approximating quench hardening responses for the standard grades of carbon and alloy steels.

END QUENCH HARDENABILITY LIMITS

"J" DISTANCE SIXTEENTHS OF AN INCH	GRADE													
	1038 H		1045 H		1522 H		1524 H		1526 H		1541 H		15B21 H	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	58	51	62	55	50	41	51	42	53	44	60	53	48	41
1.5	56	42	61	52	48	41	49	42	50	42	59	52	48	41
2	55	34	59	42	47	32	48	38	49	38	59	50	47	40
2.5	53	29	56	34	46	27	47	34	47	33	58	47	47	39
3	49	26	52	31	45	22	45	29	46	26	57	44	46	38
3.5	43	24	46	29	42	21	43	25	42	25	56	41	45	36
4	37	23	38	28	39	20	39	22	39	21	55	38	44	30
4.5	33	22	34	27	37	....	38	20	37	20	53	35	42	23
5	30	22	33	26	34	....	35	....	33	....	52	32	40	20
5.5	29	21	32	26	32	....	34	....	31	....	50	29	38	....
6	28	21	32	25	30	....	32	....	30	....	48	27	35	....
6.5	27	20	31	25	28	....	30	....	28	....	46	26	32	....
7	27	....	31	25	27	....	29	....	27	....	44	25	27	....
7.5	26	....	30	24	....	....	28	....	26	....	41	24	22	....
8	26	....	30	24	....	....	27	....	26	....	39	23	20	....
9	25	....	29	23	....	....	26	....	24	....	35	23	....	....
10	25	....	29	22	....	....	25	....	24	....	33	22	....	....
12	24	....	28	21	....	....	23	....	23	....	32	21	....	....
14	23	....	27	20	....	....	22	....	....	....	31	20	....	....
16	21	....	26	....	....	....	....	....	....	....	30	....	....	....
18	....	....	....	....	....	....	....	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....	....	....	....	....	....	....	....
22	....	....	....	....	....	....	....	....	....	....	....	....	....	....
24	....	....	....	....	....	....	....	....	....	....	....	....	....	....
26	....	....	....	....	....	....	....	....	....	....	....	....	....	....
28	....	....	....	....	....	....	....	....	....	....	....	....	....	....

"J" DISTANCE SIXTEENTHS OF AN INCH	GRADE													
	15B35 H		15B41 H		15B48 H		15B62 H		1330 H		1335 H		1340 H	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	58	51	60	53	63	56	....	60	56	49	58	51	60	53
2	56	50	59	52	62	56	....	60	56	47	57	49	60	52
3	55	49	59	52	62	55	....	60	55	44	56	47	59	51
4	54	48	58	51	61	54	....	60	53	40	55	44	58	49
5	53	39	58	51	60	53	65	59	52	35	54	38	57	46
6	51	28	57	50	59	52	65	58	50	31	52	34	56	40
7	47	24	57	49	58	42	64	57	48	28	50	31	55	35
8	41	22	56	48	57	34	64	52	45	26	48	29	54	33
9	....	....	55	44	56	31	64	43	43	25	46	27	52	31
10	30	20	55	37	55	30	63	39	42	23	44	26	51	29
11	....	....	54	32	53	29	63	37	40	22	42	25	50	28
12	27	....	53	28	51	28	63	35	39	21	41	24	48	27
13	....	....	52	26	48	27	62	35	38	20	40	23	46	26
14	26	....	51	25	45	27	62	34	37	....	39	22	44	25
15	....	....	50	25	41	26	61	33	36	....	38	22	42	25
16	25	....	49	24	38	26	60	33	35	....	37	21	41	24
18	....	....	46	23	34	25	58	32	34	....	35	20	39	23
20	24	....	42	22	32	24	54	31	33	....	34	....	38	23
22	....	....	39	21	31	23	48	30	32	....	33	....	37	22
24	22	....	36	21	30	22	43	30	31	....	32	....	36	22
26	....	....	34	20	29	21	40	29	31	....	31	....	35	21
28	20	....	33	....	29	20	37	28	31	....	31	....	35	21
30	....	....	31	....	28	....	35	27	30	....	30	....	34	20
32	....	....	31	....	28	....	34	26	30	....	30	....	34	20

END QUENCH HARDENABILITY LIMITS — Continued

"J" DISTANCE SIXTEENTHS OF AN INCH	GRADE													
	4027 H & 4028 H		4037 H		4047 H		4118 H		4130 H		4135 H		4137 H	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	52	45	59	52	64	57	48	41	56	49	58	51	59	52
2	50	40	57	49	62	55	46	36	55	46	58	50	59	51
3	46	31	54	42	60	50	41	27	53	42	57	49	58	50
4	40	25	51	35	58	42	35	23	51	38	56	48	58	49
5	34	22	45	30	55	35	31	20	49	34	56	47	57	49
6	30	20	38	26	52	32	28	....	47	31	55	45	57	48
7	28	....	34	23	47	30	27	....	44	29	54	42	56	45
8	26	....	32	22	43	28	25	....	42	27	53	40	55	43
9	25	....	30	21	40	28	24	....	40	26	52	38	55	40
10	25	....	29	20	38	27	23	....	38	26	51	36	54	39
11	24	....	28	....	37	26	22	....	36	25	50	34	53	37
12	23	....	27	....	35	26	21	....	35	25	49	33	52	36
13	23	....	26	....	34	25	21	....	34	24	48	32	51	35
14	22	....	26	....	33	25	20	....	34	24	47	31	50	34
15	22	....	26	....	33	25	....	....	33	23	46	30	49	33
16	21	....	25	....	32	25	....	....	33	23	45	30	48	33
18	21	....	25	....	31	24	....	....	32	22	44	29	46	32
20	20	....	25	....	30	24	....	....	32	21	42	28	45	31
22	....	....	25	....	30	23	....	....	32	20	41	27	44	30
24	....	....	24	....	30	23	....	....	31	....	40	27	43	30
26	....	....	24	....	30	22	....	....	31	....	39	27	42	30
28	....	....	24	....	29	22	....	....	30	....	38	26	42	29
30	....	....	23	....	29	21	....	....	30	....	38	26	41	29
32	....	....	23	....	29	21	....	....	29	....	37	26	41	29

"J" DISTANCE SIXTEENTHS OF AN INCH	GRADE													
	4140 H		4142 H		4145 H		4147 H		4150 H		4320 H		4340 H	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	60	53	62	55	63	56	64	57	65	59	48	41	60	53
2	60	53	62	55	63	55	64	57	65	59	47	38	60	53
3	60	52	62	54	62	55	64	56	65	59	45	35	60	53
4	59	51	61	53	62	54	64	56	65	58	43	32	60	53
5	59	51	61	53	62	53	63	55	65	58	41	29	60	53
6	58	50	61	52	61	53	63	55	65	57	38	27	60	53
7	58	48	60	51	61	52	63	55	65	57	36	25	60	53
8	57	47	60	50	61	52	63	54	64	56	34	23	60	52
9	57	44	60	49	60	51	63	54	64	56	33	22	60	52
10	56	42	59	47	60	50	62	53	64	55	31	21	60	52
11	56	40	59	46	60	49	62	52	64	54	30	20	59	51
12	55	39	58	44	59	48	62	51	63	53	29	20	59	51
13	55	38	58	42	59	46	61	49	63	51	28	....	59	50
14	54	37	57	41	59	45	61	48	62	50	27	....	58	49
15	54	36	57	40	58	43	60	46	62	48	27	....	58	49
16	53	35	56	39	58	42	60	45	62	47	26	....	58	48
18	52	34	55	37	57	40	59	42	61	45	25	....	58	47
20	51	33	54	36	57	38	59	40	60	43	25	....	57	46
22	49	33	53	35	56	37	58	39	59	41	24	....	57	45
24	48	32	53	34	55	36	57	38	59	40	24	....	57	44
26	47	32	52	34	55	35	57	37	58	39	24	....	57	43
28	46	31	51	34	55	35	57	37	58	38	24	....	56	42
30	45	31	51	33	55	34	56	37	58	38	24	....	56	41
32	44	30	50	33	54	34	56	36	58	38	24	....	56	40

END QUENCH HARDENABILITY LIMITS — Continued

"J" DISTANCE SIXTEENTHS OF AN INCH	GRADE													
	E 4340 H		4260 H		4720 H		4815 H		4820 H		5120 H		5130 H	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	60	53	48	41	48	41	45	38	48	41	48	40	56	49
2	60	53	45	35	47	39	44	37	48	40	46	34	55	46
3	60	53	42	27	43	31	44	34	47	39	41	28	53	42
4	60	53	39	24	39	27	42	30	46	38	36	23	51	39
5	60	53	34	21	35	23	41	27	45	34	33	20	49	35
6	60	53	31	....	32	21	39	24	43	31	30	....	47	32
7	60	53	29	....	29	....	37	22	42	29	28	....	45	30
8	60	53	27	....	28	....	35	21	40	27	27	....	42	28
9	60	53	26	....	27	....	33	20	39	26	25	....	40	26
10	60	53	25	....	26	....	31	....	37	25	24	....	38	25
11	60	53	24	....	25	....	30	....	36	24	23	....	37	23
12	60	53	23	....	24	....	29	....	35	23	22	....	36	22
13	60	52	22	....	24	....	28	....	34	22	21	....	35	21
14	59	52	22	....	23	....	28	....	33	22	21	....	34	20
15	59	52	22	....	23	....	27	....	32	21	20	....	34	....
16	59	51	21	....	22	....	27	....	31	21	....	....	33	....
18	58	51	21	....	21	....	26	....	29	20	....	....	32	....
20	58	50	20	....	21	....	25	....	28	20	....	....	31	....
22	58	49	....	....	21	....	24	....	28	....	....	....	30	....
24	57	48	....	....	20	....	24	....	27	....	....	....	29	....
26	57	47	....	....	....	....	24	....	27	....	....	....	27	....
28	57	46	....	....	....	....	23	....	26	....	....	....	26	....
30	57	45	....	....	....	....	23	....	26	....	....	....	25	....
32	57	44	....	....	....	....	23	....	25	....	....	....	24	....

"J" DISTANCE SIXTEENTHS OF AN INCH	GRADE													
	5132 H		5140 H		5150 H		5160 H		51B60 H		6150 H		8617 H	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	57	50	60	53	65	59	....	60	....	60	65	59	46	39
2	56	47	59	52	65	58	....	60	....	60	65	58	44	33
3	54	43	58	50	64	57	....	60	....	60	64	57	41	27
4	52	40	57	48	63	56	65	59	....	60	64	56	38	24
5	50	35	56	43	62	53	65	58	....	60	63	55	34	20
6	48	32	54	38	61	49	64	56	....	59	63	53	31	....
7	45	29	52	35	60	42	64	52	....	58	62	50	28	....
8	42	27	50	33	59	38	63	47	....	57	61	47	27	....
9	40	25	48	31	58	36	62	42	....	54	61	43	26	....
10	38	24	46	30	56	34	61	39	....	50	60	41	25	....
11	37	23	45	29	55	33	60	37	....	44	59	39	24	....
12	36	22	43	28	53	32	59	36	65	41	58	38	23	....
13	35	21	42	27	51	31	58	35	65	40	57	37	23	....
14	34	20	40	27	50	31	56	35	64	39	55	36	22	....
15	34	....	39	26	48	30	54	34	64	38	54	35	22	....
16	33	....	38	25	47	30	52	34	63	37	52	35	21	....
18	32	....	37	24	45	29	48	33	61	36	50	34	21	....
20	31	....	36	23	43	28	47	32	59	34	48	32	20	....
22	30	....	35	21	43	27	46	31	57	33	47	31	....	....
24	29	....	34	20	41	26	45	30	55	31	46	30	....	....
26	28	....	34	....	40	25	44	29	53	30	45	29	....	....
28	27	....	33	....	39	24	43	28	51	28	44	27	....	....
30	26	....	33	....	39	23	43	28	49	27	43	26	....	....
32	25	....	32	....	38	22	42	27	47	25	42	25	....	....

END QUENCH HARDENABILITY LIMITS — Continued

"J" DISTANCE SIXTEENTHS OF AN INCH	GRADE													
	8620 H		8622 H		8630 H		8637 H		8640 H		8645 H		8720 H	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	48	41	50	43	56	49	59	52	60	53	63	56	48	41
2	47	37	49	39	55	46	58	51	60	53	63	56	47	38
3	44	32	47	34	54	43	58	50	60	52	63	55	45	35
4	41	27	44	30	52	39	57	48	59	51	63	54	42	30
5	37	23	40	26	50	35	56	45	59	49	62	52	38	26
6	34	21	37	24	47	32	55	42	58	46	61	50	35	24
7	32	....	34	22	44	29	54	39	57	42	61	48	33	22
8	30	....	32	20	41	28	53	36	55	39	60	45	31	21
9	29	....	31	....	39	27	51	34	54	36	59	41	30	20
10	28	....	30	....	37	26	49	32	52	34	58	39	29	....
11	27	....	29	....	35	25	47	31	50	32	56	37	28	....
12	26	....	28	....	34	24	46	30	49	31	55	35	27	....
13	25	....	27	....	33	23	44	29	47	30	54	34	26	....
14	25	....	26	....	33	22	43	28	45	29	52	33	26	....
15	24	....	26	....	32	22	41	27	44	28	51	32	25	....
16	24	....	25	....	31	21	40	26	42	28	49	31	25	....
18	23	....	25	....	30	21	39	25	41	26	47	30	24	....
20	23	....	24	....	30	20	37	25	39	26	45	29	24	....
22	23	....	24	....	29	20	36	24	38	25	43	28	23	....
24	23	....	24	....	29	....	36	24	38	25	42	28	23	....
26	23	....	24	....	29	....	35	24	37	24	42	27	23	....
28	22	....	24	....	29	....	35	24	37	24	41	27	23	....
30	22	....	24	....	29	....	35	23	37	24	41	27	22	....
32	22	....	24	....	29	....	35	23	37	24	41	27	22	....

"J" DISTANCE SIXTEENTHS OF AN INCH	GRADE													
	8740 H		8822 H		9620 H		9310 H		94B17 H					
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	60	53	50	43	....	60	43	36	46	39				
2	60	53	49	42	....	60	43	35	46	39				
3	60	52	48	39	65	57	43	35	45	38				
4	60	51	46	33	64	53	42	34	45	37				
5	59	49	43	29	63	46	42	32	44	34				
6	58	46	40	27	62	41	42	31	43	29				
7	57	43	37	25	60	38	42	30	42	26				
8	56	40	35	24	58	36	41	29	41	24				
9	55	37	34	24	55	36	40	28	40	23				
10	53	35	33	23	52	35	40	27	38	21				
11	52	34	32	23	49	34	39	27	36	20				
12	50	32	31	22	47	34	38	26	34	....				
13	49	31	31	22	45	33	37	26	33	....				
14	48	31	30	22	43	33	36	26	32	....				
15	46	30	30	21	42	32	36	26	31	....				
16	45	29	29	21	40	32	35	26	30	....				
18	43	28	29	20	38	31	35	26	28	....				
20	42	28	28	....	37	31	35	25	27	....				
22	41	27	27	....	36	30	34	25	26	....				
24	40	27	27	....	36	30	34	25	25	....				
26	39	27	27	....	35	29	34	25	24	....				
28	39	27	27	....	35	29	34	25	24	....				
30	38	26	27	....	35	28	33	24	23	....				
32	35	26	27	....	34	28	33	24	23	....				

CARBURIZING INFORMATION

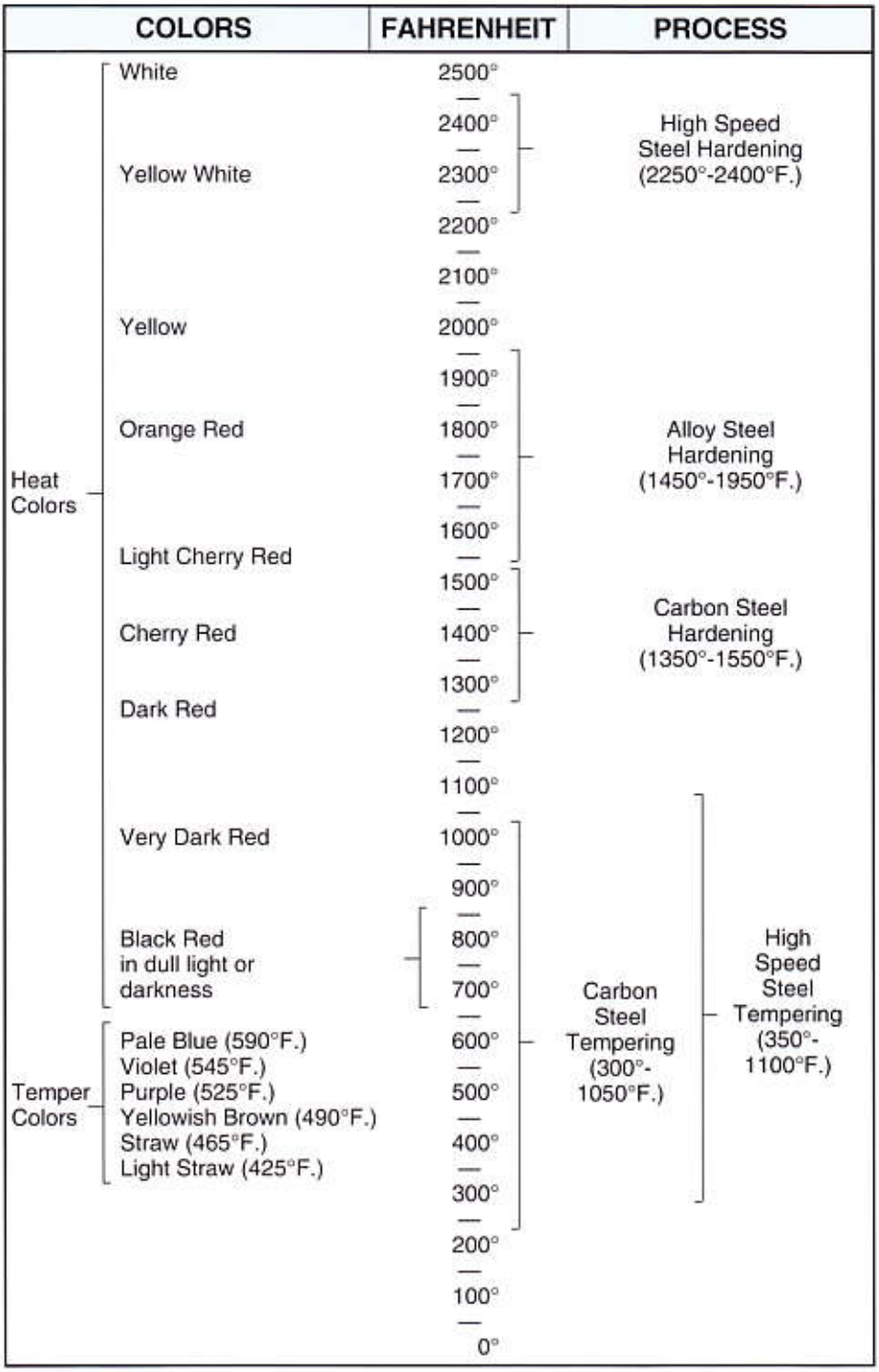
Total & Etched Case vs. Time

CASE DEPTHS BASED ON HARRIS EQUATIONS

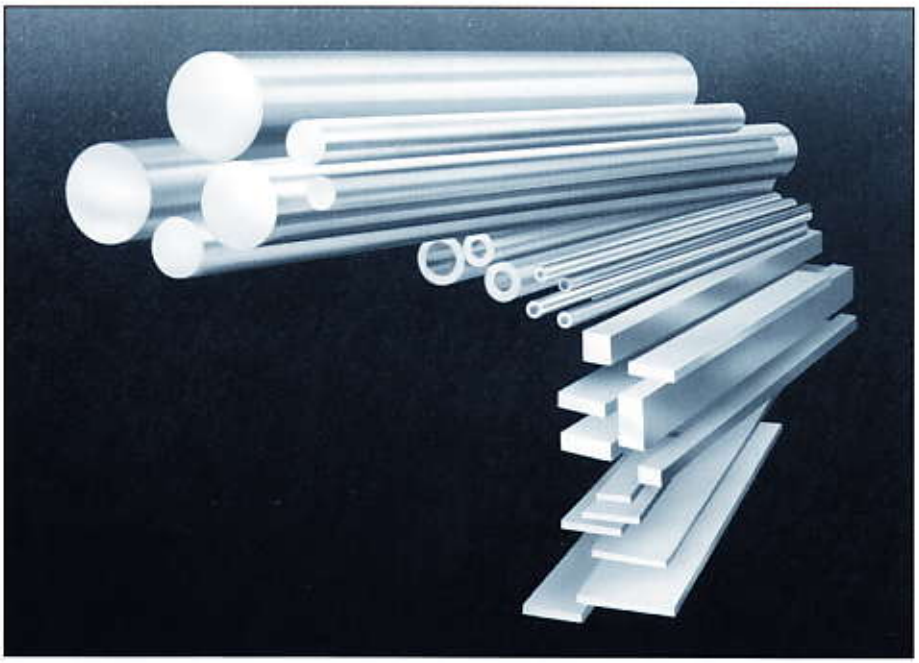
TIME (Hours)	CARBURIZING TEMPERATURE							
	1600°F		1650°F		1700°F		1750°F	
	TOTAL CASE DEPTH (INCHES)	EFFECTIVE CASE DEPTH (INCHES)	TOTAL CASE DEPTH (INCHES)	EFFECTIVE CASE DEPTH (INCHES)	TOTAL CASE DEPTH (INCHES)	EFFECTIVE CASE DEPTH (INCHES)	TOTAL CASE DEPTH (INCHES)	EFFECTIVE CASE DEPTH (INCHES)
1	.018	.013	.021	.015	.025	.019	.029	.022
2	.025	.018	.030	.022	.035	.026	.041	.031
3	.031	.022	.037	.027	.043	.032	.051	.039
4	.035	.025	.042	.031	.050	.037	.059	.045
5	.040	.029	.047	.034	.056	.042	.066	.050
6	.043	.031	.052	.038	.061	.045	.072	.055
7	.047	.034	.056	.041	.066	.049	.078	.059
8	.050	.036	.060	.044	.071	.053	.083	.063
9	.053	.038	.063	.046	.075	.056	.088	.067
10	.056	.040	.067	.049	.079	.059	.093	.071
11	.059	.042	.070	.051	.083	.062	.097	.073
12	.061	.044	.073	.053	.087	.065	.102	.077
16	.071	.051	.084	.061	.100	.075	.117	.088
20	.079	.057	.094	.069	.112	.084	.131	.099
24	.086	.062	.103	.075	.122	.092	.144	.109
30	.097	.070	.116	.085	.137	.103	.161	.122

NOTE. Total case depth values calculated to base carbon content of approximately 0.20%. Effective case depth values calculated to 0.40% carbon level. All values are for carbon and lower alloy carburizing steels such as 1018 and 8620.

TEMPERATURES AND COLORS FOR HEATING AND TEMPERING STEEL



Ask for our Heating and Tempering Steel Color Chart



SECTION INDEX
USEFUL INFORMATION

EFFECTS OF CHEMICAL ELEMENTS

Carbon and Alloy Steels

The effects of the commonly specified chemical elements on the properties of carbon and alloy steels are discussed here by considering the various elements individually. In practice, however, the effect of any particular element will often depend on the quantities of other elements also present in the steel. For example, the total effect of a combination of alloying elements on the hardenability of a steel is usually greater than the sum of their individual contributions. This type of interrelation should be taken into account whenever a change in a specified analysis is evaluated.

CARBON is the principal hardening element in steel, with each additional increment of carbon increasing the hardness and tensile strength of the steel in the as-rolled or normalized condition. As the carbon content increases above approximately .85%, the resulting increase in strength and hardness is proportionately less than it is for the lower carbon ranges. Upon quenching, the maximum attainable hardness also increases with increasing carbon, but above a content of .60%, the rate of increase is very small.

Conversely, a steel's ductility and weldability decrease as its carbon content is increased.

Carbon has a moderate tendency to segregate within the ingot, and because of its significant effect on properties, such segregation is frequently of greater importance than the segregation of other elements in the steel.

MANGANESE is present in all commercial steels, and contributes significantly to a steel's strength and hardness in much the same manner, but to a lesser extent, than does carbon. Its effectiveness depends largely upon, and is directly proportional to, the carbon content of the steel. Another important characteristic of this element is its ability to decrease the critical cooling rate during hardening, thereby increasing the steel's hardenability. Its effect in this respect is greater than that of any of the other commonly used alloying elements.

Manganese is an active deoxidizer, and shows less tendency to segregate within the ingot than do most other elements. Its presence in a steel is also highly beneficial to surface quality in that it tends to combine with sulfur, thereby minimizing the formation of iron sulfide, the causative factor of hot-shortness, or susceptibility to cracking and tearing at rolling temperatures.

BORON has the unique ability to increase the hardenability of steel when added in amounts as small as .0005%. This effect on hardenability is most pronounced at the lower carbon levels, diminishing with increasing carbon content to where, as the eutectoid composition is approached, the effect becomes negligible. Because boron is ineffective when it is allowed to combine with oxygen or nitrogen, its use is limited to aluminum-killed steels.

Unlike many other elements, boron does not increase the ferrite strength of steel. Boron additions, therefore, promote improved machinability and formability at a particular level of hardenability. It will also intensify the hardenability effects of other alloys, and in some instances, decrease costs by making possible a reduction of total alloy content.

LEAD does not alloy with steel. Instead, as added in pellet form during teeming of the ingot, it is retained in its elemental state as a fine dispersion within the steel's structure. Lead additions have no significant effect on the room temperature

EFFECTS OF CHEMICAL ELEMENTS — Continued

mechanical properties of any steel; yet, when present in the usual range of .15 to .35%, the lead additive enhances the steel's machining characteristics to a marked degree.

Although lead can be added to any steel, its use to date has been most significant with the free-machining carbon grades. Added to a base composition which has been resulfurized, rephosphorized, and nitrogen-treated, lead helps these steels achieve the optimum in machinability.

NITROGEN is inherently present in all steels, but usually only in small amounts which produce no observable effect. Present in amounts above about .004%, however, nitrogen will combine with certain other elements to precipitate as a nitride. This increases the steel's hardness and tensile and yield strengths while reducing its ductility and toughness. Such effect is similar to that of phosphorus, and is highly beneficial to the machining performance of the steel.

