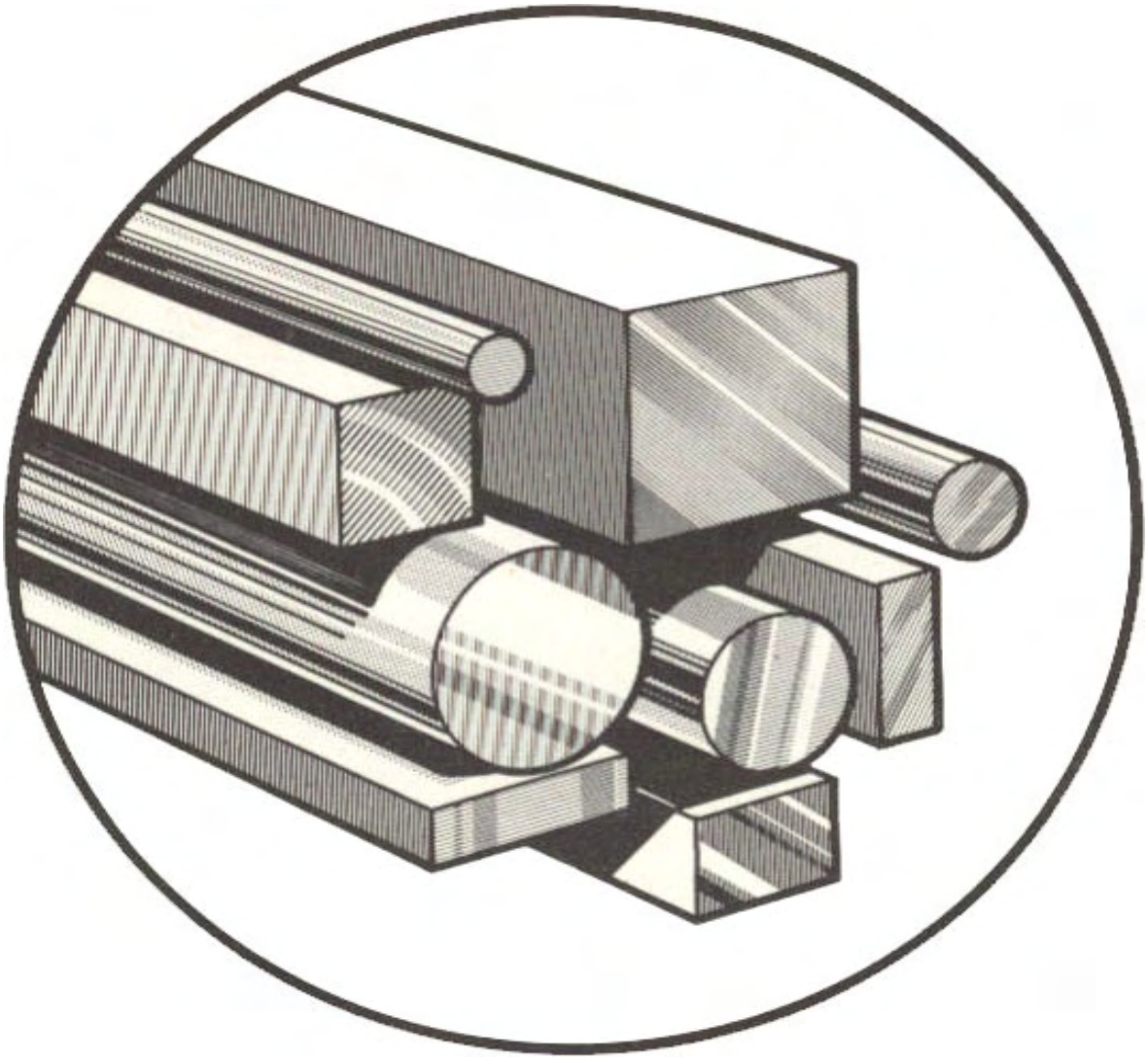
VANGUARD STEEL LTD.

STEEL PRODUCT MANUAL



VANGUARD STEEL LTD.

PRODUCT MANUAL

INDEX

(CONTINUED)

VANGUARD STEEL LTD.

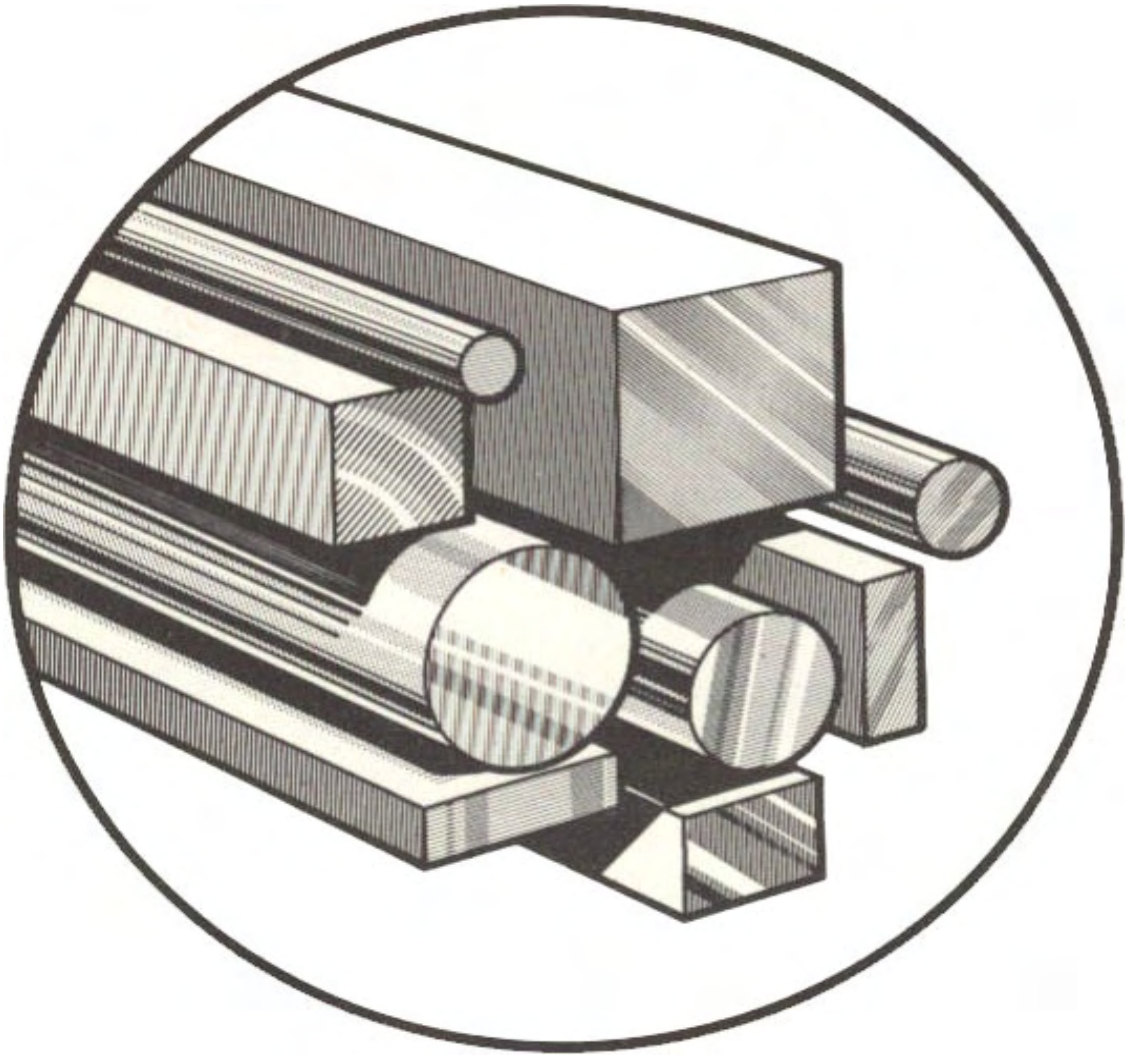
PRODUCT MANUAL

INDEX

VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 1.
ALLOY STEELS



VANGUARD STEEL LTD.

PRODUCT MANUAL

ALLOY STEELS - 3312

AISI /SAE 3312 (UNS G 33106)

A 3-1/2% NICKEL-CHROMIUM CASE HARDENING ALLOY STEEL

TYPICAL ANALYSIS

C.	Mn.	P. MAX.	S. MAX.	Si.	Ni.	Cr.
0.08/0.13	.045/0.60	0.025	0.025	0.20/0.35	3.25/3.75	1.40/1.75

A HIGH ALLOY CARBURIZING STEEL POSSESSING SUPREME TOUGHNESS AND FATIGUE RESISTANCE IN BOTH CARBURIZED AND NON-CARBURIZED CONDITION. ITS ALLOY CONTENT PROVIDES EXTREMELY HIGH CORE STRENGTH, ALLOWING THIS STEEL TO BE USED FOR TOUGHER APPLICATIONS THAN THE WIDELY USED **AISI 8620.** IT CAN BE AIR HARDENED FOR MINIMAL DISTORTION WHEN HEAT TREATING INTRICATE SHAPES. IT RETAINS EXCELLENT LOW-TEMPERATURE PROPERTIES, AND AS SUCH IS USEFUL FOR SHOCK RESISTANT MACHINE PARTS IN AREAS SUBJECT TO INTENSE COLD. IT MAY BE USED IN THE HEAT-TREATED NON-CARBURIZED CONDITION FOR APPLICATIONS REQUIRING EXTRA STRENGTH AND TOUGHNESS. NORMALLY, THIS GRADE IS SUPPLIED IN THE ANNEALED CONDITION.

TYPICAL APPLICATIONS

HEAVY DUTY GEARS, TRANSMISSION COMPONENTS, PINIONS, PISTON PINS, SPLINE SHAFTS, ROCK DRILLING BIT BODIES, PLASTIC MOLDS, ETC.

MECHANICAL PROPERTIES - ANNEALED

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

TENSILE STRENGTH, PSI	**105,000**
YIELD STRENGTH, PSI	**78,000**
ELONGATION, %	**24**
REDUCTION IN AREA, %	**64**
BRINELL HARDNESS	**212**

(CONTINUED)

ALLOY STEELS - 3312

AISI /SAE 3312 (UNS G 33106)

MECHANICAL PROPERTIES - HARDENED AND TEMPERED-UNCARBURIZED TEMPERING TEMPERATURE - 540° DEGREES CELSIUS

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

	1"	4"	8"
TENSILE STRENGTH, PSI	136,200	132,000	112,000
YIELD STRENGTH, PSI	117,700	108,500	97,000
ELONGATION, %	19	17	20
REDUCTION IN AREA, %	63	57.5	70
BRINELL HARDNESS - CORE	294	285	235

MECHANICAL PROPERTIES - HARDENED AND TEMPERED-CARBURIZED SINGLE REFININGTEMPERING TEMPERATURE - 200º DEGREES CELSIUS

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

	1"	4"	8"
TENSILE STRENGTH, PSI	172,500	152,500	148,500
YIELD STRENGTH, PSI	132,000	108,500	100,000
ELONGATION, %	20	22.5	18.5
REDUCTION IN AREA, %	60	63.5	63.5
BRINELL HARDNESS - CORE	341	311	293

THERMAL TREATMENTS	DEGREES IN CELSIUS	
FORGING	COMMENCE AT 1175-1230 °	FINISH AT 870/925 ° BURY IN MICA
ANNEALING	830/855 ° COOL IN FURNACE	
NORMALIZING	870/925 ° AIR COOL	

(CONTINUED)

ALLOY STEELS - 3312

AISI /SAE 3312 (UNS G 33106)

THERMAL TREATMENTS	DEGREES IN CELSIUS
HARDENING & TEMPERING	(UNCARBURIZED) - 815/840° OIL QUENCH, OR 840/870° AIR QUENCH. TEMPER IMMEDIATELY ACCORDING TO STRENGTH LEVEL REQUIRED AT 200/600°.
CASE HARDENING	SINGLE REFINING TREATMENT
	AFTER CARBURIZING AT 898/929° COOL TO ROOM TEMPERATURE. REHEAT TO 770/800° OIL QUENCH AND TEMPER AT 200°.

MACHINABILITY

3312 IN THE ANNEALED CONDITION HAS A MACHINABILITY RATING OF 40% OF AISI B-1112. AVERAGE SURFACE CUTTING SPEED IS 65 FEET PER MINUTE.

SHEAR STRENGTH

THE ULTIMATE SHEAR STRENGTH IS APPROXIMATELY 62% OF THE ULTIMATE TENSILE STRENGTH.

ALLOY STEELS - 4130

AISI /SAE 4130 (UNS G 41300)

CHROMIUM-MOLYBDENUM STEEL

TYPICAL ANALYSIS

C.	Mn.	P.	S.	Si.	Cr.	Mo.
.28/.33	.40/.60	.035 MAX.	.040 MAX.	.15/.35	.80/1.10	.15/.25

A THROUGH-HARDENING ALLOY OF GREAT VERSATILITY. THE CHROMIUM AND MOLYBDENUM CONTENT SUFFICES TO PROVIDE THROUGH HARDNESS PENETRATION IN FAIRLY LIGHT SECTIONS. GOOD MECHANICAL PROPERTIES MAY BE OBTAINED BY NORMALIZING WHERE THE REQUIRED STRENGTH IS NOT TOO HIGH. THIS GRADE RESPONDS TO NITRIDING FOR WEAR AND ABRASION RESISTANCE.
THE CARBON CONTENT CAUSES THIS ALLOY TO BE CONSIDERED AS AN OIL OR WATER HARDENING GRADE.

TYPICAL APPLICATIONS

SHAFTING, WELLHEAD COMPONENTS, AXLES, GEARS, SPROCKETS, TOOL JOINTS, PISTON RODS, ETC.

MECHANICAL PROPERTIES - ANNEALED

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

TENSILE STRENGTH, PSI	**80,000**
YIELD STRENGTH, PSI	**56,000**
ELONGATION, %	**25**
REDUCTION IN AREA, %	**57**
BRINELL HARDNESS	**149**

(CONTINUED)

ALLOY STEELS - 4130

AISI /SAE 4130 (UNS G 41300)

CHROMIUM-MOLYBDENUM STEEL

THERMAL TREATMENTS	DEGREES IN CELSIUS
FORGING	COMMENCE AT 1200° MAX. FINISH AT 950°
ANNEALING	830/855° COOL SLOWLY IN FURNACE
NORMALIZING	870/930° COOL IN AIR
HARDENING	840/870° WATER QUENCH 855/885° OIL QUENCH
TEMPERING	430/700° ACCORDING TO PROPERTIES REQUIRED

MACHINABILITY

4130 IN THE ANNEALED CONDITION HAS A MACHINABILITY RATING OF 72% OF AISI B-1112. AVERAGE SURFACE CUTTING SPEED IS 120 FEET PER MINUTE.

WELDABILITY

THIS GRADE MAY BE WELDED BY ANY OF THE COMMON WELDING PROCESSES. PREHEATING AND POSTHEATING ARE RECOMMENDED FOR DIFFICULT SEGMENTS. THE GRADE OF WELDING ROD TO BE USED DEPENDS UPON THE THICKNESS OF SECTION, DESIGN, SERVICE REQUIREMENTS, ETC.

ALLOY STEELS - 4140

AISI /SAE 4140 (UNS G 41400)

CHROMIUM-MOLYBDENUM STEEL

TYPICAL ANALYSIS

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

THIS CHROMIUM-MOLYBDENUM ALLOY STEEL IS OIL-HARDENING STEEL OF RELATIVELY HIGH HARDENABILITY, AND IS AMONG THE MOST WIDELY USED AND VERSATILE MACHINERY STEEL. THE CHROMIUM CONTENTS PROVIDES GOOD HARDNESS PENETRATION AND THE MOLYBDENUM IMPARTS UNIFORMITY OF HARDNESS AND HIGH STRENGTH.
THIS GRADE IS ESPECIALLY SUITABLE FOR FORGING AS IT HAS SELF-SCALING CHARACTERISTICS IT RESPONDS READILY TO HEAT TREATMENT AND IS COMPERATIVELY EASY TO MACHINE IN THE HEAT TREATED CONDITION. IN THE HEAT TREATED CONDITION TENSILE STRENGTHS OF 170,000 PSI. FOR SMALL SECTIONS AND 140,000 PSI. FOR LARGER SECTIONS ARE ATTAINABLE, ALL COMBINED WITH GOOD DUCTILITY AND RESISTANCE TO SHOCK. THIS STEEL RESISTS CREEP IN TEMPERATURES UP TO 540 DEGREES CELSIUS AND MAINTAIN ITS PROPERTIES EVEN AFTER LONG EXPOSURE AT THESE RELATIVELY HIGH WORKING TEMPERATURES.
IN THE HARDENED AND TEMPERED CONDITION, THIS STEEL POSSESSES GOOD WEAR RESISTANCE. THE WEAR RESISTANCE CAN CONSIDERABLY INCREASED BY FLAME - OR INDUCTION HARDENING, OR ALTERNATIVELY, IT MAY BE NITRIDED.

TYPICAL APPLICATIONS

SHAFTS, GEARS, BOLTS, COUPLINGS, SPINDLES, TOOL HOLDERS, SPROCKETS, HYDRAULIC MACHINERY SHAFTS. FOR THE OIL INDUSTRY-DRILL COLLARS, KELLY BARS, TOOL JOINTS, SUBS, ETC.

MECHANICAL PROPERTIES - ANNEALED

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

	1"	2-1/4"	4-1/2"	7-3/4"
TENSILE STRENGTH, PSI.	**98,000**	**101,500**	**100,000**	**100,000**
YIELD STRENGTH, PSI.	**61,000**	**62,000**	**57,000**	**58,500**
ELONGATION, % IN 2"	**23.0**	**26.0**	**25.0**	**21.0**
REDUCTION IN AREA, %	**54.0**	**55.0**	**56.0**	**59.0**
BRINELL HARDNESS	**197**	**212**	**202**	**197**

(CONTINUED)

ALLOY STEELS - 4140

AISI /SAE 4140 (UNS G 41400)

CHROMIUM-MOLYBDENUM STEEL

MECHANICAL PROPERTIES - HEAT TREATED AND STRESS RELIEVED

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

	3-1/4"	4-1/2"	6-1/4"	8"
TENSILE STRENGTH, PSI.	156,165	145,870	136,590	139,780
YIELD STRENGTH, PSI.	141,085	126,005	111,070	114,695
ELONGATION, % IN 2"	17.1	16.0	18.1	15.5
REDUCTION IN AREA, %	55.9	49.8	55.1	46.9
BRINELL HARDNESS	321	331	311	321

MECHANICAL PROPERTIES - HEAT TREATED RC 22 MAX. FOR SOUR GAS.

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

	2-1/2"	4"	6-1/4"	9-1/2"
TENSILE STRENGTH, PSI.	106,600	108,177	108,118	105,000
YIELD STRENGTH, PSI.	92,060	88,834	86,424	82,405
ELONGATION, % IN 2"	25.0	28.7	26.7	31.0
REDUCTION IN AREA, %	69.0	66.7	67.0	66.4
HARDNESS - RC	21	18	18	18

MECHANICAL PROPERTIES - HEAT TREATED TO ASTM A.193 GRADE B7

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

	3/4"	1-1/4"	2"	3"
TENSILE STRENGTH, PSI.	154,000	131,000	140,000	134,000
YIELD STRENGTH, PSI.	142,000	119,000	126,000	107,000
ELONGATION, % IN 2"	20.0	18.0	18.0	19.0
REDUCTION IN AREA, %	57.0	55.0	56.0	22.0
BRINELL HARDNESS	311	269	286	277

(CONTINUED)

ALLOY STEELS - 4140

AISI /SAE 4140 (UNS G 41400)

CHROMIUM-MOLYBDENUM STEEL

THERMAL TREATMENTS	DEGREES IN CELSIUS
FORGING	COMMENCE AT 1200° MAX. FINISH AT 950°
ANNEALING	815/850° COOL SLOWLY IN FURNACE
NORMALIZING	870/900° COOL IN AIR
HARDENING	820/870° OIL QUENCH
TEMPERING	430/700° ACCORDING TO PROPERTIES REQUIRED

MACHINABILITY

4140 IN THE ANNEALED CONDITION HAS A MACHINABILITY RATING OF 66% OF AISI B-1112.
AVERAGE SURFACE CUTTING SPEED IS 110 FEET PER MINUTE.

SHEAR STRENGTH

THE ULTIMATE SHEAR STRENGTH IS APPROXIMATELY 63% OF THE ULTIMATE TENSILE STRENGTH.

WELDABILITY

4140 IS ON THE BORDER LINE OF WELDABILITY BECAUSE OF ITS RELATIVELY HIGH CARBON CONTENT. IT CAN BE WELDED BY ANY OF THE COMMON WELDING PROCESSES PROVIDING THE SECTION IS PREHEATED AND STRESS RELIEVED AFTER WELDING.
THE GRADE OF WELDING ROD TO BE USED DEPENDS UPON THE THICKNESS OF SECTION, DESIGN, AND SERVICE REQUIREMENTS, ETC.

ALLOY STEELS - 4145 H MODIFIED HTSR

AISI /SAE 4145 (UNS G 41450) MODIFIED HTSR

CHROMIUM-MOLYBDENUM STEEL TO ASTM A 29, A 370, A 434 CLASS BD E 112

TYPICAL ANALYSIS

C.	Mn.	P.	S.	Si.	Cr.	Mo.	Ni.
.42/.49	.75/1.30	.035 MAX.	.040 MAX.	.15/.35	.75/1.20	.15/.45	1.00 MAX.

THIS ALLOY STEEL IS USED PRIMARILY FOR THE MANUFACTURE OF TOOLS IN THE OIL INDUSTRY. SUPPLIED WITH A STRAIGHTNESS TOLERANCE OF 1/8" IN ANY 5 FOOT LENGTH, WITH A GRAIN SIZE OF 6 OR FINER, AS PER ASTM E 112. THIS STEEL IS HEAT TREATED AND HARDENED BY WATER QUENCH, TEMPERED, STRESS RELIEVED AND SUPPLIED IN A ROUGH TURNED CONDITION.
ALL BARS ARE ULTRASONIC TESTED, WITH CHARPY V IMPACT @ 57 DEGREES CELSIUS FT. LBS. WITH MINIMUM AVERAGE VALUE OF 3 READINGS. NO MORE THAN ONE SINGLE VALUE SHALL BE LOWER THAN 5 FT. LBS. BELOW STATED AVERAGE VALUE.
CAN BE SUPPLIED TO COMPLY TO API SPEC. 7 IN THE MANUFACTURE OF DRILL COLLARS IN 31 TO 31-1/2 FOOT BARS.

MECHANICAL PROPERTIES - (LONGITUDINAL, 1" BELOW SURFACE).

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

	UNDER 5"	5" - 7"	7" & OVER
TENSILE STRENGTH, PSI.	**145,000**	**140,000**	**135,000**
YIELD STRENGTH, PSI.	**125,000**	**110,000**	**100,000**
ELONGATION, % IN 2"	**14.0**	**14.0**	**14.0**
REDUCTION IN AREA, MIN. %	**40-54**	**40-54**	**40-54**
HARDNESS - SURFACE BHN	**285-341**	**285-341**	**285-341**
HARDNESS - 1" BELOW SURFACE	**285**	**285**	**285**
CHARPY V-NOTCH FT. LB.	**45**	**45**	**45**

ALL TESTS ARE PERFORMED TO ASTM A 370.

WELDABILITY

4145 IS ON THE BORDER LINE OF WELDABILITY BECAUSE OF ITS RELATIVELY HIGH CARBON CONTENT. IT CAN BE WELDED BY ANY OF THE COMMON WELDING PROCESSES PROVIDING THE SECTION IS PREHEATED AND STRESS RELIEVED AFTER WELDING.
THE GRADE OF WELDING ROD TO BE USED DEPENDS UPON THE THICKNESS OF SECTION, DESIGN, AND SERVICE REQUIREMENTS, ETC.

ALLOY STEELS - 4340

AISI /SAE 4340 (UNS G 43400)

NICKEL-CHROMIUM-MOLYBDENUM STEEL

TYPICAL ANALYSIS

C.	Mn.	P.	S.	Si.	Cr.	Ni.	Mo.
.38/.43	.60/.80	.035 MAX.	.040 MAX.	.15/.35	.70/.90	1.65/2.00	.20/.30

THE "KING" OF THE HARDENING GRADES OF CONSTRUCTIONAL ALLOY STEELS. A RICH ALLOY CONTENT, THIS NICKEL-CHROMIUM-MOLYBDENUM STEEL, POSSESSES MUCH DEEPER HARDENABILITY THEN THE 4100 SERIES. THIS IS THE MOST EXTENSIVELY USED MACHINERY STEEL WITH AN EXCEPTIONAL RANGE OF STRENGTH, TOUGHNESS AND DUCTILITY. THE ADVANTAGE IS REALIZED PRINCIPALLY WHERE HIGH STRENGTH IS REQUIRED IN HEAVY SECTIONS. THE HIGH FATIGUE-TENSILE RATIO OF 4340 MAKES IT IDEAL FOR HIGHLY STRESSED PARTS OPERATING UNDER THE MOST SEVERE CONDITIONS, AND MAY BE USED IN BOTH ELEVATED AND LOW TEMPERATURE ENVIRONMENT. IT HAS REMARKABLE NON-DISTORTING PROPERTIES FOR AN ALLOY STEEL. IT HAS GOOD WEAR RESISTANCE AND SHOULD BE USED WHERE THE GREATEST MARGIN OF SAFETY IS DESIRED.

TYPICAL APPLICATIONS

COUPLINGS, HEAVY DUTY SHAFTING, GEARS, DIES, HIGH STRENGTH MACHINE PARTS, CRANKSHAFTS, ARBORS, HIGH TENSILE BOLTS AND STUDS, MINE-DRILLING PARTS, BORING BARS, DOWN HOLE DRILLING COMPONENTS ETC.

MECHANICAL PROPERTIES - ANNEALED

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

	1"	2"	4"	8"
TENSILE STRENGTH, PSI.	**114,000**	**110,000**	**106,000**	**104,000**
YIELD STRENGTH, PSI.	**91,000**	**86,000**	**85,500**	**81,500**
ELONGATION, % IN 2"	**20.0**	**23.0**	**21.0**	**22.0**
REDUCTION IN AREA, %	**46.0**	**49.0**	**50.0**	**48.0**
BRINELL HARDNESS	**229**	**223**	**217**	**217**

(CONTINUED)

ALLOY STEELS - 4340

AISI /SAE 4340 (UNS G 43400)

NICKEL-CHROMIUM-MOLYBDENUM STEEL

MECHANICAL PROPERTIES - HEAT TREATED AND STRESS RELIEVED
ASTM A 434 / BD

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

	2-1/4"	3-1/2"	5"	8"
TENSILE STRENGTH, PSI.	141,000	157,615	152,437	138,078
YIELD STRENGTH, PSI.	124,000	144,275	136,628	114,872
ELONGATION, % IN 2"	17.0	18.2	17.8	14.4
REDUCTION IN AREA, %	53.0	55.8	54.6	40.2
BRINELL HARDNESS	285	321	285/311	302/311

THERMAL TREATMENTS — DEGREES IN CELSIUS

FORGING	COMMENCE AT 1200° MAX. FINISH AT 950°
ANNEALING	830/855° COOL SLOWLY IN FURNACE
NORMALIZING	855/900° (DUE TO THE AIR HARDENING PROPERTIES OF 4340, NORMALIZING IS NOT RECOMMENDED EXCEPT WHEN FOLLOWED BY TEMPERING)
HARDENING	815/855° OIL QUENCH
TEMPERING	ACCORDING TO STRENGTH LEVEL REQUIRED

MACHINABILITY

4340 IN THE ANNEALED CONDITION HAS A MACHINABILITY RATING OF 57% OF AISI B-1112 AVERAGE SURFACE CUTTING SPEED IS 95 FEET PER MINUTE.