ALUMINUM is used in steel principally to control grain size and to achieve deoxidation. Aluminum-killed steels exhibit a high order of fracture toughness.

A specialized use of aluminum is in nitriding steels. When such steels containing .95 to 1.30% aluminum are heated in a nitrogenous medium, they achieve a thin case containing aluminum nitride. This stable compound imparts a high surface hardness and exceptional wear resistance to the steels involved.

CHROMIUM is used in constructional alloy steels primarily to increase hardenability, provide improved abrasion-resistance, and to promote carburization. Of the common alloying elements, chromium is surpassed only by manganese and molybdenum in its effect on hardenability.

Chromium forms the most stable carbide of any of the more common alloying elements, giving to high-carbon chromium steels exceptional wear resistance. And because its carbide is relatively stable at elevated temperatures, chromium is frequently added to steels used for high temperature applications.

A chromium content of 3.99% has been established as the maximum limit applicable to constructional alloy steels. Contents above this level place steels in the category of heat-resisting or stainless steels.

MOLYBDENUM exhibits a greater effect on hardenability per unit added than any other commonly specified alloying element except manganese. It is a non-oxidizing element, making it highly useful in the melting of steels where close hardenability control is desired.

Molybdenum is unique in the degree to which it increases the high-temperature tensile and creep strengths of steel. Its use also reduces a steel's susceptibility to temper brittleness.

VANADIUM improves the strength and toughness of thermally treated steels, primarily because of its ability to inhibit grain-growth over a fairly broad quenching range. It is a strong carbide-former and its carbides are quite stable. Hardenability of medium-carbon steels is increased with a minimum effect upon grain size with vanadium additions of about .04 to .05%; above this content, the hardenability effect per unit added decreases with normal quenching temperatures due to the formation of insoluble carbides. However, the hardenability can be increased with the higher vanadium contents by increasing the austenitizing temperatures.

EFFECTS OF CHEMICAL ELEMENTS — Continued

COPPER is added to steel primarily to improve the steel's resistance to corrosion. In the usual amounts of from .20 to .50%, the copper addition does not significantly affect the mechanical properties. Copper oxidizes at the surface of steel products during heating and rolling, the oxide forming at the grain boundaries and causing a hot-shortness which adversely affects surface quality.

PHOSPHORUS is generally considered an impurity except where its beneficial effect on machinability and resistance to atmospheric corrosion is desired. While phosphorus increases strength and hardness to about the same degree as carbon, it also tends to decrease ductility and toughness, or impact strength, particularly for steel in the quenched and tempered condition. The phosphorus content of most steels is therefore kept below specified maxima, which range up to .04 per cent.

In the free-machining steels, however, specified phosphorus content may run as high as .12%. This is attained by adding phosphorus to the ladle, commonly termed rephosphorizing.

SULFUR is generally considered an undesireable element except where machinability is an important consideration. Whereas sulfides in steel act as effective chip-breakers to improve machinability, they also serve to decrease transverse ductility and impact strength. Moreover, increasing sulfur impairs weldability and has an adverse effect on surface quality. Steels with the higher sulfur contents—and particularly those with .15 to .25% carbon—require appreciable surface preparation during processing. Extra discard of these steels at the mill may also be necessary to minimize the amount of segregated steel in the finished product, inasmuch as sulfur, like phosphorus, shows a strong tendency to segregate within the ingot.

SILICON is one of the principal deoxidizers used in the manufacture of both carbon and alloy steels, and depending on the type of steel, can be present in varying amounts up to .35% as a result of deoxidation. It is used in greater amounts in some steels, such as the silico-manganese steels, where its effects tend to complement those of manganese to produce unusually high strength combined with good ductility and shock-resistance in the quenched and tempered condition. In these larger quantities, however, silicon has an adverse effect on machinability, and increases the steel's susceptibility to decarburization and graphitization.

NICKEL is one of the fundamental steel-alloying elements. When present in appreciable amounts, it provides improved toughness, particularly at low temperatures; simplified and more economical thermal treatment; increased hardenability; less distortion in quenching; and improved corrosion resistance.

Nickel lowers the critical temperatures of steel, widens the temperature range for effective quenching and tempering, and retards the decomposition of austenite. In addition, nickel does not form carbides or other compounds which might be difficult to dissolve during heating for austenitizing. All these factors contribute to easier and more successful thermal treatment.

AISI/SAE NUMBERING SYSTEM

Wrought or Rolled Steel

A numerical index system is used to identify the compositions of the standard grades of AISI/SAE steels. The system uses four-digit numbers to indicate the type of alloying elements (if any) and the nominal carbon content; certain types of alloy steels use five-digit numbers. The prefix 'E' is used to designate steels which are made by the basic electric furnace process with special practices. The suffix 'H' is used to designate standard hardenability steels.

The last two digits of the four-digit designations indicate the approximate mean of the carbon range (the last three digits for the five-digit designations). For example, in the grade 4130, the '30' indicates a carbon range of 0.28 to 0.33% (for 52100 the '100' indicates 0.98 to 1.10% carbon). It is necessary, however to deviate from this rule and to interpolate numbers in the case of some carbon ranges and for variations in manganese, sulfur or other elements with the same carbon range. For example, 1215 has a carbon content of 0.09% maximum.

The first two digits of the four and five-digit designations for the various standard grades of carbon and alloy steels and their meanings are as follows:

	SERIES DESIGNATION	TYPE AND APPROXIMATE PERCENTAGES OF IDENTIFYING ELEMENTS
CARBON STEELS	10xx	Nonresulfurized, Manganese 1.00 per cent maximum
	11x	Resulfurized
	12xx	Rephosphorized and Resulfurized
	15xx	Nonresulfurized, Manganese maximum over 1.00 per cent
ALLOY STEELS	13xx	Manganese 1.75
	40xx	Molybdenum 0.25
	41xx	Chromium 0.50, 0.80 or 0.95, Molybdenum 0.12, 0.16, 0.20 or 0.30
	43xx	Nickel 1.83, Chromium 0.50 or 0.80, Molybdenum 0.25
	46xx	Nickel 0.85 or 1.83, Molybdenum 0.20 or 0.25
	47xx	Nickel 0.85 or 1.05, Chromium 0.55 or 0.45, Molybdenum 0.20, 0.35 or 0.52
	48xx	Nickel 3.40, Molybdenum 0.25
	51xx	Chromium 0.80, 0.88, 0.93, 0.95 or 1.00
	51xxx	Chromium 1.03
	52xxx	Chromium 1.45
	61xx	Chromium 0.60, or 0.95, Vanadium 0.13 or min. 0.15
	86xx	Nickel 0.55, Chromium 0.50, Molybdenum 0.20
	87xx	Nickel 0.55, Chromium 0.50, Molybdenum 0.25
	88xx	Nickel 0.55, Chromium 0.50, Molybdenum 0.35
	92xx	Silicon 2.00; Silicon 1.00 or 1.40 & Chromium 0.55
	50Bxx	Chromium 0.28 or 0.50
	51Bxx	Chromium 0.80
	81Bxx	Nickel 0.30, Chromium 0.45, Molybdenum 0.12
	94Bxx	Nickel 0.45, Chromium 0.40, Molybdenum 0.12
B denotes Boron Steel		

HEAT ANALYSIS applies to the chemical analysis representative of a heat of steel as reported to the purchaser. Heat analyses for standard AISI/SAE grades of bars, billets, blooms and slabs are listed on the following pages. Plate heat analyses ranges may differ slightly.

PRODUCT ANALYSIS is a chemical analysis on the semifinished or finished steel to determine conformance to the specification requirements. Tolerances for product analyses follow the heat analyses listings. Product analysis ranges are wider than those for heat analysis.

INCIDENTAL ELEMENTS, in small quantities, are present in steel. They are elements which are neither specified nor required and may or may not be reported in the heat analysis.

STANDARD NONRESULFURIZED CARBON STEELS

MANGANESE 1.00% MAXIMUM

HEAT CHEMICAL RANGES and LIMITS					
STEEL DESIGNATION AISI or SAE	UNS NUMBER	CHEMICAL COMPOSITION, PER CENT			
		C	Mn	P Max.	S Max.
*1005	G10050	0.06 Max.	0.35 Max.	0.040	0.050
*1006	G10060	0.08 Max.	0.25/0.40	0.040	0.050
1008	G10080	0.10 Max.	0.30/0.50	0.040	0.050
1010	G10100	0.08/0.13	0.30/0.50	0.040	0.050
1011	G10110	0.09/0.14	0.50/0.80	0.040	0.050
1012	G10120	0.10/0.15	0.30/0.60	0.040	0.050
1015	G10150	0.13/0.18	0.30/0.60	0.040	0.050
1016	G10160	0.13/0.18	0.60/0.90	0.040	0.050
1017	G10170	0.15/0.20	0.30/0.60	0.040	0.050
1018	G10180	0.15/0.20	0.60/0.90	0.040	0.050
1020	G10200	0.18/0.23	0.30/0.60	0.040	0.050
1021	G10210	0.18/0.23	0.60/0.90	0.040	0.050
1022	G10220	0.18/0.23	0.70/1.00	0.040	0.050
1023	G10230	0.20/0.25	0.30/0.60	0.040	0.050
1025	G10250	0.22/0.28	0.30/0.60	0.040	0.050
1026	G10260	0.22/0.28	0.60/0.90	0.040	0.050
1029	G10290	0.25/0.31	0.60/0.90	0.040	0.050
1030	G10300	0.28/0.34	0.60/0.90	0.040	0.050
1035	G10350	0.32/0.38	0.60/0.90	0.040	0.050
1038	G10380	0.35/0.42	0.60/0.90	0.040	0.050
1039	G10390	0.37/0.44	0.70/1.00	0.040	0.050
1040	G10400	0.37/0.44	0.60/0.90	0.040	0.050
1042	G10420	0.40/0.47	0.60/0.90	0.040	0.050
1043	G10430	0.40/0.47	0.70/1.00	0.040	0.050
1044	G10440	0.43/0.50	0.30/0.60	0.040	0.050
1045	G10450	0.43/0.50	0.60/0.90	0.040	0.050
1046	G10460	0.43/0.50	0.70/1.00	0.040	0.050
1049	G10490	0.46/0.53	0.60/0.90	0.040	0.050
1050	G10500	0.48/0.55	0.60/0.90	0.040	0.050
1053	G10530	0.48/0.55	0.70/1.00	0.040	0.050
1055	G10550	0.50/0.60	0.60/0.90	0.040	0.050
*1059	G10590	0.55/0.65	0.50/0.80	0.040	0.050
1060	G10600	0.55/0.65	0.60/0.90	0.040	0.050
1065	G10650	0.60/0.70	0.60/0.90	0.040	0.050
1070	G10700	0.65/0.75	0.60/0.90	0.040	0.050
1074	G10740	0.70/0.80	0.50/0.80	0.040	0.050
1078	G10780	0.72/0.85	0.30/0.60	0.040	0.050
1080	G10800	0.75/0.88	0.60/0.90	0.040	0.050
*1086	G10860	0.80/0.93	0.30/0.50	0.040	0.050
1090	G10900	0.85/0.98	0.60/0.90	0.040	0.050
*1095	G10950	0.90/1.03	0.30/0.50	0.040	0.050

Note 1. *Silicon.* When silicon ranges or limits are required, consult producer for ranges and limits.

Note 2. *Copper.* When copper is required, 0.20 per cent minimum is generally specified.

Note 3. *Lead.* Standard carbon steels can be produced with a lead range of 0.15/0.35 per cent, to improve machinability. Such steels are identified by inserting the letter L between the second and third numerals of the AISI number, e.g. 10L45. Lead is generally reported as a range of 0.15/0.35 per cent.

*Standard Steel Grades for Wire Rods only.

STANDARD CARBON H-STEELS

HEAT CHEMICAL RANGES and LIMITS						
STEEL DESIGNATION AISI or SAE	UNS NUMBER	CHEMICAL COMPOSITION, PER CENT				
		C	Mn	P Max.	S Max.	Si
1038H	H10380	0.34/0.43	0.50/1.00	0.040	0.050	0.15/0.35
1045H	H10450	0.42/0.51	0.50/1.00	0.040	0.050	0.15/0.35
15B21H	H15211	0.17/0.24	0.70/1.20	0.040	0.050	0.15/0.35
1522H	H15220	0.17/0.25	1.00/1.50	0.040	0.050	0.15/0.35
1524H	H15240	0.18/0.26	1.25/1.75	0.040	0.050	0.15/0.35
1526H	H15260	0.21/0.30	1.00/1.50	0.040	0.050	0.15/0.35
15B35H	H15351	0.31/0.39	0.70/1.20	0.040	0.050	0.15/0.35
1541H	H15410	0.35/0.45	1.25/1.75	0.040	0.050	0.15/0.35
15B41H	H15411	0.35/0.45	1.25/1.75	0.040	0.050	0.15/0.35
15B48H	H15481	0.43/0.53	1.00/1.50	0.040	0.050	0.15/0.35
15B62H	H15621	0.54/0.67	1.00/1.50	0.040	0.050	0.40/0.60

Note 1. If electric furnace practice is specified or required, the limits for phosphorous and sulfur are 0.025 per cent respectively and the prefix E is added.

Note 2. Standard carbon H-Steels can be produced with a lead range of 0.15/0.35 per cent. Such steels are identified by inserting the letter L between the second and third numerals of the AISI number, e.g. 15L24H. Lead is generally reported as a range of 0.15/0.35 per cent.

Note 3. Standard carbon H-Steels with boron added to improve hardenability are identified by inserting the letter "B" between the second and third digits of the AISI number. These steels can be expected to contain 0.0005 to 0.003 per cent boron.

STANDARD RESULFURIZED CARBON STEELS

HEAT CHEMICAL RANGES and LIMITS					
STEEL DESIGNATION AISI or SAE	UNS NUMBER	CHEMICAL COMPOSITION, PER CENT			
		C	Mn	P Max.	S Max.
1110	G11100	0.08/0.13	0.30/0.60	0.040	0.08/0.13
1117	G11170	0.14/0.20	1.00/1.30	0.040	0.08/0.13
1118	G11180	0.14/0.20	1.30/1.60	0.040	0.08/0.13
1123	G11230	0.20/0.27	1.20/1.50	0.040	0.06/0.09
1137	G11370	0.32/0.39	1.35/1.65	0.040	0.08/0.13
1140	G11400	0.37/0.44	0.70/1.00	0.040	0.08/0.13
1141	G11410	0.37/0.45	1.35/1.65	0.040	0.08/0.13
1144	G11440	0.40/0.48	1.35/1.65	0.040	0.23/0.33
1146	G11460	0.42/0.49	0.70/1.00	0.040	0.08/0.13
1152	G11520	0.48/0.55	0.70/1.00	0.040	0.06/0.09

Note 1. *Silicon.* When silicon ranges or limits are required, consult producer for ranges and limits.

Note 2. *Lead.* Standard carbon steels can be produced with a lead range of 0.15/0.35 per cent to improve machinability. Such steel is identified by inserting the letter L between the second and third numerals of the AISI steel designation, e.g. 11L17. Lead is generally reported as a range of 0.15/0.35 per cent.

STANDARD REPHOSPHORIZED and RESULFURIZED CARBON STEELS

HEAT CHEMICAL RANGES and LIMITS						
STEEL DESIGNATION AISI or SAE	UNS NUMBER	CHEMICAL COMPOSITION, PER CENT				
		C	Mn	P	S	Pb
1212	G12120	0.13 Max.	0.70/1.00	0.07/0.12	0.16/0.23	
1213	G12130	0.13 Max.	0.70/1.00	0.07/0.12	0.24/0.33	
1215	G12150	0.09 Max.	0.75/1.05	0.04/0.09	0.26/0.35	
12L14	G12144	0.15 Max.	0.85/1.15	0.04/0.09	0.26/0.35	0.15/0.35

Note 1. *Silicon.* It is not common practice to produce the 12XX series of steels to specified limits for silicon because of its adverse effect on machinability. When silicon ranges or limits are required for other series, consult producer for ranges and limits.

Note 2. *Lead.* Standard carbon steels can be produced with a lead range of 0.15/0.35 per cent to improve machinability. Such steel is identified by inserting the letter L between the second and third numerals of the AISI steel designation, e.g. 12L15. Lead is generally reported as a range of 0.15/0.35 per cent.

STANDARD NONRESULFURIZED CARBON STEELS

MANGANESE MAXIMUM OVER 1.00%

HEAT CHEMICAL RANGES and LIMITS					
STEEL DESIGNATION AISI or SAE	UNS NUMBER	CHEMICAL COMPOSITION, PER CENT			
		C	Mn	P Max.	S Max.
1513	G15130	0.10/0.16	1.10/1.40	0.040	0.050
1522	G15220	0.18/0.24	1.10/1.40	0.040	0.050
1524	G15240	0.19/0.25	1.35/1.65	0.040	0.050
1526	G15260	0.22/0.29	1.10/1.40	0.040	0.050
1527	G15270	0.22/0.29	1.20/1.50	0.040	0.050
1533	G15330	0.30/0.37	1.10/1.40	0.040	0.050
1534	G15340	0.30/0.37	1.20/1.50	0.040	0.050
1541	G15410	0.36/0.44	1.35/1.65	0.040	0.050
1544	G15440	0.40/0.47	0.80/1.10	0.040	0.050
1545	G15450	0.43/0.50	0.80/1.10	0.040	0.050
1546	G15460	0.44/0.52	1.00/1.30	0.040	0.050
1548	G15480	0.44/0.52	1.10/1.40	0.040	0.050
1552	G15520	0.47/0.55	1.20/1.50	0.040	0.050
1553	G15530	0.48/0.55	0.80/1.10	0.040	0.050
1566	G15660	0.60/0.71	0.85/1.15	0.040	0.050
1570	G15700	0.65/0.75	0.80/1.10	0.040	0.050
1580	G15800	0.75/0.88	0.80/1.10	0.040	0.050
1590	G15900	0.85/0.98	0.80/1.10	0.040	0.050

Note 1. *Silicon.* When silicon ranges or limits are required, consult producer for ranges and limits.
Note 1. *Copper.* When copper is required, 0.20 per cent minimum is generally specified.
Note 2. *Lead.* Standard carbon steels can be produced with a lead range of 0.15/0.35 per cent to improve machinability. Such steel is identified by inserting the letter L between the second and third numerals of the AISI steel designation, e.g. 15L27. Lead is generally reported as a range of 0.15/0.35 per cent.

PRODUCT ANALYSIS TOLERANCES

CARBON STEEL BARS

PRODUCT ANALYSIS TOLERANCES			
ELEMENT	Limit, or Maximum of Specified Range, %	Over Maximum Limit, %	Under Minimum Limit, %
Carbon[A]	0.25 and under over 0.25 to 0.55, incl. over 0.55	0.02 0.03 0.04	0.02 0.03 0.04
Manganese	0.90 and under over 0.90 to 1.65, incl.	0.03 0.06	0.03 0.06
Phosphorous[A,B]	basic steels acid bessemer steel	0.008 0.01	. . . 0.01
Sulfur[A,B]		0.008	. . .
Silicon	0.35 and under over 0.35 to 0.60, incl.	0.02 0.05	0.02 0.05
Copper	under minimum only	. . .	0.02
Lead[C]	0.15 to 0.35, incl.	0.03	0.03

[A] Rimmed and capped steels are not subject to rejection on product analysis unless misapplication is clearly indicated.
[B] Resulfurized or rephosphorized steels are not subject to rejection on product analysis for these elements unless misapplication is clearly indicated.
[C] Product analysis tolerance for lead applies both over and under to a specified range of 0.15 to 0.35%.

MERCHANT QUALITY

CARBON STEEL BARS

Merchant quality is the lowest quality for carbon steel bars. Merchant quality bars are produced to specified sizes, with appropriate control of the chemical limits or mechanical properties for non-critical uses. Bars of this quality are usually rolled from unconditioned billets. The size ranges are limited and the type of steel applied is at the producers option, i.e., rimmed, capped, semi-killed or killed steel. This quality is *not suitable* for applications which involve forging, heat treating, cold drawing, or other operations where internal soundness or relative freedom from detrimental surface imperfections is of prime importance.

CAST or HEAT CHEMICAL RANGES and LIMITS				
GRADE NO.	CHEMICAL COMPOSITION, PER CENT			
	C	Mn	P Max.	S Max.
M1008	0.10 Max.	0.25/0.60	0.04	0.05
M1010	0.07/0.14	0.25/0.60	0.04	0.05
M1012	0.09/0.16	0.25/0.60	0.04	0.05
M1015	0.12/0.19	0.25/0.60	0.04	0.05
M1017	0.14/0.21	0.25/0.60	0.04	0.05
M1020	0.17/0.24	0.25/0.60	0.04	0.05
M1023	0.19/0.27	0.25/0.60	0.04	0.05
M1025	0.20/0.30	0.25/0.60	0.04	0.05
M1031	0.26/0.36	0.25/0.60	0.04	0.05
M1044	0.40/0.50	0.25/0.60	0.04	0.05

STANDARD ALLOY STEELS

HEAT CHEMICAL RANGES and LIMITS

STEEL DESIGNATION AISI or SAE	UNS NUMBER	CHEMICAL COMPOSITION, PER CENT							
		C	Mn	P Max.	S Max.	Si	Ni	Cr	Mo
1330	G13300	0.28/0.33	1.60/1.90	0.035	0.040	0.15/0.35	—	—	—
1335	G13350	0.33/0.38	1.60/1.90	0.035	0.040	0.15/0.35	—	—	—
1340	G13400	0.38/0.43	1.60/1.90	0.035	0.040	0.15/0.35	—	—	—
4023	G40230	0.20/0.25	0.70/0.90	0.035	0.040	0.15/0.35	—	—	0.20/0.30
4027	G40270	0.25/0.30	0.70/0.90	0.035	0.040	0.15/0.35	—	—	0.20/0.30
4028	G40280	0.25/0.30	0.70/0.90	0.035	0.035/ 0.050	0.15/0.35	—	—	0.20/0.30
4037	G40370	0.35/0.40	0.70/0.90	0.035	0.040	0.15/0.35	—	—	0.20/0.30
4047	G40470	0.45/0.50	0.70/0.90	0.035	0.040	0.15/0.35	—	—	0.20/0.30
4118	G41180	0.18/0.23	0.70/0.90	0.035	0.040	0.15/0.35	—	0.40/0.60	0.08/0.15
4120*	G41200	0.18/0.23	0.90/1.20	0.035	0.040	0.15/0.35	—	0.40/0.60	0.13/0.20
4121**	G41210	0.18/0.23	0.75/1.00	0.035	0.040	0.15/0.35	—	0.45/0.65	0.20/0.30
4130	G41300	0.28/0.33	0.40/0.60	0.035	0.040	0.15/0.35	—	0.80/1.10	0.15/0.25
4131	G41310	0.28/0.33	0.50/0.70	0.035	0.040	0.15/0.35	—	0.90/1.20	0.15/0.25
4137	G41370	0.35/0.40	0.70/0.90	0.035	0.040	0.15/0.35	—	0.80/1.10	0.15/0.25
4140	G41400	0.38/0.43	0.75/1.00	0.035	0.040	0.15/0.35	—	0.80/1.10	0.15/0.25
4142	G41420	0.40/0.45	0.75/1.00	0.035	0.040	0.15/0.35	—	0.80/1.10	0.15/0.25
4145	G41450	0.43/0.48	0.75/1.00	0.035	0.040	0.15/0.35	—	0.80/1.10	0.15/0.25
4147	G41470	0.45/0.50	0.75/1.00	0.035	0.040	0.15/0.35	—	0.80/1.10	0.15/0.25
4150	G41500	0.48/0.53	0.75/1.00	0.035	0.040	0.15/0.35	—	0.80/1.10	0.15/0.25
4320	G43200	0.17/0.22	0.45/0.80	0.035	0.040	0.15/0.35	1.65/2.00	0.40/0.60	0.20/0.30
4340	G43400	0.38/0.43	0.60/0.80	0.035	0.040	0.15/0.35	1.65/2.00	0.70/0.90	0.20/0.30
E4340	G43406	0.38/0.43	0.65/0.85	0.025	0.025	0.15/0.35	1.65/2.00	0.70/0.90	0.20/0.30
4620	G46200	0.17/0.22	0.45/0.65	0.035	0.040	0.15/0.35	1.65/2.00	—	0.20/0.30
4715***	G47150	0.13/0.18	0.70/0.90	0.035	0.040	0.15/0.35	0.70/1.00	0.45/0.65	0.45/0.65
4720	G47200	0.17/0.22	0.50/0.70	0.035	0.040	0.15/0.35	0.90/1.20	0.35/0.55	0.15/0.25
4815	G48150	0.13/0.18	0.40/0.60	0.035	0.040	0.15/0.35	3.25/3.75	—	0.20/0.30
4820	G48200	0.18/0.23	0.50/0.70	0.035	0.040	0.15/0.35	3.25/3.75	—	0.20/0.30
50B46	G50461	0.44/0.49	0.75/1.00	0.035	0.040	0.15/0.35	—	0.20/0.35	—
5120	G51200	0.17/0.22	0.70/0.90	0.035	0.040	0.15/0.35	—	0.70/0.90	—
5130	G51300	0.28/0.33	0.70/0.90	0.035	0.040	0.15/0.35	—	0.80/1.10	—
5132	G51320	0.30/0.35	0.60/0.80	0.035	0.040	0.15/0.35	—	0.75/1.00	—
5140	G51400	0.38/0.43	0.70/0.90	0.035	0.040	0.15/0.35	—	0.70/0.90	—
5150	G51500	0.48/0.53	0.70/0.90	0.035	0.040	0.15/0.35	—	0.70/0.90	—
5160	G51600	0.56/0.64	0.75/1.00	0.035	0.040	0.15/0.35	—	0.70/0.90	—
51B60	G51601	0.56/0.64	0.75/1.00	0.035	0.040	0.15/0.35	—	0.70/0.90	—
E51100	G51896	0.98/1.10	0.25/0.45	0.025	0.025	0.15/0.35	—	0.90/1.15	—
E52100	G52986	0.98/1.10	0.25/0.45	0.025	0.025	0.15/0.35	—	1.30/1.60	—
6150	G61500	0.48/0.53	0.70/0.90	0.035	0.040	0.15/0.35	—	0.80/1.10	(0.15 min.V)
8615	G86150	0.13/0.18	0.70/0.90	0.035	0.040	0.15/0.35	0.40/0.70	0.40/0.60	0.15/0.25
8617	G86170	0.15/0.20	0.70/0.90	0.035	0.040	0.15/0.35	0.40/0.70	0.40/0.60	0.15/0.25
8620	G86200	0.18/0.23	0.70/0.90	0.035	0.040	0.15/0.35	0.40/0.70	0.40/0.60	0.15/0.25
8622	G86220	0.20/0.25	0.70/0.90	0.035	0.040	0.15/0.35	0.40/0.70	0.40/0.60	0.15/0.25

Continued on next page

STANDARD ALLOY STEELS — Continued

HEAT CHEMICAL RANGES and LIMITS

STEEL DESIGNATION AISI or SAE	UNS NUMBER	CHEMICAL COMPOSITION, PER CENT							
		C	Mn	P Max.	S Max.	Si	Ni	Cr	Mo
8630	G86300	0.28/0.33	0.70/0.90	0.035	0.040	0.15/0.35	0.40/0.70	0.40/0.60	0.15/0.25
3637	G86370	0.35/0.40	0.75/1.00	0.035	0.040	0.15/0.35	0.40/0.70	0.40/0.60	0.15/0.25
8640	G86400	0.38/0.43	0.75/1.00	0.035	0.040	0.15/0.35	0.40/0.70	0.40/0.60	0.15/0.25
8645	G86450	0.43/0.48	0.75/1.00	0.035	0.040	0.15/0.35	0.40/0.70	0.40/0.60	0.15/0.25
8720	G87200	0.18/0.23	0.70/0.90	0.035	0.040	0.15/0.35	0.40/0.70	0.40/0.60	0.20/0.30
8822	G88220	0.20/0.25	0.75/1.00	0.035	0.040	0.15/0.35	0.40/0.70	0.40/0.60	0.30/0.40
9259	G92590	0.56/0.64	0.75/1.00	0.035	0.040	0.70/1.10	—	0.45/0.65	—
9260	G92600	0.56/0.64	0.75/1.00	0.035	0.040	1.80/2.20	—	—	—
9310****	G93106	0.08/0.13	0.45/0.65	0.025	0.025	0.15/0.35	3.00/3.50	1.00/1.40	0.08/0.15

* Formerly EX 15
** Formerly EX 24
*** Formerly EX 30
**** SAE Only (electric furnace)

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

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

Note 3. For acid electric and acid open hearth steels, the limits for phosphorus and sulfur are 0.050 per cent respectively.

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

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

Note 6. The chemical ranges and limits shown in the table and in the notes are subject to product analysis tolerances.

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

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

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

STANDARD ALLOY H-STEELS

HEAT CHEMICAL RANGES and LIMITS									
STEEL DESIGNATION AISI or SAE	UNS NUMBER	CHEMICAL COMPOSITION, PER CENT							
		C	Mn	P Max.	S Max.	Si	Ni	Cr	Mo
1330 H	H13300	0.27/0.33	1.45/2.05	0.035	0.040	0.15/0.35	—	—	—
1335 H	H13350	0.32/0.38	1.45/2.05	0.035	0.040	0.15/0.35	—	—	—
1340 H	H13400	0.37/0.44	1.45/2.05	0.035	0.040	0.15/0.35	—	—	—
4027 H	H40270	0.24/0.30	0.60/1.00	0.035	0.040	0.15/0.35	—	—	0.20/0.30
4028 H	H40280	0.24/0.30	0.60/1.00	0.035	0.035/ 0.050	0.15/0.35	—	—	0.20/0.30
4037 H	H40370	0.34/0.41	0.60/1.00	0.035	0.040	0.15/0.35	—	—	0.20/0.30
4047 H	H40470	0.44/0.51	0.60/1.00	0.035	0.040	0.15/0.35	—	—	0.20/0.30
4118 H	H41180	0.17/0.23	0.60/1.00	0.035	0.040	0.15/0.35	—	0.30/0.70	0.08/0.15
4130 H	H41300	0.27/0.33	0.30/0.70	0.035	0.040	0.15/0.35	—	0.75/1.20	0.15/0.25
4135 H	H41350	0.32/0.38	0.60/1.00	0.035	0.040	0.15/0.35	—	0.75/1.20	0.15/0.25
4137 H	H41370	0.34/0.41	0.60/1.00	0.035	0.040	0.15/0.35	—	0.75/1.20	0.15/0.25
4140 H	H41400	0.37/0.44	0.65/1.10	0.035	0.040	0.15/0.35	—	0.75/1.20	0.15/0.25
4142 H	H41420	0.39/0.46	0.65/1.10	0.035	0.040	0.15/0.35	—	0.75/1.20	0.15/0.25
4145 H	H41450	0.42/0.49	0.65/1.10	0.035	0.040	0.15/0.35	—	0.75/1.20	0.15/0.25
4147 H	H41470	0.44/0.51	0.65/1.10	0.035	0.040	0.15/0.35	—	0.75/1.20	0.15/0.25
4150 H	H41500	0.47/0.54	0.65/1.10	0.035	0.040	0.15/0.35	—	0.75/1.20	0.15/0.25
4320 H	H43200	0.17/0.23	0.40/0.70	0.035	0.040	0.15/0.35	1.55/2.00	0.35/0.65	0.20/0.30
4340 H	H43400	0.37/0.44	0.55/0.90	0.035	0.040	0.15/0.35	1.55/2.00	0.65/0.95	0.20/0.30
E4340 H	H43406	0.37/0.44	0.60/0.95	0.035	0.025	0.15/0.35	1.55/2.00	0.65/0.95	0.20/0.30
4620 H	H46200	0.17/0.23	0.35/0.75	0.035	0.040	0.15/0.35	1.55/2.00	—	0.20/0.30
4720 H	H47200	0.17/0.23	0.45/0.75	0.035	0.040	0.15/0.35	0.85/1.25	0.30/0.60	0.15/0.25
4815 H	H48150	0.12/0.18	0.30/0.70	0.035	0.040	0.15/0.35	3.20/3.80	—	0.20/0.30
4820 H	H48200	0.17/0.23	0.40/0.80	0.035	0.040	0.15/0.35	3.20/3.80	—	0.20/0.30
50B46 H	H50461	0.43/0.50	0.65/1.10	0.035	0.040	0.15/0.35	—	0.13/0.43	—
5120 H	H51200	0.17/0.23	0.60/1.00	0.035	0.040	0.15/0.35	—	0.60/1.00	—
5130 H	H51300	0.27/0.33	0.60/1.00	0.035	0.040	0.15/0.35	—	0.75/1.20	—
5132 H	H51320	0.29/0.35	0.50/0.90	0.035	0.040	0.15/0.35	—	0.65/1.10	—
5140 H	H51400	0.37/0.44	0.60/1.00	0.035	0.040	0.15/0.35	—	0.60/1.00	—
5150 H	H51500	0.47/0.54	0.60/1.00	0.035	0.040	0.15/0.35	—	0.60/1.00	—
5160 H	H51600	0.55/0.65	0.65/1.10	0.035	0.040	0.15/0.35	—	0.60/1.00	—
51B60 H	H51601	0.55/0.65	0.65/1.10	0.035	0.040	0.15/0.35	—	0.60/1.00	—
6150 H	H61500	0.47/0.54	0.60/1.00	0.035	0.040	0.15/0.35	—	0.75/1.20	(0.15 min.V)
8617 H	H86170	0.14/0.20	0.60/0.95	0.035	0.040	0.15/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8620 H	H86200	0.17/0.23	0.60/0.95	0.035	0.040	0.15/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8622 H	H86220	0.19/0.25	0.60/0.95	0.035	0.040	0.15/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8630 H	H86300	0.27/0.33	0.60/0.95	0.035	0.040	0.15/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8637 H	H86370	0.34/0.41	0.70/1.05	0.035	0.040	0.15/0.35	0.35/0.75	0.35/0.65	0.15/0.31
8640 H	H86400	0.37/0.44	0.70/1.05	0.035	0.040	0.15/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8645 H	H86450	0.42/0.49	0.70/1.05	0.035	0.040	0.15/0.35	0.35/0.75	0.35/0.65	0.15/0.25
8720 H	H87200	0.17/0.23	0.60/0.95	0.035	0.040	0.15/0.35	0.35/0.75	0.35/0.65	0.20/0.30
8822 H	H88220	0.19/0.25	0.70/1.05	0.035	0.040	0.15/0.35	0.35/0.75	0.35/0.65	0.30/0.40
9260 H	H92600	0.55/0.65	0.65/1.10	0.035	0.040	1.70/2.20	—	—	—

See notes on next page

STANDARD ALLOY H-STEELS — Continued

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

Note 2. If electric furnace practice is specified or required for grades other than those designated (E4340 H) the limits for phosphorus and sulfur are 0.025 per cent respectively and the prefix E is added.

Note 3. For acid electric and acid open hearth steels, the limits for phosphorus and sulfur are 0.050 per cent respectively.

Note 4. Small quantities of certain elements are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: Copper, 0.35 per cent; Nickel, 0.25 per cent; Chromium, 0.20 per cent; and Molybdenum, 0.06 per cent.

Note 5. Standard alloy H-Steels can be produced with a lead range of 0.15/0.35 per cent. Such steels are identified by inserting the letter L between the second and third numeral of the AISI number, e.g. 41L40 H. Lead is generally reported as a range of 0.15/0.35 per cent.

Note 6. Where minimum and maximum sulfur content is shown, it is indicative of resulfurized steel.

END-QUENCH HARDENABILITY TESTING

Standard steel grades bearing the "H" suffix are known as "H-steels" and have been tested for hardenability. The most commonly used method of determining hardenability is the end-quench test developed by Jominy and Boegehold. In conducting the test, a 1-inch-round specimen 4 inches long is first normalized to eliminate the variable of prior microstructure, then heated uniformly to a standard austenitizing temperature. The specimen is removed from the furnace, placed in a jig, and immediately end-quenched by a jet of water maintained at room temperature. The water contacts the end-face of the specimen without wetting the sides, and quenching is continued until the entire specimen has cooled. Longitudinal flat surfaces are ground on opposite sides of the quenched specimen, and Rockwell C scale readings are taken at 16th-inch intervals for the first inch from the quenched end, and at greater intervals beyond that point until a hardness level of HRC 20 or a distance of 2 inches from the quenched end is reached. A hardenability curve is usually plotted using Rockwell C readings as ordinates and distances from the quenched end as abscissas. Representative data have been accumulated for a variety of standard grades and are shown on pages H•31-34. The data are given in tabular form to show the high and low limits applicable to each grade.

PRODUCT ANALYSIS TOLERANCES
ALLOY STEELS

PRODUCT ANALYSIS TOLERANCES		
ELEMENTS	Limit, or Maximum of Specified Range, Per Cent	Permissible Variations Over Maximum Limit or Under Minimum Limit, %
Carbon	0.30 and under over 0.30 to 0.75, incl. over 0.75	0.01 0.02 0.03
Manganese	0.90 and under over 0.90 to 2.10, incl.	0.03 0.04
Phosphorus	over maximum only	0.005
Sulfur	0.060 and under	0.005
Silicon	0.40 and under over 0.40 to 2.20, incl.	0.02 0.05
Nickel	1.00 and under over 1.00 to 2.00, incl. over 2.00 to 5.30, incl. over 5.30 to 10.00, incl.	0.03 0.05 0.07 0.10
Chromium	0.90 and under over 0.90 to 2.10, incl. over 2.10 to 3.99, incl.	0.03 0.05 0.10
Molybdenum	0.20 and under over 0.20 to 0.40, incl. over 0.40 to 1.15, incl.	0.01 0.02 0.03
Vanadium	0.10 and under over 0.10 to 0.25, incl. over 0.25 to 0.50, incl. minimum value specified, under minimum limit only	0.01 0.02 0.03 0.01
Tungsten	1.00 and under over 1.00 to 4.00, incl.	0.04 0.08
Aluminum	0.10 and under over 0.10 to 0.20, incl. over 0.20 to 0.30, incl. over 0.30 to 0.80, incl. over 0.80 to 1.80, incl.	0.03 0.04 0.05 0.07 0.10
Lead[A]	0.15 to 0.35, incl.	0.03
Copper	to 0.100 incl. over 1.00 to 2.00, incl.	0.03 0.05

[A] Product analysis tolerance for lead applies both over and under to a specified range of 0.15 to 0.35%.

FORMERLY STANDARD STEELS

HEAT CHEMICAL RANGES and LIMITS

SAE No.	UNS No.	CHEMICAL COMPOSITION, PER CENT									AISI No.	Date
		C	Mn	P, Max[b]	S, Max[b]	Si	Cr	Ni	Mo	V, Min		
1009	—	0.15 max	0.60 max	0.040 max	0.050 max	—	—	—	—	—	1009	1965
1013[c]	G10130	0.11-0.16	0.50-0.80	0.040	0.050	—	—	—	—	—	—	
1019[c]	G10190	0.15-0.20	0.70-1.00	0.040	0.050	—	—	—	—	—	—	
1033	—	0.30-0.36	0.70-1.00	0.040 max	0.050 max	—	—	—	—	—	1033	1965
1034	—	0.32-0.38	0.50-0.80	0.040 max	0.050 max	—	—	—	—	—	C1034	1968
1037[c]	G10370	0.32-0.38	0.70-1.00	0.040	0.050	—	—	—	—	—	—	
1059[c]	—	0.55-0.65	0.50-0.80	0.040 max	0.050 max	—	—	—	—	—	—	1968
1062	—	0.54-0.65	0.85-1.15	0.040 max	0.050 max	—	—	—	—	—	C1062	1953
1064[c]	G10640	0.60-0.70	0.50-0.80	0.040	0.050	—	—	—	—	—	—	
1069[c]	G10690	0.65-0.75	0.40-0.70	0.040	0.050	—	—	—	—	—	—	
1075[c]	G10750	0.70-0.80	0.40-0.70	0.040	0.050	—	—	—	—	—	—	
1084[c]	G10840	0.80-0.93	0.60-0.90	0.040	0.050	—	—	—	—	—	—	
1085	G10850	0.80-0.93	0.70-1.00	0.040	0.050	—	—	—	—	—	—	
1086[c]	G10860	0.80-0.94	0.30-0.50	0.040 max	0.050 max	—	—	—	—	—	—	1977
1108[c]	G11080	0.08-0.13	0.50-0.80	0.040	0.08-0.13	—	—	—	—	—	—	
1109	G11090	0.08-0.13	0.60-0.90	0.040 max	0.08-0.13	—	—	—	—	—	1109	1977
1111	—	0.13 max	0.60-0.90	0.07-0.12	0.10-0.15	—	—	—	—	—	B1111	1969
1112	—	0.13 max	0.70-1.00	0.07-0.12	0.16-0.23	—	—	—	—	—	B1112	1969
1113	—	0.13 max	0.70-1.00	0.07-0.12	0.24-0.33	—	—	—	—	—	B1113	1969
1114	—	0.10-0.16	1.00-1.30	0.040 max	0.08-0.13	—	—	—	—	—	C1114	1952
1115	—	0.13-0.18	0.60-0.90	0.040 max	0.08-0.13	—	—	—	—	—	1115	1965
1116	—	0.14-0.20	1.10-1.40	0.040 max	0.16-0.23	—	—	—	—	—	C1116	1952
1119	G11190	0.14-0.20	1.00-1.30	0.040 max	0.24-0.33	—	—	—	—	—	1119	1977
1120	—	0.18-0.23	0.70-1.00	0.040 max	0.08-0.13	—	—	—	—	—	1120	1965
1126	—	0.23-0.29	0.70-1.00	0.040 max	0.08-0.13	—	—	—	—	—	1126	1965
1132	G11320	0.27-0.34	1.35-1.65	0.040 max	0.08-0.13	—	—	—	—	—	1132	1977
1138	—	0.34-0.40	0.70-1.00	0.040 max	0.08-0.13	—	—	—	—	—	1138	1965
1139[c]	G11390	0.35-0.43	1.35-1.65	0.040	0.13-0.20	—	—	—	—	—	—	

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SAE No.	UNS No.	CHEMICAL COMPOSITION, PER CENT									AISI No.	Date
		C	Mn	P, Max[b]	S, Max[b]	Si	Cr	Ni	Mo	V, Min		
1145	G11450	0.42-0.49	0.70-1.00	0.040 max	0.04-0.07	—	—	—	—	—	1145	1977
1151[c]	G11510	0.48-0.55	0.70-1.00	0.040	0.08-0.13	—	—	—	—	—	—	
1211[c]	G12110	0.13 max	0.60-0.90	0.07-0.12	0.10-0.15	—	—	—	—	—		
1320	—	0.18-0.23	1.60-1.90	0.040	0.040	0.20-0.35	—	—	—	—	A1320	1956
1345	G13450	0.43-0.48	1.60-1.90	0.035	0.040	0.15-0.35	—	—	—	—		
1518	G15180	0.15-0.21	1.10-1.40	0.040 max	0.050 max	—	—	—	—	—	—	1977
1525	G15250	0.23-0.29	0.80-1.10	0.040 max	0.050 max	—	—	—	—	—	—	1977
1536	G15360	0.30-0.37	1.20-1.50	0.040	0.050	—	—	—	—	—		
1547	G15470	0.43-0.51	1.35-1.65	0.040 max	0.050 max	—	—	—	—	—	—	1977
1551	G15510	0.45-0.56	0.85-1.15	0.040	0.050	—	—	—	—	—		
1561	G15610	0.55-0.65	0.75-1.05	0.040	0.050	—	—	—	—	—		
1572	G15720	0.65-0.76	1.00-1.30	0.040 max	0.050 max	—	—	—	—	—	—	1977
2317	—	0.15-0.20	0.40-0.60	0.040	0.040	0.20-0.35	—	3.25-3.75	—	—	A2317	1956
2330	—	0.28-0.33	0.60-0.80	0.040	0.040	0.20-0.35	—	3.25-3.75	—	—	A2330	1953
2340	—	0.38-0.43	0.70-0.90	0.040	0.040	0.20-0.35	—	3.25-3.75	—	—	A2340	1953
2345	—	0.43-0.48	0.70-0.90	0.040	0.040	0.20-0.35	—	3.25-3.75	—	—	A2345	1952
2512	—	0.09-0.14	0.45-0.60	0.025	0.025	0.20-0.35	—	4.75-5.25	—	—	E2512	1953
2515	—	0.12-0.17	0.40-0.60	0.040	0.040	0.20-0.35	—	4.75-5.25	—	—	A2515	1956
2517	—	0.15-0.20	0.45-0.60	0.025	0.025	0.20-0.35	—	4.75-5.25	—	—	E2517	1959
3115	—	0.13-0.18	0.40-0.60	0.040	0.040	0.20-0.35	0.55-0.75	1.10-1.40	—	—	A3115	1953
3120	—	0.17-0.22	0.60-0.80	0.040	0.040	0.20-0.35	0.55-0.75	1.10-1.40	—	—	A3120	1956
3130	—	0.28-0.33	0.60-0.80	0.040	0.040	0.20-0.35	0.55-0.75	1.10-1.40	—	—	A3130	1956
3135	—	0.33-0.38	0.60-0.80	0.040	0.040	0.20-0.35	0.55-0.75	1.10-1.40	—	—	3135	1960
X3140	—	0.38-0.43	0.70-0.90	0.040	0.040	0.20-0.35	0.70-0.90	1.10-1.40	—	—	A3141	1947
3140	—	0.38-0.43	0.70-0.90	0.040	0.040	0.20-0.35	0.55-0.75	1.10-1.40	—	—	3140	1964
3145	—	0.43-0.48	0.70-0.90	0.040	0.040	0.20-0.35	0.70-0.90	1.10-1.40	—	—	A3145	1952

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		C	Mn	P, Max[b]	S, Max[b]	Si	Cr	Ni	Mo	V, Min		
3150	—	0.48-0.53	0.70-0.90	0.040	0.040	0.20-0.35	0.70-0.90	1.10-1.40	—	—	A3150	1952
3215	—	0.10-0.20	0.30-0.60	0.040	0.050	0.15-0.30	0.90-1.25	1.50-2.00	—	—	—	1941
3220	—	0.15-0.25	0.30-0.60	0.040	0.050	0.15-0.30	0.90-1.25	1.50-2.00	—	—	—	1941
3230	—	0.25-0.35	0.30-0.60	0.040	0.050	0.15-0.30	0.90-1.25	1.50-2.00	—	—	—	1941
3240	—	0.35-0.45	0.30-0.60	0.040	0.040	0.15-0.30	0.90-1.25	1.50-2.00	—	—	A3240	1941
3245	—	0.40-0.40	0.30-0.60	0.040	0.040	0.15-0.30	0.90-1.25	1.50-2.00	—	—	—	1941
3250	—	0.45-0.55	0.30-0.60	0.040	0.040	0.15-0.30	0.90-1.25	1.50-2.00	—	—	—	1941
3310	—	0.08-0.13	0.45-0.60	0.025	0.025	0.20-0.35	1.40-1.75	3.25-3.75	—	—	E3310	1964
3312	—	0.08-0.13	0.45-0.60	0.025	0.025	0.20-0.35	1.40-1.75	3.25-3.75	—	—	—	1948
3316	—	0.14-0.19	0.45-0.60	0.025	0.025	0.20-0.35	1.40-1.75	3.25-3.75	—	—	E3316	1956
3325	—	20-30	0.30-0.60	0.040	0.050	0.15-0.30	1.25-1.75	3.25-3.75	—	—	—	1936
3335	—	30-40	0.30-0.60	0.040	0.050	0.15-0.30	1.25-1.75	3.25-3.75	—	—	—	1936
3340	—	35-45	0.30-0.60	0.040	0.050	0.15-0.30	1.25-1.75	3.25-3.75	—	—	—	1936
3415	—	0.10-0.20	0.30-0.60	0.040	0.050	0.15-0.30	0.60-0.95	2.75-3.25	—	—	—	1941
3435	—	0.30-0.40	0.30-0.60	0.040	0.050	0.15-0.30	0.60-0.95	2.75-3.25	—	—	—	1936
3450	—	0.45-0.55	0.30-0.60	0.040	0.050	0.15-0.30	0.60-0.95	2.75-3.25	—	—	—	1936
4012	G40120	0.09-0.14	0.75-1.00	0.035	0.040	0.15-0.30	—	—	0.15-0.25	—	4012	1977
4024	G40240	0.20-0.25	0.70-0.90	0.035	0.035-0.50	0.15-0.30	—	—	0.20-0.30	—		
4032	G40320	0.30-0.35	0.70-0.90	0.035	0.040	0.15-0.30	—	—	0.20-0.30	—		
4042	G40420	0.40-0.45	0.70-0.90	0.035	0.040	0.15-0.30	—	—	0.20-0.30	—		
4053	—	0.50-0.56	0.75-1.00	0.040	0.040	0.20-0.35	—	—	0.20-0.30	—	4053	1956
4063	G40630	0.60-0.67	0.75-1.00	0.040	0.040	0.20-0.35	—	—	0.20-0.30	—	4063	1964
4068	—	0.63-0.70	0.75-1.00	0.040	0.040	0.20-0.35	—	—	0.20-0.30	—	A4068	1957
4119	—	0.17-0.22	0.70-0.90	0.040	0.040	0.20-0.35	0.40-0.60	—	0.20-0.30	—	A4119	1956
4125	—	0.23-0.28	0.70-0.90	0.040	0.040	0.20-0.35	0.40-0.60	—	0.20-0.30	—	A4125	1950
4135	G41350	0.33-0.38	0.70-0.90	0.035	0.040	0.15-0.35	0.80-1.10	—	0.15-0.25	—		
4161	G41610	0.56-0.64	0.75-1.00	0.035	0.040	0.15-0.35	0.70-0.90	—	0.25-0.35	—		

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SAE No.	UNS No.	CHEMICAL COMPOSITION, PER CENT									AISI No.	Date
		C	Mn	P, Max[b]	S, Max[b]	Si	Cr	Ni	Mo	V, Min		
4317	—	0.15-0.20	0.45-0.65	0.040	0.040	0.20-0.35	0.40-0.60	1.65-2.00	0.20-0.30	—	4317	1953
4337	G43370	0.35-0.40	0.60-0.80	0.040	0.040	0.20-0.35	0.70-0.90	1.65-2.00	0.20-0.30	—	4337	1964
4419	—	0.18-0.23	0.45-0.65	0.035	0.040	0.15-0.30	—	—	0.45-0.60	—	4520	1977
4419 H	—	0.17-0.23	0.35-0.75	0.035	0.040	0.15-0.30	—	—	0.45-0.60	—	4419H	1977
4422	G44220	0.20-0.25	0.70-0.90	0.035	0.040	0.15-0.35	—	—	0.35-0.45	—		
4427	G44270	0.24-0.29	0.70-0.90	0.035	0.040	0.15-0.35	—	—	0.35-0.45	—		
4608	—	0.06-0.11	0.25-0.45	0.040	0.040	0.25 max	—	1.40-1.75	0.15-0.25	—	4608	1956
46B12[a]	—	0.10-0.15	0.45-0.65	0.040	0.040	0.20-0.35	—	1.65-2.00	0.20-0.30	—	46B12[a]	1957
4615	G46150	0.13-0.18	0.45-0.65	0.035	0.040	0.15-0.35	—	1.65-2.00	0.20-0.30	—		
4617	G46170	0.15-0.20	0.45-0.65	0.035	0.040	0.15-0.35	—	1.65-2.00	0.20-0.30	—		
X4620	—	0.18-0.23	0.50-0.70	0.040	0.040	0.20-0.35	—	1.65-2.00	0.20-0.30	—	X4620	1956
4621	G46210	0.18-0.23	0.70-0.90	0.035	0.040	0.15-0.30	—	1.65-2.00	0.20-0.30	—	4621	1977
4621 H	—	0.17-0.23	0.60-1.00	0.035	0.040	0.15-0.30	—	1.55-2.00	0.20-0.30	—	4621H	1977
4626	G46260	0.24-0.29	0.45-0.65	0.035	0.040 max	0.15-0.35	—	0.70-1.00	0.15-0.25	—		
4640	—	0.38-0.43	0.60-0.80	0.040	0.040	0.20-0.35	—	1.65-2.00	0.20-0.30	—	A4640	1952
4718	G47180	0.16-0.21	0.70-0.90	—	—	—	0.35-0.55	0.90-1.20	0.30-0.40	—		
4812	—	0.10-0.15	0.40-0.60	0.040	0.040	0.20-0.35	—	3.25-3.75	0.20-0.30	—	4817	1956
4817	G48170	0.15-0.20	0.40-0.60	0.035	0.040	0.15-0.35	—	3.25-3.75	0.20-0.30	—		
5015	G50150	0.12-0.17	0.30-0.50	0.035	0.040	0.15-0.30	0.30-0.50	—	—	—	5015	1977
50B40[a]	B50401	0.38-0.43	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	—	—	—		
50B44[a]	G50441	0.43-0.48	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	—	—	—		
5045	—	0.43-0.48	0.70-0.90	0.040	0.040	0.20-0.35	0.55-0.75	—	—	—	5045	1953
5046	G50460	0.43-0.48	0.75-1.00	0.035	0.040	0.15-0.35	0.20-0.35	—	—	—		
50B50[a]	G50501	0.48-0.53	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	—	—	—		
5060	G50600	0.56-0.64	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	—	—	—		