(CONTINUED)

ALLOY STEELS - 4340

AISI /SAE 4340 (UNS G 43400)

NICKEL-CHROMIUM-MOLYBDENUM STEEL

SHEAR STRENGTH

THE ULTIMATE SHEAR STRENGTH IS APPROXIMATELY 66% OF THE ULTIMATE TENSILE STRENGTH.

WELDABILITY

4340 IS ON THE BORDER LINE OF WELDABILITY BECAUSE OF ITS RELATIVELY HIGH CARBON CONTENTS. IT CAN BE WELDED BY ANY OF THE COMMON WELDING PROCESSES PROVIDING THE SECTION IS PREHEATED AND STRESS RELIEVED AFTER WELDING.
THE GRADE OF WELDING ROD TO BE USED DEPENDS UPON THE THICKNESS OF SECTION, DESIGN, AND SERVICE REQUIREMENTS, ETC.

ALLOY STEELS - 8620

AISI /SAE 8620 (UNS G 86200)

NICKEL-CHROMIUM-MOLYBDENUM CASE HARDENING STEEL

TYPICAL ANALYSIS

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

AN ALLOY STEEL DESIGNED FOR CASE HARDENING APPLICATIONS. THE NICKEL IMPORTS GOOD TOUGHNESS AND DUCTILITY. THE CHROMIUM AND MOLYBDENUM CONTRIBUTE INCREASED HARDNESS PENETRATION AND WEAR, THAT MAY BE CARBURIZED. THE WELL BALANCED ALLOY CONTENT PERMITS HARDENING TO PRODUCE A HARD WEAR RESISTANT CASE COMBINED WITH A CORE STRENGTH IN THE ORDER OF 125,000 PSI. IT HAS EXCELLENT MACHINABILITY AND RESPONDS WELL TO POLISHING APPLICATIONS. WITH THE BALANCED ANALYSIS, THIS STEEL PROVIDES, UNIFORM CASE DEPTH, HARDNESS AND WEAR PROPERTIES, AND GIVES THE ADVANTAGE OF LOW DISTORTION.

TYPICAL APPLICATIONS

CARBURIZED SPLINED SHAFTS, PISTON PINS, CAM SHAFTS, GUIDE PINS, BUSHINGS AUTOMOTIVE DIFFERENTIAL PINIONS AND TRANSMISSIONS, ARBORS, BEARINGS, SLEEVES KING PINS, CARBURIZED GEARS, GENERAL ENGINEERING PURPOSES.

MECHANICAL PROPERTIES - AS SUPPLIED

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

TENSILE STRENGTH, PSI.	**85,500**
YIELD STRENGTH, PSI.	**52,000**
ELONGATION, % IN 2"	**28.0**
REDUCTION IN AREA, %	**61.0**
BRINELL HARDNESS	**186**

(CONTINUED)

ALLOY STEELS - 8620

AISI /SAE 8620 (UNS G 86200)

NICKEL-CHROMIUM-MOLYBDENUM CASE HARDENING STEEL

THERMAL TREATMENTS	DEGREES IN CELSIUS
FORGING	COMMENCE AT 1200° MAX. FINISH AT 950°
ANNEALING	856/885° COOL IN FURNACE
NORMALIZING	898/926° AIR COOL
HARDENING & TEMPERING	(UNCARBURIZED) - 815/855° OIL OR WATER QUENCH, TEMPER AT 200° TO 650° ACCORDING TO STRENGTH LEVEL REQUIRED

(CARBURIZING) - DIRECT OIL QUENCHED

1. OIL QUENCH DIRECT FROM CARBURIZING TEMPERATURE DRAW AT DESIRED TEMPERATURE FOR AT LEAST 1 - 2 HOURS PER INCH OF SECTION.

2. SINGLE REFINE - BOX COOL FROM PACK CARBURIZING OR AIR COOL FROM OTHER MEDIA. REHEAT TO 829/842º. OIL QUENCH. DRAW AT DESIRED TEMPERATURE FOR MIN. 1 - 2 HOURS PER INCH OF SECTION.

(PROVIDES GOOD CASE HARDNESS AND CORE PROPERTIES)

3. DOUBLE REFINE - BOX COOL FROM CARBURIZING MEDIA. REHEAT TO 829/842°, OIL QUENCH. REHEAT TO 760/787º, OIL QUENCH. DRAW AT DESIRED TEMPERATURE FOR MIN. 1 - 2 HOURS PER INCH OF SECTION.

(PROVIDES OPTIMUM COMBINATION OF CASE HARDNESS, CORE STRENGTH AND TOUGHNESS)

(CONTINUED)

ALLOY STEELS - 8620

AISI /SAE 8620 (UNS G 86200)

NICKEL-CHROMIUM-MOLYBDENUM CASE HARDENING STEEL

MACHINABILITY

8620 IN THE ANNEALED CONDITION HAS A MACHINABILITY RATING OF 68% OF AISI B-1112 AVERAGE SURFACE CUTTING SPEED IS 110 FEET PER MINUTE.

SHEAR STRENGTH

THE ULTIMATE SHEAR STRENGTH IS APPROXIMATELY 70% OF THE ULTIMATE TENSILE STRENGTH.

WELDABILITY

8620 IS SAFE FOR MANUAL ARC WELDING WITHOUT PRE-HEATING. HOWEVER, EVEN AT THIS LOW CARBON LEVEL, PREHEAT IS ADVISABLE IN SECTIONS GREATER THEN 1" OR WHERE A WELDMENT IS SUBJECT TO RESTRAINT AND IS UNABLE TO CONTRACT FREELY DURING COOLING. AS STEEL HARDENABILITY INCREASES, SO SHOULD THE PREHEAT TEMPERATURE.

ALLOY STEELS -EN30B

EN30B-BS 970 GRADE 835M30-BAR

A 4-1/4% NICKEL-CHROMIUM-MOLYBDENUM ALLOY STEEL

TYPICAL ANALYSIS

C.	Mn.	P.	S.	Si.	Cr.	Ni.	Mo.
.28/.33	.40/.60	0.025	0.015	.10/.35	1.10/1.24	4/4.30	.20/.40

TYPICAL APPLICATIONS

THIS STEEL MAY BE USED WHERE TOUGHNESS AND HIGH TENSILE STRENGTH ARE REQUIRED. ONE OF THE MAIN USES IS FOR PLASTIC MOULDS, BUT HAS MANY OTHER APPLICATIONS FOR EXAMPLE: DOWN HOLE TOOLS, ROCK DRILLING BIT BODIES, HEAVY DUTY CONSTRUCTION TOOLS, HEAVY DUTY SHAFTS AND ROLLS, HIGHLY STRESSED GEARS AND TRANSMISSION COMPONENTS.

MECHANICAL PROPERTIES

NORMALIZED, TEMPERED & STRESS RELEIVED-TYPICAL

	UP TO AND INCLUDING 6"	
TENSILE STRENGTH, PSI.	**160,000**	**PSI MIN**
YIELD STRENGTH, PSI.	**130,000**	**PSI MIN**
ELONGATION, % IN 2"	**13.0**	
REDUCTION IN AREA, %	**50.0**	
BRINELL HARDNESS	**320-365**	

CHARPY V-NOTCH MIN. @ -50° F.	**15 FT.-LBS.**
CHARPY V-NOTCH MIN. @ ROOM TEMPERATURE	**45 FT.-LBS.**

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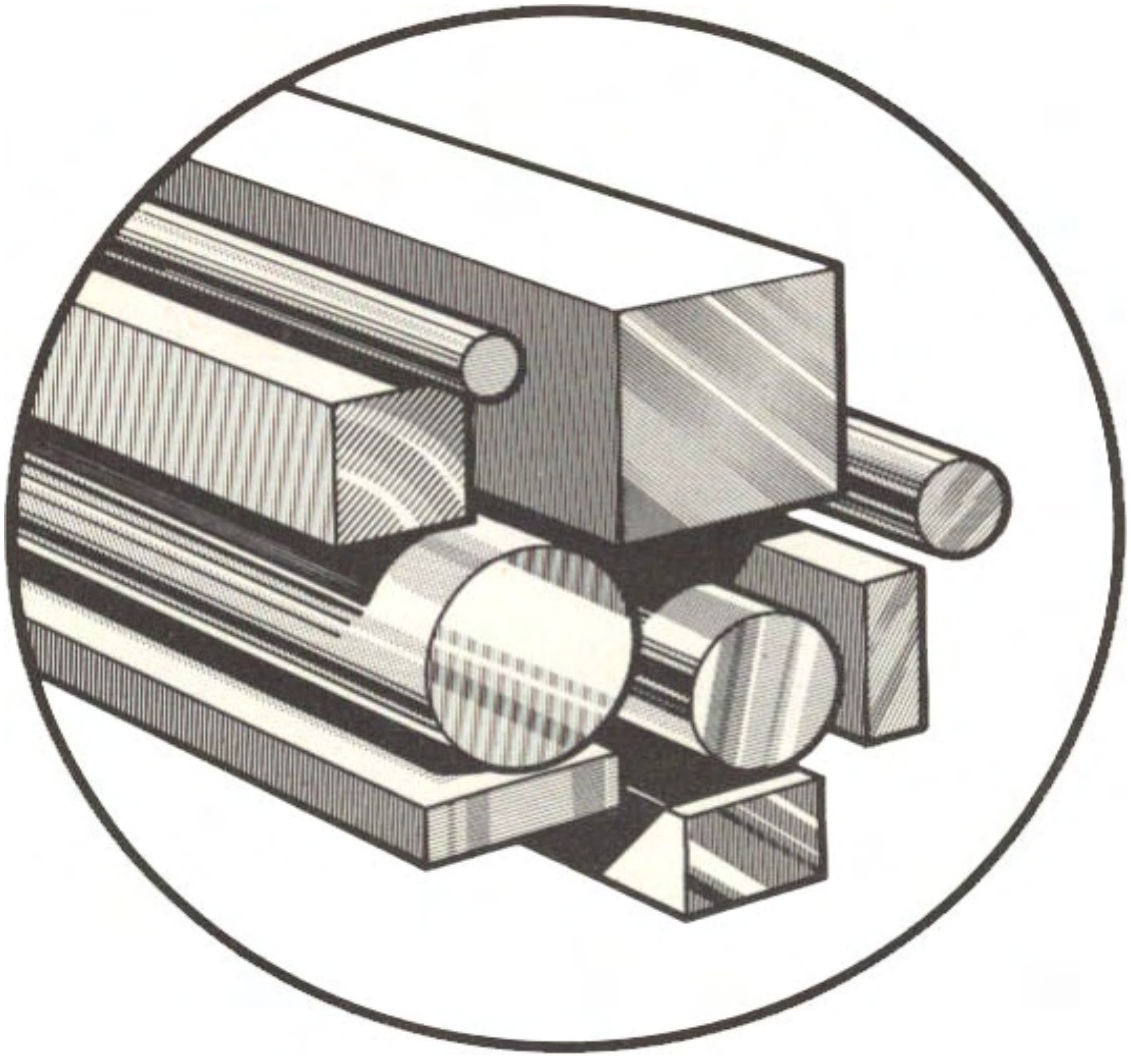
VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 2.
COLD FINISHED STEELS



VANGUARD STEEL LTD.

PRODUCT MANUAL

COLD FINISHED CARBON STEELS - 1018

AISI/SAE 1018 ASTM A 108 - UNS G 10180

TYPICAL ANALYSIS

C.	Mn.	P.	S.
.15/.20	.60/.90	.04 MAX	.05 MAX.

A LOW-CARBON STEEL, HAVING HIGHER MANGANESE CONTENT THAN CERTAIN OTHER LOW CARBON STEELS, SUCH AS 1020. BEING RICHER IN MANGANESE, 1018 IS A BETTER STEEL FOR CARBURIZED PARTS, SINCE IT PRODUCES A HARDER AND MORE UNIFORM CASE. IT ALSO HAS HIGHER MECHANICAL PROPERTIES AND BETTER MACHINING CHARACTERISTICS. THE HOT ROLLED BARS USED IN THE MANUFACTURE OF THIS PRODUCT ARE OF SPECIAL QUALITY.

MOST COLD FINISHED BARS ARE PRODUCED BY COLD DRAWING. IN THIS PROCESS, OVERSIZE HOT ROLLED BARS, WHICH HAVE BEEN CLEANED TO REMOVE SCALE, ARE DRAWN THROUGH DIES TO THE REQUIRED SIZE. THE LARGER SIZES ARE GENERALLY TURNED AND POLISHED, THE HOT ROLLED BARS HAVING BEEN MACHINE TURNED, RATHER THAN DRAWN, FOLLOWED BY ABRASIVE POLISHING. TURNED AND POLISHED BARS TEND TO HAVE A SOMEWHAT BRIGHTER FINISH THAN COLD DRAWN BARS.

TYPICAL APPLICATIONS

SUITABLE FOR PARTS REQUIRING COLD FORMING, SUCH AS CRIMPING, BENDING, OR SWAGING. ESPECIALLY SUITABLE FOR CARBURIZED PARTS REQUIRING SOFT CORE AND HIGH SURFACE HARDNESS, SUCH AS GEARS, PINIONS, WORMS, KING PINS, RATCHETS, DOGS, ETC.

MECHANICAL PROPERTIES

THE FOLLOWING VALUES ARE AVERAGE AND MAY BE CONSIDERED AS REPRESENTATIVE OF THE GRADE:

APPROXIMATE MECHANICAL PROPERTIES * ARE:

TENSILE STRENGTH, PSI	**80,000/100,000**
YIELD POINT, PSI.	**70,000/85,000**
ELONGATION, % IN 2"	**15/25**
REDUCTION IN AREA, %	**45/55**
BRINELL HARDNESS	**170/220**

* IN THE COLD DRAWN STATE ON A 1" CROSS SECTION.

(CONTINUED)

COLD FINISHED CARBON STEELS - 1018

AISI/SAE 1018 **ASTM A 108 - UNS G 10180**

MACHINABILITY

1018 HAS A MACHINABILITY RATING OF 78% OF AISI B-1112.
AVERAGE SURFACE CUTTING SPEED IS 130 FEET PER MINUTE.

WELDABILITY

THIS GRADE IS EASILY WELDED BY ALL THE WELDING PROCESSES, AND THE RESULTANT WELDS AND JOINTS ARE OF EXTREMELY HIGH QUALITY. THE GRADE OF WELDING ROD TO BE USED DEPENDS ON THE THICKNESS OF SECTION, DESIGN, SERVICE REQUIREMENTS, ETC.

HARDENING

THIS GRADE WILL RESPOND TO ANY OF THE STANDARD CARBURIZING METHODS AND SUBSEQUENT HEAT TREATMENTS. FOR A HARD CASE AND TOUGH CORE, THE FOLLOWING HEAT TREATMENT IS SUGGESTED: CARBURIZE AT 1650-1700º DEGREE FAHRENHEIT FOR APPROXIMATELY EIGHT HOURS, COOL IN BOX AND REHEAT TO 1400-1450º DEGREE FAHRENHEIT QUENCH IN WATER AND DRAW AT 300-350º DEGREE FAHRENHEIT.

SIZE TOLERANCE

ALL TOLERANCES ARE **MINUS**

DIAMETER	TOLERANCES	
1-1/2" DIA. AND UNDER	MINUS	0.002"
OVER 1-1/2" DIA. TO 2-1/2" DIA.	MINUS	0.003"
OVER 2-1/2" DIA. TO 4" DIA.	MINUS	0.004"
OVER 4" DIA. TO 6" DIA.	MINUS	0.005"
OVER 6" DIA. TO 8" DIA	MINUS	0.006"

COLD FINISHED CARBON STEELS - 12L14

AISI/SAE 12L14 **UNS G 12144**

TYPICAL ANALYSIS

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

C 12L14 IS ESSENTIALLY RESULPHURIZED AND REPHOSPHORIZED SCREW MACHINE STOCK TO WHICH LEAD HAS BEEN ADDED.

TYPICAL APPLICATIONS

USED TO MAXIMUM ADVANTAGE FOR PARTS WHERE CONSIDERABLE MACHINING IS REQUIRED SUCH AS BUSHINGS, INSERTS, COUPLINGS, AND HYDRAULIC HOSE FITTINGS. WITH GOOD DUCTILITY, THESE GRADES ARE SUITABLE FOR PARTS INVOLVING BENDING, CRIMPING, OR RIVETING.

MECHANICAL PROPERTIES

THE FOLLOWING ARE AVERAGE VALUES FOR 1" ROUND AND MAY BE CONSIDERED AS REPRESENTATIVE:

TENSILE STRENGTH, PSI	**87,500**
YIELD POINT, PSI.	**75,000**
ELONGATION, % IN 2"	**15**
REDUCTION IN AREA, %	**50**
BRINELL HARDNESS	**163/179**

MACHINABILITY

12L14 HAS A MACHINABILITY RATING OF 198% OF AISI B-1112.
AVERAGE SURFACE CUTTING SPEED IS 325 FEET PER MINUTE.

WELDABILITY

DUE TO HIGH SULPHUR CONTENT, THESE GRADES ARE NOT CONSIDERED AS WELDABLE

HARDENING

ALTHOUGH THESE GRADES WILL RESPOND TO CONVENTIONAL TREATMENTS, THEY ARE NOT CONSIDERED CASE-HARDENING STEELS. BETTER RESULTS CAN BE OBTAINED FROM 1117 OR 1018

COLD FINISHED CARBON STEELS-1045 TG&P

AISI 1045 PRECISION GROUND SHAFTING **UNS G 10450**
COLD DRAWN, GROUND AND POLISHED SHAFTING SUPPLIED IN FIBRE TUBES

TYPICAL ANALYSIS

C.	Mn.	P.	S.	Si.
.43/.50	.60/.90	.04 MAX.	.05 MAX.	.15/.35

PRECISION GROUND SHAFTING REPRESENTS THE HIGHEST DEGREE OF OVER-ALL ACCURACY, CONCENTRICITY, STRAIGHTNESS, AND SURFACE PERFECTION ATTAINABLE IN COMMERCIAL PRACTICE. AFTER BEING GROUND ON A CENTERLESS GRINDER, BARS ARE POLISHED TO A SURFACE FINISH OF RMS 25 MAX.

TYPICAL APPLICATIONS

ALL FORMS OF CLOSE TOLERANCE SHAFTING. THIS PRODUCT IS ALSO REFERRED TO AS PUMP SHAFTING, DUE TO ITS HIGH DEGREE OF STRAIGHTNESS, THAT IS SO IMPORTANT IN HIGH-SPEED SHAFTING APPLICATIONS. PRECISION SHAFTING IS ALSO USED FOR MOTOR SHAFTS, CAMSHAFTS MILL SHAFTS, AND SIMILAR APPLICATIONS WHERE HIGH-SPEED WORK NECESSITATES STRAIGHTNESS AND ACCURACY ALONG WITH THE ABILITY TO BE MACHINED UNSYMETRICALLY WITH PRACTICALLY NO DANGER OF WARPING.

MECHANICAL PROPERTIES

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

	1"	3"	7"
TENSILE STRENGTH, PSI.	**115,00**	**102,500**	**90,000**
YIELD STRENGTH, PSI.	**85,000**	**79,000**	**59,000**
ELONGATION, % IN 2"	**19%**	**17%**	**18%**
REDUCTION IN AREA, %	**32%**	**42%**	**35%**
BRINELL HARDNESS	**223**	**212**	**187**

MACHINABILITY

MACHINABILITY RATING IS APPROXIMATELY 70% OS AISI B-1112. AVERAGE SURFACE CUTTING SPEED IS 95 TO 105 FEET PER MINUTE.

(CONTINUED)

COLD FINISHED CARBON STEELS-1045 TG&P

AISI 1045 PRECISION GROUND SHAFTING **UNS G 10450**
COLD DRAWN, GROUND AND POLISHED SHAFTING SUPPLIED IN FIBRE TUBES

SHEAR STRENGTH

THE ULTIMATE SHEAR STRENGTH IS APPROXIMATELY 66% OF THE ULTIMATE TENSILE STRENGTH.

WELDABILITY

DUE TO HIGH CARBON CONTENT, THIS MATERIAL IS NOT READILY WELDED. WITH THIN SECTIONS AND FLEXIBLE DESIGN, GAS OR ARC WELDING MAY BE USED WITHOUT PREHEATING, BUT IN JOINTS OVER 1/4" TO 3/4" THICK, PREHEATING IS NECESSARY. TO DEVELOP EQUIVALENT STRENGTH IN A WELD, A LOW ALLOY FILLER IS RECOMMENDED. THE GRADE OF WELDING ROD TO BE USED DEPENDS ON THICKNESS OF SECTION, DESIGN, SERVICE REQUIREMENTS, ETC.

SIZE TOLERANCE

ALL TOLERANCES ARE **MINUS**

DIAMETER	TOLERANCES	
1-1/2" DIA. AND UNDER	MINUS	0.001"
OVER 1-1/2" DIA. TO UNDER 2-1/2" DIA.	MINUS	0.0015"
OVER 2-1/2" DIA. TO 3" DIA.	MINUS	0.002"
OVER 3" DIA. TO 4" DIA.	MINUS	0.003"
OVER 4" DIA. TO 6" DIA	MINUS	0.005"
OVER 6" DIA. TO 7" DIA	MINUS	0.006"

AVAILABLE IN METRIC AND IMPERIAL SIZES

CHROMED PLATED SHAFTING-1045

AISI/SAE 1045 CHROME PLATED SHAFTING-SUPPLIED IN FIBRE TUBES

TYPICAL ANALYSIS

C.	Mn.	P.	S.	Si.
.43/.50	.60/.90	.04 MAX.	.05 MAX.	.15/.35

THE STEEL USED IS C1045/1050 COLD FINISHED SHAFTING TO ASTM A-108-90A.
SIZE TOLERANCES ARE TO ASTM STANDARD SPECIFICATIONS A 29/A 29M
PRECISION GROUND SHAFTING REPRESENTS THE HIGHEST DEGREE OF OVER-ALL ACCURACY, CONCENTRICITY, STRAIGHTNESS, AND SURFACE PERFECTION ATTAINABLE IN COMMERCIAL PRACTICE. AFTER BEING GROUND ON A CENTERLESS GRINDER, BARS ARE POLISHED TO A SURFACE FINISH OF RMS. 25 MAX.
THE BARS ARE HARD CHROME PLATED BY ELECTROLYTICALLY DEPOSITED LAYERS OF CHROMIUM METAL ON THE SURFACE AND CONFERS THE IMPORTANT PROPERTIES OF CORROSION RESISTANCE AND WEAR RESISTANCE. BEING THAT IT IS VERY SMOOTH IT HAS A LOW COEFFICIENCY TO FRICTION.

CHROME PLATING

FINISHED THICKNESS OF CHROME	**.001" MINIMUM PER SIDE**
HARDNESS OF CHROME	**69-71 RC**
SURFACE FINISH	**RMS. 16 MAX.**

TYPICAL APPLICATIONS

HYDRAULIC SHAFTING, PUMP SHAFTS, PISTON RODS, ETC.

MECHANICAL PROPERTIES

YIELD STRENGTH, PSI	**1/2" TO 15/16" DIA.**	**75,000 APPROX..**
	1" TO 4" DIA.	**100,000 MIN.**
	4-1/4" TO 6" DIA.	**50,000 MIN.**

(CONTINUED)

CHROMED PLATED SHAFTING-1045

AISI/SAE 1045 CHROME PLATED SHAFTING-SUPPLIED IN FIBRE TUBES

SIZE TOLERANCE

ALL TOLERANCES ARE **MINUS**

DIAMETER	TOLERANCES	
1-1/2" DIA. AND UNDER	MINUS	0.0015"
OVER 1-1/2" DIA. TO UNDER 2-1/2" DIA.	MINUS	0.002"
OVER 2-1/2" DIA. TO 3" DIA.	MINUS	0.0025"
OVER 3" DIA. TO 4" DIA.	MINUS	0.0035"
OVER 4" DIA.	MINUS	0.005"

AVAILABLE IN METRIC AND IMPERIAL SIZES

INDUCTION HARDENED SHAFTING - 1045

AISI/SAE 1045 INDUCTION HARDENED AND CHROME PLATED SHAFTING

INDUCTION HARDENED AND CHROME PLATED SHAFTING, SUPPLIED IN FIBRE TUBES

TYPICAL ANALYSIS

C.	Mn.	P.	S.	Si.
.43/.50	.60/.90	.04 MAX.	.05 MAX.	.15/.35

A COLD DRAWN, PRECISION GROUND AND POLISHED SHAFTING, SEAM FREE SURFACE FINISH IS FIRST INDUCTION HARDENED TO A CASE DEPTH OF .050" TO .090" RESULTING IN A SURFACE HARDNESS OF APPROXIMATELY ROCKWELL C 5O MINIMUM, THEREBY ENSURING THE PROPERTIES OF THE BAR. THE EXTRA HARDNESS ENSURES SUPERIOR WEAR RESISTANCE. THE BARS ARE HARD CHROMED IN THE SAME MANNER AS CHROME PLATED SHAFTING ALLOWING THE SAME ADVANTAGES OF CORROSION AND WEAR RESISTANCE, BUT WITH THE INDUCTION HARDENING, THE BARS WILL GIVE SUPERIOR SERVICE.

INDUCTION HARDENING

CASE DEPTH	**.050" TO .090"**
CASE HARDNESS	**RC 50 MINIMUM SURFACE HARDNESS**

CHROME PLATING

FINISHED THICKNESS OF CHROME	**.001" MINIMUM PER SIDE**
HARDNESS OF CHROME	**69-71 RC**
SURFACE FINISH	**RMS. 16 MAX.**

TYPICAL APPLICATIONS

HYDRAULIC SHAFTING, PUMP SHAFTS, PISTON RODS, ETC.

MECHANICAL PROPERTIES

YIELD STRENGTH, PSI	**1/2" TO 15/16" DIA.**	**75,000 APPROX..**
	1" TO 4" DIA.	**100,000 MIN.**
	4-1/4" TO 6" DIA.	**50,000 MIN.**

(CONTINUED)

INDUCTION HARDENED SHAFTING - 1045

AISI/SAE 1045 INDUCTION HARDENED AND CHROME PLATED SHAFTING

INDUCTION HARDENED AND CHROME PLATED SHAFTING, SUPPLIED IN FIBRE TUBES

SIZE TOLERANCE

ALL TOLERANCES ARE **MINUS**

DIAMETER	TOLERANCES	
1-1/2" DIA. AND UNDER	MINUS	0.0015"
OVER 1-1/2" DIA. TO UNDER 2-1/2" DIA.	MINUS	0.002"
OVER 2-1/2" DIA. TO 3" DIA.	MINUS	0.0025"
OVER 3" DIA. TO 4" DIA.	MINUS	0.0035"
OVER 4" DIA.	MINUS	0.005"

AVAILABLE IN METRIC AND IMPERIAL SIZES

COLD FINISHED ALLOY STEEL - 4140 TG & P.

AISI 4140 PRECISION GROUND SHAFTING (UNS G41400)

TURNED, GROUND AND POLISHED SHAFTING, SUPPLIED IN FIBRE TUBES

TYPICAL ANALYSIS

C.	Mn.	P.	S.	Si.	Cr.	Mo.
.38/.43	.75/1.00	.035 MAX.	.04 MAX.	.15/.35	.80/1.10	.15/.25

MANUFACTURED TO ASTM A434-90A CLASS BD.
HIGH STRENGTH PRECISION GROUND SHAFTING REPRESENTS THE HIGHEST DEGREE OF OVER-ALL ACCURACY, CONCENTRICITY, STRAIGHTNESS, AND SURFACE PERFECTION ATTAINABLE IN COMMERCIAL PRACTICE. AFTER BEING GROUND ON A CENTERLESS GRINDER, BARS ARE POLISHED TO A SURFACE FINISH OF RMS 25 MAX.