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HEAT CHEMICAL RANGES and LIMITS

SAE No.	UNS No.	CHEMICAL COMPOSITION, PER CENT									AISI No.	Date
		C	Mn	P, Max[b]	S, Max[b]	Si	Cr	Ni	Mo	V, Min		
50B60 [a]	G50601	0.56-0.64	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	—	—	—		
5115	G51150	0.13-0.18	0.70-0.90	0.035	0.040	0.15-0.35	0.70-0.90	—	—	—		
5117	G51170	0.15-0.20	0.70-0.90	0.040	0.040	0.15-0.35	0.70-0.90	—	—	—		
5135	G51350	0.33-0.38	0.60-0.80	0.035	0.040	0.15-0.35	0.80-1.05	—	—	—		
5145	G51450	0.43-0.48	0.70-0.90	0.035	0.040	0.15-0.30	0.70-0.90	—	—	—		
5145 H	H51450	0.42-0.49	0.60-1.00	0.035	0.040	0.15-0.30	0.60-1.00	—	—	—	5145	1977
5147	G51470	0.46-0.51	0.70-0.95	0.035	0.040	0.15-0.35	0.85-1.15	—	—	—	5145H	1977
5152	—	0.48-0.55	0.70-0.90	0.040	0.040	0.20-0.35	0.90-1.20	—	—	—	5152	1956
5155	G51550	0.51-0.59	0.70-0.90	0.035	0.040	0.15-0.35	0.70-0.90	—	—	—	—	
50100	G50986	0.98-1.10	0.25-0.45	0.025	0.025	0.15-0.35	0.40-0.60	—	—	—	—	
6115	—	0.10-0.20	0.30-0.60	0.040	0.050	0.15-0.30	0.80-1.10	—	—	0.15	—	1936
6117	—	0.15-0.20	0.70-0.90	0.040	0.040	0.20-0.35	0.70-0.90	—	—	0.10	6117	1956
6118	G61180	0.16-0.21	0.50-0.70	0.035	0.040	0.15-0.35	0.50-0.70	—	V-0.10-0.15	—		
6120	—	0.17-0.22	0.70-0.90	0.040	0.040	0.20-0.35	0.70-0.90	—	—	0.10	6120	1961
6125	—	0.20-0.30	0.60-0.90	0.040	0.050	0.15-0.30	0.80-1.10	—	—	0.15	—	1936
6130	—	0.25-0.35	0.60-0.90	0.040	0.050	0.15-0.30	0.80-1.10	—	—	0.15	—	1936
6135	—	0.30-0.40	0.60-0.90	0.040	0.050	0.15-0.30	0.80-1.10	—	—	0.15	—	1941
6140	—	0.35-0.45	0.60-0.90	0.040	0.050	0.15-0.30	0.80-1.10	—	—	0.15	—	1936
6145	—	0.43-0.48	0.70-0.90	0.040	0.050	0.20-0.35	0.80-1.10	—	—	0.15	6145	1956
6195	—	0.90-1.05	0.20-0.45	0.030	0.035	0.15-0.30	0.80-1.10	—	—	0.15	—	1936
71360	—	0.50-0.70	0.30 max	0.035	0.040	0.15-0.30	3.00-4.00	12.00-15.00W	—	—	—	1936
71660	—	0.50-0.70	0.30 max	0.035	0.040	0.15-0.30	3.00-4.00	15.00-18.00W	—	—	—	1936
7260	—	0.50-0.70	0.30 max	0.035	0.040	0.15-0.30	0.50-1.00	1.50-2.00W	—	—	—	1936
8115	G81150	0.13-0.18	0.70-0.90	0.035	0.040	0.15-0.35	0.30-0.50	0.20-0.40	0.08-0.15	—	—	
81B45 [a]	G81451	0.43-0.48	0.75-1.00	0.035	0.040	0.15-0.35	0.35-0.55	0.20-0.40	0.08-0.15	—	—	
8625	G86250	0.23-0.28	0.70-0.90	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.70	0.15-0.25	—	—	
8627	G86270	0.25-0.30	0.70-0.90	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.70	0.15-0.25	—	—	

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SAE No.	UNS No.	CHEMICAL COMPOSITION, PER CENT									AISI No.	Date
		C	Mn	P, Max[b]	S, Max[b]	Si	Cr	Ni	Mo	V, Min		
8632	—	0.30-0.35	0.70-0.90	0.040	0.040	0.20-0.35	0.40-0.60	0.40-0.70	0.15-0.25	—	8632	1951
8635	—	0.33-0.38	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.60	0.40-0.70	0.15-0.25	—	8635	1956
8641	—	0.38-0.43	0.75-1.00	0.040	0.040-0.60	0.20-0.35	0.40-0.60	0.40-0.70	0.15-0.25	—	8641	1956
8642	G86420	0.40-0.45	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.70	0.15-0.25	—	—	
86B45[a]	G86451	0.43-0.48	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.70	0.15-0.25	—	—	
8650	G86500	0.48-0.53	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.70	0.15-0.25	—	—	
8653	—	0.50-0.56	0.75-1.00	0.040	0.040	0.20-0.35	0.50-0.80	0.40-0.70	0.15-0.25	—	8653	1956
8647	—	0.45-0.50	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.60	0.40-0.70	0.15-0.25	—	8647	1948
8655	G86550	0.51-0.59	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.70	0.15-0.25	—	—	
8660	G86600	0.56-0.64	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.70	0.15-0.25	—	—	
8715	—	0.13-0.18	0.70-0.90	0.040	0.040	0.20-0.35	0.40-0.60	0.40-0.70	0.20-0.30	—	8715	1956
8717	—	0.15-0.20	0.70-0.90	0.040	0.040	0.20-0.35	0.40-0.60	0.40-0.70	0.20-0.30	—	8717	1956
8719	—	0.18-0.23	0.60-0.80	0.040	0.040	0.20-0.35	0.40-0.60	0.40-0.70	0.20-0.30	—	8719	1952
8735	G87350	0.33-0.38	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.60	0.40-0.70	0.20-0.30	—	8735	1952
8740	G87400	0.38-0.43	0.75-1.00	0.035	0.040	0.15-0.35	0.40-0.60	0.40-0.70	0.20-0.30	—	—	
8742	G87420	0.40-0.45	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.60	0.40-0.70	0.20-0.30	—	8742	1964
8745	—	0.43-0.48	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.60	0.40-0.70	0.20-0.30	—	8745	1953
8750	—	0.48-0.53	0.75-1.00	0.040	0.040	0.20-0.35	0.40-0.60	0.40-0.70	0.20-0.30	—	8750	1956
9250	—	0.45-0.55	0.60-0.90	0.040	0.040	1.80-2.20	—	—	—	—	9250	1941
9254[c]	G92540	0.51-0.59	0.60-0.80	0.035	0.040	1.20-1.60	0.60-0.80	—	—	—	—	
9255	G92550	0.51-0.59	0.70-0.95	0.035	0.040	1.80-2.20	—	—	—	—	9255	1977
9261	—	0.55-0.65	0.75-1.00	0.040	0.040	1.80-2.20	0.10-0.25	—	—	—	9261	1956
9262	G92620	0.55-0.65	0.75-1.00	0.040	0.040	1.80-2.20	0.25-0.40	—	—	—	9262	1961
9310	G93100	0.08-0.13	0.45-0.65	0.025	0.025	0.15-0.35	1.00-1.40	3.00-3.50	0.08-0.15	—	—	
9315	—	0.13-0.18	0.45-0.65	0.025	0.025	0.20-0.35	1.00-1.40	3.00-3.50	0.08-0.15	—	E9315	1959
9317	—	0.15-0.20	0.45-0.65	0.025	0.025	0.20-0.35	1.00-1.40	3.00-3.50	0.08-0.15	—	E9317	1959
94B15[a]	G94151	0.13-0.18	0.75-1.00	0.035	0.040	0.15-0.35	0.30-0.50	0.30-0.60	0.08-0.15	—	—	

FORMERLY STANDARD STEELS — Continued

HEAT CHEMICAL RANGES and LIMITS

SAE No.	UNS No.	CHEMICAL COMPOSITION, PER CENT									AISI No.	Date
		C	Mn	P, Max[b]	S, Max[b]	Si	Cr	Ni	Mo	V, Min		
94B17[a]	G94171	0.15-0.20	0.75-1.00	0.035	0.040	0.15-0.35	0.30-0.50	0.30-0.60	0.08-0.15	—	—	
94B30[a]	G94301	0.28-0.33	0.75-1.00	0.035	0.040	0.15-0.35	0.30-0.50	0.30-0.60	0.08-0.15	—	—	
9437	—	0.35-0.40	0.90-1.20	0.040	0.040	0.20-0.35	0.30-0.50	0.30-0.60	0.08-0.15	—	9437	1950
9440	—	0.38-0.43	0.90-1.20	0.040	0.040	0.20-0.35	0.30-0.50	0.30-0.60	0.08-0.15	—	9440	1950
94B40[a]	G94401	0.38-0.43	0.75-1.00	0.040	0.040	0.20-0.35	0.30-0.60	0.30-0.60	0.08-0.15	—	94B40	1964
9442	—	0.40-0.45	0.90-1.20	0.040	0.040	0.20-0.35	0.30-0.50	0.30-0.60	0.08-0.15	—	9442	1950
9445	—	0.43-0.48	0.90-1.20	0.040	0.040	0.20-0.35	0.30-0.50	0.30-0.60	0.08-0.15	—	9445	1950
9447	—	0.45-0.50	0.90-1.20	0.040	0.040	0.20-0.35	0.30-0.50	0.30-0.60	0.08-0.15	—	9447	1950
9747	—	0.45-0.50	0.50-0.80	0.040	0.040	0.20-0.35	0.10-0.25	0.40-0.70	0.15-0.25	—	9747	1950
9763	—	0.60-0.67	0.50-0.80	0.040	0.040	0.20-0.35	0.10-0.25	0.40-0.70	0.15-0.25	—	9763	1950
9840	G98400	0.38-0.43	0.70-0.90	0.040	0.040	0.20-0.35	0.70-0.90	0.85-1.15	0.20-0.30	—	9840	1964
9845	—	0.43-0.48	0.70-0.90	0.040	0.040	0.20-0.35	0.70-0.90	0.85-1.15	0.20-0.30	—	9845	1950
9850	G98500	0.48-0.53	0.70-0.90	0.040	0.040	0.20-0.35	0.70-0.90	0.85-1.15	0.20-0.30	—	9850	1961
43BV12[a]	—	0.08-0.13	0.75-1.00	—	—	0.20-0.35	0.40-0.60	1.65-2.00	0.20-0.30	0.03	—	
43BV14[a]	—	0.10-0.15	0.45-0.65	—	—	0.20-0.35	0.40-0.60	1.65-2.00	0.08-0.15	0.03	—	

[a]Boron content 0.0005-0.003%.
[b]Limits apply to semi-finished products for forgings, bars, wire rods, and seamless tubing.
[c]These grades remain standard for wire rods.

AISI/SAE NUMBERING SYSTEM
STAINLESS & HEAT RESISTING STEELS

The traditional AISI system for identifying grades of stainless and heat resisting steels uses three digits; the first indicates series or group and the second two identify the specific type. Suffixes are used to indicate variation in chemistry ranges.

SAE uses a five digit designation with the last three digits being the same as the corresponding AISI designation. A suffix is added to the SAE five digit designation to indicate free machining steels and variations in carbon or silicon range.

The six character UNS Numbering System (UNS) uses an "S" followed by five digits to identify stainless steels. The first three digits are often identical to the AISI grade designation.

STAINLESS STEEL IDENTIFICATION

AISI SERIES DESIGNATION	SAE SERIES DESIGNATIONS	UNS SERIES DESIGNATIONS	GROUPS
2xx	302xx	S2xxxx	CHROMIUM-NICKEL-MANGANESE; non-hardenable, austenitic and non-magnetic.
3xx	303xx	S3xxxx	CHROMIUM-NICKEL; non-hardenable, austenitic and non-magnetic.
4xx	514xx	S4xxxx	CHROMIUM; hardenable, martensitic and magnetic.
4xx	514xx	S4xxxx	CHROMIUM; non-hardenable, ferritic and magnetic.
5xx	515xx	S5xxxx	CHROMIUM; low chromium heat resisting.

SIZE TOLERANCES
STAINLESS & HEAT RESISTING STEELS

COLD FINISHED ROUND BARS

SPECIFIED SIZE (INCHES)			SIZE TOLERANCE[a,b] OVER AND UNDER NOMINAL (INCHES)
>0.050	to	5/16	0.001
5/16	to	1/2	0.0015
1/2	to	1	0.002
1	to	1 1/2	0.0025
1 1/2	to	4[c]	0.003

[a] Bars can be produced with size tolerance all over nominal, all under nominal or any combination of over and under if the total spread for a specified size is not less than shown in the table.
[b] When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown.
[c] For bars over 4" diameter consult with the producer.

STAINLESS and HEAT RESISTING STEELS

CAST or HEAT ANALYSIS

TYPE	UNS NUMBER	Chemical Composition, Percent. Maximum unless otherwise shown.[a]								
		C	Mn	P	S	Si	Cr	Ni	Mo	Other Elements
20Cb-3®	(N08020)	0.06	2.00	0.035	0.035	1.00	19.00/ 21.00	32.50/ 35.00	2.00/ 3.00	Cu 3.00/4.00 Cb 8XC 1.00
20Mo-4®	(N08024)	0.03	1.00	0.035	0.035	0.50	22.5/ 25.0	35.0/ 40.0	3.50/ 5.00	Cb 0.15/0.35
20Mo-6[b]	(N08026)	0.03	1.00	0.03	0.03	0.50	22.00/ 26.00	33.00/ 37.00	5.00/ 6.70	Cu 2.00/4.00
330[b]	(N08330)	0.08	2.00	0.040	0.030	0.075 1.50	17.0/ 20.0	34.0/ 37.0	—	Cu 1.00; Pb 0.005 Sn 0.025
AL-6X	(N08366)	0.03	2.00	0.040	0.030	1.00	20.0/ 22.0	23.5/ 25.5	6.00 7.00	
AL-6XN®	(N08367)	0.03	2.00	0.040	0.03	1.00	20.0/ 22.0	23.50/ 25.50	6.00/ 7.00	N 0.18/0.25 Cu 0.75
JS700	(N08700)	0.04	2.00	0.04	0.03	1.00	19.0/ 23.0	24.0/ 26.0	4.3/ 5.0	Cb 8XC Min/ 0.40 Max
904L	(N08904)	0.02	2.00	0.045	0.035	1.00	19.0/ 23.0	23.0/ 28.0	4.00/ 5.00	Cu 1.00/2.00
XM-13[c]	(S13800)	0.05	0.10	0.01	0.008	0.10	12.25/ 13.25	7.50/ 8.50	2.00/ 2.50	Al 0.90/1.3 N 0.010
XM-12[c]	(S15500)	0.07	1.00	0.040	0.030	1.00	14.00/ 15.50	3.50/ 5.50		Cu 2.50/4.50 Cb 0.15/0.45
632c	(S15700)	0.09	1.00	0.040	0.030	1.00	14.00/ 16.00	6.50/ 7.75	2.00/ 3.00	Al 0.75/1.50
630[c]	(S17400)	0.07	1.00	0.040	0.030	1.00	15.00/ 17.50	3.00/ 5.00		Cu 3.00/5.00 Cb 0.15/0.45
631[c]	(S17700)	0.09	1.00	0.040	0.040	1.00	16.00/ 18.00	6.50/ 7.75		Al 0.75/1.50
XM-34[c]	(S18200)	0.08	1.25/ 2.50	0.040	0.15/ 0.40	1.00	17.50 19.50	—	1.50/ 2.50	
201	(S20100)	0.15	5.50/ 7.50	0.060	0.030	0.75	16.00/ 18.00	3.50/ 5.50		N 0.25
202	(S20200)	0.15	7.50/ 10.00	0.060	0.030	0.75	17.00/ 19.00	4.00/ 6.00		N 0.25
203	(S20300)	0.08	5.00/ 6.50	0.040	0.18/ 0.35	1.00	16.00/ 18.00	5.00/ 6.50	0.50	Cu 1.75/2.25
205	(S20500)	0.12/ 0.25	14.00/ 15.50	0.060	0.030	0.75	16.50/ 18.00	1.00/ 1.75		N 0.32/0.40
XM-19[c]	(S20910)	0.06	4.00/ 6.00	0.040	0.030	1.00	20.50/ 23.50	11.50/ 13.50	1.50/ 3.00	N 0.20/0.40 Cb 0.10/0.30
SCF-19®	(S21000)	0.10	4.0/ 7.0	0.03	0.03	6.00	18.00/ 23.00	16.0/ 20.0	4.0/ 6.0	N 0.15; Cu 2.00
15-15LC®	(S21300)	0.25	15.0/ 18.0	0.05	0.05	1.00	16.00/ 21.00	3.00	0.50/ 3.0	N 0.20/0.80 Cu 0.5/2.0
XM-11[c]	(S21904)	0.30	8.0/ 10.0	0.040	0.030	1.00	19.00/ 21.50	5.50/ 7.50	—	N 0.45

STAINLESS and HEAT RESISTING STEELS — Continued

CAST or HEAT ANALYSIS										
TYPE	UNS NUMBER	Chemical Composition, Percent. Maximum unless otherwise shown.[a]								
		C	Mn	P	S	Si	Cr	Ni	Mo	Other Elements
XM-28[c]	(S24100)	0.15	11.00/ 14.00	0.060	0.030	1.00	16.50/ 19.00	0.50/ 2.50	—	N 0.45
18-8 PLUS®	(S28200)	0.15	17.00/ 19.00	0.040	0.030	1.00	17.0/ 19.0	—	0.75/ 1.25	N 0.40/0.60
301	(S30100)	0.15	2.00	0.045	0.030	0.75	16.00/ 18.00	6.00/ 8.00	—	N 0.10
302	(S30200)	0.15	2.00	0.045	0.030	0.75	17.00/ 19.00	8.00/ 10.00	—	N 0.10
302B	(S30215)	0.15	2.00	0.045	0.030	2.00/ 3.00	17.00/ 19.00	8.00/ 10.00	—	
303	(S30300)	0.15	2.00	0.20	0.15 Min	1.00	17.00/ 19.00	8.00/ 10.00	—	
303Se	(S30323)	0.15	2.00	0.20	0.060	1.00	17.00/ 19.00	8.00/ 10.00	—	Se 0.15 Min
XM-2[c]	(S30345)	0.15	2.00	0.05	0.11/ 0.16	1.00	17.00/ 19.00	8.00/ 10.00	0.40/ 0.60	Al 0.60/1.00
304	(S30400)	0.08	2.00	0.045	0.030	0.75	18.00/ 20.00	8.00/ 10.50	—	N 0.10
304L	(S30403)	0.030	2.00	0.045	0.030	0.75	18.00/ 20.00	8.00/ 12.00	—	N 0.10
304H	(S30409)	0.04/ 0.10	2.00	0.045	0.030	0.75	18.00/ 20.00	8.00/ 10.50	—	N 0.10
304Cu	(S30430)	0.08	2.00	0.045	0.030	0.75	17.00/ 19.00	8.00/ 10.00	—	Cu 3.00/4.00
302HQ-FM®	(S30431)	0.06	2.00	0.040	0.14	1.00	16.00/ 19.00	9.0/ 11.0	—	Cu 1.30/2.40
304N	(S30451)	0.08	2.00	0.045	0.030	0.75	18.00/ 20.00	8.00/ 10.50	—	N 0.10/0.16
304LN	(S30453)	0.030	2.00	0.045	0.030	0.75	18.00/ 20.00	8.00/ 12.00	—	N 0.10/0.16
305	(S30500)	0.12	2.00	0.045	0.030	0.75	17.00/ 19.00	10.50/ 13.00	—	
308	(S30800)	0.08	2.00	0.045	0.030	1.00	19.00/ 21.00	10.00/ 12.00	—	
309	(S30900)	0.20	2.00	0.045	0.030	1.00	22.00/ 24.00	12.00/ 15.00	—	
309S	(S30908)	0.08	2.00	0.045	0.030	1.00	22.00/ 24.00	12.00/ 15.00	—	
310	(S31000)	0.25	2.00	0.045	0.030	1.50	24.00/ 26.00	19.00/ 22.00	—	
310S	(S31008)	0.08	2.00	0.045	0.030	1.50	24.00/ 26.00	19.00/ 22.00	—	
316	(S31600)	0.08	2.00	0.045	0.030	0.75	16.00/ 18.00	10.00/ 14.00	2.00/ 3.00	N 0.10

STAINLESS and HEAT RESISTING STEELS — Continued

CAST or HEAT ANALYSIS

TYPE	UNS NUMBER	Chemical Composition, Percent. Maximum unless otherwise shown.[a]								
		C	Mn	P	S	Si	Cr	Ni	Mo	Other Elements
316L	(S31603)	0.030	2.00	0.045	0.030	0.75	16.00/ 18.00	10.00/ 14.00	2.00/ 3.00	N 0.10
316H	(S31609)	0.04/ 0.10	2.00	0.045	0.030	0.75	16.00/ 18.00	10.00/ 14.00	2.00/ 3.00	N 0.10
316F	(S31620)	0.08	2.00	0.20	0.10 Min	1.00	16.00/ 18.00	10.00/ 14.00	1.75/ 2.50	N 0.10
316N	(S31651)	0.08	2.00	0.045	0.030	0.75	16.00/ 18.00	10.00/ 14.00	2.00/ 3.00	N 0.10/0.16
316LN	(S31653)	0.030	2.00	0.045	0.030	0.75	16.00/ 18.00	10.00/ 14.00	2.00/ 3.00	N 0.10/0.16
317	(S31700)	0.08	2.00	0.045	0.030	0.75	18.00/ 20.00	11.00/ 15.00	3.00/ 4.00	N 0.10
317L	(S31703)	0.030	2.00	0.045	0.030	0.75	18.00/ 20.00	11.00/ 15.00	3.00/ 4.00	N 0.10
	(S31725)	0.03	2.00	0.045	0.030	0.75	18.0/ 20.0	13.50/ 17.50	4.0/ 5.0	N 0.10 Cu 0.75
AL2205	(S31803)	0.030	2.00	0.030	0.020	1.00	21.0/ 23.0	4.50/ 6.50	2.50/ 3.50	N 0.08/0.20
321	(S32100)	0.08	2.00	0.045	0.030	0.75	17.00/ 19.00	9.00/ 12.00	—	Ti 5(C+N) Min 0.70 Max
321H	(S32109)	0.04/ 0.10	2.00	0.045	0.030	0.75	17.00/ 19.00	9.00/ 12.00	—	Ti 4(C+N) Min 0.70 Max
	(S32550)	0.04	1.50	0.040	0.03	1.00	24.0/ 27.00	4.50/ 6.50	2.90/ 3.90	N 0.10/0.25 Cu 1.50/2.50
329	(S32900)	0.08	2.00	0.040	0.030	0.75	23.00/ 28.00	2.50/ 5.00	1.00/ 2.00	
7-MoPLUS®	(S32950)	0.03	2.00	0.035	0.010	0.60	26.0/ 29.0	3.50/ 5.20	1.00/ 2.50	N 0.15/0.35
332		0.08	2.00	0.040	0.030	0.75	19.00/ 23.00	30.00/ 34.00	—	Ti 0.60 Al 0.60
334		0.08	1.00	0.040	0.030	0.75	18.00/ 22.00	18.00/ 22.00	—	Ti 0.60 Al 0.60
347	(S34700)	0.08	2.00	0.045	0.030	0.75	17.00/ 19.00	9.00/ 13.00	—	Cb 10XC Min 1.00 Max
347H	(S34709)	0.04/ 0.10	2.00	0.045	0.030	0.75	17.00/ 19.00	9.00/ 13.00	—	Cb 8XC Min 1.00 Max
348	(S34800)	0.08	2.00	0.045	0.030	0.75	17.00/ 19.00	9.00/ 13.00	—	Cb+Ta 10XC Min 1.00 Max Ta 0.10 Max Co 0.20 Max
348H	(S34809)	0.04/ 0.10	2.00	0.045	0.030	0.75	17.00/ 19.00	9.00/ 13.00	—	Cb+Ta 8XC Min 1.00 Max Ta 0.10 Max Co 0.20 Max
633[c]	(S35000)	0.070/ 0.11	0.50/ 1.25	0.040	0.030	0.50	16.00/ 17.00	4.00/ 5.00	2.50/ 3.25	N 0.07/0.13
634[c]	(S35500)	0.10/ 0.15	0.50/ 1.25	0.040	0.030	0.50	15.00/ 16.00	4.00/ 5.00	2.50/ 3.25	N 0.07/0.13

STAINLESS and HEAT RESISTING STEELS — Continued

CAST or HEAT ANALYSIS										
TYPE	UNS NUMBER	Chemical Composition, Percent. Maximum unless otherwise shown.[a]								
		C	Mn	P	S	Si	Cr	Ni	Mo	Other Elements
384	(S38400)	0.08	2.00	0.045	0.030	1.00	15.00/ 17.00	17.00/ 19.00	—	
403	(S40300)	0.15	1.00	0.040	0.030	0.50	11.50/ 13.00	—	—	
405	(S40500)	0.08	1.00	0.040	0.030	1.00	11.50/ 14.50	0.60	—	Al 0.10/0.30
409	(S40900)	0.08	1.00	0.045	0.045	1.00	10.50/ 11.75	0.50	—	Ti 6XC Min/ 0.75 Max
410	(S41000)	0.15	1.00	0.040	0.030	1.00	11.50/ 13.50	0.75	—	
410S	(S41008)	0.08	1.00	0.040	0.030	1.00	11.50/ 13.50	0.60	—	
414	(S41400)	0.15	1.00	0.040	0.030	1.00	11.50/ 13.50	1.25/ 2.50	—	
F6NM[c]	(S41500)	0.05	0.50/ 1.00	0.030	0.030	0.60	11.5/ 14.0	3.50/ 5.50	0.50/ 1.00	
416	(S41600)	0.15	1.25	0.060	0.15 Min	1.00	12.00/ 14.00	—	—	
420	(S42000)	Over 0.15	1.00	0.040	0.030	1.00	12.00/ 14.00	—	—	
	(S42010)	0.15/ 0.30	1.00	0.040	0.030	1.00	13.5/ 15.0	0.25/ 1.00	0.40/ 1.00	
420F	(S42020)	Over 0.15	1.25	0.060	0.15 Min	1.00	12.00/ 14.00	—	—	
422	(S42200)	0.20/ 0.25	0.50/ 1.00	0.025	0.025	0.50	11.0/ 12.50	0.50/ 1.00	0.90/ 1.25	V 0.20/0.30 W 0.90/1.25
429	(S42900)	0.12	1.00	0.040	0.030	1.00	14.00/ 16.00	0.75	—	
430	(S43000)	0.12	1.00	0.040	0.030	1.00	16.00/ 18.00	0.75	—	
430F	(S43020)	0.12	1.25	0.060	0.15 Min	1.00	16.00/ 18.00	—	—	
431	(S43100)	0.20	1.00	0.040	0.030	1.00	15.00/ 17.00	1.25/ 2.50		
434	(S43400)	0.12	1.00	0.040	0.030	1.00	16.00/ 18.00	—	0.75/ 1.25	
436	(S43600)	0.12	1.00	0.040	0.030	1.00	16.00/ 18.00	—	0.75/ 1.25	Cb 5XC Min/ 0.70 Max
439	(S43900)	0.07	1.00	0.040	0.030	1.00	17.00/ 19.00	0.50	—	Ti 0.20+4 (C+N) Min/1.10 Max Al 0.15 N 0.04
440A	(S44002)	0.60/ 0.75	1.00	0.040	0.030	1.00	16.00/ 18.00	—	0.75	

STAINLESS and HEAT RESISTING STEELS — Continued

CAST or HEAT ANALYSIS

TYPE	UNS NUMBER	Chemical Composition, Percent. Maximum unless otherwise shown.[a]								
		C	Mn	P	S	Si	Cr	Ni	Mo	Other Elements
440B	(S44003)	0.75/ 0.95	1.00	0.040	0.030	1.00	16.00/ 18.00	—	0.75	
440C	(S44004)	0.95/ 1.20	1.00	0.040	0.030	1.00	16.00/ 18.00	—	0.75	
440F	(S44020)	0.95/ 1.20	1.25	0.040	0.15 Min	1.00	16.00/ 18.00	0.75	0.75	
442	(S44200)	0.20	1.00	0.040	0.030	1.00	18.00/ 23.00	—	0.60	
444	(S44400)	0.025	1.00	0.040	0.030	1.00	17.50/ 19.50	— —	1.75/ 2.50	N 0.035 Ti+Cb=0.20+4(C+N) Min/0.80 Max
446	(S44600)	0.20	1.50	0.040	0.030	1.00	23.00/ 27.00	—	—	N 0.25
XM-27[c]	(S44627)	0.010	0.40	0.020	0.020	0.040	25.00/ 27.5	0.50	0.75/ 1.50	N 0.015; Cu 0.20 Cb 0.05/0.20 Ni+Cu 0.50
	(S44735)	0.030	1.00	0.040	0.030	1.00	28.0/ 30.0	1.00	3.60/ 4.20	N 0.045 Ti+Cb 6(C+N) Min/1.00 Max
	(S44800)	0.010	0.300	0.025	0.020	0.20	28.0/ 30.0	2.0/ 2.5	3.5/ 4.2	N 0.015; Cu 0.15 (C+N) 0.025
XM-25c	(S45000)	0.05	1.00	0.030	0.030	1.00	14.0/ 16.0	5.0/ 7.0	0.50/ 1.00	Cu 1.25/1.75 Cb 8XC Min
XM-16c	(S45500)	0.05	0.50	0.040	0.030	0.50	11.0/ 12.5	7.50/ 9.50	0.50	Cu 1.50/2.50 Cb 0.10/0.50
501	(S50100)	0.10 Min	1.00	0.040	0.030	1.00	4.00/ 6.00	—	0.40/ 0.65	
502	(S50200)	0.10	1.00	0.040	0.030	1.00	4.00/ 6.00	—	0.40/ 0.65	
503	(S50300)	0.15	1.00	0.040	0.040	1.00	6.00/ 8.00	—	0.45/ 0.65	
504	(S50400)	0.15	1.00	0.040	0.040	1.00	8.00/ 10.00	—	0.90/ 1.00	

a. The analyses listed in this table present the standard Specialty Steel Industry of the United States (SSIUS) analyses for these grades. Variations from these ranges or limits for some of the elements are governed by the individual product specifications of the various technical societies. b. This alloy with less than 50% Fe is classified as a Nickel alloy by ASTM. c. ASTM

STANDARD TOOL STEELS

		TYPE	NOMINAL IDENTIFYING ELEMENTS, %							
			C	Mn	Si	W	Mo	Cr	V	Co
WATER HARDENING		W1	0.60/1.40[a]	0.25	—	—	—	—	—	—
		W2	0.60/1.40[a]	0.25	—	—	—	—	0.25	—
		W5	1.10	0.25	—	—	—	0.50	—	—
COLD WORK TOOL STEELS	Oil Hardening	O1	0.90	1.20	—	0.50	—	0.50	—	—
		O2	0.90	1.60	—	—	—	—	—	—
		O6	1.45	0.80	1.00	—	0.25	—	—	—
		O7	1.20	—	—	1.75	—	0.75	—	—
	Med-Alloy Air Hardening	A2	1.00	0.60	—	—	1.00	5.00	—	—
		A4	1.00	2.00	—	—	1.00	1.00	—	—
		A6	0.70	2.00	—	—	1.25	1.00	—	—
		A7	2.25	—	—	1.00[b]	1.00	5.25	4.75	—
		A8	0.55	—	—	1.25	1.25	5.00	—	—
		A9[c]	0.50	—	—	—	1.40	5.00	1.00	—
		A10[d]	1.35	1.80	1.25	—	1.50	—	—	—
		A11	2.45	0.50	0.90	—	1.30	5.25	9.75	—
	High-C & High Cr	D2	1.50	—	—	—	1.00	12.00	1.00	—
		D3	2.50	—	—	—	—	12.00	—	—
		D4	2.25	—	—	—	1.00	12.00	—	—
		D5	1.50	—	—	—	1.00	12.00	—	3.00
		D7	2.35	—	—	—	1.00	12.00	4.00	—
SHOCK RESISTING		S1	0.50	—	—	2.50	—	1.50	—	—
		S2	0.50	—	1.00	—	0.50	—	—	—
		S4	0.55	0.80	2.00	—	—	—	—	—
		S5	0.55	0.80	2.00	—	0.40	—	—	—
		S6	0.45	1.40	2.25	—	0.40	1.50	—	—
		S7	0.50	0.60	—	—	1.40	3.25	—	—
HOT WORK	Cr-Types	H10	0.40	—	1.0	—	2.50	3.25	0.40	—
		H11	0.35	—	1.0	—	1.50	5.00	0.40	—
		H12	0.35	—	1.0	1.50	1.50	5.00	0.40	—
		H13	0.35	—	1.0	—	1.50	5.00	1.00	—
		H14	0.40	—	1.0	5.00	—	5.00	—	—
		H19	0.40	—	—	4.25	—	4.25	2.00	4.25

[a]Various carbon contents are available. [b]Optional. [c]A9 has 1.50 Ni. [d]A10 has 1.80 Ni.

STANDARD TOOL STEELS — Continued

		TYPE	NOMINAL IDENTIFYING ELEMENTS, %					
			C	W	Mo	Cr	V	Co
HOT WORK	W-Type	H21	0.35	9.00	—	3.50	0.50	—
		H22	0.35	11.00	—	2.00	0.40	—
		H23	0.30	12.00	—	12.00	1.00	—
		H24	0.45	15.00	—	3.00	0.50	—
		H26	0.50	18.00	—	4.00	1.00	—
		H42	0.60	6.00	5.00	4.00	2.00	—
HIGH SPEED	Molybdenum Types	M1[a]	0.85	1.50	8.50	4.00	1.00	—
		M2[a]	0.85; 1.00	6.00	5.00	4.00	2.00	—
		M3-1	1.05	6.00	5.00	4.00	2.40	—
		M3-2	1.20	6.00	5.00	4.00	3.00	—
		M4	1.30	5.50	4.50	4.00	4.00	—
		M6	0.80	4.00	5.00	4.00	1.50	12.00
		M7	1.00	1.75	8.75	4.00	2.00	—
		M10[a]	0.85; 1.00	—	8.00	4.00	2.00	—
		M33	0.90	1.50	9.50	4.00	1.15	8.00
		M34	0.90	2.00	8.00	4.00	2.00	8.00
		M36	0.85	6.00	5.00	4.00	2.00	8.00
		M41	1.10	6.75	3.75	4.25	2.00	5.00
		M42	1.10	1.50	9.50	3.75	1.15	8.00
		M46[b]	1.25	2.00	8.25	4.00	3.20	8.25
		M48	1.50	10.00	5.25	3.75	3.10	9.00
		M62	1.30	6.25	10.50	3.75	2.00	—
	Tungsten Types	T1[a]	0.75	18.00	—	4.00	1.00	—
		T4	0.75	18.00	—	4.00	1.00	5.00
		T5	0.80	18.00	—	4.00	2.00	8.00
		T6	0.80	20.00	—	4.50	1.50	12.00
		T8	0.75	14.00	—	4.00	2.00	5.00
		T15	1.50	12.00	—	4.00	5.00	5.00
INT. H.S.		M50	0.85	—	—	4.00	4.00	1.00
		M52	0.90	1.25	—	4.00	4.00	2.00

[a]Other carbon contents may be available. [b]Available in two silicon contents.

FORMERLY STANDARD TOOL STEELS

	TYPE	NOMINAL IDENTIFYING ELEMENTS, %							
		C	Mn	Si	W	Mo	Cr	V	Co
HIGH SPEED	M8[a]	0.80	—	—	5.00	5.00	4.00	1.50	—
	M15	1.50	—	—	6.50	3.50	4.00	5.00	5.00
	M30	0.80	—	—	2.00	8.00	4.00	1.25	5.00
	M35	0.80	—	—	6.00	5.00	4.00	2.00	5.00
	M43	1.20	—	—	2.75	8.00	3.75	1.60	8.25
	M44	1.15	—	—	5.25	6.25	4.25	2.00	12.00
	M45	1.25	—	—	8.00	5.00	4.25	1.60	5.50
	M47	1.10	—	—	1.50	9.50	3.75	1.25	5.00
	T2	0.80	—	—	18.00	—	4.00	2.00	—
	T3	1.05	—	—	18.00	—	4.00	3.00	—
	T7	0.75	—	—	14.00	—	4.00	2.00	—
	T9	1.20	—	—	18.00	—	4.00	4.00	—
HOT WORK	H15	0.40	—	—	—	5.00	5.00	—	—
	H16	0.55	—	—	7.00	—	7.00	—	—
	H20	0.35	—	—	9.00	—	2.00	—	—
	H25	0.25	—	—	15.00	—	4.00	0.50	—
	H41	0.65	—	—	1.50	8.00	4.00	1.00	—
	H43	0.55	—	—	—	8.00	4.00	2.00	—
COLD WORK	D1	1.00	—	—	—	1.00	12.00	—	—
	D6	2.25	—	—	1.25	—	12.00	—	—
	A3	1.25	—	—	—	1.00	5.00	1.00	—
	A5	1.00	3.00	—	—	1.00	1.00	—	—
SHOCK RESIST.	S3	0.50	—	—	1.00	—	0.75	—	—
MOLD	P1	0.10	—	—	—	—	—	—	—
	P2[b]	0.07	—	—	—	0.20	2.00	—	—
	P3[c]	0.10	—	—	—	—	0.60	—	—
	P4	0.07	—	—	—	0.75	5.00	—	—
	P5	0.10	—	—	—	—	2.25	—	—
SPECIAL PURPOSE	L1	1.00	—	—	—	—	1.25	—	—
	L3	1.00	—	—	—	—	1.50	0.20	—
	L4	1.00	0.60	—	—	—	1.50	0.25	—
	L5	1.00	1.00	—	—	0.25	1.00	—	—
	L7	1.00	0.35	—	—	0.40	1.40	—	—
	F1	1.00	—	—	1.25	—	—	—	—
	F2	1.25	—	—	3.50	—	—	—	—
	F3	1.25	—	—	2.50	—	0.75	—	—
WATER HARDENING	W3	1.00	—	—	—	—	—	0.50	—
	W4[d]	0.60/1.40	—	—	—	—	0.25	—	—
	W6	1.00	—	—	—	—	0.25	0.25	—
	W7	1.00	—	—	—	—	0.50	0.20	—

[a]M8 has 1.25 Cb; [b]P2 has 0.50 Ni; [c]P3 has 1.25 Ni; [d]Various carbon contents

FRACTIONS OF AN INCH AND DECIMAL EQUIVALENTS

1/64	.015625
1/32	.03125
3/64	.046875
1/16	.09375
5/64	.078125
3/32	.09375
7/64	.109375
1/8	.125
9/64	.140625
5/32	.15625
11/64	.171875
3/16	.1875
13/64	.203125
7/32	.21875
15/64	.234375
1/4	.250
17/64	.265625
9/32	.28125
19/64	.296875
5/16	.3125
21/64	.328125
11/32	.34375
23/64	.359375
3/8	.375
25/64	.390625
13/32	.40625
27/64	.421875
7/16	.4375
29/64	.453125
15/32	.46875
31/64	.484375
1/2	.500
33/64	.515625
17/32	.53125
35/64	.546875
9/16	.5625
37/64	.578125
19/32	.59375
39/64	.609375
5/8	.625
41/64	.640625
21/32	.65625
43/64	.671875
11/16	.6875
45/64	.703125
23/32	.71875
47/64	.734375
3/4	.750
49/64	.765625
25/32	.78125
51/64	.796875
13/16	.8125
53/64	.828125
27/32	.84375
55/64	.859375
7/8	.875
57/64	.890625
29/32	.90625
59/64	.921875
15/16	.9375
61/64	.953125
31/32	.96875
63/64	.984375
1	1.0000

WIRE AND SHEET METAL GAUGES

GA. NO.	AMER. OR B.&S.	BIRM.	STAND. OR W.&M.	U.S.S. FOR SHEETS
00	.3648	.380	.3310	.3370
0	.3249	.340	.3065	.3064
1	.2893	.300	.2930	.2757
2	.2576	.284	.2625	.2604
3	.2294	.259	.2437	.2451
4	.2043	.238	.2253	.2298
5	.1819	.220	.2070	.2145
6	.1620	.203	.1920	.1991
7	.1443	.180	.1770	.1838
8	.1285	.165	.1620	.1685
9	.1144	.148	.1483	.1532
10	.1019	.134	.1350	.1379
11	.0907	.120	.1205	.1225
12	.0808	.109	.1055	.1072
13	.0720	.095	.0915	.0919
14	.0641	.083	.0800	.0766
15	.0571	.072	.0720	.0689
16	.0508	.065	.0625	.0613
17	.0453	.058	.0540	.0551
18	.0403	.049	.0475	.0490
19	.0359	.042	.0410	.0429
20	.0320	.035	.0348	.0368
21	.0285	.032	.03175	.0337
22	.0253	.028	.0286	.0306
23	.0226	.025	.0258	.0276
24	.0201	.022	.0230	.0245
25	.0179	.020	.0204	.0214
26	.0159	.018	.0181	.0184
27	.0142	.016	.0173	.0169
28	.0126	.014	.0162	.0153
29	.0113	.013	.0150	.0138
30	.0100	.012	.0140	.0123
31	.00893	.010	.0132	.0107
32	.00795	.009	.0128	.0100
33	.00708	.008	.0118	.0092
34	.00630	.007	.0104	.0084
35	.00561	.005	.0095	.0077
36	.00500	.004	.0090	.0069
37	.00445	—	.0085	.0065
38	.00396	—	.0080	.0061

We stock Birmingham Gauge Tubing, and Spring Steel Sheets. Spring Steel Wire is Standard Gauge.

DECIMALS OF ONE FOOT

FOR EACH 1/16 OF AN INCH

INCHES	FEET	INCHES	FEET	INCHES	FEET
1/16	.0052	4 1/16	.3385	8 1/16	.6719
1/8	.0104	4 1/8	.3437	8 1/8	.6771
3/16	.0156	4 3/16	.3490	8 3/16	.6823
1/4	.0208	4 1/4	.3542	8 1/4	.6875
5/16	.0260	4 5/16	.3594	8 5/16	.6927
3/8	.0312	4 3/8	.3646	8 3/8	.6979
7/16	.0365	4 7/16	.3698	8 7/16	.7031
1/2	.0417	4 1/2	.3750	8 1/2	.7083
9/16	.0469	4 9/16	.3802	8 9/16	.7135
5/8	.0521	4 5/8	.3854	8 5/8	.7188
11/16	.0573	4 11/16	.3906	8 11/16	.7240
3/4	.0625	4 3/4	.3958	8 3/4	.7292
13/16	.0677	4 13/16	.4010	8 13/16	.7344
7/8	.0729	4 7/8	.4062	8 7/8	.7396
15/16	.0781	4 15/16	.4115	8 15/16	.7448
1	.0833	5	.4167	9	.7500
1 1/16	.0885	5 1/16	.4219	9 1/16	.7552
1 1/8	.0937	5 1/8	.4271	9 1/8	.7604
1 3/16	.0990	5 3/16	.4323	9 3/16	.7656
1 1/4	.1042	5 1/4	.4375	9 1/4	.7708
1 5/16	.1094	5 5/16	.4427	9 5/16	.7760
1 3/8	.1146	5 3/8	.4479	9 3/8	.7812
1 7/16	.1198	5 7/16	.4531	9 7/16	.7865
1 1/2	.1250	5 1/2	.4583	9 1/2	.7917
1 9/16	.1302	5 9/16	.4635	9 9/16	.7969
1 5/8	.1354	5 5/8	.4688	9 5/8	.8021
1 11/16	.1406	5 11/16	.4740	9 11/16	.8073
1 3/4	.1458	5 3/4	.4792	9 3/4	.8125
1 13/16	.1510	5 13/16	.4844	9 13/16	.8177
1 7/8	.1562	5 7/8	.4896	9 7/8	.8229
1 15/16	.1615	5 15/16	.4948	9 15/16	.8281
2	.1667	6	.5000	10	.8333
2 1/16	.1719	6 1/16	.5052	10 1/16	.8385
2 1/8	.1771	6 1/8	.5104	10 1/8	.8437
2 3/16	.1823	6 3/16	.5156	10 3/16	.8490
2 1/4	.1875	6 1/4	.5208	10 1/4	.8542
2 5/16	.1927	6 5/16	.5260	10 5/16	.8594
2 3/8	.1979	6 3/8	.5312	10 3/8	.8646
2 7/16	.2031	6 7/16	.5365	10 7/16	.8698
2 1/2	.2083	6 1/2	.5417	10 1/2	.8750
2 9/16	.2135	6 9/16	.5469	10 9/16	.8802
2 5/8	.2188	6 5/8	.5521	10 5/8	.8854
2 11/16	.2240	6 11/16	.5573	10 11/16	.8906
2 3/4	.2292	6 3/4	.5625	10 3/4	.8958
2 13/16	.2344	6 13/16	.5677	10 13/16	.9010
2 7/8	.2396	6 7/8	.5729	10 7/8	.9062
2 15/16	.2448	6 15/16	.5781	10 15/16	.9115
3	.2500	7	.5833	11	.9167
3 1/16	.2552	7 1/16	.5885	11 1/16	.9219
3 1/8	.2604	7 1/8	.5937	11 1/8	.9271
3 3/16	.2656	7 3/16	.5990	11 3/16	.9323
3 1/4	.2708	7 1/4	.6042	11 1/4	.9375
3 5/16	.2760	7 5/16	.6094	11 5/16	.9427
3 3/8	.2812	7 3/8	.6146	11 3/8	.9479
3 7/16	.2865	7 7/16	.6198	11 7/16	.9531
3 1/2	.2917	7 1/2	.6250	11 1/2	.9583
3 9/16	.2969	7 9/16	.6302	11 9/16	.9635
3 5/8	.3021	7 5/8	.6354	11 5/8	.9688
3 11/16	.3073	7 11/16	.6406	11 11/16	.9740
3 3/4	.3125	7 3/4	.6458	11 3/4	.9792
3 13/16	.3177	7 13/16	.6510	11 13/16	.9844
3 7/8	.3229	7 7/8	.6562	11 7/8	.9896
3 15/16	.3281	7 15/16	.6615	11 15/16	.9948
4	.3333	8	.6667		

HARDNESS CONVERSION NUMBERS

FOR STEEL — Based on Rockwell

Rockwell C-Scale Numers (HRC)*

Rockwell C-scale hardness No.	Vickers hardness No.	Brinell hardness No., 3000-kg load, 10mm ball		Rockwell hardness No.,		Rockwell superficial hardness No., superficial Brale indenter			Knoop hardness No., 500-g load and greater	Shore Scleroscope hardness No.	Tensile strength (approx.) 1000 psi	Rockwell C-scale hardness No.
		Standard ball	Tungsten carbide ball	A scale, 60-kg load Brale indenter	B scale, 100-kg load, 1/16-in diam. ball	15N scale, 15-kg load	30N scale, 30-kg load	45N scale, 45-kg load				
68	940	...	...	85.6	...	93.2	84.4	75.4	920	97	...	68
67	900	...	...	85.0	...	92.9	83.6	74.2	895	95	...	67
66	865	...	...	84.5	...	92.5	82.8	73.3	870	92	...	66
65	832	...	(739)	83.9	...	92.2	81.9	72.0	846	91	...	65
64	800	...	(722)	83.4	...	91.8	81.1	71.0	822	88	...	64
63	772	...	(705)	82.8	...	91.4	80.1	69.9	799	87	...	63
62	746	...	(688)	82.3	...	91.1	79.3	68.8	776	85	...	62
61	720	...	(670)	81.8	...	90.7	78.4	67.7	754	83	...	61
60	697	...	(654)	81.2	...	90.2	77.5	66.6	732	81	...	60
59	674	...	(634)	80.7	...	89.8	76.6	65.5	710	80	351	59
58	653	...	615	80.1	...	89.3	75.7	64.3	690	78	338	58
57	633	...	595	79.6	...	88.9	74.8	63.2	670	76	325	57
56	613	...	577	79.0	...	88.3	73.9	62.0	650	75	313	56
55	595	...	560	78.5	...	87.9	73.0	60.9	630	74	301	55
54	577	...	543	78.0	...	87.4	72.0	59.8	612	72	292	54
53	560	...	525	77.4	...	86.9	71.2	58.6	594	71	283	53
52	544	(500)	512	76.8	...	86.4	70.2	57.4	576	69	273	52
51	528	(487)	496	76.3	...	85.9	69.4	56.1	558	68	264	51
50	513	(475)	481	75.9	...	85.5	68.5	55.0	542	67	255	50
49	498	(464)	469	75.2	...	85.0	67.6	53.8	526	66	246	49
48	484	(451)	455	74.7	...	84.5	66.7	52.5	510	64	238	48
47	471	442	443	74.1	...	83.9	65.8	51.4	495	63	229	47
46	458	432	432	73.6	...	83.5	64.8	50.3	480	62	221	46
45	446	421	421	73.1	...	83.0	64.0	49.0	466	60	215	45
44	434	409	409	72.5	...	82.5	63.1	47.8	452	58	208	44
43	423	400	400	72.0	...	82.0	62.2	46.7	438	57	201	43
42	412	390	390	71.5	...	81.5	61.3	45.5	426	56	194	42
41	402	381	381	70.9	...	80.9	60.4	44.3	414	55	188	41
40	392	371	371	70.4	...	80.4	59.5	43.1	402	54	182	40
39	382	362	362	69.9	...	79.9	58.6	41.9	391	52	177	39
38	372	353	353	69.4	...	79.4	57.7	40.8	380	51	171	38
37	363	344	344	68.9	...	78.8	56.8	39.6	370	50	166	37
36	354	336	336	68.4	(109.0)	78.3	55.9	38.4	360	49	161	36
35	345	327	327	67.9	(108.5)	77.7	55.0	37.2	351	48	157	35
34	336	319	319	67.4	(108.0)	77.2	54.2	36.1	342	47	153	34
33	327	311	311	66.8	(107.5)	76.6	53.3	34.9	334	46	149	33
32	318	301	301	66.3	(107.0)	76.1	52.1	33.7	326	44	145	32
31	310	294	294	65.8	(106.0)	75.6	51.3	32.5	318	43	141	31
30	302	286	286	65.3	(105.5)	75.0	50.4	31.3	311	42	138	30
29	294	279	279	64.7	(104.5)	74.5	49.5	30.1	304	41	135	29
28	286	271	271	64.3	(104.0)	73.9	48.6	28.9	297	40	131	28
27	279	264	264	63.8	(103.0)	73.3	47.7	27.8	290	39	128	27
26	272	258	258	63.3	(102.5)	72.8	46.8	26.7	284	38	125	26
25	266	253	253	62.8	(101.5)	72.2	45.9	25.5	278	38	122	25
24	260	247	247	62.4	(101.0)	71.6	45.0	24.3	272	37	119	24
23	254	243	243	62.0	100.0	71.0	44.0	23.1	266	36	117	23
22	248	237	237	61.5	99.0	70.5	43.2	22.0	261	35	114	22
21	243	231	231	61.0	98.5	69.9	42.3	20.7	256	35	112	21