TYPICAL APPLICATIONS

ALL FORMS OF CLOSE TOLERANCE SHAFTING. MOTOR SHAFTS, CAMSHAFTS, HYDRAULIC SHAFTS, MILL SHAFTS, AND SIMILAR APPLICATIONS WHERE HIGH-SPEED WORK NECESSITATES STRAIGHTNESS AND ACCURACY ALONG WITH THE ABILITY TO BE MACHINED UNSYMMETRICALLY WITH PRACTICALLY NO DANGER OF WARPING; BOLTS, PINS, STUDS, ETC.

MECHANICAL PROPERTIES

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

	1-1/2"	2-1/4"	4-1/2"
TENSILE STRENGTH, PSI.	**155,300**	**150,900**	**140,700**
YIELD STRENGTH, PSI.	**132,600**	**133,600**	**116,700**
ELONGATION, % IN 2"	**15**	**17**	**14**
REDUCTION IN AREA, %	**57**	**54**	**49**
BRINELL HARDNESS	**321**	**321**	**288**

SIZE TOLERANCE

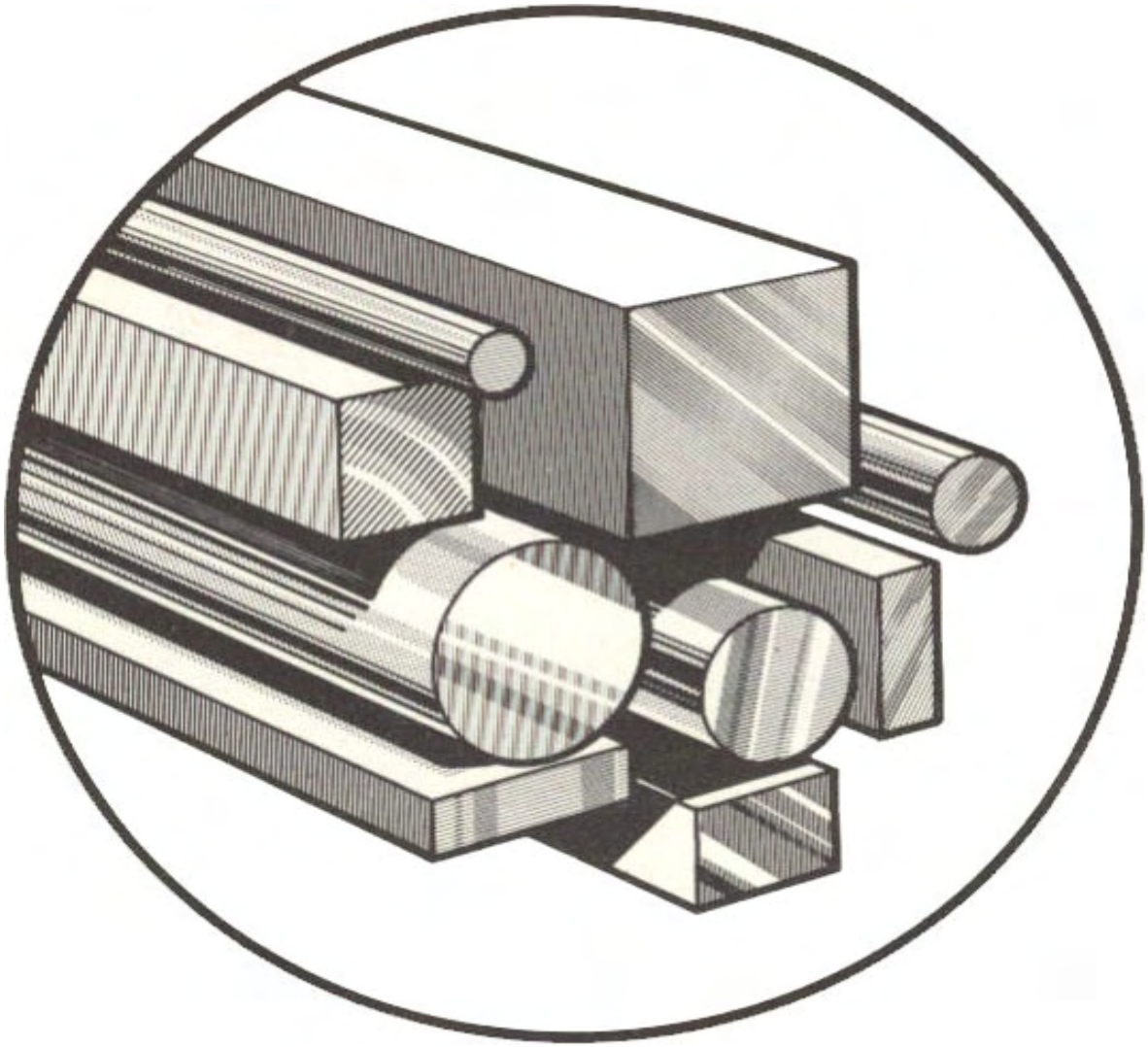
ALL TOLERANCES ARE **MINUS**

DIAMETER	TOLERANCES	
1-1/2" DIA. AND UNDER	MINUS	0.001"
OVER 1-1/2" DIA. TO UNDER 2-1/2" DIA.	MINUS	0.0015"
OVER 2-1/2" DIA. TO 3" DIA.	MINUS	0.002"
OVER 3" DIA. TO 4" DIA.	MINUS	0.003"
OVER 4" DIA.	MINUS	0.005"

VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 3.
HOT ROLLED STEELS



VANGUARD STEEL LTD.

PRODUCT MANUAL

HOT ROLLED CARBON STEELS - 1020

AISI/SAE 1020 **ASTM A576 UNS G 10200**

TYPICAL ANALYSIS

C.	Mn.	P.	S.
.17/.24	.25/.60	.04 MAX.	.05 MAX.

A GENERAL PURPOSE MILD STEEL, LOW-CARBON MACHINERY STEEL, HAVING GOOD OVER-ALL MECHANICAL PROPERTIES. EASILY MACHINABLE AND WELDABLE. SUITABLE FOR HEAT TREATMENT AND IDEAL FOR CARBURIZING

TYPICAL APPLICATIONS

GENERAL PURPOSE STRUCTURAL AND MISCELLANEOUS NON-CRITICAL APPLICATIONS, GENERAL ENGINEERING PARTS, SHAFTS, AGRICULTURAL IMPLEMENTS, HUBS, ETC.

MECHANICAL PROPERTIES - AS SUPPLIED

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

TENSILE STRENGTH, PSI	**58,000**	
YIELD STRENGTH, PSI	**36,000**	**MIN.**
ELONGATION, %	**36**	
REDUCTION IN AREA, %	**59**	
BRINELL HARDNESS	**120**	

MACHINABILITY

1020 IN THE AS SUPPLIED CONDITION HAS A MACHINABILITY RATING OF 72%,.
BASED ON AISI 1212 AS 100%.
AVERAGE SURFACE CUTTING SPEED IS 120 FEET PER MINUTE.

WELDABILITY

THIS GRADE IS EASILY WELDED BY ALL WELDING PROCESSES.
THE RESULTANT WELDS AND JOINTS ARE OF EXTREMELY HIGH QUALITY.
WELDING ROD TO BE USED DEPENDS UPON THE THICKNESS OF SECTION, DESIGN, SERVICE REQUIREMENTS, ETC.

VANGUARD STEEL LTD.

PRODUCT MANUAL

HOT ROLLED CARBON STEELS - 1040-1045

AISI/SAE 1040-1045 **ASTM A576 UNS G 10400-G 10450**

TYPICAL ANALYSIS

	C.	Mn.	P. MAX.	S. MAX.
1040	0.37/0.44	0.60/0.90	0.040	0.050
1045	0.43/0.50	0.60/0.90	0.040	0.050

A GENERAL PURPOSE MILD STEEL, MEDIUM-CARBON FINE GRAIN MACHINERY STEEL. IN THE PRODUCTION OF THIS GRADE, SPECIAL CONTROLS ARE USED FOR CHEMICAL COMPOSITION, HEATING, ROLLING AND SURFACE PREPARATION. THESE BARS ARE SUITABLE FOR APPLICATIONS OF FORGING, COLD DRAWING, MACHINING, HEAT TREATING (INCLUDING FLAME HARDENING). GOOD WEAR RESISTANCE CAN BE OBTAINED BY FLAME OR INDUCTION HARDENING.

TYPICAL APPLICATIONS

AXLES, BOLTS, SHAFTS, MACHINERY PARTS, LIGHTLY STRESSED GEARS, PINIONS FORMING DIES.

MECHANICAL PROPERTIES - AS SUPPLIED.

THE FOLLOWING ARE AVERAGE VALUES AND MAY BE CONSIDERED AS REPRESENTATIVE:

TENSILE STRENGTH, PSI	**87,000**
YIELD STRENGTH, PSI	**52,500**
ELONGATION, %	**25**
REDUCTION IN AREA, %	**49**
BRINELL HARDNESS	**180**

(CONTINUED)

HOT ROLLED CARBON STEELS - 1040-1045

AISI/SAE 1040-1045 **ASTM A576 UNS G 10400-G 10450**

THERMAL TREATMENTS	DEGREES IN CELSIUS
FORGING	COMMENCE AT 1150° MAX. FINISH AT 950°
ANNEALING	800/830° SURFACE COOL
NORMALIZING	870/920° COOL IN AIR
HARDENING	840/870° WATER QUENCH 855/885° OIL QUENCH
TEMPERING	430/700° ACCORDING TO PROPERTIES REQUIRED

MACHINABILITY

1040 IN THE AS ROLLED BAR HAS A MACHINABILITY RATING OF 62% OF AISI B-1112.
AVERAGE SURFACE CUTTING SPEED IS 105 FEET PER MINUTE.

SHEAR STRENGTH

THE ULTIMATE SHEAR STRENGTH IS APPROXIMATELY 66% OF THE ULTIMATE TENSILE STRENGTH.

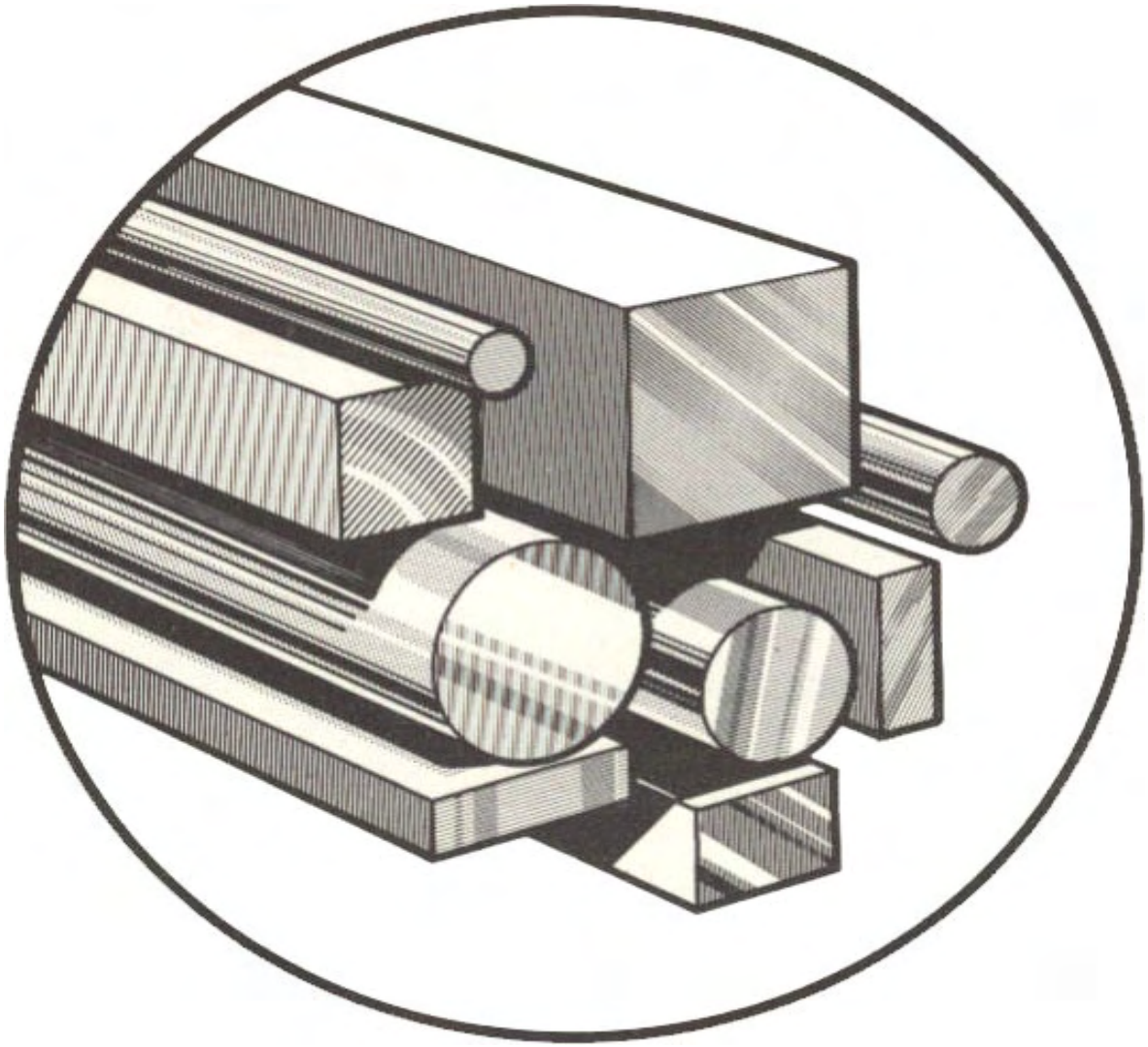
WELDABILITY

DUE TO HIGH CARBON CONTENT, THIS MATERIAL IS NOT READILY WELDED. WITH THIN SECTIONS AND FLEXIBLE DESIGN, GAS OR ARC WELDING MAY BE USED WITHOUT PREHEATING, BUT IN JOINTS OVER 1/2" TO 3/4" THICK, PREHEATING IS NECESSARY. TO DEVELOP EQUIVALENT STRENGTH IN A WELD, A LOW ALLOY FILLER IS RECOMMENDED. THE GRADE OF WELDING ROD TO BE USED DEPENDS ON THICKNESS OF SECTION, DESIGN, SERVICE REQUIREMENTS, ETC.

VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 4.
TOOL STEELS



VANGUARD STEEL LTD.

PRODUCT MANUAL

TOOL STEELS-AISI O-1

AISI O-1 UNS T 31501
LOW MANGANESE, OIL HARDENING-DIMENSIONALLY STABLE, COLD WORK TOOL STEEL

TYPICAL ANALYSIS

C.	Mn.	Si.	Cr.	W.	V.	Mo.
0.90	1.00		0.50	0.50	0.15	

AN ECONOMICAL MEDIUM-ALLOY OIL HARDENING STEEL. SAFE AND UNIFORM HARDENING WITH GOOD MACHINABILITY, MINIMUM SIZE CHANGE. THIS STEEL HAS EXCELLENT ABILITY TO KEEP A KEEN CUTTING EDGE. IT HAS HIGH WEAR RESISTANCE WITH SATISFACTORY TOUGHNESS.

TYPICAL APPLICATIONS

MACHINE TAPS, STAYBOLT TAPS, THREAD CHASERS, MILLING CUTTERS, REAMERS, PRECISION SHAPING KNIVES AND WOODWORKING TOOLS, DIE PLATES AND PUNCHES, HIGH-PRODUCTION CUTTERS FOR PAPER AND SIMILAR THIN MATERIALS, ROLLER DIES, COLD WORK DIES AND ROLL FORMING APPLICATIONS, ETC.

THERMAL TREATMENTS	DEGREES IN CELSIUS
FORGING	**1050-850°**
ANNEALING	**740-760° TENSILE STRENGTH AS ANNEALED (41-48 TONS/SQ. INCH) 191-219 BHN**
HARDENING	**780-820° IN OIL OR HOT BATH (200-230°) MIN. SOAK 10 MINUTES**
TEMPERING MAXIMUM WEAR	**150-205°**
TEMPERING MAXIMUM TOUGHNESS	**230-315°**
QUENCHING MEDIUM	**OIL**
OBTAINABLE HARDNESS - HRC	**63-66**
WEAR RESISTANCE	**MEDIUM**
TOUGHNESS	**MEDIUM**
DISTORTION IN HEAT TREATING	**VERY LOW**
MACHINABILITY	**HIGH**
RED HARDNESS	**LOW**

VANGUARD STEEL LTD.

PRODUCT MANUAL

TOOL STEELS-AISI A-2

AISI A-2 UNS T 30102
5% CHROME AIR HARDENING-COLD WORK TOOL STEEL

TYPICAL ANALYSIS

C.	Mn.	Si.	Cr.	W.	V.	Mo.
1.00			5.00		0.15	1.00

A DEEP HARDENING STEEL WITH EXCELLENT TOUGHNESS, OUTSTANDING WEAR RESISTANCE AND GOOD MACHINING PROPERTIES.

TYPICAL APPLICATIONS

TOOLS AND DIES FOR BLANKING, PUNCHING, PIERCING, BENDING, PLANISHING, FORMING, EMBOSSING, TUBE AND ROD DRAWING, DEEP DRAWING, THREAD DRAWING, SHEAR BLADES, TRIMMING TOOLS, GAUGES, GROOVED ROLLS, HEAVILY STRESSED WOODWORKING TOOLS, ETC.

THERMAL TREATMENTS	DEGREES IN CELSIUS
FORGING	**1050-900°**
ANNEALING	**840-870° TENSILE STRENGTH AS ANNEALED (44-51 TONS/SQ. INCH) 204-234 BHN**
HARDENING	**950-980° IN AIR OR OIL.**
TEMPERING MAXIMUM WEAR	**175-205°**
TEMPERING MAXIMUM TOUGHNESS	**DOUBLE TEMPER AT 480°**
QUENCHING MEDIUM	**AIR**
OBTAINABLE HARDNESS - HRC	**63-65**
WEAR RESISTANCE	**HIGH**
TOUGHNESS	**MEDIUM**
DISTORTION IN HEAT TREATING	**LOWEST**
MACHINABILITY	**MEDIUM**
RED HARDNESS	**HIGH**

VANGUARD STEEL LTD.

PRODUCT MANUAL

TOOL STEELS-AISI D-2

AISI D-2 UNS T 30402
11-1/2% HIGH CHROME - DIMENSIONALLY STABLE, COLD WORK TOOL STEEL

TYPICAL ANALYSIS

C.	MN.	SI.	CR.	W.	V.	MO.
1.50			11.50		0.80	0.75

A DEEP HARDENING STEEL WITH EXCELLENT TOUGHNESS, OUTSTANDING WEAR RESISTANCE AND GOOD MACHINING PROPERTIES. TUNGSTEN-MOLYBDENUM-VANADIUM VARIANT OF THE HIGH-CARBON, HIGH-CHROMIUM, TYPE OF STEEL.

TYPICAL APPLICATIONS

HIGH-EFFICIENCY CUTTING TOOLS (DIES AND PUNCHES), BLANKING TOOLS, WOOD-WORKING TOOLS, SHEAR BLADES FOR CUTTING THIN MATERIALS, THREAD ROLLING DIES; DRAWING, DEEP DRAWING AND EXTRUSION TOOLS, PRESSING TOOLS, COLD ROLLS FOR MULTIPLE ROLLER STANDS, GAUGES, PLASTIC MOLDS, ETC.

THERMAL TREATMENTS	DEGREÈS IN CELSIUS
FORGING	**1050-850°**
ANNEALING	**800-850° TENSILE STRENGTH AS ANNEALED (44-51 TONS/SQ. INCH) 204-234 BHN FURNACE COOLING TO 600° AT ABOUT 10° PER HOUR**
HARDENING	**970-1000°**
TEMPERING MAXIMUM WEAR	**175-205°**
TEMPERING MAXIMUM TOUGHNESS	**DOUBLE TEMPER AT 480°**
QUENCHING MEDIUM	**AIR**
OBTAINABLE HARDNESS - HRC.	**63-65**
WEAR RESISTANCE	**VERY HIGH**
TOUGHNESS	**LOW**
DISTORTION IN HEAT TREATING	**LOWEST**
MACHINABILITY	**LOW**
RED HARDNESS	**HIGH**

VANGUARD STEEL LTD.

PRODUCT MANUAL

TOOL STEELS-AISI H-13

AISI H-13 UNS T 20813
5% CHROMIUM, HOT WORK TOOL STEEL.

TYPICAL ANALYSIS

C.	MN.	SI.	CR.	W.	V.	MO.
0.40			5.00		1.10	1.30

DESIGNED TO RESIST ABRASION AND WASHING ACTION; IT HAS EXCELLENT SHOCK RESISTANCE. THIS STEEL HAS ENOUGH RED HARDNESS TO RETAIN ITS PROPERTIES AT HIGH OPERATING TEMPERATURE.

TYPICAL APPLICATIONS

DIES FOR HOT METALWORKING, (SHEARING, FORMING, PUNCHING, EXTRUDING, AND TRIMMING), DUMMY BLOCKS, AND MANDRELS. ALSO USED FOR STRUCTURAL APPLICATIONS WHERE HIGH ENGINEERING STRENGTHS AT ELEVATED TEMPERATURES ARE REQUIRED.

THERMAL TREATMENTS	DEGREES IN CELSIUS
FORGING	**1100-900$^{\delta}$**
ANNEALING	**800-840° TENSILE STRENGTH AS ANNEALED (44-51 TONS/SQ. INCH) 204-234 BHN**
HARDENING	**1040-1080°**
TEMPERING	**600-650°**
NITRIDING	**500-520° GAS OR SALT BATH**
QUENCHING MEDIUM	**AIR OIL**
OBTAINABLE HARDNESS - HRC.	**50-54 52-56**
WEAR RESISTANCE	**MEDIUM**
TOUGHNESS	**VERY HIGH**
DISTORTION IN HEAT TREATING	**VERY LOW**
MACHINABILITY	**HIGH**
RED HARDNESS	**HIGH**

VANGUARD STEEL LTD.

PRODUCT MANUAL

TOOL STEELS-AISI S-7

AISI S-7 UNS T 41907
SHOCK RESISTING TOOL STEEL

TYPICAL ANALYSIS

C.	MN.	SI.	CR.	W.	Ni.	MO.
0.50			3.25			1.40

DESIGNED FOR USE WHERE THE ABILITY TO WITHSTAND REPEATED BLOWS AT NORMAL OPERATING TEMPERATURES IS MORE IMPORTANT THAN THE ABILITY TO RESIST WEAR AND ABRASION

TYPICAL APPLICATIONS

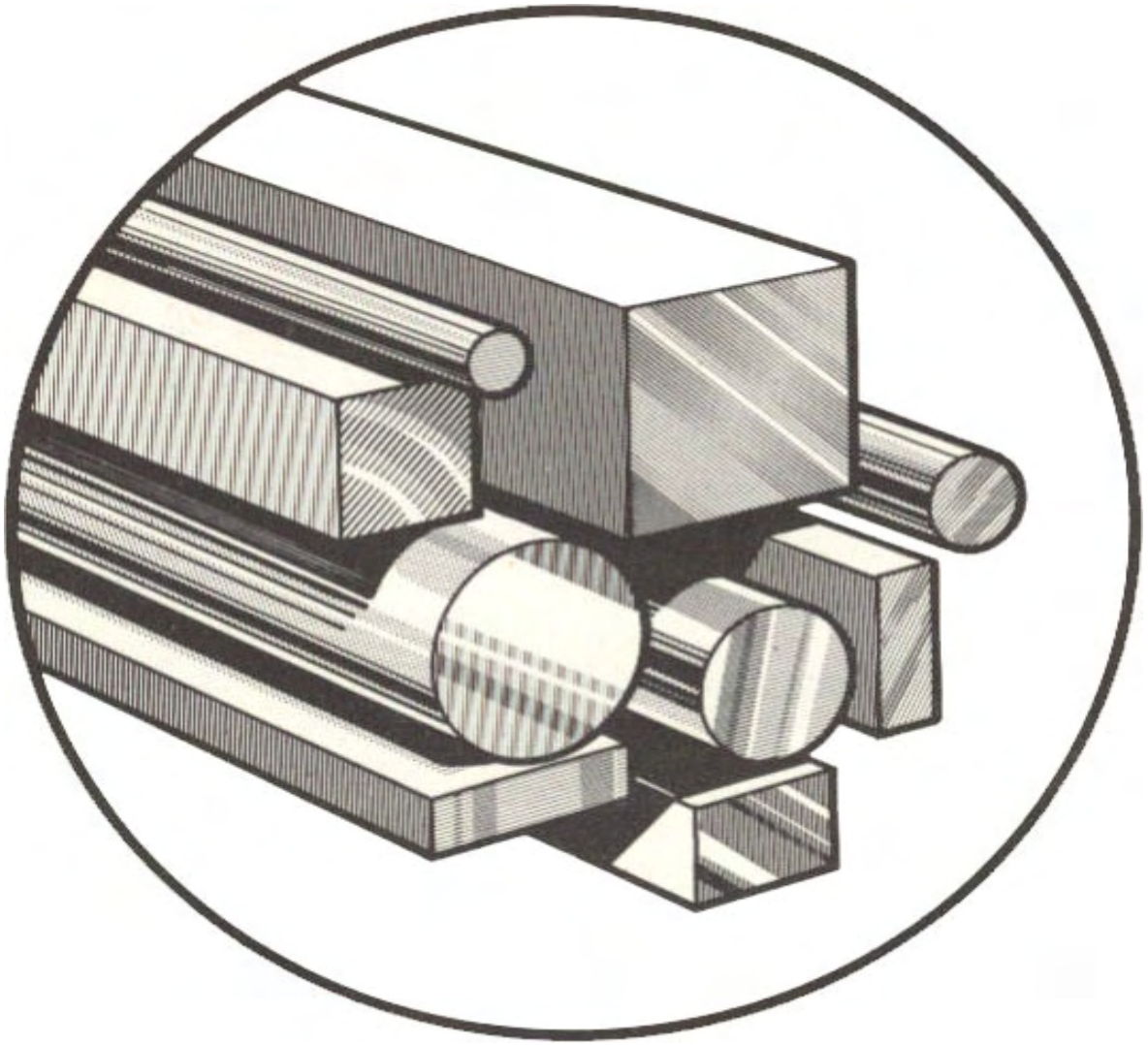
HAND AND PNEUMATIC TOOLS FOR CHIPPING, PUNCHING, RIVETING, AS WELL AS DRIFT PINS, GRIPPERS, MANDRELS, HEAVY DUTY BLANKING AND FORMING DIES, AND SHEAR BLADES.

THERMAL TREATMENTS	DEGREES IN CELSIUS
FORGING	**1120-950$^{\delta}$**
ANNEALING	**815-840° TENSILE STRENGTH AS ANNEALED (45-52 TONS/SQ. INCH) 187-223 BHN**
HARDENING	**925-950°**
TEMPERING MAXIMUM WEAR	**205-260°**
TEMPERING MAXIMUM TOUGHNESS	**480-540°**
QUENCHING MEDIUM	**AIR SECTIONS GREATER THAN 2-1/2" FLASH OIL QUENCH**
OBTAINABLE HARDNESS - HRC.	**45-57**
WEAR RESISTANCE	**MEDIUM**
TOUGHNESS	**VERY HIGH**
DISTORTION IN HEAT TREATING	**LOWEST**
MACHINABILITY	**MEDIUM**
RED HARDNESS	**HIGH**

VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 5.
DRILL RODS



VANGUARD STEEL LTD.

PRODUCT MANUAL

POLISHED DRILLRODS

CARBON **AISI W-1**
OIL HARDENING **AISI O- 1**

TYPICAL ANALYSIS

	C.	Mn.	Si.	Cr.	W.	V.	Mo.
W -1	1.00	0.30	0.30				
O - 1	0.90	1.20	0.35	0.50	0.50	0.20	

SUPPLIED IN THE ANNEALED STATE WITH A FINELY GROUND AND POLISHED SURFACE. ITS HIGH ACCURACY TO SIZE, UNIFORM PROPERTIES THAT ARE FREE FROM DEFECTS AND DECARBURIZATION, OPENS A WIDE FIELD OF APPLICATIONS FOR THESE DRILLRODS.

TYPICAL APPLICATIONS

DRILLS, TAPS, DIES, ARBORS, BALANCE STAFFS, CUTTING-OFF TOOLS, CHASERS, ENGRAVERS TOOLS, JEWELERS TOOLS, GAUGES, MACHINERY PARTS, MILLING TOOLS, PINS, PUNCHES, PINIONS, PIVOTS, ROLLER BEARINGS, THREADING DIES ETC; ALSO FOR GUIDE RODS AND ADJUSTING PINS IN TOOL MANUFACTURING AND GENERAL ENGINEERING, EJECTING MANDRELS, SURGICAL INSTRUMENTS, AXLES AND SHAFTS IN PRECISION MECHANICS.

MECHANICAL PROPERTIES - ANNEALED

TENSILE STRENGTH	**38-44 TONS/SQ. INCH**
BRINELL HARDNESS	**174-207**

THERMAL TREATMENTS — DEGREES IN CELSIUS

AISI W-1

HOT FORMING	**1000-800°**
ANNEALING	**690-710°**
HARDENING	**760-780° IN WATER**
TEMPERING	**AS REQUIRED**
OBTAINABLE HARDNESS - HRC	**64-66**

(CONTINUED)

POLISHED DRILLRODS

CARBON **AISI W-1**
OIL HARDENING **AISI O- 1**

THERMAL TREATMENTS	DEGREES IN CELSIUS
AISI O-1	
HOT FORMING	**1050-850°**
ANNEALING	**740-760°**
HARDENING	**790-830° IN OIL**
TEMPERING	**100-300°**
OBTAINABLE HARDNESS - HRC	**64-66**

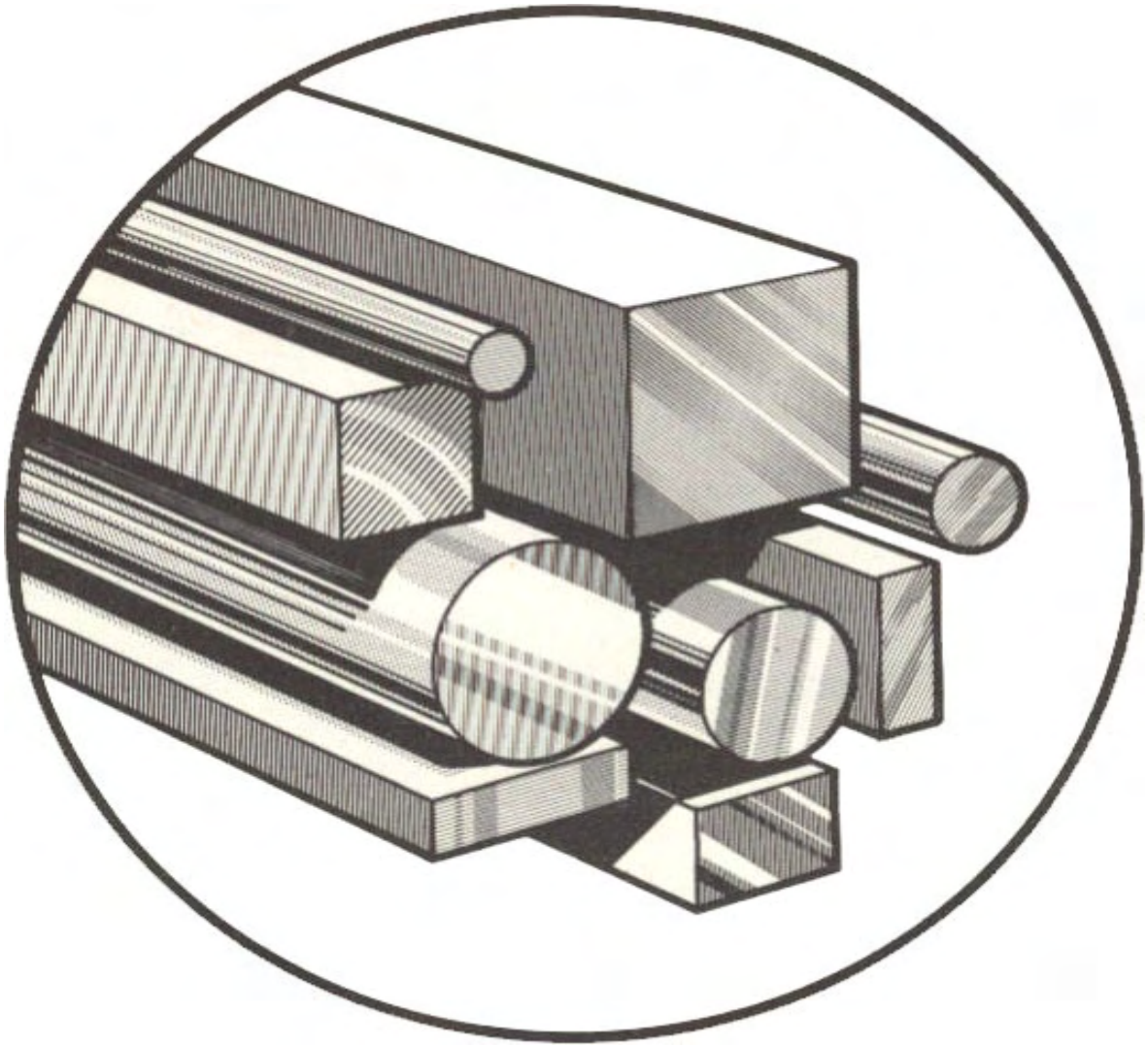
TOLERANCES	PLUS OR MINUS
UP TO 0.124"	.0003"
0.125" TO 0.499"	.0005"
0.500" TO 2.000"	.001"

AVAILABLE IN METRIC AND IMPERIAL SIZES.

VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 6.
FLATGROUND STOCK



VANGUARD STEEL LTD.

PRODUCT MANUAL

PRECISION FLAT GROUND STOCK

OIL HARDENING **AISI O 1**
AIR HARDENING **AISI A 2**

TYPICAL ANALYSIS

	C.	Mn.	Si.	Cr.	W.	V.	Mo.
O-1	0.90	1.20	0.30	0.50	0.50	0.20	
A-2	1.00	0.50	0.30	5.00		0.25	1.10

SUPPLIED IN THE ANNEALED STATE WITH A PRECISION GROUND, DECARB-FREE SURFACE, ARE AVAILABLE IN CONVENIENT, EASY TO WORK SIZES, AT A LOWER COST THAN IF PRODUCED INDIVIDUALLY FROM HOT ROLLED OR FORGED STOCK.

TYPICAL APPLICATIONS

CUTTING TOOLS AND DIES, BLANKING AND PUNCHING DIES, TRIM BLADES, TOOLS FOR THE WOODWORKING, PULP AND PAPER, TEXTILE AND PLASTICS INDUSTRIES. MACHINERY, JIGS AND FIXTURES, PARTS SUBJECT TO WEAR, STAMPS, PUNCHES, TEMPLATES, TOOLS GAUGES, LEVERS, CAMS, ETC.

THERMAL TREATMENT AISI O-1	**DEGREES IN CELSIUS**
ANNEALING	**760-785° SLOW COOL IN FURNACE; HARDNESS AS ANNEALED 190-220 BHN.**
STRESS RELIEVING	**PREHEAT 650-705° HIGH HEAT 775-815°**
QUENCH	**IN OIL**
TEMPERING	**THIS OPERATION SHOULD FOLLOW HARDENING IMMEDIATELY, ACCORDING TO PROPERTIES REQUIRED. FOR MAXIMUM WEAR 150-205° FOR MAXIMUM TOUGHNESS 230-315°**
OBTAINABLE HARDNESS	**63-65 RC**

(CONTINUED)

PRECISION FLAT GROUND STOCK

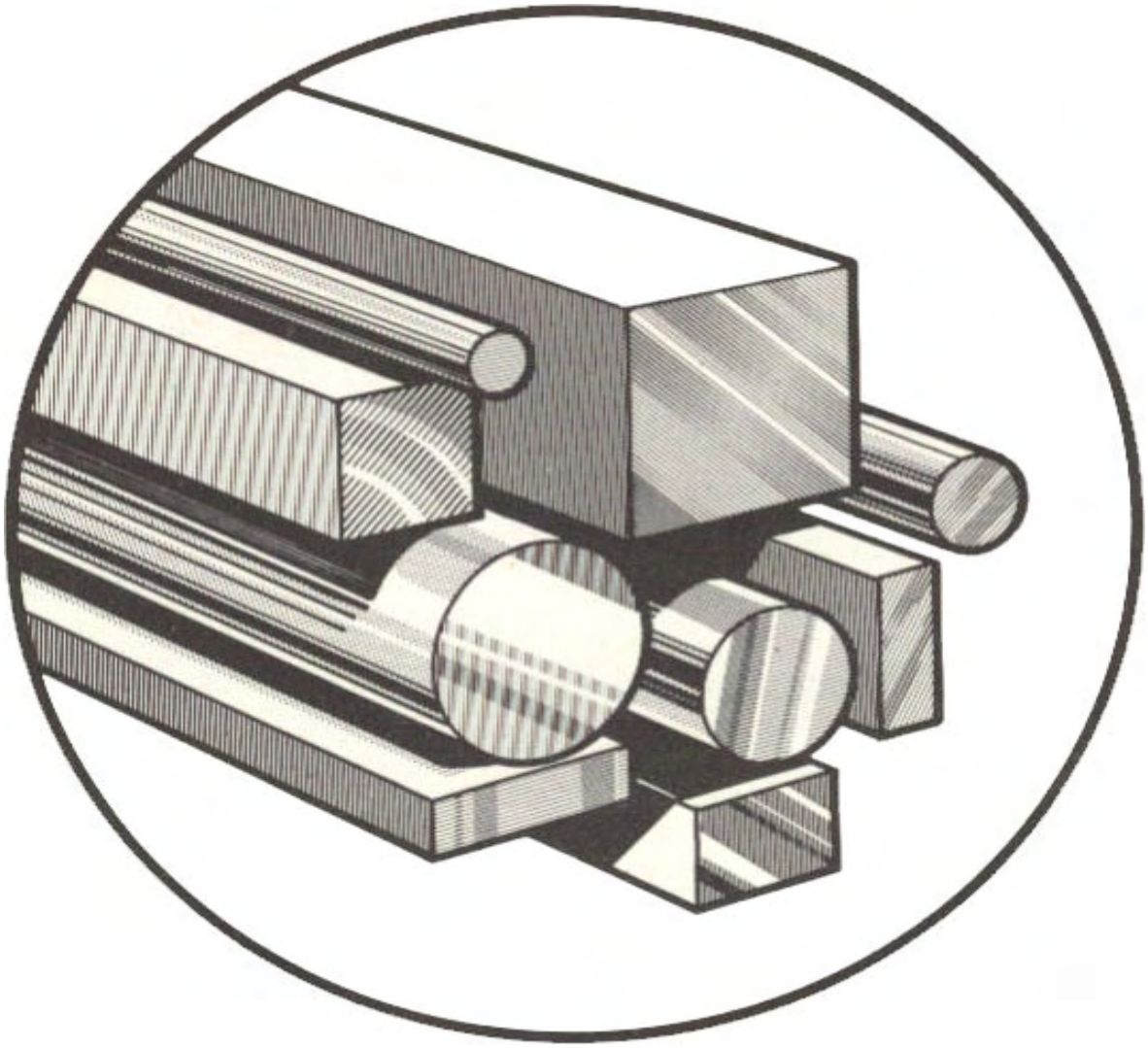
OIL HARDENING **AISI O 1**
AIR HARDENING **AISI A 2**

THERMAL TREATMENT AISI A-2	DEGREES IN CELSIUS
ANNEALING	830-860° SLOW COOL IN FURNACE; HARDNESS AS ANNEALED 204-234 BHN.
STRESS RELIEVING	PREHEAT 650-705° HIGH HEAT 940-980°
QUENCH	IN AIR OR SALT AT 540-595°
TEMPERING	THIS OPERATION SHOULD FOLLOW HARDENING IMMEDIATELY, ACCORDING TO PROPERTIES REQUIRED. FOR MAXIMUM WEAR 175-205° FOR MAXIMUM TOUGHNESS DOUBLE TEMPER AT 480°
OBTAINABLE HARDNESS	63-65 RC

VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 7.
MACHINING ALLOWANCES



VANGUARD STEEL LTD.

PRODUCT MANUAL

ALLOWANCE FOR MACHINING BARS

HOT ROLLED BARS

WHEN PURCHASING BARS THAT ARE TO BE MACHINED, IT IS ADVISABLE TO MAKE ADEQUATE ALLOWANCES TO REMOVE SURFACE IMPERFECTIONS AND SPECIFY HOT ROLLED SIZES ACCORDINGLY.
THESE ALLOWANCES REQUIRE CONSIDERATION OF MILL MANUFACTURING PRACTICES, THE LENGTH AND SIZE OF BAR, STRAIGHTNESS, SIZE TOLERANCE, OUT OF ROUND TOLERANCE.
IN ORDER TO MINIMIZE OR ELIMINATE THE INCIDENT OF SURFACE DEFECTS ON MACHINED PARTS, AND IN ORDER TO MINIMIZE THERMAL CRACKING FROM HEAT TREATMENT, ADEQUATE ALLOWANCE SHOULD PERMIT STOCK REMOVAL FROM THE SURFACE OF NOT LESS THAN THE AMOUNTS SHOWN IN THE FOLLOWING TABLE.

	DIAMETER IN INCHES				**MINIMUM MACHINING ALLOWANCE PER SIDE. (INCHES).**
UP TO	5/8"			INCL.	0.016
OVER	5/8"	TO	7/8"	INCL.	0.021
OVER	7/8"	TO	1"	INCL.	0.023
OVER	1"	TO	1-1/8"	INCL.	0.025
OVER	1-1/8"	TO	1-1/4"	INCL.	0.028
OVER	1-1/4"	TO	1-3/8"	INCL.	0.030
OVER	1-3/8"	TO	1-1/2"	INCL.	0.033
OVER	1-1/2"	TO	2"	INCL.	0.042
OVER	2"	TO	2-1/2"	INCL.	0.052
OVER	2-1/2"	TO	3-1/2"	INCL.	0.072
OVER	3-1/2"	TO	4-1/2"	INCL.	0.090
OVER	4-1/2"	TO	5-1/2"	INCL.	0.110
OVER	5-1/2"	TO	6-1/2"	INCL.	0.125
OVER	6-1/2"	TO	8-1/4"	INCL.	0.155
OVER	8-1/4"	TO	10"	INCL.	0.203

ROUGH TURNED BARS

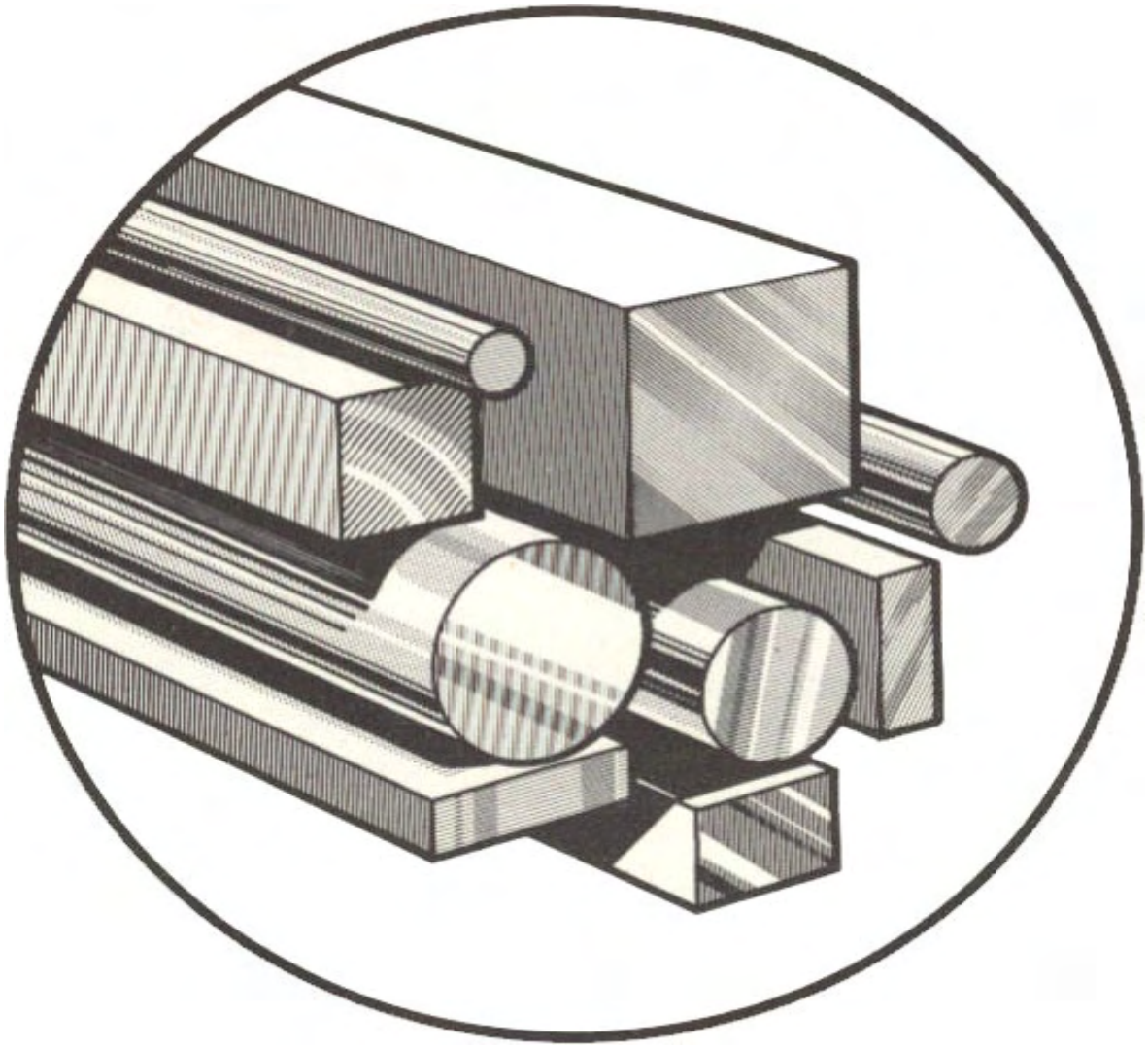
OVER	10"	TO	14"	INCL.	1/8"
OVER	14"				3/16"

REMOVAL FOR AIRCRAFT QUALITY ALLOYS SUBJECT TO MAGNETIC PARTICLE INSPECTION WILL REQUIRE APPROX. TWICE THE ABOVE MACHINING ALLOWANCE IN ACCORDANCE WITH **AISI** STANDARDS.

VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 8.
THEORETICAL WEIGHTS



THEORETICAL WEIGHTS

WEIGHTS ARE FOR ESTIMATING PURPOSES ONLY !

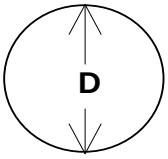
ALL WEIGHTS ARE THEORETICAL. THEY ARE COMPUTED ON THE BASIS OF THE SPECIFIC GRAVITIES OF THE METALS INVOLVED !

THE WEIGHTS SHOWN WOULD BE ACCURATE IF STEEL COULD ALWAYS BE PRODUCED TO EXACT SIZE. THIS IS SELDOM POSSIBLE IN COMMERCIAL PRACTICE.

ACCURACY OF DIMENSIONS, PARTICULARLY OF HOT ROLLED STEEL PRODUCTS, IS INFLUENCED BY MANY FACTORS, SUCH AS MILL DESIGN, HEATING, PRACTICE, REDUCTION BETWEEN PASSES, ROLL WEAR, ROLL PRESSURE, COMPOSITION OF STEEL, AND STANDARD TOLERANCES !

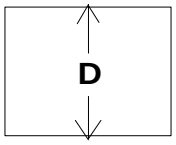
WEIGHT FORMULAS

STEEL BARS WEIGHTS ARE BASED ON .2836 LBS. PER CUBIC INCH. ALUMINUM WEIGHTS ARE BASED ON .098 LBS. PER CUBIC INCH (1100 ALLOY). SEE NEXT PAGE FOR CONVERSION FACTORS FOR OTHER ALLOYS.



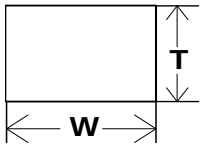
ROUND **D = SIZE IN INCHES**

STEEL	LBS. PER LINEAL FOOT	=	2.6729 X D X D
	LBS. PER LINEAL INCH	=	.22274 X D X D
ALUMINUM	LBS. PER LINEAL FOOT	=	.92400 X D X D



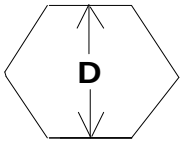
SQUARE **D = SIZE IN INCHES**

STEEL	LBS. PER LINEAL FOOT	=	3.4032 X D X D
	LBS. PER LINEAL INCH	=	.2836 X D X D
ALUMINUM	LBS. PER LINEAL FOOT	=	1.18 X D X D



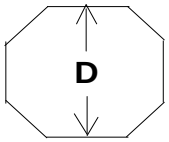
FLATS

STEEL	LBS. PER LINEAL FOOT	=	3.4032 X T X W
	LBS. PER LINEAL INCH	=	.2836 X T X W
ALUMINUM	LBS. PER LINEAL FOOT	=	1.18 X T X W



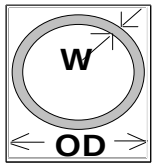
HEXAGON **D = SIZE IN INCHES**

STEEL	LBS. PER LINEAL FOOT	=	2.9473 X D X D
	LBS. PER LINEAL INCH	=	.2456 X D X D
ALUMINUM	LBS. PER LINEAL FOOT	=	1.02 X D X D



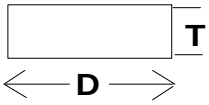
OCTAGONS **D = SIZE IN INCHES**

STEEL	LBS. PER LINEAL FOOT	=	2.8193 X D X D
	LBS. PER LINEAL INCH	=	.23494 X D X D
ALUMINUM	LBS. PER LINEAL FOOT	=	.9740 X D X D



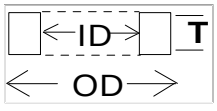
TUBING **OD = INCHES W = INCHES**

STEEL	LBS. PER LINEAL FOOT	=	10.68 X (OD-W) X W
	LBS. PER LINEAL INCH	=	.890 X (OD-W) X W
ALUMINUM	LBS. PER LINEAL FOOT	=	3.70 X (OD-W) X W



CIRCLE **D = INCHES T = INCHES**

STEEL .222274 X T X D X D
ALUMINUM .077 X T X D X D



RINGS **OD = INCHES ID = INCHES T = INCHES**

STEEL .222274 X T X (OD X OD - ID X ID)
ALUMINUM .0770 X T X (OD X OD - ID X ID)

WEIGHT CONVERSION FACTORS

TO OBTAIN WEIGHT OF	DENSITY LBS. PER CUBIC INCH	MULTIPLY STEEL WEIGHT BY
ALUMINUM		
1100	0.098	0.346
2011	0.102	0.360
2014	0.101	0.357
2017	0.101	0.357
2024	0.101	0.357
3003	0.099	0.350
5005	0.098	0.346
5052	0.097	0.343
5056	0.095	0.336
5083	0.096	0.339
5086	0.096	0.339
6061	0.098	0.346
6063	0.097	0.343
7075	0.101	0.357
7178	0.102	0.360
STAINLESS		
300 SERIES	0.286	1.010
400 SERIES	0.283	1.000
NICKEL		
200	0.321	1.132
201	0.321	1.132
400	0.319	1.125
600	0.304	1.072
625	0.305	1.075
718	0.297	1.047
X750	0.298	1.051
800	0.287	1.012
800H	0.287	1.012
825	0.294	1.037
904L	0.291	1.026
MAGNESIUM	0.065	0.229
BERYLLIUM	0.067	0.236
TITANIUM	0.163	0.575
ZIRCONIUM	0.230	0.812
CAST IRON	0.258	0.911
ZINC	0.258	0.911
BRASS	0.307	1.084
COLOMBIUM	0.310	1.095
COPPER	0.324	1.144
MOLYBDENUM	0.369	1.303
SILVER	0.379	1.339
LEAD	0.410	1.448
TANTALUM	0.600	2.120
TUNGSTEN	0.697	2.462
GOLD	0.698	2.446

THEORETICAL WEIGHTS-ROUNDS

INCH SIZE	WEIGHT IN POUNDS PER FOOT	PER INCH	INCH SIZE	WEIGHT IN POUNDS PER FOOT	PER INCH
			3	24.060	2.0050
1/16	0.010	0.0009	1/16	25.069	2.0891
1/8	0.042	0.0035	1/8	26.103	2.1752
3/16	0.094	0.0078	3/16	27.157	2.2631
1/4	0.167	0.0139	1/4	28.233	2.3527
5/16	0.261	0.0218	5/16	29.329	2.4441
3/8	0.376	0.0313	3/8	30.446	2.5372
7/16	0.512	0.0426	7/16	31.584	2.6320
1/2	0.668	0.0557	1/2	32.743	2.7286
9/16	0.846	0.0705	9/16	33.923	2.8269
5/8	1.044	0.0870	5/8	35.124	2.9270
11/16	1.263	0.1053	11/16	36.345	3.0288
3/4	1.504	0.1253	3/4	37.588	3.1323
13/16	1.765	0.1470	13/16	38.851	3.2376
7/8	2.046	0.1705	7/8	40.135	3.3446
15/16	2.349	0.1958	15/16	41.440	3.4534
1	2.673	0.2228	**4**	42.770	3.5642
1/16	3.017	0.2515	1/16	44.113	3.6761
1/8	3.383	0.2819	1/8	45.481	3.7901
3/16	3.769	0.3141	3/16	46.870	3.9058
1/4	4.176	0.3480	1/4	48.279	4.0233
5/16	4.604	0.3837	5/16	49.710	4.1425
3/8	5.053	0.4211	3/8	51.161	4.2634
7/16	5.523	0.4603	7/16	52.633	4.3861
1/2	6.014	0.5012	1/2	54.126	4.5105
9/16	6.526	0.5438	9/16	55.640	4.6367
5/8	7.058	0.5882	5/8	57.175	4.7646
11/16	7.612	0.6343	11/16	58.731	4.8942
3/4	8.186	0.6821	3/4	60.307	5.0256
13/16	8.781	0.7317	13/16	61.905	5.1587
7/8	9.397	0.7831	7/8	63.523	5.2936
15/16	10.034	0.8362	15/16	65.162	5.4302
2	10.690	0.8908	**5**	66.820	5.5683
1/16	11.370	0.9475	1/16	68.504	5.7086
1/8	12.070	1.0058	1/8	70.205	5.8504
3/16	12.790	1.0659	3/16	71.928	5.9940
1/4	13.532	1.1276	1/4	73.672	6.1393
5/16	14.294	1.1911	5/16	75.436	6.2864
3/8	15.077	1.2564	3/8	77.222	6.4351
7/16	15.881	1.3234	7/16	79.028	6.5857
1/2	16.706	1.3921	1/2	80.855	6.7379
9/16	17.551	1.4626	9/16	82.703	6.8919
5/8	18.418	1.5348	5/8	84.572	7.0477
11/16	19.305	1.6088	11/16	86.462	7.2052
3/4	20.214	1.6845	3/4	88.373	7.3644
13/16	21.143	1.7619	13/16	90.304	7.5254
7/8	22.093	1.8411	7/8	92.257	7.6881
15/16	23.064	1.9220	15/16	94.230	7.8525