*See notation at bottom of next page

HARDNESS CONVERSION NUMBERS

FOR STEEL — Based on Rockwell

Rockwell B-Scale Numers (HRB)*

Rockwell B-scale hardness No.	Vickers hardness No.	Brinell hardness No., 10mm diam. ball		Rockwell hardness No.,		Rockwell superficial hardness No., 1/16 in. diam. ball			Knoop hardness No., 500-g load and greater	Shore Scleroscope hardness No.	Tensile strength (approx.) 1000 psi	Rockwell B-scale hardness No.
		500-kg load	3000-kg load	A scale, 60-kg load Brale indenter	C scale, 150-kg load, Brale indented	15T scale, 15-kg load	30T scale, 30-kg load	45T scale, 45-kg load				
98	228	189	228	60.2	(19.9)	92.5	81.8	70.9	241	34	107	98
97	222	184	222	59.5	(18.6)	92.1	81.1	69.9	236	33	104	97
96	216	179	216	58.9	(17.2)	91.8	80.4	68.9	231	32	102	96
95	210	175	210	58.3	(15.7)	91.5	79.8	67.9	226	...	99	95
94	205	171	205	57.6	(14.3)	91.2	79.1	66.9	221	31	97	94
93	200	167	200	57.0	(13.0)	90.8	78.4	65.9	216	30	94	93
92	195	163	195	56.4	(11.7)	90.5	77.8	64.8	211	...	92	92
91	190	160	190	55.8	(10.4)	90.2	77.1	63.8	206	29	90	91
90	185	157	185	55.2	(9.2)	89.9	76.4	62.8	201	28	88	90
89	180	154	180	54.6	(8.0)	89.5	75.8	61.8	196	27	86	89
88	176	151	176	54.0	(6.9)	89.2	75.1	60.8	192	...	84	88
87	172	148	172	53.4	(5.8)	88.9	74.4	59.8	188	26	82	87
86	169	145	169	52.8	(4.7)	88.6	73.8	58.8	184	26	81	86
85	165	142	165	52.3	(3.6)	88.2	73.1	57.8	180	25	79	85
84	162	140	162	51.7	(2.5)	87.9	72.4	56.8	176	...	78	84
83	159	137	159	51.1	(1.4)	87.6	71.8	55.8	173	24	76	83
82	156	135	153	50.6	(0.3)	87.3	71.1	54.8	170	24	75	82
81	153	133	153	50.0	...	86.9	70.4	53.8	167	...	73	81
80	150	130	150	49.5	...	86.6	69.7	52.8	164	23	72	80
79	147	128	147	48.9	...	86.3	69.1	51.8	161	...	70	79
78	144	126	144	48.4	...	86.0	68.4	50.8	158	22	69	78
77	141	124	141	47.9	...	85.6	67.7	49.8	155	22	68	77
76	139	122	139	47.3	...	85.3	67.1	48.8	152	...	67	76
75	137	120	137	46.8	...	85.0	66.4	47.8	150	21	66	75
74	135	118	135	46.3	...	84.7	65.7	46.8	148	21	65	74
73	132	116	132	45.8	...	84.3	65.1	45.8	145	...	64	73
72	130	114	130	45.3	...	84.0	64.4	44.8	143	20	63	72
71	127	112	127	44.8	...	83.7	63.7	43.8	141	20	62	71
70	125	110	125	44.3	...	83.4	63.1	42.8	139	...	61	70
69	123	109	123	43.8	...	83.0	62.4	41.8	137	19	60	69
68	121	107	121	43.3	...	82.7	61.7	40.8	135	19	59	68
67	119	106	119	42.8	...	82.4	61.0	39.8	133	19	58	67
66	117	104	117	42.3	...	82.1	60.4	38.7	131	...	57	66
65	116	102	116	41.8	...	81.8	59.7	37.7	129	18	56	65
64	114	101	114	41.4	...	81.4	59.0	36.7	127	18	...	64
63	112	99	112	40.9	...	81.1	58.4	35.7	125	18	...	63
62	110	98	110	40.4	...	80.8	57.7	34.7	124	...	...	62
61	108	96	108	40.0	...	80.5	57.0	33.7	122	17	...	61
60	107	95	107	39.5	...	80.1	56.4	32.7	120	...	...	60
59	106	94	106	39.0	...	79.8	55.7	31.7	118	...	...	59
58	104	92	104	38.6	...	79.5	55.0	30.7	117	...	...	58
57	103	91	103	38.1	...	79.2	54.4	29.7	115	...	...	57
56	101	90	101	37.7	...	78.8	53.7	28.7	114	...	...	56
55	100	89	100	37.2	...	78.5	53.0	27.7	112	...	...	55

* For carbon and alloy steels in the annealed, normalized, and quenched-and-tempered conditions; less accurate for cold worked condition and for austenitic steels. The values in **boldface type** correspond to the values in the joint SAE-ASM-ASTM hardness conversions as printed in ASTM E140. Table 2. The values in parentheses are beyond normal range and are given for information only.

HARDNESS CONVERSION NUMBERS
FOR STEEL — Based on Brinell

Brinell Hardness Numbers (HB)*

Brinell indentation diam. mm	Brinell hardness No., 3000-kg load, 10mm Tungsten carbide ball	Vickers hardness No.	Rockwell hardness No.			Rockwell superficial hardness No., superficial Brale indenter			Knoop hardness No., 500-g load and greater	Shore Scleroscope hardness No.	Tensile strength (approx.) 1000 psi	Brinell indentation diam. mm
			A scale, 60-kg load Brale indenter	B scale, 100-kg load, 1/16-in diam. ball	C scale, 150-kg load, Brale indenter	15N scale, 15-kg load	30N scale, 30-kg load	45N scale, 45-kg load				
2.25	(745)	840	84.1	...	65.3	92.3	82.2	72.2	852	91	...	2.25
2.30	(712)	783	83.1	...	63.4	91.6	80.5	70.4	808	...	...	2.30
2.35	(682)	737	82.2	...	61.7	91.0	79.0	68.5	768	84	...	2.35
2.40	(653)	697	81.2	...	60.0	90.2	77.5	66.5	732	81	...	2.40
2.45	627	667	80.5	...	58.7	89.6	76.3	65.1	703	79	347	2.45
2.50	601	640	79.8	...	57.3	89.0	75.1	63.5	677	77	328	2.50
2.55	578	615	79.1	...	56.0	88.4	73.9	62.1	652	75	313	2.55
2.60	555	591	78.4	...	54.7	87.8	72.7	60.6	626	73	298	2.60
2.65	534	569	77.8	...	53.5	87.2	71.6	59.2	604	71	288	2.65
2.70	514	547	76.9	...	52.1	86.5	70.3	57.6	579	70	273	2.70
2.75	... 495	539 528	76.7 76.3	... ...	51.6 51.0	86.3 85.9	69.9 69.4	56.9 56.1	571 558	... 68	269 263	2.75
2.80	... 477	516 508	75.9 75.6	... ...	50.3 49.6	85.6 85.3	68.7 68.2	55.2 54.5	545 537	... 66	257 252	2.80
2.85	... 461	495 491	75.1 74.9	... ...	48.8 48.5	84.9 84.7	67.4 67.2	53.5 53.2	523 518	... 65	244 242	2.85
2.90	... 444	474 472	74.3 74.2	... ...	47.2 47.1	84.1 84.0	66.0 65.8	51.7 51.5	499 496	... 63	231 229	2.90
2.95	429	455	73.4	...	45.7	83.4	64.6	49.9	476	61	220	2.95
3.00	415	440	72.8	...	44.5	82.8	63.5	48.4	459	59	212	3.00
3.05	401	425	72.0	...	43.1	82.0	62.3	46.9	441	58	202	3.05
3.10	388	410	71.4	...	41.8	81.4	61.1	45.3	423	56	193	3.10
3.15	375	396	70.6	...	40.4	80.6	59.9	43.6	407	54	184	3.15
3.20	363	383	70.0	...	39.1	80.0	58.7	42.0	392	52	177	3.20
3.25	352	372	69.3	(110.0)	37.9	79.3	57.6	40.5	379	51	172	3.25
3.30	341	360	68.7	(109.9)	36.6	78.6	56.4	39.1	367	50	164	3.30
3.35	331	350	68.1	(108.5)	35.5	78.0	55.4	37.8	356	48	159	3.35
3.40	321	339	67.5	(108.0)	34.3	77.3	54.3	36.4	345	47	154	3.40
3.45	311	328	66.9	(107.5)	33.1	76.7	53.3	34.4	336	46	149	3.45
3.50	302	319	66.3	(107.0)	32.1	76.1	52.2	33.8	327	45	146	3.50
3.55	293	309	65.7	(106.0)	30.9	75.5	51.2	32.4	318	43	142	3.55
3.60	285	301	65.3	(105.5)	29.9	75.0	50.3	31.2	310	42	138	3.60
3.65	277	292	64.6	(104.5)	28.8	74.4	49.3	29.9	302	41	134	3.65
3.70	269	284	64.1	(104.0)	27.6	73.7	48.3	28.5	294	40	131	3.70
3.75	262	276	63.6	(103.0)	26.6	73.1	47.3	27.3	286	39	127	3.75
3.80	255	269	63.0	(102.0)	25.4	72.5	46.2	26.0	279	38	123	3.80

*See notation at bottom of next page

HARDNESS CONVERSION NUMBERS

FOR STEEL — Based on Brinell

Brinell Hardness Numbers (HB)*

Brinell indentation diam. mm	Brinell hardness No., 3000-kg load, 10mm Tungsten carbide ball	Vickers hardness No.	Rockwell hardness No.			Rockwell superficial hardness No., superficial Brale indenter			Knoop hardness No., 500-g load and greater	Shore Scleroscope hardness No.	Tensile strength (approx.) 1000 psi	Brinell indentation diam. mm
			A scale, 60-kg load Brale indenter	B scale, 100-kg load, 1/16-in diam. ball	C scale, 150-kg load, Brale indenter	15N scale, 15-kg load	30N scale, 30-kg load	45N scale, 45-kg load				
3.85	**248**	**261**	**62.5**	(101.1)	**24.2**	**71.7**	**45.1**	**24.5**	272	37	120	3.85
3.90	**241**	**253**	**61.8**	100.0	**22.8**	**70.9**	**43.9**	**22.8**	265	36	116	3.90
3.95	**235**	**247**	**61.4**	99.0	**21.7**	**70.3**	**42.9**	**21.5**	259	35	114	3.95
4.00	**229**	**241**	**60.8**	98.2	**20.5**	**69.7**	**41.9**	**20.1**	253	34	111	4.00
4.05	223	234	...	97.3	(19.0)	...	...	...	247	...	107	4.05
4.10	217	228	...	96.4	(17.7)	...	...	...	242	33	105	4.10
4.15	212	222	...	95.5	(16.4)	...	...	...	237	32	102	4.15
4.20	207	218	...	94.6	(15.2)	...	...	...	232	31	100	4.20
4.25	201	212	...	93.7	(13.8)	...	...	...	227	...	98	4.25
4.30	197	207	...	92.8	(12.7)	...	...	...	222	30	95	4.30
4.35	192	202	...	91.9	(11.5)	...	...	...	217	29	93	4.35
4.40	187	196	...	90.9	(10.2)	...	...	...	212	...	90	4.40
4.45	183	192	...	90.0	(9.0)	...	...	...	207	28	89	4.45
4.50	179	188	...	89.0	(8.0)	...	...	...	202	27	87	4.50
4.55	174	182	...	88.0	(6.7)	...	...	...	198	...	85	4.55
4.60	170	178	...	87.0	(5.4)	...	...	...	194	26	83	4.60
4.65	167	175	...	86.0	(4.4)	...	...	...	190	...	81	4.65
4.70	163	171	...	85.0	(3.3)	...	...	...	186	25	79	4.70
4.75	159	167	...	83.9	(2.0)	...	...	...	182	...	78	4.75
4.80	156	163	...	82.9	(0.9)	...	...	...	178	24	76	4.80
4.85	152	159	...	81.9	...	...	...	...	174	...	75	4.85
4.90	149	156	...	80.8	...	...	...	...	170	23	73	4.90
4.95	146	153	...	79.7	...	...	...	...	166	...	72	4.95
5.00	143	150	...	78.6	...	...	...	...	163	22	71	5.00
5.10	137	143	...	76.4	...	...	...	...	157	21	67	5.10
5.20	131	137	...	74.2	...	...	...	...	151	...	65	5.20
5.30	126	132	...	72.0	...	...	...	...	145	20	63	5.30
5.40	121	127	...	69.8	...	...	...	...	140	19	60	5.40
5.50	116	122	...	67.6	...	...	...	...	135	18	58	5.50
5.60	111	117	...	65.4	...	...	...	...	131	17	56	5.60

* For carbon and alloy steels in the annealed, normalized, and quenched-and-tempered conditions; less accurate for cold worked condition and for austenitic steels. Values in **boldface type** correspond to the values in the joint SAE-ASM-ASTM hardness conversions as printed in ASTM E140. Table 3. Values in parentheses are beyond normal range and are given for information only.

METRIC CONVERSION FACTORS

ENGLISH UNITS TO METRIC

TO CONVERT FROM	TO	MULTIPLY BY
angstrom	m	1.0000×10^{-10}(a)
atm	Pa	1.0133×10^{5}
Btu(b)	J	1.054×10^{3}
Btu(b)/ft²·h	W/m²	3.1525
Btu(b)/ft²·h·°F	W/m²·K	5.6745
Btu(b)/ft/h·ft²·°F	W/m·K	1.7296
Btu(b)/ft²·s	W/m²	1.135×10^{4}
Btu(b)·in./ft²·h°F	W/m·K	1.4413×10^{-1}
Btu(b)·in./s·ft²°F	W/m·K	5.1887×10^{2}
Btu(b)/lbm·°F	J/kg·K	4.1840×10^{3}
cal(b)	J	4.1840 (a)
cal(b)/cm·s·°C	W/m·K	4.1840×10^{2}(a)
cal(b)/g	J/kg	4.1840×10^{3}(a)
cal(b)/g·°C	J/kg·K	4.1840×10^{3}(a)
circ mil	m²	5.0671×10^{-10}
°C	K	$t_K = t_C + 273.15$
degree	rad	1.7453×10^{-2}
dyne/cm²	Pa	1.0000×10^{-1}(a)
°F	°C	$t_C = (t_F - 32)/1.8$
°F	K	$t_K = (t_F + 459.67)/1.8$
ft	m	3.0480×10^{-1}
ft²	m²	9.2903×10^{-2}
ft³	m³	2.8317×10^{-2}
ft of water(c)	Pa	2.9890×10^{3}
ft²/h (thermal diffusivity)	m²/s	2.58064×10^{-5}(a)
ft·lbf	J	1.3558
ft·lbf/s	W	1.3558
ft/s	m/s	3.0480×10^{-1}
gauss	T	1.0000×10^{-4}(a)
gallon(d)	m³	3.7854×10^{-3}
g/cm³	kg/m³	1.0000×10^{3}(a)
g/cm³	Mg/m³	1.0000(a)
hp(e)	W	7.4570×10^{2}
hp(f)	W	7.4600×10^{2}
in.	m	2.5400×10^{-2}
in.²	m²	6.4516×10^{-4}
in.³	m³	1.6387×10^{-5}
in. of Hg(g)	Pa	3.3864×10^{3}
in. of water(c)	Pa	2.4908×10^{2}
K	°C	$t_C = t_K - 273.15$
kgf	N	9.80665(a)
kgf/mm²	Pa	9.80665×10^{6}(a)

METRIC CONVERSION FACTORS — Continued
ENGLISH UNITS TO METRIC

TO CONVERT FROM	TO	MULTIPLY BY
ksi	MPa	6.8948
ksi	Pa	6.8948×10^{6}
ksi$\sqrt{in.}$	MPa$\sqrt{m}$	1.089
lb(h)	kg	4.5359×10^{-1}
lb/in.^{3}	kg/m^3	2.7680×10^{4}
lbf	N	4.4482
lbf·in.	N·m	1.1298×10^{-1}
lbf·ft	N·m	1.3558
MPa$\sqrt{m}$	MNm$^{-3/2}$	1.0000(a)
µin.	m	2.5400×10^{-8}(a)
mil	m	2.5400×10^{-5}(a)
N/m^2	Pa	1.0000(a)
oersted	A/m	79.578
oz/ft^2	kg/m^2	3.0515×10^{-1}
psi	Pa	6.8948×10^{3}
°R	K	$t_K = t_R/1.8$
ton(j)	kg	9.0718×10^{2}
ton(k)	kg	1.0160×10^{3}
ton/in.^{2}	Pa	1.3786×10^{4}
tonne	kg	1.0000×10^{3}(a)
torr	Pa	1.3332×10^{2}
Ω/circ mil·ft	Ω·m	1.6624×10^{-9}

(a) Exactly. (b) Thermochemical. (c) At 4 °C (39.2 °F). (d) U.S. liquid.
(e) Mechanical (1 hp = 550 ft·lbf/s). (f) Electrical. (g) At 0°C (32 °F).
(g) Avoirdupois. (j) Short; equal to 2000 lbm. (k) Long; 2240 lbm.

NOTE: To convert from metric to English units reverse the process and **divide** by the factor in the right hand column. EXAMPLE — convert 2 meters to inches:

$$2 \text{ meters} \div 0.0254 \frac{\text{meters}}{\text{inch}} = 78.740 \text{ inches}$$

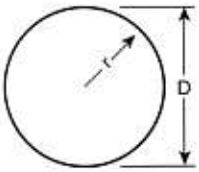
THEORETICAL WEIGHTS of STEEL BARS

ROUNDS, SQUARES, HEXAGONS AND FLATS*

SIZE (INCHES)	ROUND WT. PER FT. (POUNDS)	SQUARE WT. PER FT. (POUNDS)	HEXAGON WT. PER FT. (POUNDS)	SIZE (INCHES)	ROUND WT. PER FT. (POUNDS)	SQUARE WT. PER FT. (POUNDS)	HEXAGON WT. PER FT. (POUNDS)
1/32	0.0026	0.0033	0.0028	2 7/16	15.89	20.22	17.51
1/16	0.0104	0.0133	0.0115	2 1/2	16.71	21.27	18.42
3/32	0.0235	0.0299	0.0259	2 5/8	18.42	23.45	20.31
1/8	0.0417	0.0532	0.0460	2 3/4	20.21	25.74	22.29
5/32	0.0653	0.0831	0.0720	2 7/8	22.09	28.13	24.37
3/16	0.0940	0.1196	0.1036	3	24.05	30.63	26.53
7/32	0.1279	0.1629	0.1410	3 1/8	26.11	33.24	28.78
1/4	0.1671	0.2127	0.1842	3 1/4	28.24	35.95	31.13
9/32	0.2114	0.2692	0.2331	3 3/8	30.45	38.77	33.58
5/16	0.2611	0.3324	0.2878	3 1/2	32.74	41.69	36.11
11/32	0.3158	0.4022	0.3483	3 5/8	35.13	44.73	38.73
3/8	0.3759	0.4786	0.4145	3 3/4	37.59	47.86	41.45
13/32	0.4412	0.5617	0.4865	3 7/8	40.14	51.50	44.26
7/16	0.5116	0.6515	0.5642	4	42.77	54.46	47.16
15/32	0.5873	0.7479	0.6477	4 1/8	45.49	57.19	50.15
1/2	0.6683	0.8509	0.7369	4 1/4	48.28	61.48	53.24
17/32	0.7544	0.9606	0.8319	4 3/8	51.16	65.15	56.42
9/16	0.8458	1.077	0.9327	4 1/2	54.13	68.92	59.69
19/32	0.9424	1.200	1.039	4 5/8	57.18	72.81	63.05
5/8	1.044	1.329	1.151	4 3/4	60.13	76.79	66.51
21/32	1.151	1.466	1.269	4 7/8	63.53	80.89	70.05
11/16	1.263	1.609	1.393	5	66.83	85.09	73.69
23/32	1.381	1.758	1.523	5 1/8	70.21	89.39	77.42
3/4	1.504	1.915	1.658	5 1/4	73.68	93.81	81.25
25/32	1.632	2.077	1.799	5 3/8	77.23	98.33	85.16
13/16	1.765	2.247	1.946	5 1/2	80.87	103.0	89.16
27/32	1.903	2.424	2.098	5 5/8	84.58	107.7	93.26
7/8	2.046	2.606	2.256	5 3/4	88.38	112.5	97.45
29/32	2.195	2.795	2.421	5 7/8	92.27	117.5	102.7
15/16	2.349	2.991	2.591	6	96.23	122.5	106.1
31/32	2.509	3.194	2.766	6 1/2	112.9	143.8	124.5
1	2.673	3.404	2.947	7	131.0	166.8	144.4
1 1/16	3.018	3.842	3.328	7 1/2	150.4	191.4	165.8
1 1/8	3.384	4.308	3.731	8	171.1	217.8	188.6
1 3/16	3.770	4.800	4.156	8 1/2	193.1	245.9	212.9
1 1/4	4.176	5.319	4.606	9	216.5	275.7	238.7
1 5/16	4.605	5.863	5.077	9 1/2	241.2	307.1	266.0
1 3/8	5.054	6.435	5.573	10	267.3	340.3	294.7
1 7/16	5.524	7.033	6.091	11	323.4	411.8	356.6
1 1/2	6.014	7.658	6.632	12	384.9	490.1	424.4
1 9/16	6.526	8.310	7.197	13	451.7	575.1	498.1
1 5/8	7.058	8.988	7.783	14	523.9	667.0	577.7
1 11/16	7.612	9.692	8.394	15	601.4	765.7	663.1
1 3/4	8.187	10.42	9.028	16	684.3	871.2	754.5
1 13/16	8.782	11.18	9.680	17	772.5	983.5	851.7
1 7/8	9.398	11.96	10.36	18	866.0	1,102.6	954.9
1 15/16	10.03	12.77	11.06	19	946.9	1,228.6	1,063.9
2	10.69	13.61	11.79	20	1,069.2	1,361.3	1,178.9
2 1/16	11.37	14.48	12.54	21	1,178.7	1,500.8	1,299.7
2 1/8	12.07	15.37	13.31	22	1,293.7	1,647.2	1,426.4
2 3/16	12.79	16.29	14.10	23	1,414.0	1,800.3	1,559.1
2 1/4	13.53	17.23	14.93	24	1,539.6	1,960.2	1,697.6
2 5/16	14.29	18.20	15.77	25	1,670.5	2,127.0	1,842.0
2 3/8	15.08	19.20	16.63	26	1,806.9	2,300.6	1,992.3

*Flats. To determine the theoretical weight in pounds per linear foot, multiply the width in inches times the thickness in inches times 3.404. (To determine the theoretical weight in kilograms per linear metre, multiply pounds per foot by 1.488164).

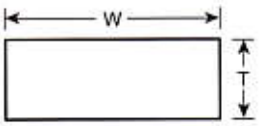
AREAS/WEIGHTS FOR BARS AND TUBES



AREA = $3.1416 \times r^2$
= $0.7584 \times D^2$

CIRCUMFERENCE = $3.1416 \times D$

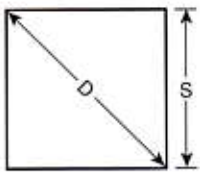
WEIGHT PER FOOT (ROUND STEEL BAR) = $2.6729 \times D^2$ (LBS)



AREA = $W \times T$

CIRCUMFERENCE = $2 \times (W + T)$

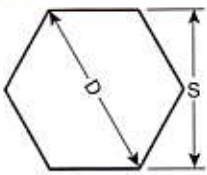
WEIGHT PER FOOT (FLAT STEEL BAR) = $W \times T \times 3.4032$ (LBS)



AREA = S^2
$D = 1.4142 \times S$

CIRCUMFERENCE = $4 \times S$

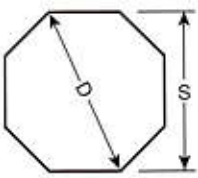
WEIGHT PER FOOT (SQUARE STEEL BAR) = $3.4032 \times S^2$ (LBS)



AREA = $0.8660 \times S^2$
$D = 1.1547 \times S$

CIRCUMFERENCE = $3 \times D$
= $3.4641 \times S$

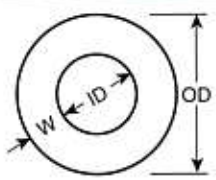
WEIGHT PER FOOT (HEXAGON STEEL BAR) = $2.9473 \times S^2$ (LBS)



AREA = $0.8284 \times S^2$
$D = 1.0824 \times S$

CIRCUMFERENCE = $3.0613 \times D$
= $3.3137 \times S$

WEIGHT PER FOOT (OCTAGON STEEL BAR) = $2.8193 \times S^2$ (LBS)



AREA = $0.7854 \times (OD^2 - ID^2)$
= $3.1416 \times W \times (D - W)$
$ID = OD - (2 \times W)$

WEIGHT PER FOOT (ROUND STEEL TUBE) = $10.6915 \times W \times (OD - W)$ (LBS)
= $2.6729 \times (OD^2 - ID^2)$ (LBS)

NOTE: Weight calculations based on 1 cubic inch = 0.2836 pound.