THEORETICAL WEIGHTS-ROUNDS

INCH SIZE	WEIGHT IN POUNDS PER FOOT	PER INCH	INCH SIZE	WEIGHT IN POUNDS PER FOOT	PER INCH
6	96.220	8.0183	**9**	216.500	18.0417
1/16	98.240	8.1866	1/16	219.522	18.2935
1/8	100.276	8.3563	1/8	222.561	18.5467
3/16	102.332	8.5277	3/16	225.620	18.8017
1/4	104.410	8.7008	1/4	228.700	19.0583
5/16	106.509	8.8757	5/16	231.801	19.3167
3/8	108.628	9.0524	3/8	234.923	19.5769
7/16	110.769	9.2307	7/16	238.066	19.8388
1/2	112.930	9.4108	1/2	241.229	20.1024
9/16	115.112	9.5927	9/16	244.414	20.3678
5/8	117.315	9.7763	5/8	247.619	20.6349
11/16	119.539	9.9616	11/16	250.845	20.9038
3/4	121.784	10.1487	3/4	254.093	21.1744
13/16	124.050	10.3375	13/16	257.361	21.4467
7/8	126.336	10.5280	7/8	260.650	21.7208
15/16	128.644	10.7203	15/16	263.959	21.9966
7	131.000	10.9167	**10**	267.300	22.2750
1/16	133.321	11.1101	1/16	270.642	22.5535
1/8	135.691	11.3076	1/8	274.014	22.8345
3/16	138.082	11.5069	3/16	277.407	23.1173
1/4	140.494	11.7079	1/4	280.822	23.4018
5/16	142.927	11.9106	5/16	284.257	23.6881
3/8	145.381	12.1151	3/8	287.713	23.9761
7/16	147.855	12.3213	7/16	291.189	24.2658
1/2	150.351	12.5292	1/2	294.687	24.5573
9/16	152.867	12.7389	9/16	298.206	24.8505
5/8	155.404	12.9503	5/8	301.745	25.1454
11/16	157.962	13.1635	11/16	305.306	25.4421
3/4	160.541	13.3784	3/4	308.887	25.7406
13/16	163.141	13.5951	13/16	312.489	26.0408
7/8	165.762	13.8135	7/8	316.112	26.3427
15/16	168.403	14.0336	15/16	319.756	26.6463
8	171.100	14.2583	**11**	323.400	26.9500
1/16	173.749	14.4791	1/16	327.107	27.2589
1/8	176.453	14.7044	1/8	330.813	27.5678
3/16	179.178	14.9315	3/16	334.541	27.8784
1/4	181.924	15.1604	1/4	338.289	28.1907
5/16	184.691	15.3909	5/16	342.058	28.5048
3/8	187.479	15.6232	3/8	345.848	28.8207
7/16	190.288	15.8573	7/16	349.659	29.1383
1/2	193.117	16.0931	1/2	353.491	29.4576
9/16	195.967	16.3306	9/16	357.344	29.7786
5/8	198.839	16.5699	5/8	361.217	30.1014
11/16	201.731	16.8109	11/16	365.112	30.4260
3/4	204.644	17.0537	3/4	369.027	30.7523
13/16	207.578	17.2982	13/16	372.964	31.0803
7/8	210.533	17.5444	7/8	376.921	31.4101
15/16	213.508	17.7924	15/16	380.899	31.7416

THEORETICAL WEIGHTS-ROUNDS

INCH SIZE	WEIGHT IN POUNDS PER FOOT	PER INCH	INCH SIZE	WEIGHT IN POUNDS PER FOOT	PER INCH
12	384.900	32.0750	**21**	1179.000	98.2500
1/4	401.102	33.4252	1/4	1206.981	100.5818
1/2	417.641	34.8034	1/2	1235.548	102.9623
3/4	434.513	36.2094	3/4	1264.449	105.3707
13	451.700	37.6417	**22**	1294.000	107.8333
1/4	469.261	39.1051	1/4	1323.253	110.2710
1/2	487.136	40.5947	1/2	1353.156	112.7630
3/4	505.345	42.1121	3/4	1383.393	115.2827
14	523.888	43.6573	**23**	1413.964	117.8303
1/4	542.765	45.2304	1/4	1444.870	120.4058
1/2	561.977	46.8314	1/2	1476.109	123.0091
3/4	581.523	48.4603	3/4	1507.683	125.6402
15	601.400	50.1167	**24**	1539.590	128.2992
1/4	621.616	51.8014	1/4	1571.832	130.9860
1/2	642.164	53.5137	1/2	1604.408	133.7007
3/4	663.046	55.2539	3/4	1637.318	136.4432
16	684.260	57.0217	**25**	1670.563	139.2135
1/4	705.813	58.8177	1/4	1704.141	142.0117
1/2	727.697	60.6414	1/2	1738.053	144.8378
3/4	749.916	62.4930	3/4	1772.300	147.6916
17	772.500	64.3750	**26**	1806.880	150.5734
1/4	795.355	66.2796	1/4	1841.795	153.4829
1/2	818.576	68.2146	1/2	1877.044	156.4203
3/4	842.131	70.1775	3/4	1912.627	159.3856
18	866.000	72.1667	**27**	1948.544	162.3787
1/4	890.243	74.1869	1/4	1984.795	165.3996
1/2	914.800	76.2333	1/2	2021.381	168.4484
3/4	939.691	78.3076	3/4	2058.300	171.5250
19	964.900	80.4083	**28**	2095.554	174.6295
1/4	990.477	82.5397	1/4	2133.141	177.7618
1/2	1016.370	84.6975	1/2	2171.063	180.9219
3/4	1042.598	86.8832	3/4	2209.319	184.1099
20	1069.000	89.0833	**29**	2247.909	187.3257
1/4	1096.056	91.3380	1/4	2286.833	190.5694
1/2	1123.286	93.6072	1/2	2326.091	193.8409
3/4	1150.851	95.9042	3/4	2365.684	197.1403

THEORETICAL WEIGHTS-SQUARES

INCH SIZE	WEIGHT IN POUNDS PER FOOT	PER INCH
1/8	0.053	0.0044
3/16	0.120	0.0100
1/4	0.213	0.0177
5/16	0.332	0.0277
3/8	0.479	0.0399
7/16	0.651	0.0543
1/2	0.851	0.0709
9/16	1.077	0.0897
5/8	1.329	0.1108
11/16	1.609	0.1340
3/4	1.914	0.1595
13/16	2.247	0.1872
7/8	2.606	0.2171
15/16	2.991	0.2493
1	3.403	0.2836
1/8	4.307	0.3589
3/16	4.799	0.3999
1/4	5.318	0.4431
5/16	5.863	0.4885
3/8	6.434	0.5362
7/16	7.032	0.5860
1/2	7.657	0.6381
9/16	8.309	0.6924
5/8	8.987	0.7489
11/16	9.691	0.8076
3/4	10.422	0.8685
13/16	11.180	0.9317
7/8	11.964	0.9970
15/16	12.775	1.0646
2	13.613	1.1344
1/8	15.368	1.2806
3/16	16.285	1.3571
1/4	17.229	1.4357
5/16	18.199	1.5166
3/8	19.196	1.5997
7/16	20.220	1.6850
1/2	21.270	1.7725
9/16	22.347	1.8622
5/8	23.450	1.9542
11/16	24.580	2.0483
3/4	25.737	2.1447
13/16	26.920	2.2433
7/8	28.130	2.3441
15/16	29.366	2.4472

INCH SIZE	WEIGHT IN POUNDS PER FOOT	PER INCH
3	30.629	2.552
1/4	35.946	2.996
1/2	41.689	3.474
3/4	47.858	3.988
4	54.451	4.538
1/4	61.470	5.123
1/2	68.915	5.743
3/4	76.785	6.399
5	85.080	7.090
1/2	102.947	8.579
6	122.515	10.210
7	166.757	13.896
8	217.805	18.150
9	275.659	22.972
10	340.320	28.360
11	411.787	34.316
12	490.061	40.838
13	575.141	47.928
14	667.027	55.586
15	765.720	63.810
16	871.219	72.602
17	983.525	81.960
18	1102.637	91.886

THEORETICAL WEIGHTS-HEXAGONS

INCH SIZE	WEIGHT IN POUNDS PER FOOT	PER INCH
3/16	0.104	0.0086
1/4	0.184	0.0154
5/16	0.288	0.0240
3/8	0.414	0.0345
7/16	0.564	0.0470
1/2	0.737	0.0614
9/16	0.933	0.0777
5/8	1.151	0.0959
11/16	1.393	0.1161
3/4	1.658	0.1382
13/16	1.946	0.1621
7/8	2.257	0.1880
15/16	2.590	0.2159
1	2.947	0.2456
3/16	4.156	0.3463
1/4	4.605	0.3838
5/16	5.077	0.4231
3/8	5.572	0.4644
7/16	6.090	0.5075
1/2	6.631	0.5526
9/16	7.196	0.5996
5/8	7.783	0.6486
11/16	8.393	0.6994
3/4	9.026	0.7522
13/16	9.682	0.8069
7/8	10.362	0.8635
15/16	11.064	0.9220
2	11.789	0.9824
3/16	14.103	1.1753
1/4	14.921	1.2434
5/16	15.761	1.3134
3/8	16.625	1.3854
7/16	17.511	1.4593
1/2	18.421	1.5351
9/16	19.353	1.6128
5/8	20.309	1.6924
11/16	21.287	1.7739
3/4	22.289	1.8574
13/16	23.314	1.9428
7/8	24.361	2.0301
15/16	25.432	2.1193
3	26.526	2.2105
1/4	31.131	2.5942
1/2	36.104	3.0087
3/4	41.446	3.4539
4	47.157	3.9297

THEORETICAL WEIGHTS-OCTAGONS

INCH SIZE	WEIGHT IN POUNDS PER FOOT	PER INCH
3/16	0.099	0.0083
1/4	0.176	0.0147
5/16	0.275	0.0229
3/8	0.396	0.0330
7/16	0.540	0.0450
1/2	0.705	0.0587
9/16	0.892	0.0743
5/8	1.101	0.0918
11/16	1.333	0.1110
3/4	1.586	0.1322
13/16	1.861	0.1551
7/8	2.159	0.1799
15/16	2.478	0.2065
1	2.819	0.2349
3/16	3.976	0.3313
1/4	4.405	0.3671
5/16	4.857	0.4047
3/8	5.330	0.4442
7/16	5.826	0.4855
1/2	6.343	0.5286
9/16	6.883	0.5736
5/8	7.445	0.6204
11/16	8.028	0.6690
3/4	8.634	0.7195
13/16	9.262	0.7718
7/8	9.912	0.8260
15/16	10.583	0.8819
2	11.277	0.9398
3/16	13.491	1.1242
1/4	14.273	1.1894
5/16	15.077	1.2564
3/8	15.903	1.3252
7/16	16.751	1.3959
1/2	17.621	1.4684
9/16	18.513	1.5427
5/8	19.427	1.6189
11/16	20.363	1.6969
3/4	21.321	1.7767
13/16	22.301	1.8584
7/8	23.303	1.9419
15/16	24.327	2.0273
3	25.374	2.1145
1/4	29.779	2.4816
1/2	34.536	2.8780
3/4	39.646	3.3039
4	45.109	3.7591

THEORETICAL WEIGHTS-FLATS

INCH SIZE		WEIGHT IN POUNDS PER FOOT	PER INCH
1/16			
X	1/4	0.053	0.0044
	3/8	0.080	0.0066
	1/2	0.106	0.0089
	5/8	0.133	0.0111
	3/4	0.160	0.0133
	7/8	0.186	0.0155
	1	0.213	0.0177
	1-1/8	0.239	0.0199
	1-1/4	0.266	0.0222
	1-1/2	0.319	0.0266
	1-3/4	0.372	0.0310
	2	0.425	0.0355
	2-1/2	0.532	0.0443
	3	0.638	0.0532
3/32			
X	3/8	0.120	0.0100
	1/2	0.159	0.0133
	5/8	0.199	0.0166
	3/4	0.239	0.0199
	7/8	0.279	0.0233
	1	0.319	0.0266
	1-1/8	0.359	0.0299
	1-1/4	0.399	0.0332
	1-1/2	0.478	0.0399
	1-3/4	0.558	0.0465
	2	0.638	0.0531
	2-1/2	0.797	0.0664
	3	0.957	0.0797
1/8			
X	3/16	0.080	0.0066
	1/4	0.106	0.0089
	5/16	0.133	0.0111
	3/8	0.160	0.0133
	1/2	0.213	0.0177
	5/8	0.266	0.0222
	3/4	0.319	0.0266
	7/8	0.372	0.0310
	1	0.425	0.0355
	1-1/8	0.479	0.0399
	1-1/4	0.532	0.0443
	1-1/2	0.638	0.0532
	1-3/4	0.744	0.0620
	2	0.851	0.0709
	2-1/4	0.957	0.0798

INCH SIZE		WEIGHT IN POUNDS PER FOOT	PER INCH
1/8			
X	2-1/2	1.064	0.0886
	3	1.276	0.1064
	3-1/2	1.489	0.1241
	4	1.702	0.1418
	4-1/2	1.914	0.1595
	5	2.127	0.1773
	6	2.552	0.2127
	12	5.105	0.4254
1/4			
X	5/16	0.266	0.0222
	3/8	0.319	0.0266
	1/2	0.425	0.0355
	9/16	0.479	0.0399
	5/8	0.532	0.0443
	3/4	0.638	0.0532
	7/8	0.744	0.0620
	1	0.851	0.0709
	1-1/8	0.957	0.0798
	1-1/4	1.064	0.0886
	1-3/8	1.127	0.0939
	1-1/2	1.276	0.1064
	1-5/8	1.383	0.1152
	1-3/4	1.489	0.1241
	2	1.702	0.1418
	2-1/4	1.914	0.1595
	2-1/2	2.127	0.1773
	2-3/4	2.340	0.1950
	3	2.552	0.2127
	3-1/4	2.765	0.2304
	3-1/2	2.978	0.2482
	3-3/4	3.191	0.2659
	4	3.403	0.2836
	4-1/2	3.829	0.3191
	5	4.254	0.3545
	5-1/2	4.679	0.3900
	6	5.105	0.4254
	7	5.956	0.4963
	8	6.806	0.5672
	10	8.508	0.7090
	12	10.210	0.8508

THEORETICAL WEIGHTS-FLATS

INCH SIZE		WEIGHT IN POUNDS PER FOOT	PER INCH
5/16			
X	3/8	0.399	0.0332
	1/2	0.532	0.0443
	5/8	0.665	0.0554
	3/4	0.798	0.0665
	7/8	0.931	0.0775
	1	1.064	0.0886
	1-1/8	1.196	0.0997
	1-1/4	1.329	0.1108
	1-3/8	1.462	0.1219
	1-5/8	1.728	0.1440
	1-3/4	1.861	0.1551
	2	2.127	0.1773
	2-1/4	2.393	0.1994
	2-1/2	2.659	0.2216
	3	3.191	0.2659
	3-1/2	3.722	0.3102
	4	4.254	0.3545
	4-1/2	4.786	0.3988
	5	5.318	0.4431
	5-1/2	5.849	0.4874
	6	6.381	0.5318
	7	7.445	0.6204
	8	8.508	0.7090
	10	10.635	0.8863
	12	12.762	1.0635
3/8			
X	7/16	0.558	0.0465
	1/2	0.638	0.0532
	5/8	0.798	0.0665
	3/4	0.957	0.0798
	7/8	1.117	0.0931
	1	1.276	0.1064
	1-1/8	1.436	0.1196
	1-1/4	1.595	0.1329
	1-3/8	1.755	0.1462
	1-1/2	1.914	0.1595
	1-5/8	2.074	0.1728
	1-3/4	2.233	0.1861
	2	2.552	0.2127
	2-1/4	2.871	0.2393
	2-1/2	3.191	0.2659
	2-3/4	3.510	0.2925
	3	3.829	0.3191
	3-1/4	4.148	0.3456
	3-3/8	4.307	0.3589
3/8			
X	3-1/2	4.467	0.3722
	4	5.105	0.4254
	4-1/4	5.424	0.4520
	4-1/2	5.743	0.4786
	5	6.381	0.5318
	5-1/2	7.019	0.5849
	6	7.657	0.6381
	8	10.210	0.8508
	10	12.762	1.0635
	12	15.314	1.2762
7/16			
X	1/2	0.744	0.0620
	5/8	0.931	0.0775
	3/4	1.117	0.0931
	7/8	1.303	0.1086
	1	1.489	0.1241
	1-1/4	1.861	0.1551
	1-1/2	2.233	0.1861
	1-3/4	2.606	0.2171
	2	2.978	0.2482
	2-1/4	3.350	0.2792
	2-1/2	3.722	0.3102
	3	4.467	0.3722
	3-1/2	5.211	0.4343
	4	5.956	0.4963
	5	7.445	0.6204
1/2			
X	5/8	1.064	0.0886
	3/4	1.276	0.1064
	7/8	1.489	0.1241
	1	1.702	0.1418
	1-1/8	1.914	0.1595
	1-1/4	2.127	0.1773
	1-3/8	2.340	0.1950
	1-1/2	2.552	0.2127
	1-5/8	2.765	0.2304
	1-3/4	2.978	0.2482
	2	3.403	0.2836
	2-1/4	3.829	0.3191
	2-1/2	4.254	0.3545
	2-3/4	4.679	0.3900
	3	5.105	0.4254
	3-1/4	5.530	0.4609
	3-1/2	5.956	0.4963

THEORETICAL WEIGHTS-FLATS

INCH SIZE		WEIGHT IN POUNDS PER FOOT	PER INCH
1/2			
X	4	6.806	0.5672
	4-1/4	7.232	0.6027
	4-1/2	7.657	0.6381
	5	8.508	0.7090
	5-1/2	9.359	0.7799
	6	10.210	0.8508
	7	11.911	0.9926
	8	13.613	1.1344
	9	15.314	1.2762
	10	17.016	1.4180
	12	20.419	1.7016
5/8			
X	3/4	1.595	0.1329
	7/8	1.861	0.1551
	1	2.127	0.1773
	1-1/8	2.393	0.1994
	1-1/4	2.659	0.2216
	1-3/8	1.375	0.1146
	1-1/2	3.191	0.2659
	1-3/4	3.722	0.3102
	2	4.254	0.3545
	2-1/4	4.786	0.3988
	2-1/2	5.318	0.4431
	2-3/4	5.849	0.4874
	3	6.381	0.5318
	3-1/4	6.913	0.5761
	3-1/2	7.445	0.6204
	4	8.508	0.7090
	4-1/4	9.040	0.7533
	4-1/2	9.572	0.7976
	5	10.635	0.8863
	6	12.762	1.0635
	7	14.889	1.2408
	8	17.016	1.4180
	12	25.524	2.1270
3/4			
X	7/8	2.233	0.1861
	1	2.552	0.2127
	1-1/8	2.871	0.2393
	1-1/4	3.191	0.2659
	1-3/8	3.510	0.2925
	1-1/2	3.829	0.3191
	1-5/8	4.148	0.3456
	1-3/4	4.467	0.3722

INCH SIZE		WEIGHT IN POUNDS PER FOOT	PER INCH
3/4			
X	2	5.105	0.4254
	2-1/4	5.743	0.4786
	2-1/2	6.381	0.5318
	2-3/4	7.019	0.5849
	3	7.657	0.6381
	3-1/4	8.295	0.6913
	3-1/2	8.933	0.7445
	4-1/2	11.486	0.9572
	5	12.762	1.0635
	5-1/2	14.038	1.1699
	6	15.314	1.2762
	7	17.867	1.4889
	8	20.419	1.7016
	9	22.972	1.9143
	10	25.524	2.1270
	12	30.629	2.5524
7/8			
X	1	2.978	0.2482
	1-1/8	3.350	0.2792
	1-1/4	3.722	0.3102
	1-3/8	4.094	0.3412
	1-1/2	4.467	0.3722
	1-3/4	5.211	0.4343
	2	5.956	0.4963
	2-1/4	6.700	0.5583
	2-1/2	7.445	0.6204
	2-5/8	7.817	0.6514
	2-3/4	8.189	0.6824
	3	8.933	0.7445
	3-1/2	10.422	0.8685
	4	11.911	0.9926
	4-3/4	14.145	1.1787
	5	14.889	1.2408
	6	17.867	1.4889
	7	20.845	1.7371
	8	23.822	1.9852
	12	35.734	2.9778
1			
X	1-1/8	3.829	0.3191
	1-1/4	4.254	0.3545
	1-3/8	4.679	0.3900
	1-1/2	5.105	0.4254
	1-3/4	5.956	0.4963
	2	6.806	0.5672

THEORETICAL WEIGHTS-FLATS

INCH SIZE		WEIGHT IN POUNDS PER FOOT	PER INCH
1			
X	2-1/4	7.657	0.6381
	2-1/2	8.508	0.7090
	2-3/4	9.359	0.7799
	3	10.210	0.8508
	3-1/4	11.060	0.9217
	3-1/2	11.911	0.9926
	4	13.613	1.1344
	4-1/2	15.314	1.2762
	5	17.016	1.4180
	5-1/2	18.718	1.5598
	6	20.419	1.7016
	7	23.822	1.9852
	8	27.226	2.2688
	9	30.629	2.5524
	10	34.032	2.8360
	12	40.838	3.4032
1-1/8			
X	2	7.657	0.6381
	3	11.486	0.9572
	4	15.314	1.2762
	4-1/2	17.229	1.4357
	5	19.143	1.5953
	6	22.972	1.9143
	8	30.629	2.5524
1-1/4			
X	1-1/2	6.381	0.5318
	1-3/4	7.445	0.6204
	2	8.508	0.7090
	2-1/4	9.572	0.7976
	2-1/2	10.635	0.8863
	2-3/4	11.699	0.9749
	3	12.762	1.0635
	3-1/4	13.826	1.1521
	3-1/2	14.889	1.2408
	4	17.016	1.4180
	4-1/2	19.143	1.5953
	5	21.270	1.7725
	5-1/2	23.397	1.9498
	6	25.524	2.1270
	7	29.778	2.4815
	8	34.032	2.8360
	10	42.540	3.5450
	12	51.048	4.2540
1-1/2			
X	1-3/4	8.933	0.7445
	2	10.210	0.8508
	2-1/4	11.486	0.9572
	2-1/2	12.762	1.0635
	2-3/4	14.038	1.1699
	3	15.314	1.2762
	3-1/2	17.867	1.4889
	4	20.419	1.7016
	4-1/2	22.972	1.9143
	5	25.524	2.1270
	5-1/2	28.076	2.3397
	6	30.629	2.5524
	7	35.734	2.9778
	8	40.838	3.4032
	10	51.048	4.2540
	12	61.258	5.1048
1-3/4			
X	2	11.911	0.9926
	2-1/4	13.400	1.1167
	2-1/2	14.889	1.2408
	2-3/4	16.378	1.3648
	3	17.867	1.4889
	3-1/2	20.845	1.7371
	4	23.822	1.9852
	4-1/2	26.800	2.2334
	5	29.778	2.4815
	6	35.734	2.9778
2			
X	2-1/4	15.314	1.2762
	2-1/2	17.016	1.4180
	2-3/4	18.718	1.5598
	3	20.419	1.7016
	3-1/2	23.822	1.9852
	4	27.226	2.2688
	4-1/2	30.629	2.5524
	5	34.032	2.8360
	6	40.838	3.4032
	7	47.645	3.9704
	8	54.451	4.5376
	10	68.064	5.6720
	12	81.677	6.8064

THEORETICAL WEIGHTS-FLATS

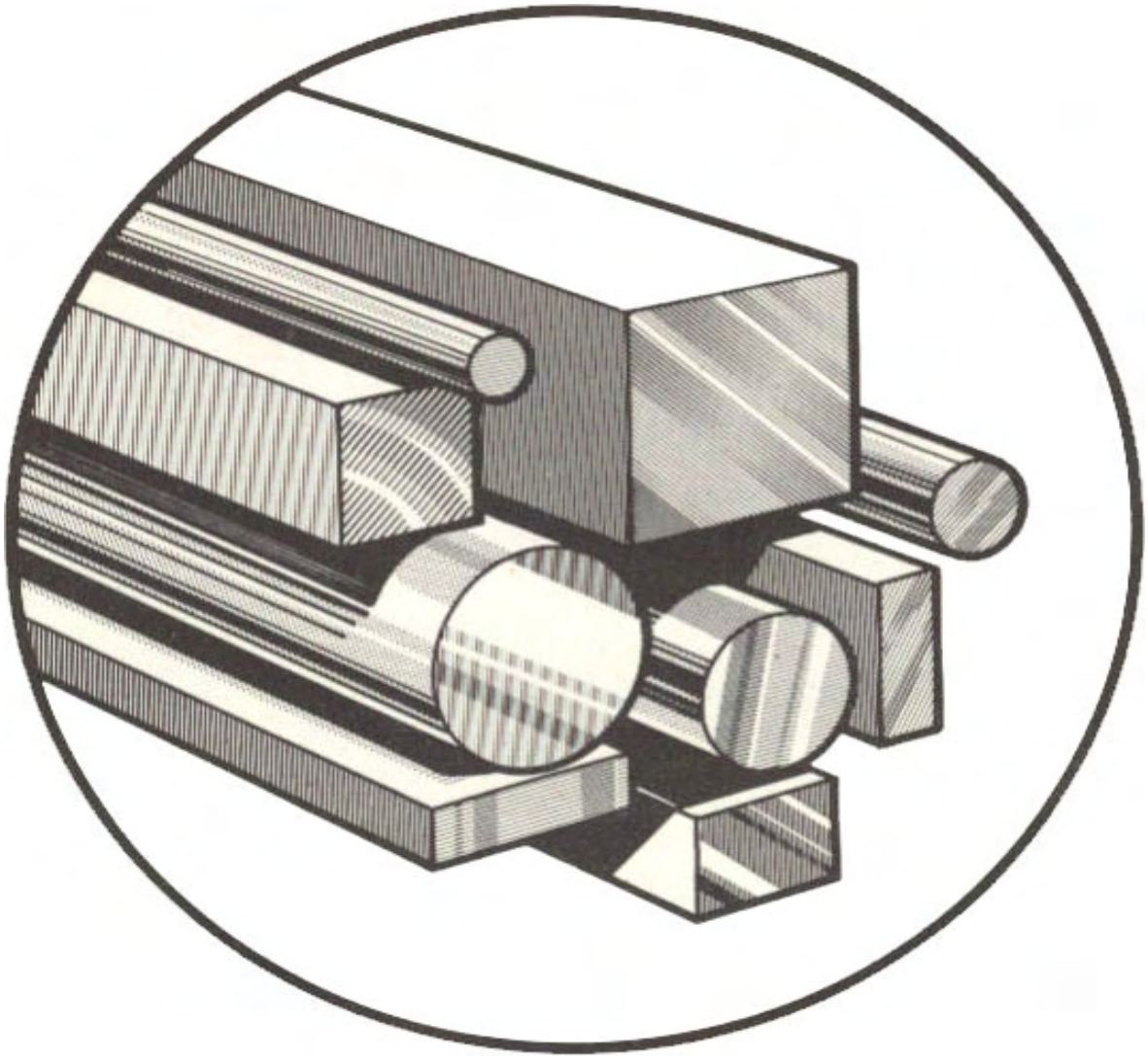
INCH SIZE		WEIGHT IN POUNDS PER FOOT	PER INCH
2-1/2			
X	2-3/4	23.397	1.9498
	3	25.524	2.1270
	3-1/2	29.778	2.4815
	4	34.032	2.8360
	4-1/2	38.286	3.1905
	5	42.540	3.5450
	6	51.048	4.2540
	8	68.064	5.6720
	9	76.572	6.3810
	10	85.080	7.0900
	12	102.096	8.5080

INCH SIZE		WEIGHT IN POUNDS PER FOOT	PER INCH
3			
X	3-1/2	35.734	2.9778
	4	40.838	3.4032
	4-1/2	45.943	3.8286
	5	51.048	4.2540
	6	61.258	5.1048
	7	71.467	5.9556
	8	81.677	6.8064
	10	102.096	8.5080

VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 9.
ALLOYING ELEMENTS IN STEEL



ALLOYING ELEMENTS IN STEEL

ALLOYING ELEMENTS ARE CLASSIFIED ACCORDING TO THEIR FACULTY IN FORMING CARBIDES, AUSTENITE OR FERRITE, AND WITH A VIEW TO THE PURPOSE FOR WHICH THEY ARE ADDED TO ORDINARY STEELS.
ACCORDING TO THE ALLOYING PERCENTAGE, EVERY ELEMENT CAN IMPART UNIQUE AND SPECIFIC CHARACTERISTICS TO THE STEEL. THE COMBINATION OF VARIOUS ELEMENTS, AS UTILIZED IN MODERN METALLURGY, CAN ENHANCE THIS EFFECT. HOWEVER, CERTAIN COMBINATIONS OF ALLOYING ELEMENTS MAY RESULT IN CONSTITUENTS WHICH, FAR FROM PRODUCING A FAVORABLE CUMULATIVE EFFECT WITH REGARD TO A CERTAIN PROPERTY, MAY COUNTERACT EACH OTHER.
THE MERE PRESENCE OF ALLOYING ELEMENTS IN STEEL IS BUT A BASIC CONDITION FOR THE DESIRED CHARACTERISTIC WHICH CAN BE OBTAINED ONLY BY PROPER PROCESSING AND HEAT TREATMENT.
THE PRINCIPAL EFFECT AND INFLUENCES OF ALLOYING AND ACCOMPANYING ELEMENTS ARE OUTLINED BELOW.

CARBON (C .)

CARBON IS PRESENT IN ALL STEEL AND IS THE PRINCIPAL HARDENING ELEMENT, DETERMINING THE LEVEL OF HARDNESS OR STRENGTH ATTAINABLE BY QUENCHING. IT RAISES TENSILE STRENGTH, HARDNESS, RESISTANCE TO WEAR AND ABRASION AS THE CARBON CONTENT OF STEEL IS INCREASED, IT LOWERS DUCTILITY, TOUGHNESS, AND MACHINABILITY. CARBON HAS A MODERATE TENDENCY TO SEGREGATE WITHIN THE INGOT.

ALUMINUM (Al.)

STRONGEST AND MOST FREQUENTLY USED DEOXIDISER AND DEGASIFIER; FAVORS INSENSIBILITY TO AGEING. ADDED IN SMALL AMOUNTS, IT HELPS FINE GRAIN FORMATION. SINCE IT COMBINES WITH NITROGEN TO FORM VERY HARD NITRIDES, IT IS A FAVORABLE ALLOY CONSTITUENT IN NITRIDING STEELS. ALUMINUM-KILLED STEELS EXHIBIT A HIGH ORDER OF FRACTURE TOUGHNESS.

ANTIMONY (Sb.)

HARMFUL TO STEEL, AS IT GENERALLY DIMINISHES TOUGHNESS.

ARSENIC (As.)

INJURIOUS TO STEEL AS IT INCREASES TEMPER BRITTLENESS, DECREASES TOUGHNESS AND IMPAIRS WELDABILITY.

BERYLLIUM (Be.)

USED FOR PRECIPITATION HARDENING WITH SOME SACRIFICE OF TOUGHNESS. VERY SUSCEPTIBLE TO DEOXIDATION. STRONG AFFINITY TO SULFUR, RARELY USED FOR STEEL ALLOYS.

(CONTINUED)

ALLOYING ELEMENTS IN STEEL

BORON (B.)

ADDED IN AMOUNTS OF 0.0005 TO 0.03% IT SIGNIFICANTLY INCREASES THE HARDENABILITY OF STEEL. THIS EFFECT ON HARDENABILITY IS PARTICULARLY EFFECTIVE AT LOWER CARBON LEVELS. UNLIKE MANY OTHER ELEMENTS BORON DOES NOT AFFECT THE FERRITE STRENGTH OF STEEL, IT CAN BE USED TO INCREASE THE HARDENABILITY OF STEEL WITHOUT SACRIFICING DUCTILITY, FORMABILITY OR MACHINABILITY OF STEEL IN THE ANNEALED CONDITION.

CALCIUM (Ca.)

IN THE SILICOCALCIUM COMBINATION, IT IS USED FOR DEOXIDATION. CALCIUM ENHANCES THE NON-SCALING PROPERTIES OF HEAT CONDUCTOR ALLOYS.

CHROMIUM (Cr.)

OF ALL THE COMMON ALLOYING ELEMENTS, CHROMIUM RANKS NEAR THE TOP IN PROMOTING HARDENABILITY. IT MAKES THE STEEL APT FOR OIL OR AIR HARDENING. IT REDUCES THE CRITICAL COOLING RATE REQUIRED FOR MARTENSITE FORMATION, INCREASES HARDENABILITY AND THUS IMPROVES THE APTITUDE FOR HEAT TREATMENT. ON THE OTHER HAND, IMPACT STRENGTH IS WEAKENED.

CHROMIUM FORMS CARBIDES THAT IMPROVE EDGE-HOLDING CAPACITY AND WEAR RESISTANCE. HIGH TEMPERATURE STRENGTH AND RESISTANCE TO HIGH PRESSURE HYDROGENATION ARE ALSO ENHANCED. NON-SCALING PROPERTIES ARE BOOSTED BY INCREASING CHROMIUM CONTENTS.

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.

COBALT (Co.)

DOES NOT CREATE CARBIDES, IT INHIBITS GRAIN GROWTH AT ELEVATED TEMPERATURES AND CONSIDERABLY IMPROVES THE RETENTION OF HARDNESS AND HOT STRENGTH; THEREFORE IT IS A FREQUENT ALLOY CONSTITUENT IN HIGH SPEED STEELS, HOT WORK STEELS AND HIGH-TEMPERATURE STEELS. IT ENCOURAGES THE FORMATION OF GRAPHITE. IT ALSO INTENSIFIES THE INDIVIDUAL EFFECTS OF OTHER MAJOR ELEMENTS IN MORE COMPLEX STEELS.

COPPER (Cu.)

IS ADDED TO STEEL PRIMARILY TO IMPROVE THE STEEL'S RESISTANCE TO ATMOSPHERIC CORROSION. AMOUNTS ADDED TO STEELS FOR THIS PURPOSE TYPICALLY RANGE FROM 0.20 TO 0.50%.

COPPER IS SCARCELY USED FOR STEEL ALLOYS BECAUSE IT CONCENTRATES UNDER THE OXIDE LAYER AND, BY PENETRATING THE GRAIN BOUNDARY, IMPARTS THE STEEL A SURFACE LIABLE TO SUFFER IN HOT WORKING OPERATIONS. IT IS THEREFORE REGARDED AS BEING HARMFUL TO STEEL.

(CONTINUED)

ALLOYING ELEMENTS IN STEEL

HYDROGEN (H.)

HARMFUL TO STEEL, IT CAUSES EMBRITTLEMENT BY DECREASING OF ELONGATION AND REDUCTION OF AREA WITHOUT ANY INCREASE OF YIELD POINT AND TENSILE STRENGTH. IT IS THE SOURCE OF THE REDOUBTABLE SNOW-FLAKE FORMATION AND FAVORS THE FORMATION OF GHOST LINES. ATOMIC HYDROGEN ENGENDERED BY PICKLING PENETRATES INTO THE STEEL AND FORMS BLOWHOLES. AT ELEVATED TEMPERATURES MOIST HYDROGEN ACTS AS A DECARBURIZING AGENT.

LEAD (Pb.)

USED IN QUANTITIES OF .15 TO .35% FOR FREE-MACHINING STEEL AS ITS VERY FINE, SUSPENSION-LIKE DISTRIBUTION (LEAD IS INSOLUBLE IN STEEL) PERMITS TO OBTAIN SHORT CHIPS AND CLEAN SURFACES, HENCE AN IMPROVED MACHINABILITY. LEAD AMOUNTS AS MENTIONED ABOVE WILL IN NO WAY AFFECT THE MECHANICAL PROPERTIES OF STEEL.

MANGANESE (Mn.)

MANGANESE CONTRIBUTES TO STRENGTH AND HARDNESS, BUT TO A LESSER DEGREE THAN CARBON. THE AMOUNT OF INCREASE IN THESE PROPERTIES IS DEPENDENT UPON THE CARBON CONTENT. MANGANESE IS A DEOXIDIZER AND DEGASIFIER REACTING FAVORABLY WITH SULFUR TO IMPROVE FORGEABILITY AND SURFACE QUALITY AS IT CONVERTS SULFUR TO MANGANESE SULFIDES, THEREBY, REDUCING THE RISK OF HOT SHORTNESS, OR SUSCEPTIBILITY TO CRACKING AND TEARING, AT ROLLING TEMPERATURES.

MANGANESE INCREASES TENSILE STRENGTH, HARDNESS, HARDENABILITY, RESISTANCE TO WEAR, AND INCREASES THE RATE OF CARBON PENETRATION IN CARBURIZING.

IT HAS A MODERATE TENDENCY TO SEGREGATE. THE PRESENCE OF MANGANESE INCREASES THE COEFFICIENCY OF THERMAL EXPANSION BUT REDUCES BOTH THERMAL AND ELECTRICAL CONDUCTIVITY.

MOLYBDENUM (Mo.)

IS CHIEFLY USED IN CONJUNCTION WITH OTHER ALLOYING ELEMENTS. ITS PRESENCE REDUCES THE CRITICAL COOLING RATE AND IMPROVES HARDENABILITY, HARDNESS AND TOUGHNESS, AS WELL AS CREEP RESISTANCE AND STRENGTH AT ELEVATED TEMPERATURES. IT HELPS TO PREVENT TEMPER BRITTLENESS AND PROMOTES FINE-GRAINED STRUCTURE. IT INCREASES BOTH YIELD POINT AND TENSILE STRENGTH. IT FORMS CARBIDES READILY AND THUS IMPROVES THE CUTTING PROPERTIES IN HIGH SPEED STEELS. IT IMPROVES MACHINABILITY AND RESISTANCE TO CORROSION AND IT INTENSIFIES THE EFFECTS OF OTHER ALLOYING ELEMENTS.

(CONTINUED)

ALLOYING ELEMENTS IN STEEL

NICKEL (Ni.)

INCREASES CONSIDERABLY THE IMPACT STRENGTH OF ENGINEERING STEELS, EVEN IN LOW TEMPERATURE RANGES, AND IS THEREFORE USED AS AN ALLOYING ELEMENT IN STEELS FOR CASE-HARDENING AND FOR HARDENING AND TEMPERING AS WELL AS IN LOW-TEMPERATURE STEELS. NICKEL LESSENS DISTORTION IN QUENCHING AND BROADENS THE TEMPERATURE RANGE FOR SUCCESSFUL HEAT TREATMENT. IT INCREASES STRENGTH AND HARDNESS WITHOUT SACRIFICING DUCTILITY AND TOUGHNESS. IT ALSO INCREASES RESISTANCE TO CORROSION AND SCALING AT ELEVATED TEMPERATURES WHEN INTRODUCED IN SUITABLE QUANTITIES IN HIGH-CHROMIUM (STAINLESS) STEELS.

NITROGEN (N.)

IS PRESENT IN ALL STEELS, BUT USUALLY IN SMALL AMOUNTS; IT WILL COMBINE WITH CERTAIN OTHER ELEMENTS TO PRECIPITATE AS A NITRIDE. THIS INCREASES HARDNESS, TENSILE AND YIELD STRENGTH, BUT IT DECREASES TOUGHNESS AND DUCTILITY.

OXYGEN (O)

INJURIOUS TO STEEL; ITS SPECIFIC INFLUENCE DEPENDS ON THE TYPE AND COMPOSITION OF ITS COMPOUNDS IN STEEL AND ON THEIR SHAPE AND DISTRIBUTION. IT WEAKENS MECHANICAL PROPERTIES, IN PARTICULAR IMPACT STRENGTH, ESPECIALLY IN THE TRANSVERSE DIRECTION, WHEREAS THE TENDENCY TO AGEING BRITTLENESS, RED SHORT-NESS, WOODY AND SLANTY FRACTURE IS INCREASED.

PHOSPHORUS (P.)

IN APPRECIABLE AMOUNTS, PHOSPHORUS INCREASES THE STRENGTH AND HARDNESS OF HOT ROLLED STEEL TO ABOUT THE SAME DEGREE AS CARBON, BUT AT THE SACRIFICE OF DUCTILITY AND TOUGHNESS, PARTICULARLY IN THE QUENCHED AND TEMPERED CONDITION. CONSEQUENTLY, FOR MOST APPLICATIONS, PHOSPHORUS IS GENERALLY MAINTAINED BELOW A SPECIFIC MAXIMUM. THIS VARIES WITH THE GRADE AND QUALITY LEVEL. IN CERTAIN LOW CARBON FREE MACHINING STEELS, HIGHER PHOSPHORUS CONTENT IS SPECIFIED FOR ITS BENEFICIAL EFFECT ON MACHINABILITY. PHOSPHORUS HAS A PRONOUNCED TENDENCY TO SEGREGATE.

SILICON (Si.)

ONE OF THE PRINCIPAL DEOXIDIZERS USED IN STEELMAKING AND THEREFORE, THE AMOUNT OF SILICON PRESENT IS RELATED TO THE TYPE OF STEEL. SILICON ENHANCES RESISTANCE TO SCALING AND IS THEREFORE USED AS AN ALLOYING AGENT IN HIGH-TEMPERATURE STEELS. SINCE, HOWEVER, IT IMPAIRS HOT AND COLD WORKABILITY, MACHINABILITY, ITS ALLOYING PERCENTAGES SHOULD BE STRICTLY CONTROLLED. IT HAS ONLY A SLIGHT TENDENCY TO SEGREGATE. IN THE LOWER CARBON STEELS, INCREASED SILICON CONTENT IS DETRIMENTAL TO SURFACE QUALITY. WHERE SILICON KILLED STEEL IS REQUIRED, ADDITIONAL BILLET CONDITIONING IS NECESSARY TO ENSURE A GOOD QUALITY SURFACE, PARTICULARLY WITH RESULFURIZED STEEL.

(CONTINUED)

ALLOYING ELEMENTS IN STEEL

SULFUR (S.)

OF ALL COMPANION ELEMENTS IN STEEL, SULFUR SHOWS THE STRONGEST TENDENCY TO SEGREGATE. IRON SULFIDES PRODUCE RED OR HOT-SHORTNESS BECAUSE THE LOW MELTING EUTECTIC FORMS A NETWORK AROUND THE GRAINS SO THAT THESE HOLD BUT LOOSELY TOGETHER, AND GRAIN BOUNDARIES MAY EASILY BREAK UP DURING HOT FORMING; THESE PHENOMENA ARE EVEN ENHANCED BY OXYGEN. SINCE SULFUR HAS A PARTICULARLY GOOD AFFINITY TO MANGANESE, IT CAN BE FIXED IN THE FORM OF MANGANESE SULFIDES WHICH ARE THE LEAST DANGEROUS OF ALL INCLUSIONS, BEING FINELY DISPERSED IN STEEL AND HAVING A HIGH MELTING POINT. SULFUR IS USED AS AN ALLOYING ADDITION IN FREE-CUTTING STEELS; THE FINELY DISPERSED SULFIDE INCLUSION INTERRUPT THE CONTINUITY OF METAL STRUCTURE, THUS PRODUCING SHORT CHIPS IN MACHINING. SULFUR DECREASES WELDABILITY, IMPACT TOUGHNESS, AND DUCTILITY.

TIN (Sn.)

CAN RENDER STEEL SUSCEPTIBLE TO TEMPER EMBRITTLEMENT AND HOT SHORTNESS.

VANADIUM (V.)

REFINES THE PRIMARY GRAIN; HENCE ALSO THE AS-CAST STRUCTURE. ADDITIONS OF VANADIUM UP TO 0.05% INCREASE THE HARDENABILITY OF MEDIUM-CARBON STEELS ; LARGER ADDITIONS APPEAR TO REDUCE THE HARDENABILITY DUE TO THE FORMATION OF CARBIDES THAT HAVE DIFFICULTY DISSOLVING IN AUSTENITE. IT IS A STRONG CARBIDE FORMER, INCREASES WEAR RESISTANCE, RETENTION OF CUTTING EDGES AND HIGH-TEMPERATURE STRENGTH. THEREFORE, PREFERRED AS AN ADDITIONAL ALLOY MATERIAL IN HIGH-SPEED STEELS, HOT WORK AND HIGH TEMPERATURE STEELS. VANADIUM GREATLY IMPROVES RED HARDNESS AND DIMINISHES OVERHEATING SENSIBILITY.

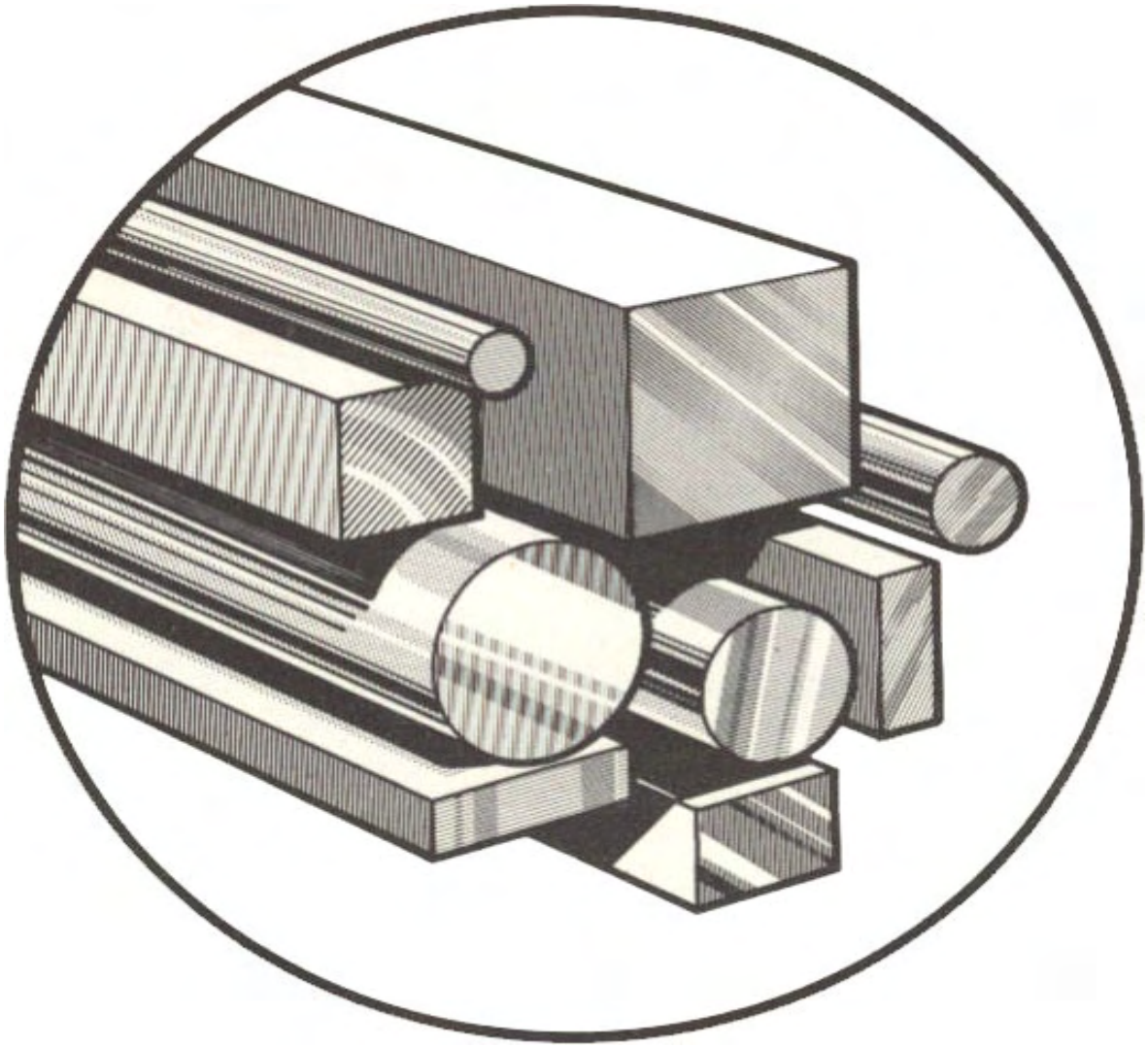
WOLFRAM (W. = TUNGSTEN Tu.)

POWERFUL CARBIDE-FORMER; ITS CARBIDES ARE VERY HARD. IT IMPROVES TOUGHNESS AND INHIBITS GRAIN-GROWTH. IT INCREASES HOT STRENGTH AND HARDNESS RETENTION AS WELL AS WEAR RESISTANCE AT HIGH TEMPERATURES (RED HEAT) AND CUTTING POWER. IT IS A FAVORITE ALLOYING ELEMENT IN HIGH SPEED AND HOT WORK STEELS, HIGH TEMPERATURE STEELS AND SUPERHARD STEELS.

VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 10.
CHEMICAL COMPOSITIONS



VANGUARD STEEL LTD.

PRODUCT MANUAL

CHEMICAL COMPOSITIONS

INDEX SYSTEM FOR VARIOUS AISI AND SAE STEELS

THE AMERICAN STANDARD DESIGNATIONS (AISI, SAE) REVEAL THE BASIC COMPOSITION OF A GIVEN STEEL GRADE. THE FOLLOWING IS A KEY TO THE SYSTEM CLASSIFICATION EMPLOYED BY AISI (AMERICAN IRON AND STEEL INSTITUTE) AND SAE (SOCIETY OF AUTOMOTIVE ENGINEERS).
THE FIRST DIGIT OF THE DESIGNATION INDICATES THE STEEL GROUP. "1" MEANING UNALLOYED STEEL, "2" Ni. STEEL, "3" NiCr. STEEL AND SO ON. THE SECOND DIGIT INDICATES THE APPROXIMATE PERCENTAGE OF THE GOVERNING ALLOYING CONSTITUENTS. THE LAST TWO DIGITS INDICATE THE MEAN CARBON CONTENT MULTIPLIED BY 100.

EXAMPLES: AISI 1055 = UNALLOYED STEEL WITH 0.55% C.
AISI 2345 = NICKEL STEEL WITH APPROX. 3% Ni. AND 0.45% C.
AISI 4042 = MOLYBDENUM STEEL WITH 0.42% C.

FOR HIGHER ALLOYED STEELS (E.G. STAINLESS, HEAT RESISTING AND OTHER AUSTENITIC STEELS), HOWEVER, THIS SYSTEM HAS BEEN ABANDONED.

AISI (SAE)	TYPE OF STEEL
	CARBON STEELS
10XX	UNALLOYED STEEL
11XX	RESULFURIZED FREE MACHINING STEEL
12XX	REPHOSPHORIZED AND RESULFURIZED FREE MACHINING STEEL
	MANGANESE STEELS
13XX	1.75% MANGANESE
	NICKEL STEELS
23XX	3.50% NICKEL
25XX	5.00% NICKEL

(CONTINUED)

CHEMICAL COMPOSITIONS

	NICKEL-CHROMIUM STEELS
31XX	1.25% NICKEL 0.60% CHROMIUM
32XX	1.75% NICKEL 1.00% CHROMIUM
33XX	3.50% NICKEL 1.50% CHROMIUM
34XX	3.00% NICKEL 0.77% CHROMIUM
	MOLYBDENUM STEELS
40XX	0.20 AND 0.25% MOLYBDENUM
44XX	0.40 AND 0.52% MOLYBDENUM
	CHROMIUM-MOLYBDENUM STEELS
41XX	0.50, 0.80 AND 0.95% Cr. 0.12, 0.20, 0.25 AND 0.30% Mo.
	NICKEL-CHROMIUM-MOLYBDENUM STEELS
43XX	1.82% Ni. 0.50 AND 0.80% Cr. 0.25% Mo.
43BVXX	1.82% Ni. 0.50% Cr. 0.12 AND 0.25% Mo. 0.03% MIN. V.
47XX	1.05% Ni. 0.45% Cr. 0.20 AND 0.35% Mo.
81XX	0.30% Ni. 0.40% Cr. 0.12% Mo.
86XX	0.55% Ni. 0.50% Cr. 0.20% Mo.
87XX	0.55% Ni. 0.50% Cr. 0.25% Mo.
88XX	0.55% Ni. 0.50% Cr. 0.35% Mo.
93XX	3.25% Ni. 1.20% Cr. 0.12% Mo.
94XX	0.45% Ni. 0.40% Cr. 0.12% Mo.
97XX	0.55% Ni. 0.20% Cr. 0.20% Mo.
98XX	1.00% Ni. 0.80% Cr. 0.25% Mo.
	NICKEL-MOLYBDENUM STEELS
46XX	0.85 AND 1.82% Ni. 0.20 AND 0.25% Mo.
48XX	3.5% Ni. 0.25% Mo.

(CONTINUED)

CHEMICAL COMPOSITIONS

	CHROMIUM STEELS
50XX	0.27, 0.40, 0.50 AND 0.65% Cr.
51XX	0.80, 0.87, 0.92, 0.95 1.00 AND 1.05% Cr.
501XX	0.50% Cr.
511XX	1.02% Cr.
521XX	1.45% Cr.

	CHROME-VANADIUM STEELS
61XX	0.60, 0.80 AND 0.95% Cr. 0.10 AND 0.15% MIN. V.

	SILICON-MANGANESE STEELS
92XX	1.40 AND 2.00% Si. 0.65. 0.82 AND 0.85% Mn. 0.00 AND 0.65% Cr.