WEIGHTS OF ALLOYS AND METALS

ALLOYS AND METALS	LB. PER CU. FT.	LB. PER CU. IN.
Aluminum	163	0.0975
Aluminum and Tin:		
Al 91%, Sn 9%	178	0.103
Aluminum, Copper, and Tin:		
Al 85%, Cu 7.5%, Sn 7.5%	188	0.1087
Al 6.25%, Cu 87.5%, Sn 6.25%	459	0.2656
Al 5%, Cu 5%, Sn 90%	425	0.2459
Aluminum and Magnesium:		
Al 70%, Mg 30%	125	0.0723
Aluminum and Zinc:		
Al 91%, Zn 9%	175	0.1012
Antimony	419	0.2391
Babbitt Alloy	454	0.2627
Bismuth	611	0.3541
Bismuth, Lead, and Tin:		
Bi 53%, Pb 40%, Sn 7%	659	0.3813
Wood's Metal:		
Bi 50%, Pb 25%, Cd 12.5%, Sn 12.5%	605	0.3501
Brass:		
Cu 90%, Zn 10%	536	0.3101
Cu 70%, Zn 30%	527	0.3049
Cu 60%, Zn 40%	521	0.3015
Cu 50%, Zn 50%	511	0.2957
Bronze:		
Cu 90%, Sn 10%	548	0.3171
Cu 85%, Sn 15%	555	0.3211
Cu 80%, Sn 20%	545	0.3153
Cu 75%, Sn 25%	551	0.3188
Cu 90%, Al 10%	480	0.2777
Cu 95%, Al 5%	522	0.302
Cu 97%, Al 3%	542	0.3136
Bronze, Phosphorus, Average	537	0.3107
Bronze, Tobin, Average	503	0.291
Cadmium and Tin:		
Cd 32%, Sn 68%	480	0.2777
Chromium	436	0.2579
Cobalt	533	0.3216
Copper	557	0.323
Copper and Nickel:		
Cu 60%, Ni 40%	554	0.3206
German Silver:		
Cu 60%, Zn 20%, Ni 20%	530	0.3067
Cu 52%, Zn 26%, Ni 22%	527	0.3049
Cu 59%, Zn 30%, Ni 11%	520	0.3009
Cu 63%, Zn 30%, Ni 7%	518	0.2997
Gold	1208	0.6973
Gold and Copper:		
Au 98%, Cu 2%	1176	0.6805
Au 90%, Cu 10%	1071	0.6197
Au 86%, Cu 14%	1027	0.5943
Gun Metal, Average	544	0.3148
Iridium	1396	0.809
Iron, Cast	450	0.2604
Iron, Wrought	480	0.2777
Lead	708	0.409

Continued on next page

WEIGHTS OF ALLOYS AND METALS — Continued

ALLOYS AND METALS	LB. PER CU. FT.	LB. PER CU. IN.
Lead and Antimony:		
Pb 30%, Sb 70%	450	0.2604
Pb 37%, Sb 63%	460	0.2662
Pb 44%, Sb 56%	475	0.2748
Pb 63%, Sb 37%	514	0.2974
Pb 83%, Sb 17%	596	0.3449
Pb 90%, Sb 10%	658	0.3807
Lead and Bismuth:		
Bi 67%, Pb 33%	639	0.3697
Bi 50%, Pb 50%	656	0.3796
Bi 33%, Pb 67%	682	0.3946
Bi 25%, Pb 75%	697	0.4033
Bi 17%, Pb 83%	702	0.4062
Bi 12%, Pb 88%	703	0.4068
Lead and Tin:		
Pb 87.5%, Sn 12.5%	661	0.3825
Pb 84%, Sn 16%	644	0.3726
Pb 63.7%, Sn 36.3%	588	0.3402
Pb 46.7%, Sn 53.3%	545	0.3153
Pb 30.5%, Sn 69.5%	514	0.2974
Magnesium	109	0.0628
Manganese	499	0.260
Manganese, Copper, and Nickel:		
Mn 12%, Cu 84%, Ni 4%	530	0.3067
Mercury	849	0.489
Nickel	550	0.320
Osmium	1402	0.812
Palladium	712	0.433
Platinum	1344	0.774
Platinum and Iridium:		
Pt 90%, Iridium 10%	1348	0.780
Rhodium	755	0.452
Ruthenium	765	0.441
Silver	654	0.380
Steel, Cast	490	0.2835
Tin	460	0.264
Tin and Antimony:		
Sn 50%, Sb 50%	424	0.2453
Sn 75%, Sb 25%	442	0.2557
Tin and Bismuth:		
Bi 78%, Sn 22%	587	0.3396
Bi 63%, Sn 37%	570	0.3298
Bi 50%, Sn 50%	546	0.3159
Bi 37%, Sn 63%	530	0.3067
Bi 22%, Sn 78%	504	0.2916
Tin and Lead:		
Sn 97%, Pb 3%	456	0.2638
Sn 89%, Pb 11%	475	0.2748
Sn 80%, Pb 20%	487	0.2818
Sn 67%, Pb 33%	512	0.2962
Sn 50%, Pb 50%	550	0.3182
Titanium	224	0.163
Tungsten	1078.7	0.698
Zinc	437	0.258

ARC WELDING OF HARDENABLE CARBON STEELS

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Carbon steels are defined as steels that contain up to 2% C, 1.65% Mn, 0.6% Si, and 0.6% Cu. Phosphorus and sulfur may also be present in these steels in concentrations up to 0.04 and 0.05%, respectively. Carbon content and the steel making process used (acid or basic) are frequently used as guidelines for the classification of carbon steels. Carbon content, however, because of its well-defined effects on the properties of steel, is considered the most common criterion for classification.

Low-carbon steels, those containing less than 0.25% C, are generally easy to join by any arc welding process. Welds of acceptable quality usually can be produced without the need for preheating, postheating, or special welding techniques, provided the sections being welded are less than 1 in. thick and that severe joint restraint does not exist. Filler-metal selection is seldom critical for welding low-carbon steel and is based mainly on tensile-strength requirement.

Medium-carbon steels, those containing 0.25 to 0.50% C, can also be satisfactorily welded by all of the arc welding processes. Because of the formation of greater amounts of martensite in the weld zone and the higher hardness of the martensite, preheating or postheating, or both are often necessary.

For joint designs and welding processes and procedures that induce high weld cooling rates, preheat is used to inhibit martensite formation and allow upper transformation products to form. Postweld heat treatment also is used to temper martensite and restore toughness in the HAZ. Modification in welding procedure — for example, the use of large V-grooves or multiple passes — also decrease the cooling rate and the probability of weld cracking. In multiple-pass welding, the final weld bead should be deposited in such a manner that it is surrounded on both sides by weld metal from previous passes. By so doing, the HAZ that results from the deposition of the previous-pass weld beads is tempered by the heat from the final-pass bead.

Selection of filler materials for arc welding becomes more critical as the carbon content of the steel increases. Steels with higher carbon contents are more susceptible to hydrogen-induced cracking; therefore, low-hydrogen electrodes and processes ordinarily are used. As the carbon content of the steel being welded approaches 0.50%, low-hydrogen conditions become mandatory.

High-carbon steels, with more than 0.50% C, are difficult to weld because of their susceptibility to cracking. Excessive hardness and brittleness often occur.

For best results in SMAW, the use of low-hydrogen electrodes is recommended. Similarly, for other arc welding processes, low-hydrogen practice is mandatory. Both preheating and postweld stress relieving or tempering usually are required. Austenitic stainless steel electrodes sometimes are used for welding high-carbon steel to obtain greater notch toughness in the joint. However, the HAZ may still be hard and brittle, and pre-heating and post weld stress relieving may be necessary.

Successful welding for high-carbon steel requires the development of specific welding procedures for each application. Composition, thickness and configuration of the component parts, and the service requirements must be considered. For each application, the welding procedure should be qualified by tests before it is adopted. High-carbon steels frequently are welded using procedures suggested for tool steels, which are discussed in the TOOL STEEL section.

ARC WELDING OF AISI/SAE ALLOY BAR STEELS

(Reprinted from METALS HANDBOOK, 9th Ed., with permission of the publisher, ASM International, Metals Park, Ohio)

The steels discussed in this section are the widely used hot rolled and cold finished bar steels, ranging in carbon content from 0.09 to 0.64% and in alloy content (excluding manganese and silicon) from zero (the 13xx series) to approximately 4.0% (the 48xx series). These steels are capable of developing maximum as-quenched hardness from approximately 36 to 65 HRC. The hardenability ranges from only slightly higher than that of plain carbon steels to that characterized by steels such as 4140H and 4340H. The weldability of these steels generally decreases as hardenability increases.

Table A lists 18 representative AISI alloy steels within the range of 0.18 to 0.53% C content. Alloy steels containing more than 0.53% C are seldom welded. The table includes the alloy steels that are most frequently selected for weldments, with 4130 being the most widely used, because it combines high strength in the heat treated condition with acceptable weldability. AISI steels 4140 and 4340 are also used extensively for weldments, but are more difficult to weld without cracking than 4130 steel.

SHIELDED METAL ARC WELDING (Stick Welding): Table A lists covered electrodes commonly used for producing high-strength welds in 18 alloy steels by SMAW. In Table A, E7018 (or E7018-A1, carbon-molybdenum) is shown as the choice for six steels. This electrode, a low-hydrogen iron-powder type, provides an as-welded joint having minimum tensile strength of 70 ksi. The minimum tensile strength of deposited weld metal is denoted by the first two of four, or the first three of five, digits in each electrode designation. For single-pass welds, the strength specified for the deposited weld metal usually increases as carbon content of the base metal increases.

TABLE A

METAL	ELECTRODE	METAL	ELECTRODE	METAL	ELECTRODE
1330	E7018	4130	E10016-D2	4640	E12018-M
1340	E10016-D2	4140	E12018-M	5120	E8016-B2
4023	E7018-A1	4150	E12018-M	5145	E9016-B3
4028	E7018-A1	4320	E7018-A1	8620	E7018-A1
4047	E10016-D2	4340	E12018-M	8630	E11018-M
4118	E7018-A1	4620	E8016-C1	8640	E12018-M

All of the electrodes listed in Table A are low-hydrogen types. Low-hydrogen electrodes almost always are recommended for welding alloy steels to help prevent cracking.

Unless a joint of maximum strength is required, a lower strength filler metal can often be used and the susceptibility to cracking thereby decreased. For instance, the electrode shown in the table as commonly used for welding 4130 steel is D10016-D2, but if a lower as-welded strength is acceptable, E7018-A1 can be used.

FLUX CORED ARC WELDING: Flux cored electrodes are selected largely on the basis of the mechanical properties of the deposited weld metal. Because susceptibility to cracking increases as strength increases, the lower strength filler metals should be used if the lower strength is acceptable. For joining 4130 to 4130 in one example, a weld of acceptable strength was made with an electrode wire that resulted in an as-welded composition of 0.15% C, 1.60% Mn, 0.55% Si, 0.70 % Cr, and 0.75% Mo. One advantage of FCAW of alloy steels is that cored electrode wires of special composition are more readily obtained than are solid wires of special composition. When only moderate strength is required, low-carbon steel electrodes are used. When strength requirements are higher, alloy steel electrode wires that provide weld metal to match or nearly match the alloy composition of the base metal are most commonly used. Low alloy filler metals used for FCAW of AISI-SAE bar steels are covered in AWS A5.29.

GAS METAL ARC WELDING (MIG Welding): High quality electrode wires of virtually any composition are obtainable for GMAW. The carbon content of the electrode wire should generally be lower than that of the base metal to minimize the formation of hard, brittle transformation products that may cause cracking. For instance, in welding 4130 steel, an electrode containing no more than about 0.20% C should be used. If the completed weldment is to be heat treated (for example, quenched and tempered), a filler metal of similar composition should be used. Low-alloy steel filler metals used for GMAW of AISI-SAE bar steels are covered in AWS A5.28.

SUBMERGED ARC WELDING: SAW electrodes are intended primarily for welding low-carbon steel, but they are also used for alloy steel weldments.

Filler metal that matches the base metal in alloy content is usually recommended when a submerged arc weld of maximum strength is required, but the carbon content of the filler metal should be lower than (often no more than half) that of the base metal, as previously described for GMAW.

GAS TUNGSTEN ARC WELDING (TIG Welding): In many applications, alloy steels are welded by GTAW without filler metal. Selection of filler metal (if used) for GTAW generally presents fewer problems than for the other arc welding processes. In GTAW, the filler metal is fed into the weld pool, not into the arc, which is an advantage because it results in more efficient alloy transfer and thus enables more accurate control over the composition of the weld metal. It is generally recommended that filler metals match the base metal composition, but higher alloys are selected whenever special properties are needed.

PREHEATING: Suggested preheating and interpass temperatures for 18 alloy bar steels are given in Table B. These suggested temperatures are based on the use of low-hydrogen electrodes. The preheating temperature increases with the carbon content or hardenability of the steel and with the section thickness. If local preheating is used, the full thickness of the joint and about 3 in. (or a distance equal to base-metal thickness, whichever is smaller) on either side of the joint, should be preheated. The preheating temperatures suggested in Table B are intended as a guide.

TABLE B

SUGGESTED PREHEAT & INTERPASS TEMPERATURES for Various Alloy Steel Bars

	TEMPERATURE, °F for Section Thickness				TEMPERATURE, °F for Section Thickness		
STEEL	to ½ in.	½ to 1 in.	1 to 2 in.	STEEL	to ½ in.	½ to 1 in.	1 to 2 in.
1330	350-450	400-500	450-550	4320	200-300	350-450	400-500
1340	400-500	500-600	600-700	4340	600-700	600-700	600-700
4023	100 min	200-300	250-350	4620	100 min	200-300	250-350
4028	200-300	250-350	400-500	4640	350-450	400-500	450-500
4047	400-500	450-550	500-600	5120	100 min	200-300	250-350
4118	200-300	350-450	400-500	5145	400-500	450-550	500-600
4130	300-400	400-500	450-550	8620	100 min	200-300	250-350
4140	400-500	600-700	600-700	8630	200-300	250-300	400-500
4150	600-700	600-700	600-700	8640	350-450	400-500	450-550

Under certain circumstances, such as very low restraint, alloy steels can be welded successfully without preheating. Often, preheating of the entire weldment is impractical, so that if preheating is needed, it must be done locally.

POSTHEATING: Generally, postheating is specified for the steels in Table B that contain more than about 0.35% C, although there are many exceptions. One practice for welding these higher carbon steels is to use a preheating and interpass temperature that is just above the M_S temperature for the particular steel, and then to hold at this temperature for at least 1 hour. The objective is to permit the weld metal to transform from austenite to softer microconstituents, rather than to martensite, and thereby to minimize the possibility of cracking without undue sacrifice in mechanical properties.

Stress relieving usually is required and may be mandatory for weldments of all of the steels listed in Table B, if the weldment is to be put into service without being quenched and tempered. If a weldment is to be quenched and tempered, stress relieving can usually be omitted. Dimensional stability and notch toughness usually determine the need for stress relief.

In preferred practice, the heating for stress relieving, or for the austenitizing that precedes quenching, should begin before the weldment cools to a temperature below the interpass temperature. However, this procedure is not always practical, and in some applications the weldment remains at room temperature for an indefinite time before being stress relieved. Drafts of air impinging on the weldment while it is cooling to room temperature should be avoided.

For complete, or almost complete, stress relief, the weldment should be heated to 1100 to 1200°F and held for one hour per inch of maximum base-metal thickness. If heating in this range is impractical, partial stress relief can be attained by heating at a lower temperature (for instance, 900°F) for several hours.

GLOSSARY OF STEEL INDUSTRY TERMS

A

age hardening. Hardening by aging, usually after rapid cooling or cold working. See *aging.*

aging. A change in the properties of certain metals and alloys that occurs at ambient or moderately elevated temperatures after hot working or a heat treatment (quench aging in ferrous alloys, natural or artificial aging in ferrous and nonferrous alloys) or after a cold working operation (strain aging). The change in properties is often, but not always, due to a phase change (precipitation), but never involves a change in chemical composition of the metal or alloy. See also *age hardening, precipitation hardening, strain aging.*

air-hardening steel. A steel containing sufficient carbon and other alloying elements so as to harden fully during cooling in air or other gaseous media from a temperature above its transformation range. This term should be restricted to steels that are capable of being hardened by cooling in air in fairly large sections, about 2 in. or more in diameter. Same as self-hardening steel.

AISI. *Abbreviation for American Iron and Steel Institute.*

alloy. A substance having metallic properties and being composed of two or more chemical elements of which at least one is a *metal.*

alloying element. An element which is added to a metal (and which remains within the metal) to effect changes in properties.

alloy steel. Steel containing specified quantities of alloying elements (other than carbon and the commonly accepted amounts of manganese, copper, silicon, sulfur and phosphorus) within the limits recognized for constructional alloy steels, added to effect changes in mechanical or physical properties.

annealing. A generic term denoting a treatment, consisting of heating to and holding at a suitable temperature followed by cooling at a suitable rate, used primarily to soften metallic materials, but also to simultaneously produce desired changes in other properties or in microstructure. The purpose of such changes may be, but is not confined to: improvement of machinability, facilitation of cold work, improvement of mechanical or electrical properties, and/or increase in stability of dimensions. When the term is used unqualifiedly, full annealing is implied. When applied only for the relief of stress, the process is properly called *stress relieving* or stress-relief annealing.

In ferrous alloys, annealing usually is done above the upper critical temperature, but the time-temperature cycles vary widely both in maximum temperature attained and in cooling rate employed, depending on composition, material condition, and results desired. When applicable, the following commercial process names should be used: *black annealing, blue annealing, box annealing, bright annealing, cycle annealing, flame annealing, full annealing, graphitizing, in-process annealing, isothermal annealing, malleablizing, orientation annealing, process annealing, quench annealing, spheroidizing, subcritical annealing.*

ASTM. *Abbreviation for American Society for Testing and Materials.*

Ar_{cm}, Ar_1, Ar_3, Ar_4, Ar', Ar". Defined under *transformation temperature.*

austempering. A heat treatment for ferrous alloys in which a part is quenched from the austenitizing temperature at a rate fast enough to avoid formation of ferrite or pearlite and then held at a temperature just above M_s until transformation to bainite is complete.

austenite. A solid solution of one or more elements in face-centered cubic iron. Unless otherwise designated (such as nickel austenite), the solute is generally assumed to be carbon.

austenitizing. Forming austenite by heating a ferrous alloy into the transformation range (partial austenitizing) or above the transformation range (complete austenitizing). When used without qualification, the term implies complete austenitizing.

AWS. *Abbreviation for American Welding Society.*

B

bainite. A metastable aggregate of ferrite and cementite resulting from the transformation of austenite at temperatures below the pearlite range but above M_s. Bainite formed in the upper part of the bainite transformation range has a feathery appearance; bainite formed in the lower part of the range has an acicular appearance resembling that of tempered martensite.

baking. (1) Heating to a low temperature in order to remove gases. (2) Curing or hardening surface coatings such as paints by exposure to heat. (3) Heating to drive off moisture, as in baking of sand cores after molding.

banded structure. A segregated structure consisting of alternating nearly parallel bands of different composition, typically aligned in the direction of primary hot working.

beach marks. Progression marks on a fatigue fracture surface that indicate successive positions of the advancing crack front. The classic appearance is of irregular elliptical or semielliptical rings, radiating outward from one or more origins. Beach marks (also

GLOSSARY OF STEEL INDUSTRY TERMS — Continued

known as clamshell marks or tide marks) are typically found on service fractures where the part is loaded randomly, intermittently, or with periodic variations in mean stress or alternating stress.

billet. (1) A solid semifinished round or square product that has been hot worked by forging, rolling or extrusion; usually smaller than a *bloom*. (2) A general term for wrought starting stock used in making forgings or extrusions.

blank carburizing. Simulating the carburizing operation without introducing carbon. This is usually accomplished by using an inert material in place of the carburizing agent, or by applying a suitable protective coating to the ferrous alloy.

bloom. (1) A semifinished hot rolled product, rectangular in cross section, produced on a blooming mill. See also *billet*. For steel, the width of a bloom is not more than twice the thickness, and the cross-sectional area is usually not less than about 230 cm^2 (36 $in.^2$). Steel blooms are sometimes made by forging. (2) A visible exudation or efflorescence on the surface of an electroplating bath. (3) A bluish fluorescent cast to a painted surface caused by deposition of a thin film of smoke, dust or oil. (4) A loose, flowerlike corrosion product that forms when certain metals are exposed to a moist environment.

blue brittleness. Brittleness exhibited by some steels after being heated to some temperature within the range of about 200 to 370 °C (400 to 700 °F), particularly if the steel is worked at the elevated temperature. Killed steels are virtually free of this kind of brittleness.

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 fracture. Separation of a solid accompanied by little or no macroscopic plastic deformation. Typically, brittle fracture occurs by rapid crack propagation with less expenditure of energy than for ductile fracture.

brittleness. The quality of a material that leads to crack propagation without appreciable plastic deformation.

burning. (1) Permanently damaging a metal or alloy by heating to cause either incipient melting or intergranular oxidation. See *overheating*. (2) In grinding, getting the work hot enough to cause discoloration or to change the microstructure by tempering or hardening.

C

capped steel. A type of steel similar to rimmed steel, usually cast in a bottle-top ingot mold, in which the application of a mechanical or a chemical cap renders the rimming action incomplete by causing the top metal to solidify. The surface condition of capped steel is much like that of rimmed steel, but certain other characteristics are intermediate between those of *rimmed steel* and those of *semikilled steel*.

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

carbon equivalent. (1) for cast iron, an empirical relationship of the total carbon, silicon and phosphorus contents expressed by the formula:

$$CE = TC + {}^1/_3(Si + P)$$

(2) For rating of weldability:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

carbonitriding. A case hardening process in which a suitable ferrous material is heated above the lower transformation temperature in a gaseous atmosphere of such composition as to cause simultaneous absorption of carbon and nitrogen by the surface and, by diffusion, create a concentration gradient. The process is completed by cooling at a rate that produces the desired properties in the workpiece.

carbon steel. Steel having no specified minimum quantity for any alloying element (other than the commonly accepted amounts of manganese, silicon and copper) and containing only an incidental amount of any element other than carbon, silicon, manganese, copper, sulfur and phosphorus.

carburizing. Absorption and diffusion of carbon into solid ferrous alloys by heating, to a temperature usually above Ac_3, in contact with a suitable carbonaceous material. A form of *case hardening* that produces a carbon gradient extending inward from the surface, enabling the surface layer to be hardened either by quenching directly from the carburizing temperature or by cooling to room temperature, then reaustenitizing and quenching.

case. That portion of a ferrous alloy, extending inward from the surface, whose composition has been altered so that it can be *case hardened*. Typically considered to be the portion of the alloy (*a*) whose composition has been measurably altered from the original composition, (*b*) that appears dark on an etched cross section, or (*c*) that has a hardness, after hardening, equal to or greater than a specified value. Contrast with *core* (2).

GLOSSARY OF STEEL INDUSTRY TERMS — Continued

case hardening. A generic term covering several processes applicable to steel that change the chemical composition of the surface layer by absorption of carbon, nitrogen, or a mixture of the two and, by diffusion, create a concentration gradient. The processes commonly used are *carburizing* and *quench hardening; cyaniding; nitriding;* and *carbonitriding.* The use of the applicable specific process name is preferred.

cast iron. A generic term for a large family of cast ferrous alloys in which the carbon content exceeds the solubility of carbon austenite at the eutectic temperature. Most cast irons contain at least 2% carbon, plus silicon and sulfur, and may or may not contain other alloying elements. For the various forms *gray cast iron, white cast iron, malleable cast iron* and *ductile cast iron,* the word "cast" is often left out, resulting in "gray iron," "white iron," "malleable iron" and "ductile iron," respectively.

cementite. A compound of iron and carbon, known chemically as iron carbide and having the approximate chemical formula Fe_3C. It is characterized by an orthorhombic crystal structure. When it occurs as a phase in steel, the chemical composition will be altered by the presence of manganese and other carbide-forming elements.

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. Contrast with *Izod test.*

chevron pattern. A fractographic pattern of radial marks (shear edges) that look like nested letters "V"; sometimes called a herringbone pattern. Chevron patterns are typically found on brittle fracture surfaces in parts whose widths are considerably greater than their thicknesses. The points of the chevrons can be traced back to the fracture origin.

cleanup allowance. See *finish allowance.*

cold drawing. Reducing the cross section of a metal bar, rod or tube by drawing it through a die at a temperature below the recrystallization range, usually room temperature.

cold rolling. Reducing the cross section of a metal bar or sheet in a rolling mill below the recrystallization temperature, usually room temperature.

cold work. Permanent strain in a metal accompanied by strain hardening.

cold working. Deforming metal plastically under conditions of temperature and strain rate that induce strain hardening. Usually, but not necessarily, conducted at room temperature. Contrast with *hot working.*

combined carbon. The part of the total carbon in steel or cast iron that is present as other than *free carbon.*

compacted graphite cast iron. Cast iron having a graphite shape intermediate between the flake form typical of gray cast iron and the spherical form of fully spherulitic ductile cast iron. Also known as CG iron or vermicular iron, compacted graphite cast iron is produced in a manner similar to that for ductile cast iron, but using a technique that inhibits the formation of fully spherulitic graphite nodules.

compressive strength. The maximum compressive stress that a material is capable of developing, based on original area of cross section. If a material fails in compression by a shattering fracture, the compressive strength has a very definite value. If a material does not fail in compression by a shattering fracture, the value obtained for compressive strength is an arbitrary value depending upon the degree of distortion that is regarded as indicating complete failure of the material.

continuous casting. A casting technique in which a cast shape is continuously withdrawn through the bottom of the mold as it solidifies, so that its length is not determined by mold dimensions. Used chiefly to produce semifinished mill products such as billets, blooms, ingots, slabs and tubes. See also *strand casting.*

core. (1) A specially formed material inserted in a mold to shape the interior or other part of a casting that cannot be shaped as easily by the pattern. (2) In a ferrous alloy prepared for *case hardening,* that portion of the alloy that is not part of the *case.* Typically considered to be the portion that (*a*) appears light on an etched cross section, (*b*) has an essentially unaltered chemical composition, or (*c*) has a hardness, after hardening, less than a specified value.

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

corrosion embrittlement. The severe loss of ductility of a metal resulting from corrosive attack, usually intergranular and often not visually apparent.

creep. Time-dependent strain occurring under stress. The creep strain occurring at a diminishing rate is called primary creep; that occurring at a minimum and almost constant rate, secondary creep; and that occurring at an accelerating rate, tertiary creep.

critical point. (1) The temperature or pressure at which a change in crystal structure, phase or physical properties occurs. Same as *transformation temperature.* (2) In an equilibrium diagram, that specific value of composition, temperature or pressure, or combinations thereof, at which the phases of a heterogeneous system are in equilibrium.

GLOSSARY OF STEEL INDUSTRY TERMS — Continued

critical temperature. (1) Synonymous with *critical point* if the pressure is constant. (2) The temperature above which the vapor phase cannot be condensed to liquid by an increase in pressure.

critical temperature ranges. Synonymous with *transformation ranges*, which is the preferred term.

crystalline fracture. A pattern of brightly reflecting crystal facets on the fracture surface of a polycrystalline metal, resulting from cleavage fracture of many individual crystals.

crystallization. (1) The separation, usually from a liquid phase on cooling, of a solid crystalline phase. (2) Sometimes erroneously used to explain fracturing that actually has occurred by fatigue.

Curie temperature. The temperature of magnetic transformation below which a metal or alloy is ferromagnetic and above which it is paramagnetic.

cyaniding (liquid carbonitriding). A case hardening process in which a ferrous material is heated above the lower transformation range in a molten salt containing cyanide to cause simultaneous absorption of carbon and nitrogen at the surface and, by diffusion, create a concentration gradient. *Quench hardening* completes the process.