CHEMICAL COMPOSITIONS

NONRESULFURIZED CARBON STEELS -

	CHEMICAL COMPOSITION LIMITS, IN %				
AISI/SAE	C.	Si.	Mn.	P. MAX.	S. MAX.
1005	0.60 MAX.	0.10 MAX.	0.35 MAX.	0.04	0.05
1006	0.08 MAX.	0.10 MAX.	0.25-0.40	0.04	0.05
1008	0.10 MAX.	0.10 MAX.	0.25-0.50	0.04	0.05
1009	0.15 MAX.	0.10 MAX.	0.60 MAX.	0.04	0.05
1010	0.08-0.13	0.10 MAX.	0.30-0.60	0.04	0.05
1011	0.80-0.12	0.10 MAX.	0.60-0.90	0.04	0.05
1012	0.10-0.15	0.10 MAX.	0.30-0.60	0.04	0.05
1013	0.11-0.16	0.10 MAX.	0.50-0.80	0.04	0.05
1015	0.13-0.18	0.10 MAX.	0.30-0.60	0.04	0.05
1016	0.13-0.18	0.10-0.20	0.60-0.90	0.04	0.05
1017	0.15-0.20	0.10-0.20	0.30-0.60	0.04	0.05
1018	0.15-0.20	0.10-0.20	0.60-0.90	0.04	0.05
1019	0.15-0.20	0.10-0.20	0.70-1.00	0.04	0.05
1020	0.18-0.23	0.10-0.20	0.30-0.60	0.04	0.05
1021	0.18-0.23	0.10-0.20	0.60-0.90	0.04	0.05
1022	0.18-0.23	0.10-0.20	0.70-1.00	0.04	0.05
1023	0.20-0.25	0.10-0.20	0.30-0.60	0.04	0.05
1025	0.22-0.28	0.10-0.20	0.30-0.60	0.04	0.05
1026	0.22-0.28	0.10-0.20	0.60-0.90	0.04	0.05
1030	0.28-0.34	0.10-0.20	0.60-0.90	0.04	0.05
1035	0.32-0.38	0.10-0.20	0.60-0.90	0.04	0.05
1037	0.32-0.38	0.10-0.20	0.70-1.00	0.04	0.05
1038	0.35-0.42	0.10-0.20	0.60-0.90	0.04	0.05
1039	0.37-0.44	0.10-0.20	0.70-1.00	0.04	0.05
1040	0.37-0.44	0.10-0.20	0.60-0.90	0.04	0.05
1042	0.40-0.47	0.10-0.20	0.60-0.90	0.04	0.05
1043	0.40-0.70	0.10-0.20	0.70-1.00	0.04	0.05

(CONTINUED)

CHEMICAL COMPOSITIONS

NONRESULFURIZED CARBON STEELS -

	CHEMICAL COMPOSITION LIMITS, IN %				
AISI/SAE	**C.**	**Si.**	**Mn.**	**P. MAX.**	**S. MAX.**
1044	0.43-0.50	0.10-0.20	0.30-0.60	0.04	0.05
1045	0.43-0.50	0.10-0.20	0.60-0.90	0.04	0.05
1046	0.43-0.50	0.10-0.20	0.70-1.00	0.04	0.05
1049	0.46-0.53	0.10-0.20	0.60-0.90	0.04	0.05
1050	0.48-0.55	0.10-0.20	0.60-0.90	0.04	0.05
1053	0.48-0.55	0.10-0.20	0.70-1.00	0.04	0.05
1055	0.50-0.60	0.10-0.20	0.60-0.90	0.04	0.05
1060	0.55-0.65	0.10-0.20	0.60-0.90	0.04	0.05
1064	0.60-0.70	0.10-0.20	0.50-0.80	0.04	0.05
1065	0.60-0.70	0.10-0.20	0.60-0.90	0.04	0.05
1070	0.65-0.75	0.10-0.20	0.60-0.90	0.04	0.05
1074	0.70-0.80	0.10-0.20	0.50-0.80	0.04	0.05
1078	0.72-0.85	0.10-0.20	0.30-0.60	0.04	0.05
1080	0.75-0.88	0.10-0.20	0.60-0.90	0.04	0.05
1084	0.80-0.93	0.10-0.20	0.60-0.90	0.04	0.05
1090	0.85-0.98	0.10-0.20	0.60-0.90	0.04	0.05
1095	0.90-1.03	0.10-0.20	0.30-0.50	0.04	0.05
1513	0.10-0.16	0.10-0.20	1.10-1.40	0.04	0.05
1522	0.18-0.24	0.10-0.20	1.10-1.40	0.04	0.05
1524	0.19-0.25	0.10-0.20	1.35-1.65	0.04	0.05
1526	0.22-0.29	0.10-0.20	1.10-1.40	0.04	0.05
1527	0.22-0.29	0.10-0.20	1.20-1.50	0.04	0.05
1541	0.36-0.44	0.10-0.20	1.35-1.65	0.04	0.05
1548	0.44-0.52	0.10-0.20	1.10-1.40	0.04	0.05
1551	0.45-0.56	0.10-0.20	1.10-1.40	0.04	0.05
1552	0.47-0.55	0.10-0.20	1.20-1.50	0.04	0.05
1561	0.55-0.65	0.10-0.20	0.75-1.05	0.04	0.05
1566	0.60-0.71	0.10-0.20	0.85-1.15	0.04	0.05

(CONTINUED)

CHEMICAL COMPOSITIONS

RESULFURIZED CARBON STEELS -

	CHEMICAL COMPOSITION LIMITS, IN %				
AISI/SAE	C.	Si.	Mn.	P. MAX.	S.
1110	0.08-0.13	0.10 MAX.	0.30-0.60	0.04	0.08-0.13
1117	0.14-0.20	0.20 MAX.	1.00-1.30	0.04	0.08-0.13
1118	0.14-0.20	0.20 MAX.	1.30-1.60	0.04	0.08-0.13
1119	0.14-0.20	0.20 MAX.	1.00-1.30	0.04	0.24-0.33
1139	0.35-0.43	0.20 MAX.	1.35-1.65	0.04	0.12-0.20
1140	0.37-0.44	0.20 MAX.	0.70-1.00	0.04	0.08-0.13
1141	0.37-0.45	0.20 MAX.	1.35-1.65	0.04	0.08-0.13
1144	0.40-0.48	0.20 MAX.	1.36-1.65	0.04	0.24-0.33
1145	0.42-0.49	0.20 MAX.	0.70-1.00	0.04	0.04-0.07
1146	0.42-0.49	0.20 MAX.	0.70-1.00	0.04	0.08-0.13
1151	0.48-0.55	0.20 MAX.	0.70-1.00	0.04	0.08-0.13

RESULFURIZED AND REPHOSPHORIZED CARBON STEELS -

	CHEMICAL COMPOSITION LIMITS, IN %					
AISI/SAE	C.	Si.	Mn.	P.	S.	Pb.
1211	0.13 MAX.		0.60-0.90	0.07-0.12	0.10-0.15	
1211	0.13 MAX.		0.70-1.00	0.07-0.12	0.16-0.23	
1213	0.13 MAX.		0.70-1.00	0.07-0.12	0.24-0.33	
1215	0.09 MAX.		0.75-1.05	0.04-0.09	0.26-0.35	
12L14	0.15 MAX.		0.85-1.15	0.04-0.90	0.26-0.35	0.15-0.35

CHEMICAL COMPOSITIONS

NOTES PERTAINING TO ALLOY STEELS.

MOST GRADES ARE NORMALLY MANUFACTURED BY THE BASIC OPEN HEARTH OR BASIC OXYGEN PROCESS BUT MAY BE MANUFACTURED BY THE BASIC ELECTRIC FURNACE PROCESS WITH ADJUSTMENTS IN PHOSPHOROUS AND SULFUR. IN THE TABLES ON THE FOLLOWING PAGES, SOME GRADES, WITH A PREFIX LETTER E, ARE NORMALLY MADE ONLY BY THE BASIC ELECTRIC FURNACE PROCESS.

THE **PHOSPHORUS AND SULFUR** LIMITATIONS FOR EACH PROCESS ARE AS FOLLOWS:

	MAXIMUM PERCENT	
	P.	**S.**
BASIC ELECTRIC FURNACE	0.025	0.025
BASIC OPEN HEARTH	0.035	0.04
ACID ELECTRIC FURNACE	0.05	0.05
ACID OPEN HEARTH	0.05	0.05

SMALL QUANTITIES OF CERTAIN ELEMENTS ARE PRESENT IN ALLOY STEELS WHICH ARE NOT SPECIFIED OR REQUIRED. THESE ELEMENTS ARE CONSIDERED AS INCIDENTAL AND MAY BE PRESENT TO THE FOLLOWING MAXIMUM AMOUNTS:

COPPER	0.35%
NICKEL	0.25%
CHROMIUM	0.20%
MOLYBDENUM	0.06%

STANDARD ALLOY STEELS CAN BE PRODUCED WITH A LEAD RANGE OF 0.15/0.35 PERCENT. SUCH STEELS ARE IDENTIFIED BY INSERTING THE LETTER "L" BETWEEN THE SECOND AND THIRD NUMERALS OF THE AISI NUMBER, FOR EXAMPLE, 41L40 . A HEAT ANALYSIS FOR LEAD IS NOT DETERMINABLE, SINCE LEAD IS ADDED TO THE LADLE STREAM AS THE STEEL IS BEING POURED.

BORON STEELS CONTAIN .0005/.003 PERCENT BORON.

(CONTINUED)

CHEMICAL COMPOSITIONS

ALLOY STEELS-CHEMICAL COMPOSITION LIMITS, IN %

AISI/SAE	C.	Mn.	P. MAX.	S. MAX.	Si.	Ni.	Cr.	Mo.
1330	0.28-0.33	1.60-1.90	0.035	0.04	0.15-0.35	------	------	------
1335	0.33-0.38	1.60-1.90	0.035	0.04	0.15-0.35	------	------	------
1340	0.38-0.43	1.60-1.90	0.035	0.04	0.15-0.35	------	------	------
1345	0.43-0.48	1.60-1.90	0.035	0.04	0.15-0.35	------	------	------
3312	0.10-0.15	0.45-0.60	0.025	0.025	0.15-0.35	3.25-3.75	1.40-1.75	------
4012	0.09-0.14	0.75-1.00	0.035	0.04	0.15-0.35	------	------	0.15-0.25
4023	0.09-0.25	0.70-0.90	0.035	0.04	0.15-0.35	------	------	0.15-0.25
4024	0.20-0.25	0.70-0.90	0.035	0.035-0.050	0.15-0.35	------	------	0.20-0.30
4027	0.25-0.30	0.70-0.90	0.035	0.04	0.15-0.35	------	------	0.20-0.30
4028	0.25-0.30	0.70-0.90	0.035	0.035-0.050	0.15-0.35	------	------	0.20-0.30
4032	0.30-0.35	0.70-0.90	0.035	0.04	0.15-0.35	------	------	0.20-0.30
4037	0.35-0.40	0.70-0.90	0.035	0.04	0.15-0.35	------	------	0.20-0.30
4042	0.40-0.45	0.70-0.90	0.035	0.04	0.15-0.35	------	------	0.20-0.30
4047	0.45-0.50	0.70-0.90	0.035	0.04	0.15-0.35	------	------	0.20-0.30
4118	0.18-0.23	0.70-0.90	0.035	0.04	0.15-0.35	------	0.40-0.60	0.08-0.15
4130	0.28-0.33	0.40-0.60	0.035	0.04	0.15-0.35	------	0.80-1.10	0.15-0.25
4135	0.33-0.38	0.70-0.90	0.035	0.04	0.15-0.35	------	0.80-1.10	0.15-0.25
4137	0.35-0.40	0.70-0.90	0.035	0.04	0.15-0.35	------	0.80-1.10	0.15-0.25
4140	0.38-0.43	0.75-1.00	0.035	0.04	0.15-0.35	------	0.80-1.10	0.15-0.25
4142	0.40-0.45	0.75-1.00	0.035	0.04	0.15-0.35	------	0.80-1.10	0.15-0.25
4145	0.43-0.48	0.75-1.00	0.035	0.04	0.15-0.35	------	0.80-1.10	0.15-0.25
4147	0.45-0.50	0.75-1.00	0.035	0.04	0.15-0.35	------	0.80-1.10	0.15-0.25
4150	0.48-0.53	0.75-1.00	0.035	0.04	0.15-0.35	------	0.80-1.10	0.15-0.25
4161	0.56-0.64	0.75-1.00	0.035	0.04	0.15-0.35	------	0.70-0.90	0.15-0.25
4320	0.17-0.22	0.45-0.65	0.035	0.04	0.15-0.35	1.65-2.00	0.40-0.60	0.20-0.30
4340	0.38-0.43	0.65-0.80	0.035	0.04	0.15-0.35	1.65-2.00	0.70-0.90	0.20-0.30
E4340	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

(CONTINUED)

CHEMICAL COMPOSITIONS

ALLOY STEELS-CHEMICAL COMPOSITION LIMITS, IN %

AISI/SAE	C.	Mn.	P. MAX.	S. MAX.	Si.	Ni.	Cr.	Mo.
4615	0.13-0.18	0.45-0.65	0.035	0.04	0.15-0.35	1.65-2.00	------	0.20-0.30
4620	0.17-0.22	0.45-0.65	0.035	0.04	0.15-0.35	1.65-2.00	------	0.20-0.30
4621	0.18-0.23	0.70-0.90	0.035	0.04	0.15-0.35		------	
4626	0.24-0.29	0.45-0.65	0.035	0.04	0.15-0.35	0.70-1.00	------	0.15-0.25
4720	0.17-0.22	0.50-0.70	0.035	0.04	0.15-0.35	0.90-1.20	0.35-0.55	0.15-0.25
4815	0.13-0.18	0.40-0.60	0.035	0.04	0.15-0.35	3.25-3.75	------	0.20-0.30
4817	0.15-0.20	0.40-0.60	0.035	0.04	0.15-0.35	3.25-3.75	------	0.20-0.30
4820	0.18-0.23	0.50-0.70	0.035	0.04	0.15-0.35	3.25-3.75	------	0.20-0.30
5015	0.12-0.17	0.30-0.50	0.035	0.04	0.15-0.35	------	0.30-0.50	------
5115	0.13-0.18	0.70-0.90	0.035	0.04	0.15-0.35	------	0.70-0.90	------
5120	0.17-0.22	0.70-0.90	0.035	0.04	0.15-0.35	------	0.70-0.90	------
5130	0.28-0.33	0.70-0.90	0.035	0.04	0.15-0.35	------	0.80-1.10	------
5132	0.30-0.35	0.60-0.80	0.035	0.04	0.15-0.35	------	0.70-1.00	------
5135	0.33-0.38	0.60-0.80	0.035	0.04	0.15-0.35	------	0.80-1.05	------
5140	0.38-0.43	0.70-0.90	0.035	0.04	0.15-0.35	------	0.70-0.90	------
5145	0.43-0.48	0.70-0.90	0.035	0.04	0.15-0.35	------	0.70-0.90	------
5147	0.46-0.51	0.70-0.90	0.035	0.04	0.15-0.35	------	0.85-1.15	------
5150	0.48-0.53	0.70-0.90	0.035	0.04	0.15-0.35	------	0.70-0.90	------
5155	0.51-0.59	0.70-0.90	0.035	0.04	0.15-0.35	------	0.70-0.90	------
5160	0.56-0.61	0.70-0.90	0.035	0.04	0.15-0.35	------	0.70-0.90	------
E50100	0.98-1.10	0.70-0.90	0.035	0.04	0.15-0.35	------	0.40-0.60	------
E51100	0.98-1.10	0.70-0.90	0.035	0.04	0.15-0.35	------	0.90-1.15	------
E52100	0.98-1.10	0.70-0.90	0.035	0.04	0.15-0.35	------	1.30-1.60	------
6118	0.16-0.21	0.50-0.70	0.035	0.04	0.15-0.35	------	0.50-0.70	(0.10-0.15 V)
6150	0.48-0.53	0.70-0.90	0.035	0.04	0.15-0.35	------	0.80-1.10	(0.15 MIN. V)
8115	0.13-0.18	0.70-0.90	0.035	0.04	0.15-0.35	0.20-0.40	0.30-0.50	0.80-0.15

(CONTINUED)

CHEMICAL COMPOSITIONS

ALLOY STEELS-CHEMICAL COMPOSITION LIMITS, IN %

AISI/SAE	C.	Mn.	P. MAX.	S. MAX.	Si.	Ni.	Cr.	Mo.
8615	0.13-0.18	0.70-0.90	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8617	0.15-0.20	0.70-0.90	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8620	0.18-0.23	0.70-0.90	0.035	0.04	0.15-0.35	0.40-0.70	0.34-0.60	0.15-0.25
8622	0.25-0.30	0.70-0.90	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8625	0.28-0.33	0.70-0.90	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8627	0.35-0.40	0.75-1.00	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8640	0.38-0.43	0.75-1.00	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8642	0.40-0.45	0.75-1.00	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8645	0.43-0.48	0.75-1.00	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8650	0.48-0.53	0.75-1.00	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8655	0.51-0.59	0.75-1.00	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8660	0.56-0.64	0.75-1.00	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.15-0.25
8720	0.18-0.23	0.70-0.90	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.20-0.30
8740	0.38-0.43	0.75-1.00	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.20-0.30
8822	0.20-0.25	0.75-1.00	0.035	0.04	0.15-0.35	0.40-0.70	0.40-0.60	0.30-0.40
9254	0.51-0.59	0.60-0.80	0.035	0.04	1.20-1.60	------	0.40-0.60	------
9255	0.51-0.59	0.70-0.95	0.035	0.04	1.80-2.20	------	0.40-0.60	------
9260	0.56-0.64	0.75-1.00	0.035	0.04	1.80-2.20	------	------	------
E9310	0.08-0.13	0.45-0.65	0.025	0.025	0.15-0.30	3.00-3.50	1.00-1.40	0.08-0.15
STANDARD BORON STEEL								
50B44	0.43-0.48	0.75-1.00	0.035	0.04	0.15-0.35	------	0.20-0.60	------
50B46	0.44-0.49	0.75-1.00	0.035	0.04	0.15-0.35	------	0.20-0.35	------
50B50	0.48-0.53	0.75-1.00	0.035	0.04	0.15-0.35	------	0.40-0.60	------
50B60	0.56-0.64	0.75-1.00	0.035	0.04	0.15-0.35	------	0.40-0.60	------
51B60	0.56-0.64	0.75-1.00	0.035	0.04	0.15-0.35	------	0.70-0.90	------
81B45	0.43-0.48	0.75-1.00	0.035	0.04	0.15-0.35	0.20-0.40	0.35-0.55	0.08-0.15
94B17	0.15-0.20	0.75-1.00	0.035	0.04	0.15-0.35	0.30-0.60	0.30-0.50	0.08-0.15
94B30	0.28-0.23	0.75-1.00	0.035	0.04	0.15-0.35	0.30-0.60	0.30-0.50	0.08-0.15

CHEMICAL COMPOSITIONS

TOOL STEELS-CHEMICAL COMPOSITION LIMITS, IN %

AISI/SAE	C.	Mn.	Si.	W.	Mo.	Cr.	V.	Co.
TUNGSTEN TYPE HIGH SPEED TOOL STEELS								
T1	0.75	------	------	18.00	------	4.00	1.00	------
T2	0.80	------	------	18.00	------	4.00	2.00	------
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
MOLYBDENUM TYPE HIGH SPEED TOOL STEEL								
M1	0.85	------	------	1.50	8.50	4.00	1.00	------
M2	0.85-1.00	------	------	6.00	5.00	4.00	2.00	------
M3 CL.1	1.05	------	------	6.00	5.00	4.00	2.40	------
M3 CL.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	0.85-1.00	------	------	------	8.00	4.00	2.00	------
M30	0.80	------	------	2.00	8.00	4.00	1.25	5.00
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	0.80	------	------	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
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
M46	1.25	------	------	2.00	8.25	4.00	3.20	8.25
M47	1.10	------	------	1.50	9.50	3.75	1.25	5.00

(CONTINUED)

CHEMICAL COMPOSITIONS

TOOL STEELS-CHEMICAL COMPOSITION LIMITS, IN %

AISI/SAE	C.	Mn.	Si.	W.	Mo.	Cr.	V.	Co.
CHROMIUM TYPE HOT WORK TOOL STEELS								
H10	0.40	------	------	------	2.50	3.25	0.40	------
H11	0.35	------	------	------	1.50	5.00	0.40	------
H12	0.35	------	------	1.50	1.50	5.00	0.40	------
H13	0.35	------	------	------	1.50	5.00	1.00	------
H14	0.40	------	------	5.00	------	5.00	------	------
H19	0.40	------	------	4.25	------	4.25	2.00	4.25
TUNGSTEN TYPE HOT WORK TOOL STEELS								
H21	0.35	------	------	9.00	------	3.50	------	------
H22	0.35	------	------	11.00	------	2.00	------	------
H23	0.30	------	------	12.00	------	12.00	------	------
H24	0.45	------	------	15.00	------	3.00	------	------
H25	0.25	------	------	15.00	------	4.00	------	------
H26	0.50	------	------	18.00	------	4.00	1.00	------
MOLYBDENUM TYPE HOT WORK TOOL STEELS								
H41	0.65	------	------	1.50	8.00	4.00	1.00	------
H42	0.60	------	------	6.00	5.00	4.00	2.00	------
H43	0.55	------	------	------	8.00	4.00	2.00	------
HIGH CARBON HIGH CHROMIUM TYPE COLD WORK TOOL STEELS								
D2	1.50	------	------	------	1.00	12.00	1.00	------
D3	2.25	------	------	------	------	12.00	------	------
D4	2.25	------	------	------	1.00	12.00	------	------
D5	1.50	------	------	------	1.00	12.00	------	3.00
(D6)	2.10	------	------	0.80	------	12.00	------	------
D7	2.35	------	------	------	1.00	12.00	4.00	------

(CONTINUED)

CHEMICAL COMPOSITIONS

TOOL STEELS-CHEMICAL COMPOSITION LIMITS, IN %

AISI/SAE	C.	Mn.	Si.	W.	Mo.	Cr.	V.	Ni.
MEDIUM ALLOY AIR HARDENING TYPE COLD WORK TOOL STEELS								
A2	1.00	------	------	------	1.00	5.00	------	------
A3	1.25	------	------	------	1.00	5.00	1.00	------
A4	1.00	2.00	------	------	1.00	1.00	------	------
A6	0.70	2.00	------	------	1.25	1.00	------	------
A7	2.25	------	------	1.00 *	1.00	5.25	4.75	------
A8	0.55	------	------	1.25	1.25	5.00	------	------
A9	0.50	------	------	------	1.40	5.00	1.00	1.50
A10	1.35	1.80	------	------	1.50	------	------	1.80
OIL HARDENING TYPE COLD WORK TOOL STEELS								
O1	0.90	1.00	------	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	------	------
SHOCK RESISTING TOOL STEELS								
S1	0.50	------	------	2.50	------	1.50	------	------
S2	0.50	------	1.00	------	0.50	------	------	------
S5	0.55	0.80	2.00	------	0.40	------	------	------
S6	0.45	1.40	2.25	------	0.40	1.50	------	------
S7	0.50	------	------	------	1.40	3.25	------	------
MOLD STEELS								
P2	0.07	------	------	------	0.20	2.00	------	0.50
P3	0.10	------	------	------	------	0.60	------	1.25
P4	0.07	------	------	------	0.75	5.00	------	------
P5	0.10	------	------	------	------	2.25	------	------
P6	0.10	------	------	------	------	1.50	------	3.50
P20	0.35	------	------	------	0.40	1.70	------	4.00
P21	0.20	------	------	------	------	------	1.20 Al.	------

*** OCCASIONALLY**

CHEMICAL COMPOSITIONS

TOOL STEELS-CHEMICAL COMPOSITION LIMITS, IN %

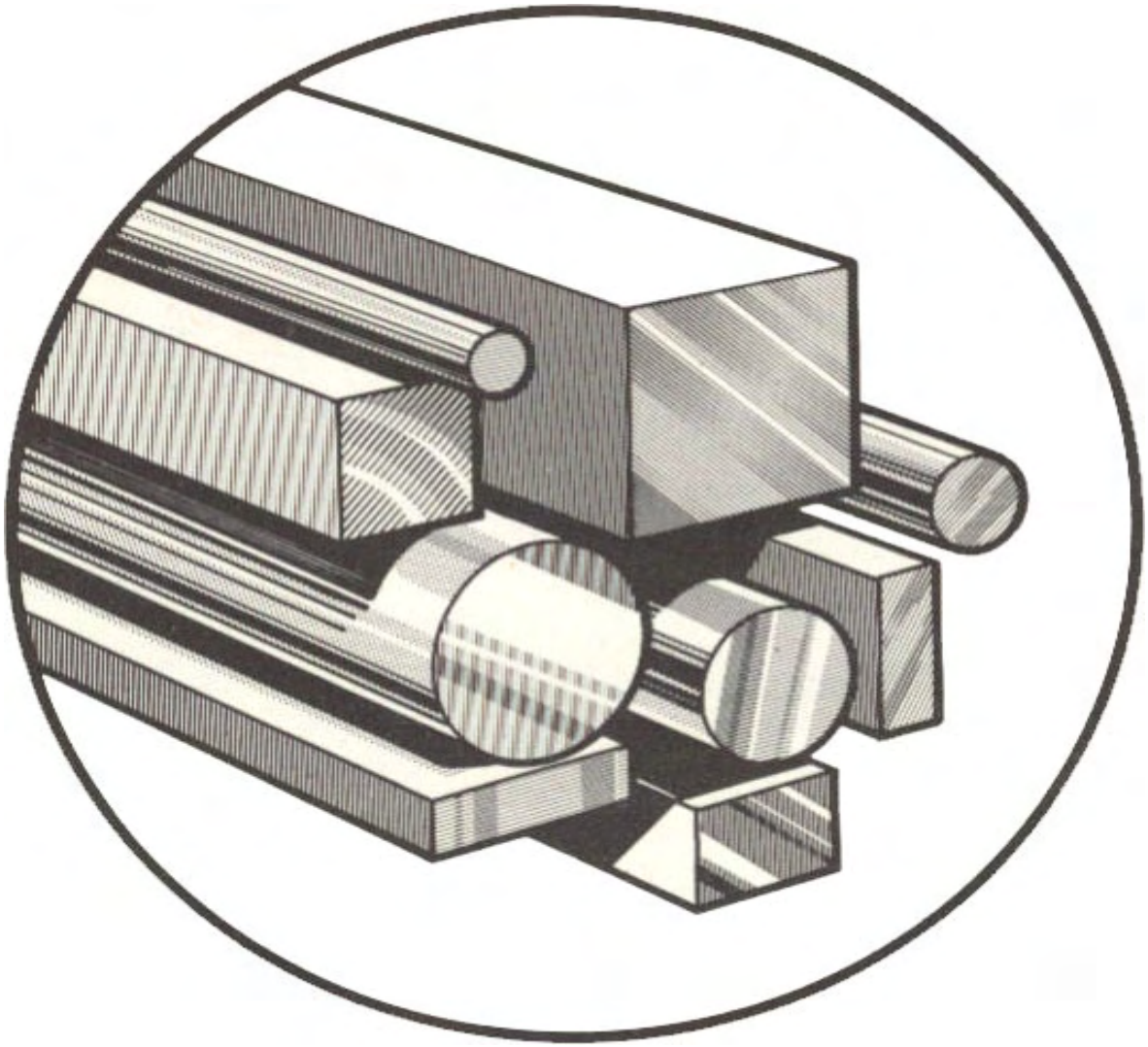
AISI/SAE	C.	Mn.	Si.	W.	Mo.	Cr.	V.	Ni.
LOW ALLOY TYPE SPECIAL PURPOSE TOOL STEELS								
L2	0.50-1.10	------	------	------	------	1.00	0.20	------
L3	1.00	------	------	------	------	1.50	0.20	------
L6	0.70	------	------	------	0.25 *	0.75	------	1.50
OTHER TYPES OF SPECIAL PURPOSE TOOL STEELS								
F1	1.00	------	------	1.25	------	------	------	------
F2	1.25	------	------	3.50	------	------	------	------
WATER HARDENING TOOL STEELS								
W1	0.60-1.40	------	------	------	------	------		------
W2	0.60-1.40	------	------	------	------	------	0.25	------
W5	1.10	------	------	------	------	0.50	------	------

*** OCCASIONALLY**

VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 11.
CONVERSIONS



VANGUARD STEEL LTD.