D

dead soft. A condition of minimum hardness and tensile strength.

decarburization. Loss of carbon from the surface of a ferrous alloy as a result of heating in a medium (atmosphere) that reacts with the carbon.

diffusion. (1) Spreading of a constituent in a gas, liquid or solid, tending to make the composition of all parts uniform. (2) The spontaneous movement of atoms or molecules to new sites within a material, as occurs in carburizing.

direct quenching. (1) Quenching carburized parts directly from the carburizing operation. (2) Also used for quenching pearlitic malleable parts directly from the malleablizing operation.

distortion. Any deviation from an original size, shape or contour that occurs because of the application of stress or the release of residual stress.

double tempering. A treatment in which a quench-hardened ferrous metal is subjected to two complete tempering cycles, usually at substantially the same temperature, for the purpose of ensuring completion of the tempering reaction and promoting stability of the resulting microstructure. Primarily used for alloy and high speed tool steels.

drawing. (1) Forming recessed parts by forcing the plastic flow of metal in dies. (2) Reducing the cross section of bar stock, wire or tubing by pulling through a die. (3) A misnomer for tempering (see *temper*).

ductile cast iron. A *cast iron* that has been treated while molten with an element such as magnesium or cerium to induce the formation of free graphite as nodules or spherulites, which imparts a measurable degree of ductility to the cast metal. Also known as nodular cast iron, spherulitic graphite cast iron and SG iron.

ductile fracture. Fracture characterized by tearing of metal accompanied by appreciable gross plastic deformation and expenditure of considerable energy.

ductility. The ability of a material to deform plastically without fracturing, measured by elongation or reduction of area in a tensile test, by height of cupping in an Erichsen test or by other means.

E

elasticity. Ability of a solid to deform in direct proportion to and in phase with increases or decreases in applied force.

elastic limit. The maximum stress to which a material may be subjected without any permanent strain remaining upon complete release of stress.

end-quench hardenability test. A laboratory procedure for determining the hardenability of a steel or other ferrous alloy; widely referred to as the Jominy test. Hardenability is determined by heating a standard specimen above the upper critical temperature, placing the hot specimen in a fixture so that a stream of cold water impinges on one end, and, after cooling to room temperature is completed, measuring the hardness near the surface of the specimen at regularly spaced intervals along its length. The data are normally plotted as hardness versus distance from the quenched end.

endurance limit. The maximum stress below which a material can presumably endure and infinite number of stress cycles. If the stress is not completely reversed, the value of the mean stress, the minimum stress or the stress ratio also should be stated.

etching. (1) Subjecting the surface of a metal to preferential chemical or electrolytic attack in order to reveal structural details for metallographic examination. (2) Chemically or electrochemically removing tenacious films from a metal surface to condition the surface for a subsequent treatment, such as painting or electroplating.

GLOSSARY OF STEEL INDUSTRY TERMS — Continued

F

fatigue. The phenomenon leading to fracture under repeated or fluctuating stresses having a maximum value less than the tensile strength of the material. Fatigue fractures are progressive, beginning as minute cracks that grow under the action of the fluctuating stress.

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.

file hardness. Hardness as determined by the use of a file of standardized hardness on the assumption that a material that cannot be cut with the file is as hard as, or harder than, the file. Files covering a range of hardnesses may be employed.

finish allowance. The amount of excess metal surrounding the intended final configuration of a formed part; sometimes called forging envelope, machining allowance, or cleanup allowance.

flame hardening. A process for hardening the surfaces of hardenable ferrous alloys in which an intense flame is used to heat the surface layers above the upper transformation temperature, whereupon the workpiece is immediately quenched.

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

free carbon. The part of the total carbon in steel or cast iron that is present in elemental form as graphite or temper carbon. Contrast with *combined carbon.*

G

grain. An individual crystal in a polycrystalline metal or alloy; it may or may not contain twinned regions and subgrains.

grain growth. An increase in the average size of the grains in polycrystalline metal, usually as a result of heating at an elevated temperature.

graphitic steel. Alloy steel made so that part of the carbon is present as graphite.

gray cast iron. A *cast iron* that gives a gray fracture due to the presence of flake graphite. Often called gray iron.

grinding burn. See *burning* (2).

grinding cracks. Shallow cracks formed in the surfaces of relatively hard materials because of excessive grinding heat or the high sensitivity of the material. See *grinding sensitivity.*

grinding sensitivity. Susceptibility of a material to surface damage such as *grinding cracks;* it can be affected by such factors as hardness, microstructure, hydrogen content and residual stress.

grinding stress. *Residual stress,* generated by grinding, in the surface layer of work. It may be tensile or compressive or both.

H

hard chromium. Chromium electrodeposited for engineering purposes (such as to increase the wear resistance of sliding metal surfaces) rather than as a decorative coating. It is usually applied directly to basis metal and is customarily thicker than a decorative deposit, but not necessarily harder.

hardenability. The relative ability of a ferrous alloy to form martensite when quenched from a temperature above upper critical temperature. Hardenability is commonly measured as the distance below a quenched surface at which the metal exhibits a specific hardness (50 HRC, for example) or a specific percentage of martensite in the microstructure.

hardening. Increasing hardness by suitable treatment, usually involving heating and cooling. When applicable, the following more specific terms should be used: *age hardening, case hardening, flame hardening, induction hardening, precipitation hardening* and *quench hardening.*

hardness. Resistance of metal to plastic deformation, usually by indentation. However, the term may also refer to stiffness or temper, or to resistance to scratching, abrasion or cutting. Indentation hardness may be measured by various hardness tests, such as *Brinell, Rockwell* and *Vickers.*

H-band steel. Alloy steel produced to specified limits of hardenability; the chemical composition range may be slightly different from that of the corresponding grade of ordinary alloy steel.

heat-affected zone. That portion of the base metal that was not melted during brazing, cutting or welding, but whose microstructure and mechanical properties were altered by the heat.

heat-treatment. Heating and cooling a solid metal or alloy in such a way as to obtain desired conditions or properties. Heating for the sole purpose of hot working is excluded from the meaning of this definition.

hot-working. Deforming metal plastically at such a temperature and strain rate that recrystallization takes place simultaneously with the deformation, thus avoiding any strain hardening.

hydrogen embrittlement. A condition of low ductility in metals resulting from the absorption of hydrogen.

GLOSSARY OF STEEL INDUSTRY TERMS — Continued

I

impact energy. The amount of energy required to fracture a material, usually measured by means of an *Izod test* or *Charpy test*. The type of specimen and test conditions affect the values and therefore should be specified.

impact strength. Same as *impact energy*.

impact test. A test to determine the behavior of materials when subjected to high rates of loading, usually in bending, tension or torsion. The quantity measured is the energy absorbed in breaking the specimen by a single blow, as in *Charpy* and *Izod* tests.

inclusions. Particles of foreign material in a metallic matrix. The particles are usually compounds (such as oxides, sulfides or silicates), but may be of any substance that is foreign to (and essentially insoluble in) the matrix.

indication. In inspection, a response to a nondestructive stimulus that implies the presence of an *imperfection*. The indication must be interpreted to determine if (*a*) it is a true indication or a *false indication* and (*b*) whether or not a true indication represents an unacceptable deviation.

induction hardening. A surface-hardening process in which only the surface layer of a suitable ferrous workpiece is heated by electromagnetic induction to a temperature above the upper critical temperature and immediately quenched.

ingot. A casting of simple shape, suitable for hot working or remelting.

internal stress. See preferred term, *residual stress*.

isothermal transformation. A change in phase that takes place at a constant temperature. The time required for transformation to be completed, and in some instances the time delay before transformation begins, depends on the amount of supercooling below (or superheating above) the equilibrium temperature for the same transformation.

Izod test. A pendulum-type 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. Contrast with *Charpy test*.

J

Jominy test. See *end-quench hardenability test*.

K

killed steel. Steel treated with a strong deoxidizing agent such as silicon or aluminum in order to reduce the oxygen content to such a level that no reaction occurs between carbon and oxygen during solidification.

Knoop hardness. Microhardness determined from the resistance of metal to indentation by a pyramidal diamond indenter, having edge angles of 172° 30' and 130°, making a rhombohedral impression with one long and one short diagonal.

M

machinability. The relative ease of machining a metal.

machinability index. A relative measure of the machinability of an engineering material under specified standard conditions.

malleability. The characteristic of metals that permits plastic deformation in compression without rupture.

malleable cast iron. A cast iron made by prolonged annealing of *white cast iron* in which decarburization or graphitization, or both, take place to eliminate some or all of the cementite. The graphite is in the form of temper carbon. If decarburization is the predominant reaction, the product will exhibit a light fracture surface, hence "whiteheart malleable;" otherwise, the fracture surface will be dark, hence, "blackheart malleable." Ferritic malleable has a predominantly ferritic matrix; pearlitic malleable may contain pearlite, spheroidite or tempered martensite depending on heat treatment and desired hardness.

maraging. A precipitation-hardening treatment applied to a special group of iron-base alloys to precipitate one or more intermetallic compounds in a matrix of essentially carbon-free martensite. NOTE: The first developed series of maraging steels contained, in addition to iron, more than 10% nickel and one or more supplemental hardening elements. In this series, aging is done at 480 °C (900 °F).

marquenching. See *martempering*.

martempering. (1) A hardening procedure in which an austenitized ferrous workpiece is quenched in an appropriate medium whose temperature is maintained substantially at the M_s of the workpiece, held in the medium until its temperature is uniform throughout—but not long enough to permit bainite to form—and then cooled in air. The treatment is frequently followed by tempering. (2) When the process is applied to carburized material, the controlling M_s temperature is that of the case. This variation of the process is frequently called marquenching.

GLOSSARY OF STEEL INDUSTRY TERMS — Continued

martensite. A generic term for microstructures formed by diffusionless phase transformation in which the parent and product phases have a specific crystallographic relationship. Martensite is characterized by an acicular pattern in the microstructure in both ferrous and nonferrous alloys. In alloys where the solute atoms occupy interstitial positions in the martensitic lattice (such as carbon in iron), the structure is hard and highly strained; but where the solute atoms occupy substitutional positions (such as nickel in iron), the martensite is soft and ductile. The amount of high-temperature phase that transforms to martensite on cooling depends to a large extent on the lowest temperature attained, there being a rather distinct beginning temperature (M_s) and a temperature at which the transformation is essentially complete (M_f).

McQuaid-Ehn test. A test for revealing grain size after heating into the austenitic temperature range. Eight standard McQuaid-Ehn grain sizes are used for rating structures, No. 8 being finest, No. 1 coarsest.

mechanical properties. The properties of a material that reveal its elastic and inelastic behavior when force is applied, thereby indicating its suitability for mechanical applications; for example, modulus of elasticity, tensile strength, elongation, hardness, and fatigue limit. Compare with *physical properties.*

metallography. The science dealing with the constitution and structure of metals and alloys as revealed by the unaided eye or by such tools as low-powered magnification, optical microscopy, electron microscopy and diffraction or x-ray techniques.

metallurgy. The science and technology of metals and alloys. Process metallurgy is concerned with the extraction of metals from their ores and with refining of metals; physical metallurgy, with the physical and mechanical properties of metals as affected by composition, processing and environmental conditions; and mechanical metallurgy, with the response of metals to applied forces.

M_f temperature. For any alloy system, the temperature at which martensite formation on cooling is essentially finished. See *transformation* temperature for the definition applicable to ferrous alloys.

microhardness. The hardness of a material as determined by forcing an indenter such as a Vickers or Knoop indenter into the surface of the material under very light load; usually, the indentations are so small that they must be measured with a microscope. Capable of determining hardnesses of different micro-constituents within a structure, or of measuring steep hardness gradients such as those encountered in case hardening.

microstructure. The structure of a metal as revealed by microscopic examination of the etched surface of a polished specimen.

mild steel. *Carbon steel* with a maximum of about 0.25% C and in a soft condition (not work hardened).

M_s temperature. For any alloy system, the temperature at which martensite starts to form on cooling. See *transformation temperature* for the definition applicable to ferrous alloys.

N

nitriding. Introducing nitrogen into the surface layer of a solid ferrous alloy by holding at a suitable temperature (below Ac_1 for ferritic steels) in contact with a nitrogenous material, usually ammonia or molten cyanide of appropriate composition. Quenching is not required to produce a hard case.

nitrocarburizing. Any of several processes in which both nitrogen and carbon are absorbed into the surface layers of a ferrous material at temperatures below the lower critical temperature and, by diffusion create a concentration gradient. Nitrocarburizing is done mainly to provide an antiscuffing surface layer and to improve fatigue resistance. Compare with *carbonitriding.*

nodular cast iron. See preferred term, *ductile cast iron.*

nondestructive inspection. Inspection by methods that do not destroy the part nor impair its serviceability.

nonmetallic inclusions. See *inclusions.*

normalizing. Heating a ferrous alloy to a suitable temperature above the transformation range and then cooling in air to a temperature substantially below the transformation range.

notch brittleness. Susceptibility of a material to brittle fracture at points of stress concentration. For example, in a notch tensile test, the material is said to be notch brittle if the *notch strength* is less than the tensile strength of an unnotched specimen. Otherwise, it is said to be notch ductile.

notch sensitivity. A measure of the reduction in strength of a metal caused by the presence of stress concentration. Values can be obtained from static, impact or fatigue tests.

O

overheating. Heating a metal or alloy to such a high temperature that its properties are impaired. When the original properties cannot be restored by further heat treating, by mechanical working or by a combination of working and heat treating, the overheating is known as *burning.*

GLOSSARY OF STEEL INDUSTRY TERMS — Continued

oxidation. (1) A reaction in which there is an increase in valence resulting from a loss of electrons. Contrast with *reduction.* (2) A corrosion reaction in which the corroded metal forms an oxide; usually applied to reaction with a gas containing elemental oxygen, such as air.

P

passivation. The changing of a chemically active surface of a metal to a much less reactive state.

pearlite. A metastable lamellar aggregate of ferrite and cementite resulting from the transformation of austenite at temperatures above the bainite range.

physical properties. Properties of a metal or alloy that are relatively insensitive to structure and can be measured without the application of force; for example, density, electrical conductivity, coefficient of thermal expansion, magnetic permeability and lattice parameter. Does not include chemical reactivity. Compare with *mechanical properties.*

pickling. Removing surface oxides from metals by chemical or electrochemical reaction.

pipe. (1) The central cavity formed by contraction in metal, especially ingots, during solidification. (2) An imperfection in wrought or cast products resulting from such a cavity. (3) A tubular metal product.

plastic deformation. Deformation that does or will remain permanent after removal of the load that caused it.

precipitation hardening. Hardening caused by precipitation of a constituent from a supersaturated solid solution. See also *age hardening* and *aging.*

proportional limit. The maximum stress at which strain remains directly proportional to stress.

pseudocarburizing. See *blank carburizing.*

Q

quench cracking. Fracture of a metal during quenching from elevated temperature. Most frequently observed in hardened carbon steel, alloy steel or tool steel parts of high hardness and low toughness. Cracks often emanate from fillets, holes, corners or other stress raisers and result from high stresses due to the volume changes accompanying transformation to martensite.

quench hardening. (1) Hardening suitable alpha-beta alloys (most often certain copper or titanium alloys) by solution treating and quenching to develop a martensite-like structure. (2) In ferrous alloys, hardening by austenitizing and then cooling at a rate such that a substantial amount of austenite transforms to martensite.

quenching. Rapid cooling. When applicable, the following more specific terms should be used: *direct quenching, fog quenching, hot quenching, interrupted quenching, selective quenching, spray quenching* and *time quenching.*

R

ratchet marks. Lines on a fatigue fracture surface that result from the intersection and connection of fatigue fractures propagating from multiple origins. Ratchet marks are parallel to the over-all direction of crack propagation and are visible to the unaided eye or at low magnification.

recrystallization. (1) Formation of a new, strain-free grain structure from that existing in cold worked metal, usually accomplished by heating. (2) The change from one crystal structure to another, as occurs on heating or cooling through a critical temperature.

reduction of area. (1) Commonly, the difference, expressed as a percentage of original area, between the original cross-sectional area of a tensile test specimen and the minimum cross-sectional area measured after complete separation. (2) The difference, expressed as a percentage of original area, between original cross-sectional area and that after straining of the specimen.

residual elements. Elements present in an alloy in small quantities, but not added intentionally.

residual stress. Stress present in a body that is free of external forces or thermal gradients.

rimmed steel. A low-carbon steel containing sufficient iron oxide to give a continuous evolution of carbon monoxide while the ingot is solidifying, resulting in a case or rim of metal virtually free of voids. Sheet and strip products made from rimmed steel ingots have very good surface quality.

rock candy fracture. A fracture that exhibits separated-grain facets, most often used to describe intergranular fractures in large-grained metals.

Rockwell hardness test. An indentation hardness test based on the depth of penetration of a specified penetrator into the specimen under certain arbitrarily fixed conditions.

rust. A corrosion product consisting of hydrated oxides of iron. Applied only to ferrous alloys.

S

scaling. (1) Forming a thick layer of oxidation products on metals at high temperature. (2) Depositing water-insoluble constituents on a metal surface, as in cooling tubes and water boilers.

GLOSSARY OF STEEL INDUSTRY TERMS — Continued

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

screw stock. Free-machining bar, rod or wire.

semikilled steel. Steel that is incompletely deoxidized and contains sufficient dissolved oxygen to react with the carbon to form carbon monoxide and thus offset solidification shrinkage.

sensitization. In austenitic stainless steels, the precipitation of chromium carbides, usually at grain boundaries, on exposure to temperatures of about 550 to 850 °C (about 1000 to 1550 °F), leaving the grain boundaries depleted of chromium and therefore susceptible to preferential attack by a corroding (oxidizing) medium.

shear fracture. A ductile fracture in which a crystal (or a polycrystalline mass) has separated by sliding or tearing under the action of shear stresses.

shear strength. The stress required to produce fracture in the plane of cross section, the conditions of loading being such that the directions of force and of resistance are parallel and opposite although their paths are offset a specified minimum amount. The maximum load divided by the original cross-sectional area of a section separated by shear.

Shore hardness test. Same as *Scleroscope test.*

size effect. Effect of the dimensions of a piece of metal on its mechanical and other properties and on manufacturing variables such as forging reduction and heat treatment. In general, the mechanical properties are lower for a larger size.

slack quenching. Incomplete hardening of steel due to quenching from the austenit-izing temperature at a rate lower than the critical cooling rate for the particular steel, resulting in formation of one or more transformation products in addition to martensite.

slag. A nonmetallic product resulting from the mutual dissolution of flux and nonmetallic impurities in smelting, refining, and certain welding operations.

snap temper. A precautionary interim stress-relieving treatment applied to high-hardenability steels immediately after quenching to prevent cracking because of delay in tempering them at the prescribed higher temperature.

soaking. Prolonged holding at a selected temperature to effect homogenization of structure or composition.

solution heat treatment. Heating an alloy to a suitable temperature, holding at that temperature long enough to cause one or more constituents to enter into solid solution, and then cooling rapidly enough to hold these constituents in solution.

spheroidite. An aggregate of iron or alloy carbides of essentially spherical shape dispersed throughout a matrix of ferrite.

spheroidizing. Heating and cooling to produce a spheroidal or globular form of carbide in steel. Spheroidizing methods frequently used are:

1 Prolonged holding at a temperature just below Ae_1.
2 Heating and cooling alternately between temperatures that are just above and just below Ae_1.
3 Heating to a temperature above Ae_1 or Ae_3 and then cooling very slowly in the furnace or holding at a temperature just below Ae_1.
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.)

spherulitic graphite cast iron. Same as *ductile cast iron.*

stainless steel. Any of several steels containing 12 to 30% chromium as the principal alloying element; they usually exhibit *passivity* in aqueous environments.

steel. An iron-base alloy, malleable in some temperature ranges 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 steel 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% and ingot iron considerably less.

stiffness. The ability of a metal or shape to resist elastic deflection. For identical shapes, the stiffness is proportional the modulus of elasticity. For a given material, the stiffness increases with increasing moment of inertia, which is computed from cross-sectional dimensions.

stopping off. (1) Applying a *resist.* (2) Depositing a metal (copper, for example) in localized areas to prevent carburization, decarburization or nitriding in those areas. (3) Filling in a portion of a mold cavity to keep out molten metal.

GLOSSARY OF STEEL INDUSTRY TERMS — Continued

strain. A measure of the relative change in the size or shape of a body. Linear strain is the change per unit length of linear dimension. True strain (or natural strain) is the natural logarithm of the ratio of the length at the moment of observation to the original gage length. Conventional strain is the linear strain over the original gage length. Shearing strain (or shear strain) is the change in angle (expressed in radians) between two lines originally at right angles. When the term "strain" is used alone it usually refers to the linear strain in the direction of applied stress.

strain-age embrittlement. A loss in ductility accompanied by an increase in hardness and strength that occurs when low-carbon steel (especially rimmed or capped steel) is aged following plastic deformation. The degree of embrittlement is a function of aging time and temperature, occurring in a matter of minutes at about 200 °C (400 °F) but requiring a few hours to a year at room temperature.

strain aging. Aging induced by cold working. See *aging*.

strain hardening. An increase in hardness and strength caused by plastic deformation at temperatures below the recrystallization range.

strand casting. A generic term describing *continuous casting* of one or more elongated shapes such as billets, blooms or slabs; if two or more strands are cast simultaneously, they are often of identical cross section.

stress. Force per unit area, often thought of as force acting through a small area within a plane. It can be divided into components, normal and parallel to the plane, called normal stress and shear stress, respectively. True stress denotes the stress where force and area are measured at the same time. Conventional stress, as applied to tension and compression tests, is force divided by original area. Nominal stress is the stress computed by simple elasticity formulas, ignoring stress raisers and disregarding plastic flow; in a notch test, for example, it is bending moment divided by minimum section modulus.

stress-concentration factor (K_t). A multiplying factor for applied stress that allows for the presence of a structural discontinuity such as a notch or hole; K_t equals the ratio of the greatest stress in the region of the discontinuity to the nominal stress for the entire section.

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

stress raisers. Changes in contour or discontinuities in structure that cause local increases in stress.

stress relieving. Heating to a suitable temperature, holding long enough to reduce residual stresses and then cooling slowly enough to minimize the development of new residual stresses.

stringer. In wrought materials, an elongated configuration of microconstituents or foreign material aligned in the direction of working. Commonly, the term is associated with elongated oxide or sulfide inclusions in steel.

substrate. Layer of metal underlying a coating, regardless of whether that layer is the basis metal.

superficial Rockwell hardness test. Form of Rockwell hardness test using relatively light loads that produce minimum penetration by the indenter. Used for determining surface hardness or hardness of thin sections or small parts, or where a large hardness impression might be harmful.

surface hardening. A generic term covering several processes applicable to a suitable ferrous alloy that produces, by quench hardening only, a surface layer that is harder or more wear resistant than the core. There is no significant alteration of the chemical composition of the surface layer. The processes commonly used are *induction hardening, flame hardening* and *shell hardening*. Use of the applicable specific process name is preferred.

T

temper. (1) In heat treatment, to reheat hardened steel or hardened cast iron to some temperature below the eutectoid temperature for the purpose of decreasing hardness and increasing toughness. The process also is sometimes applied to normalized steel. (2) In tool steels, temper is sometimes but inadvisedly, used to denote carbon content. (3) In nonferrous alloys and in some ferrous alloys (steels that cannot be hardened by heat treatment), the hardness and strength produced by mechanical or thermal treatment, or both, and characterized by a certain structure, mechanical properties or reduction in area during cold working.

temper brittleness. Brittleness that results when certain steels are held within, or are cooled slowly through, a certain range of temperatures below the transformation range. This brittleness is manifested as an upward shift in ductile-to-brittle transition temperature, but only rarely produces a low value of reduction in area in a smooth-bar tension test of the embrittled material.

GLOSSARY OF STEEL INDUSTRY TERMS — Continued

temper color. A thin, tightly adhering oxide skin (only a few molecules thick) that forms when steel is tempered at a low temperature, or for a short time, in air or a mildly oxidizing atmosphere. The color, which ranges from straw to blue depending on the thickness of the oxide skin, varies with both tempering time and temperature.

tensile strength. In tensile testing, the ratio of maximum load to original cross-sectional area. Also called *ultimate strength*. Compare with *yield strength*.

thermal stresses. Stresses in metal resulting from non-uniform temperature distribution.

torsion. A twisting action resulting in shear stresses and strains.

total carbon. The sum of the free and combined carbon (including carbon in solution) in a ferrous alloy.

toughness. Ability of a metal to absorb energy and deform plastically before fracturing. It is usually measured by the energy absorbed in a notch impact test, but the area under the stress-strain curve in tensile testing is also a measure of toughness.

transformation range. Those ranges of temperature within which a phase forms during heating and transforms during cooling. 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. This term is sometimes used to denote the limiting temperature of a transformation range. The following symbols are used for irons and steels:

Ac_{cm}. In hypereutectoid steel, the temperature at which solution of cementite in austenite is completed during heating.

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_4. The temperature at which austenite transforms to delta ferrite during heating.

Ae_{cm}, Ae_1, Ae_3, Ae_4. The temperatures of phase changes at equilibrium.

Ar_{cm}. In hypereutectoid steel, the temperature at which precipitation of cementite starts during cooling.

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_4. The temperature at which delta ferrite transforms to austenite during cooling.

Ar'. The temperature at which transformation of austenite to pearlite starts during cooling.

M_f. The temperature at which transformation of austenite to martensite is completed during cooling.

M_s (or Ar"). The temperature at which transformation of austenite to martensite starts during cooling.

NOTE: All these changes, except formation of martensite, occur at lower temperatures during cooling than during heating, and depend on the rate of change of temperature.

transverse. Literally, "across," usually signifying a direction or plane perpendicular to the direction of working. In rolled plate or sheet, the direction across the width is often called long transverse, and the direction through the thickness, short transverse.

U

ultimate strength. The maximum conventional stress (tensile, comprehensive or shear) that a material can withstand.

V

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

W

weldability. A specific or relative measure of the ability of a material to be welded under a given set of conditions. Implicit in this definition is the ability of the completed weldment to fulfill all functions for which the part was designed.

white cast iron. *Cast iron* that shows a white fracture because the carbon is in combined form.

work hardening. Same as *strain hardening*.

wrought iron. A commercial iron consisting of slag (iron silicate) fibers entrained in a ferrite matrix.

Y

yield strength. The stress at which a material exhibits a specified deviation from proportionality of stress and strain. An offset of 0.2% is used for many metals. Compare with *tensile strength*.

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