PRODUCT MANUAL

CONVERSIONS

TABLE

TO OBTAIN	MULTIPLY BY	TO FIND	TO CONVERT	MULTIPLY BY	TO OBTAIN
DISTANCE					
INCH	2.54	CENTIMETER		0.3937	INCH
INCHES	25.4	MILLIMETERS		0.03937	INCHES
FEET	0.3048	METERS		3.281	FEET
YARDS	0.9144	METERS		1.094	YARDS
MILES (STATUTE)	1.609	KILOMETER		0.6214	MILES (STATUTE)
WEIGHT					
OUNCES-AVOIRDUPOIS	28.35	GRAMS		0.0353	OUNCES-AVOIRDUPOIS
POUNDS	0.4536	KILOGRAMS		2.205	POUNDS
SHORT TONS (2000 LBS.)	0.9072	METRIC TONS		1.102	SHORT TONS
LONG TONS (2240 LBS.)	1.016	METRIC TONS		0.9842	LONG TONS
AREA					
SQUARE INCHES	645.2	SQ. MILLIMETERS		0.00155	SQUARE INCHES
CUBIC INCHES	16.387	CUBIC CENTIMETERS		0.06102	CUBIC INCHES
CUBIC FEET	0.02832	CUBIC METERS		35.31	CUBIC FEET
CUBIC YARDS	0.7646	CUBIC METERS		1.308	CUBIC YARDS
IMPACT ENERGY VALUE					
FOOT-POUNDS	1.35582	JOULES		0.73754	FOOT-POUNDS
BRITISH THERMAL UNIT	1.0555	KILOJOULES		0.947817	BRITISH THERMAL UNIT
PRESSURE					
LBS. PER SQ. INCH	0.07031	kg/cm2		14.2233	LBS. PER SQ. INCH
LBS. PER SQ. INCH	0.007	N/mm2 (Mpa)		145.04	LBS. PER SQ. INCH
LBS. PER SQ. FOOT	0.0004883	kg/cm2		2048.1552	LBS. PER SQ. FOOT
TONS/PSI	157.488	kg/cm2		0.0063497	TONS/PSI
POUNDS PER FOOT	1.4882	kg/m		0.67195	POUNDS PER FOOT
POUNDS PER YARD	0.49605	kg/m		2.01592	POUNDS PER YARD
TEMPERATURE					
DEGREES FAHRENHEIT	X .5556 X (ºF - 32)	= DEGREES CELSIUS			
DEGREES CELSIUS	X (1.8 X ºC) + 32	= DEGREES FAHRENHEIT			

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CONVERSIONS

CONVERSION OF FRACTIONS OF AN INCH TO DECIMAL EQUIVALENT AND MILLIMETERS

INCHES	DECIMAL	MM	INCHES	DECIMAL	MM
1/64	0.015625	0.3969	**33/64**	0.515625	13.0969
1/32	0.03125	0.7938	**17/32**	0.53125	13.4938
3/64	0.046875	1.1906	**35/64**	0.546875	13.8906
1/16	0.0625	1.5875	**9/16**	0.5625	14.2875
5/64	0.078125	1.9844	**37/64**	0.578125	14.6844
3/32	0.09375	2.3812	**19/32**	0.59375	15.0812
7/64	0.109375	2.7781	**39/64**	0.609375	15.4781
1/8	0.125	3.175	**5/8**	0.625	15.875
9/64	0.140625	3.5719	**41/64**	0.640625	16.2719
5/32	0.15625	3.9687	**21/32**	0.65625	16.6688
11/64	0.171875	4.3656	**43/64**	0.671875	17.0656
3/16	0.1875	4.7625	**11/16**	0.6875	17.4625
13/64	0.203125	5.1594	**45/64**	0.703125	17.8594
7/32	0.21875	5.5562	**23/32**	0.71875	18.2562
13/64	0.234375	5.9531	**47/64**	0.734375	18.6531
1/4	0.25	6.35	**3/4**	0.75	19.05
17/64	0.265625	6.7469	**49/64**	0.765625	19.4469
9/32	0.28125	7.1438	**25/32**	0.78125	19.8438
19/64	0.296875	7.5406	**51/64**	0.796875	20.2406
5/16	0.3125	7.9375	**13/16**	0.8125	20.6375
21/64	0.328125	8.3344	**53/64**	0.828125	21.0344
11/32	0.34375	8.7312	**27/32**	0.84375	21.4312
23/64	0.359375	9.1281	**55/64**	0.859375	21.8281
3/8	0.375	9.525	**7/8**	0.875	22.225
25/64	0.390625	9.9219	**57/64**	0.890625	22.6219
13/32	0.40625	10.3188	**29/32**	0.90625	23.0188
27/64	0.421875	10.7156	**59/64**	0.921875	23.4156
7/16	0.4375	11.1125	**15/16**	0.9375	23.8125
29/64	0.453125	11.5094	**61/64**	0.953125	24.2094
15/32	0.46875	11.9062	**31/32**	0.96875	24.6062
31/64	0.484375	12.3031	**63/64**	0.984375	25.0031
1/2	0.50	12.7	**1**	1.00	25.4

CONVERSIONS

TEMPERATURE CONVERSIONS

THE MIDDLE COLUMNS OF NUMBERS REFER TO THE TEMPERATURE EITHER IN DEGREES OF CELSIUS OR FAHRENHEIT TO BE CONVERTED. WHEN CONVERTING FROM DEGREES OF FAHRENHEIT TO DEGREES OF CELSIUS, READ THE CELSIUS EQUIVALENT IN THE COLUMN HEADED " º C ". WHEN CONVERTING FROM CELSIUS TO FAHRENHEIT, READ THE FAHRENHEIT EQUIVALENT IN THE COLUMN HEADED " º F ".

º F	º C	º F	º C	º F	º C
-458.00	-272.22	**-388.00**	-233.33	**-320.00**	-195.56
-456.00	-271.11	**-386.00**	-232.22	**-318.00**	-194.44
-454.00	-270.00	**-384.00**	-231.11	**-316.00**	-193.33
-432.00	-257.78	**-382.00**	-230.00	**-314.00**	-192.22
-450.00	-267.78	**-380.00**	-228.89	**-312.00**	-191.11
-448.00	-266.67	**-378.00**	-227.78	**-310.00**	-190.00
-446.00	-265.56	**-376.00**	-226.67	**-308.00**	-188.89
-444.00	-264.44	**-374.00**	-225.56	**-310.00**	-190.00
-442.00	-263.33	**-372.00**	-224.44	**-308.00**	-188.89
-440.00	-262.22	**-370.00**	-223.33	**-306.00**	-187.78
-438.00	-261.11	**-368.00**	-222.22	**-304.00**	-186.67
-436.00	-260.00	**-366.00**	-221.11	**-302.00**	-185.56
-434.00	-258.89	**-364.00**	-220.00	**-300.00**	-184.44
-432.00	-257.78	**-362.00**	-218.89	**-288.00**	-177.78
-430.00	-256.67	**-360.00**	-217.78	**-286.00**	-176.67
-428.00	-255.56	**-368.00**	-222.22	**-284.00**	-175.56
-426.00	-254.44	**-356.00**	-215.56	**-282.00**	-174.44
-424.00	-253.33	**-354.00**	-214.44	**-280.00**	-173.33
-422.00	-252.22	**-352.00**	-213.33	**-278.00**	-172.22
-420.00	-251.11	**-350.00**	-212.22	**-276.00**	-171.11
-418.00	-250.00	**-348.00**	-211.11	**-274.00**	-170.00
-416.00	-248.89	**-346.00**	-210.00	-457.60 **-272.00**	-168.89
-412.00	-246.67	**-344.00**	-208.89	-454.00 **-270.00**	-167.78
-410.00	-245.56	**-342.00**	-207.78	-450.40 **-268.00**	-166.67
-408.00	-244.44	**-340.00**	-206.67	-446.80 **-266.00**	-165.56
-406.00	-243.33	**-338.00**	-205.56	-443.20 **-264.00**	-164.44
-404.00	-242.22	**-336.00**	-204.44	-439.60 **-262.00**	-163.33
-402.00	-241.11	**-334.00**	-203.33	-436.00 **-260.00**	-162.22
-400.00	-240.00	**-332.00**	-202.22	-432.40 **-258.00**	-161.11
-398.00	-238.89	**-330.00**	-201.11	-428.80 **-256.00**	-160.00
-396.00	-237.78	**-328.00**	-200.00	-425.20 **-254.00**	-158.89
-394.00	-236.67	**-326.00**	-198.89	-421.60 **-252.00**	-157.78
-392.00	-235.56	**-324.00**	-197.78	-418.00 **-250.00**	-156.67
-390.00	-234.44	**-322.00**	-196.67	-414.40 **-248.00**	-155.56

(CONTINUED)

CONVERSIONS

TEMPERATURE CONVERSIONS

THE MIDDLE COLUMNS OF NUMBERS REFER TO THE TEMPERATURE EITHER IN DEGREES OF CELSIUS OR FAHRENHEIT TO BE CONVERTED. WHEN CONVERTING FROM DEGREES OF FAHRENHEIT TO DEGREES OF CELSIUS, READ THE CELSIUS EQUIVALENT IN THE COLUMN HEADED " º C ". WHEN CONVERTING FROM CELSIUS TO FAHRENHEIT, READ THE FAHRENHEIT EQUIVALENT IN THE COLUMN HEADED " º F ".

º F		º C	º F		º C	º F		º C
-410.80	**-246.00**	-154.44	-288.40	**-178.00**	-116.67	-166.00	**-110.00**	-78.89
-407.20	**-244.00**	-153.33	-284.80	**-176.00**	-115.56	-162.40	**-108.00**	-77.78
-403.60	**-242.00**	-152.22	-281.20	**-174.00**	-114.44	-158.80	**-106.00**	-76.67
-400.00	**-240.00**	-151.11	-277.60	**-172.00**	-113.33	-155.20	**-104.00**	-75.56
-396.40	**-238.00**	-150.00	-274.00	**-170.00**	-112.22	-151.60	**-102.00**	-74.44
-392.80	**-236.00**	-148.89	-270.40	**-168.00**	-111.11	-148.00	**-100.00**	-73.33
-389.20	**-234.00**	-147.78	-266.80	**-166.00**	-110.00	-144.40	**-98.00**	-72.22
-385.60	**-232.00**	-146.67	-263.20	**-164.00**	-108.89	-140.80	**-96.00**	-71.11
-382.00	**-230.00**	-145.56	-259.60	**-162.00**	-107.78	-137.20	**-94.00**	-70.00
-378.40	**-228.00**	-144.44	-256.00	**-160.00**	-106.67	-133.60	**-92.00**	-68.89
-374.80	**-226.00**	-143.33	-252.40	**-158.00**	-105.56	-130.00	**-90.00**	-67.78
-371.20	**-224.00**	-142.22	-248.80	**-156.00**	-104.44	-126.40	**-88.00**	-66.67
-367.60	**-222.00**	-141.11	-245.20	**-154.00**	-103.33	-122.80	**-86.00**	-65.56
-364.00	**-220.00**	-140.00	-241.60	**-152.00**	-102.22	-119.20	**-84.00**	-64.44
-360.40	**-218.00**	-138.89	-238.00	**-150.00**	-101.11	-115.60	**-82.00**	-63.33
-356.80	**-216.00**	-137.78	-234.40	**-148.00**	-100.00	-112.00	**-80.00**	-62.22
-353.20	**-214.00**	-136.67	-230.80	**-146.00**	-98.89	-108.40	**-78.00**	-61.11
-349.60	**-212.00**	-135.56	-227.20	**-144.00**	-97.78	-104.80	**-76.00**	-60.00
-346.00	**-210.00**	-134.44	-223.60	**-142.00**	-96.67	-101.20	**-74.00**	-58.89
-342.40	**-208.00**	-133.33	-220.00	**-140.00**	-95.56	-97.60	**-72.00**	-57.78
-338.80	**-206.00**	-132.22	-216.40	**-138.00**	-94.44	-94.00	**-70.00**	-56.67
-335.20	**-204.00**	-131.11	-212.80	**-136.00**	-93.33	-90.40	**-68.00**	-55.56
-331.60	**-202.00**	-130.00	-209.20	**-134.00**	-92.22	-86.80	**-66.00**	-54.44
-328.00	**-200.00**	-128.89	-205.60	**-132.00**	-91.11	-83.20	**-64.00**	-53.33
-324.40	**-198.00**	-127.78	-202.00	**-130.00**	-90.00	-79.60	**-62.00**	-52.22
-320.80	**-196.00**	-126.67	-198.40	**-128.00**	-88.89	-76.00	**-60.00**	-51.11
-317.20	**-194.00**	-125.56	-194.80	**-126.00**	-87.78	-72.40	**-58.00**	-50.00
-313.60	**-192.00**	-124.44	-191.20	**-124.00**	-86.67	-68.80	**-56.00**	-48.89
-310.00	**-190.00**	-123.33	-187.60	**-122.00**	-85.56	-65.20	**-54.00**	-47.78
-306.40	**-188.00**	-122.22	-184.00	**-120.00**	-84.44	-61.60	**-52.00**	-46.67
-302.80	**-186.00**	-121.11	-180.40	**-118.00**	-83.33	-58.00	**-50.00**	-45.56
-299.20	**-184.00**	-120.00	-176.80	**-116.00**	-82.22	-54.40	**-48.00**	-44.44
-295.60	**-182.00**	-118.89	-173.20	**-114.00**	-81.11	-50.80	**-46.00**	-43.33
-292.00	**-180.00**	-117.78	-169.60	**-112.00**	-80.00	-47.20	**-44.00**	-42.22

(CONTINUED)

CONVERSIONS

TEMPERATURE CONVERSIONS

THE MIDDLE COLUMNS OF NUMBERS REFER TO THE TEMPERATURE EITHER IN DEGREES OF CELSIUS OR FAHRENHEIT TO BE CONVERTED. WHEN CONVERTING FROM DEGREES OF FAHRENHEIT TO DEGREES OF CELSIUS, READ THE CELSIUS EQUIVALENT IN THE COLUMN HEADED " º C ". WHEN CONVERTING FROM CELSIUS TO FAHRENHEIT, READ THE FAHRENHEIT EQUIVALENT IN THE COLUMN HEADED " º F ".

º F		º C	º F		º C	º F		º C
-43.60	**-42.00**	-41.11	78.80	**26.00**	-3.33	201.20	**94.00**	34.44
-40.00	**-40.00**	-40.00	82.40	**28.00**	-2.22	204.80	**96.00**	35.56
-36.40	**-38.00**	-38.89	86.00	**30.00**	-1.11	208.40	**98.00**	36.67
-32.80	**-36.00**	-37.78	89.60	**32.00**	0.00	212.00	**100.00**	37.78
-29.20	**-34.00**	-36.67	93.20	**34.00**	1.11	215.60	**102.00**	38.89
-25.60	**-32.00**	-35.56	96.80	**36.00**	2.22	219.20	**104.00**	40.00
-22.00	**-30.00**	-34.44	100.40	**38.00**	3.33	222.80	**106.00**	41.11
-18.40	**-28.00**	-33.33	104.00	**40.00**	4.44	226.40	**108.00**	42.22
-14.80	**-26.00**	-32.22	107.60	**42.00**	5.56	230.00	**110.00**	43.33
-11.20	**-24.00**	-31.11	111.20	**44.00**	6.67	233.60	**112.00**	44.44
-7.60	**-22.00**	-30.00	114.80	**46.00**	7.78	237.20	**114.00**	45.56
-4.00	**-20.00**	-28.89	118.40	**48.00**	8.89	240.80	**116.00**	46.67
-0.40	**-18.00**	-27.78	122.00	**50.00**	10.00	244.40	**118.00**	47.78
3.20	**-16.00**	-26.67	125.60	**52.00**	11.11	248.00	**120.00**	48.89
6.80	**-14.00**	-25.56	129.20	**54.00**	12.22	251.60	**122.00**	50.00
10.40	**-12.00**	-24.44	132.80	**56.00**	13.33	255.20	**124.00**	51.11
14.00	**-10.00**	-23.33	136.40	**58.00**	14.44	258.80	**126.00**	52.22
17.60	**-8.00**	-22.22	140.00	**60.00**	15.56	262.40	**128.00**	53.33
21.20	**-6.00**	-21.11	143.60	**62.00**	16.67	266.00	**130.00**	54.44
24.80	**-4.00**	-20.00	147.20	**64.00**	17.78	269.60	**132.00**	55.56
28.40	**-2.00**	-18.89	150.80	**66.00**	18.89	273.20	**134.00**	56.67
32.00	**0.00**	-17.78	154.40	**68.00**	20.00	276.80	**136.00**	57.78
35.60	**2.00**	-16.67	158.00	**70.00**	21.11	280.40	**138.00**	58.89
39.20	**4.00**	-15.56	161.60	**72.00**	22.22	284.00	**140.00**	60.00
42.80	**6.00**	-14.44	165.20	**74.00**	23.33	287.60	**142.00**	61.11
46.40	**8.00**	-13.33	168.80	**76.00**	24.44	291.20	**144.00**	62.22
50.00	**10.00**	-12.22	172.40	**78.00**	25.56	294.80	**146.00**	63.33
53.60	**12.00**	-11.11	176.00	**80.00**	26.67	298.40	**148.00**	64.44
57.20	**14.00**	-10.00	179.60	**82.00**	27.78	302.00	**150.00**	65.56
60.80	**16.00**	-8.89	183.20	**84.00**	28.89	305.60	**152.00**	66.67
64.40	**18.00**	-7.78	186.80	**86.00**	30.00	309.20	**154.00**	67.78
68.00	**20.00**	-6.67	190.40	**88.00**	31.11	312.80	**156.00**	68.89
71.60	**22.00**	-5.56	194.00	**90.00**	32.22	316.40	**158.00**	70.00
75.20	**24.00**	-4.44	197.60	**92.00**	33.33	320.00	**160.00**	71.11

(CONTINUED)

CONVERSIONS

TEMPERATURE CONVERSIONS

THE MIDDLE COLUMNS OF NUMBERS REFER TO THE TEMPERATURE EITHER IN DEGREES OF CELSIUS OR FAHRENHEIT TO BE CONVERTED. WHEN CONVERTING FROM DEGREES OF FAHRENHEIT TO DEGREES OF CELSIUS, READ THE CELSIUS EQUIVALENT IN THE COLUMN HEADED " º C ". WHEN CONVERTING FROM CELSIUS TO FAHRENHEIT, READ THE FAHRENHEIT EQUIVALENT IN THE COLUMN HEADED " º F ".

º F		º C	º F		º C	º F		º C
323.60	**162.00**	72.22	464.00	**240.00**	115.56	586.40	**308.00**	153.33
327.20	**164.00**	73.33	467.60	**242.00**	116.67	590.00	**310.00**	154.44
330.80	**166.00**	74.44	471.20	**244.00**	117.78	593.60	**312.00**	155.56
334.40	**168.00**	75.56	474.80	**246.00**	118.89	597.20	**314.00**	156.67
338.00	**170.00**	76.67	478.40	**248.00**	120.00	600.80	**316.00**	157.78
341.60	**172.00**	77.78	482.00	**250.00**	121.11	604.40	**318.00**	158.89
345.20	**174.00**	78.89	485.60	**252.00**	122.22	608.00	**320.00**	160.00
348.80	**176.00**	80.00	489.20	**254.00**	123.33	611.60	**322.00**	161.11
352.40	**178.00**	81.11	492.80	**256.00**	124.44	615.20	**324.00**	162.22
356.00	**180.00**	82.22	496.40	**258.00**	125.56	618.80	**326.00**	163.33
359.60	**182.00**	83.33	500.00	**260.00**	126.67	622.40	**328.00**	164.44
363.20	**184.00**	84.44	503.60	**262.00**	127.78	626.00	**330.00**	165.56
366.80	**186.00**	85.56	507.20	**264.00**	128.89	629.60	**332.00**	166.67
370.40	**188.00**	86.67	510.80	**266.00**	130.00	633.20	**334.00**	167.78
392.00	**200.00**	93.33	514.40	**268.00**	131.11	636.80	**336.00**	168.89
395.60	**202.00**	94.44	518.00	**270.00**	132.22	640.40	**338.00**	170.00
399.20	**204.00**	95.56	521.60	**272.00**	133.33	644.00	**340.00**	171.11
402.80	**206.00**	96.67	525.20	**274.00**	134.44	647.60	**342.00**	172.22
406.40	**208.00**	97.78	528.80	**276.00**	135.56	651.20	**344.00**	173.33
410.00	**210.00**	98.89	532.40	**278.00**	136.67	654.80	**346.00**	174.44
413.60	**212.00**	100.00	536.00	**280.00**	137.78	658.40	**348.00**	175.56
417.20	**214.00**	101.11	539.60	**282.00**	138.89	662.00	**350.00**	176.67
420.80	**216.00**	102.22	543.20	**284.00**	140.00	665.60	**352.00**	177.78
424.40	**218.00**	103.33	546.80	**286.00**	141.11	669.20	**354.00**	178.89
428.00	**220.00**	104.44	550.40	**288.00**	142.22	672.80	**356.00**	180.00
431.60	**222.00**	105.56	554.00	**290.00**	143.33	676.40	**358.00**	181.11
435.20	**224.00**	106.67	557.60	**292.00**	144.44	680.00	**360.00**	182.22
438.80	**226.00**	107.78	561.20	**294.00**	145.56	683.60	**362.00**	183.33
442.40	**228.00**	108.89	564.80	**296.00**	146.67	687.20	**364.00**	184.44
446.00	**230.00**	110.00	568.40	**298.00**	147.78	690.80	**366.00**	185.56
449.60	**232.00**	111.11	572.00	**300.00**	148.89	694.40	**368.00**	186.67
453.20	**234.00**	112.22	575.60	**302.00**	150.00	698.00	**370.00**	187.78
456.80	**236.00**	113.33	579.20	**304.00**	151.11	701.60	**372.00**	188.89
460.40	**238.00**	114.44	582.80	**306.00**	152.22	705.20	**374.00**	190.00

(CONTINUED)

CONVERSIONS

TEMPERATURE CONVERSIONS

THE MIDDLE COLUMNS OF NUMBERS REFER TO THE TEMPERATURE EITHER IN DEGREES OF CELSIUS OR FAHRENHEIT TO BE CONVERTED. WHEN CONVERTING FROM DEGREES OF FAHRENHEIT TO DEGREES OF CELSIUS, READ THE CELSIUS EQUIVALENT IN THE COLUMN HEADED " º C ". WHEN CONVERTING FROM CELSIUS TO FAHRENHEIT, READ THE FAHRENHEIT EQUIVALENT IN THE COLUMN HEADED " º F ".

º F		º C	º F		º C	º F		º C
708.80	**376.00**	191.11	824.00	**440.00**	226.67	978.80	**526.00**	274.44
712.40	**378.00**	192.22	827.60	**442.00**	227.78	982.40	**528.00**	275.56
716.00	**380.00**	193.33	831.20	**444.00**	228.89	986.00	**530.00**	276.67
719.60	**382.00**	194.44	834.80	**446.00**	230.00	989.60	**532.00**	277.78
723.20	**384.00**	195.56	838.40	**448.00**	231.11	993.20	**534.00**	278.89
726.80	**386.00**	196.67	842.00	**450.00**	232.22	996.80	**536.00**	280.00
730.40	**388.00**	197.78	845.60	**452.00**	233.33	1000.40	**538.00**	281.11
734.00	**390.00**	198.89	849.20	**454.00**	234.44	1004.00	**540.00**	282.22
737.60	**392.00**	200.00	852.80	**456.00**	235.56	1007.60	**542.00**	283.33
741.20	**394.00**	201.11	856.40	**458.00**	236.67	1011.20	**544.00**	284.44
744.80	**396.00**	202.22	860.00	**460.00**	237.78	1014.80	**546.00**	285.56
748.40	**398.00**	203.33	863.60	**462.00**	238.89	1018.40	**548.00**	286.67
752.00	**400.00**	204.44	867.20	**464.00**	240.00	1040.00	**560.00**	293.33
755.60	**402.00**	205.56	874.40	**468.00**	242.22	1043.60	**562.00**	294.44
759.20	**404.00**	206.67	878.00	**470.00**	243.33	1047.20	**564.00**	295.56
762.80	**406.00**	207.78	881.60	**472.00**	244.44	1050.80	**566.00**	296.67
766.40	**408.00**	208.89	885.20	**474.00**	245.56	1054.40	**568.00**	297.78
770.00	**410.00**	210.00	888.80	**476.00**	246.67	1058.00	**570.00**	298.89
773.60	**412.00**	211.11	892.40	**478.00**	247.78	1061.60	**572.00**	300.00
777.20	**414.00**	212.22	932.00	**500.00**	260.00	1065.20	**574.00**	301.11
780.80	**416.00**	213.33	935.60	**502.00**	261.11	1068.80	**576.00**	302.22
784.40	**418.00**	214.44	939.20	**504.00**	262.22	1072.40	**578.00**	303.33
788.00	**420.00**	215.56	942.80	**506.00**	263.33	1076.00	**580.00**	304.44
791.60	**422.00**	216.67	946.40	**508.00**	264.44	1079.60	**582.00**	305.56
795.20	**424.00**	217.78	950.00	**510.00**	265.56	1083.20	**584.00**	306.67
798.80	**426.00**	218.89	953.60	**512.00**	266.67	1086.80	**586.00**	307.78
802.40	**428.00**	220.00	957.20	**514.00**	267.78	1090.40	**588.00**	308.89
806.00	**430.00**	221.11	960.80	**516.00**	268.89	1094.00	**590.00**	310.00
809.60	**432.00**	222.22	964.40	**518.00**	270.00	1097.60	**592.00**	311.11
813.20	**434.00**	223.33	968.00	**520.00**	271.11	1101.20	**594.00**	312.22
816.80	**436.00**	224.44	971.60	**522.00**	272.22	1104.80	**596.00**	313.33
820.40	**438.00**	225.56	975.20	**524.00**	273.33	1108.40	**598.00**	314.44

(CONTINUED)

CONVERSIONS

TEMPERATURE CONVERSIONS

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º F		º C	º F		º C	º F		º C
1112.00	**600.00**	315.56	1868.00	**1020.00**	548.89	2480.00	**1360.00**	737.78
1130.00	**610.00**	321.11	1886.00	**1030.00**	554.44	2498.00	**1370.00**	743.33
1148.00	**620.00**	326.67	1904.00	**1040.00**	560.00	2516.00	**1380.00**	748.89
1166.00	**630.00**	332.22	1922.00	**1050.00**	565.56	2534.00	**1390.00**	754.44
1184.00	**640.00**	337.78	1940.00	**1060.00**	571.11	2552.00	**1400.00**	760.00
1220.00	**660.00**	348.89	1958.00	**1070.00**	576.67	2570.00	**1410.00**	765.56
1256.00	**680.00**	360.00	1976.00	**1080.00**	582.22	2588.00	**1420.00**	771.11
1274.00	**690.00**	365.56	1994.00	**1090.00**	587.78	2606.00	**1430.00**	776.67
1292.00	**700.00**	371.11	2012.00	**1100.00**	593.33	2624.00	**1440.00**	782.22
1310.00	**710.00**	376.67	2030.00	**1110.00**	598.89	2642.00	**1450.00**	787.78
1328.00	**720.00**	382.22	2048.00	**1120.00**	604.44	2660.00	**1460.00**	793.33
1346.00	**730.00**	387.78	2066.00	**1130.00**	610.00	2678.00	**1470.00**	798.89
1436.00	**780.00**	415.56	2084.00	**1140.00**	615.56	2696.00	**1480.00**	804.44
1454.00	**790.00**	421.11	2102.00	**1150.00**	621.11	2714.00	**1490.00**	810.00
1472.00	**800.00**	426.67	2120.00	**1160.00**	626.67	2732.00	**1500.00**	815.56
1490.00	**810.00**	432.22	2138.00	**1170.00**	632.22	2750.00	**1510.00**	821.11
1508.00	**820.00**	437.78	2156.00	**1180.00**	637.78	2768.00	**1520.00**	826.67
1526.00	**830.00**	443.33	2174.00	**1190.00**	643.33	2786.00	**1530.00**	832.22
1544.00	**840.00**	448.89	2192.00	**1200.00**	648.89	2804.00	**1540.00**	837.78
1580.00	**860.00**	460.00	2210.00	**1210.00**	654.44	2822.00	**1550.00**	843.33
1598.00	**870.00**	465.56	2228.00	**1220.00**	660.00	2840.00	**1560.00**	848.89
1616.00	**880.00**	471.11	2246.00	**1230.00**	665.56	2858.00	**1570.00**	854.44
1652.00	**900.00**	482.22	2264.00	**1240.00**	671.11	2876.00	**1580.00**	860.00
1670.00	**910.00**	487.78	2282.00	**1250.00**	676.67	2894.00	**1590.00**	865.56
1688.00	**920.00**	493.33	2300.00	**1260.00**	682.22	2912.00	**1600.00**	871.11
1706.00	**930.00**	498.89	2318.00	**1270.00**	687.78	2930.00	**1610.00**	876.67
1724.00	**940.00**	504.44	2336.00	**1280.00**	693.33	2948.00	**1620.00**	882.22
1742.00	**950.00**	510.00	2354.00	**1290.00**	698.89	2966.00	**1630.00**	887.78
1760.00	**960.00**	515.56	2372.00	**1300.00**	704.44	2984.00	**1640.00**	893.33
1778.00	**970.00**	521.11	2390.00	**1310.00**	710.00	3002.00	**1650.00**	898.89
1796.00	**980.00**	526.67	2408.00	**1320.00**	715.56	3020.00	**1660.00**	904.44
1814.00	**990.00**	532.22	2426.00	**1330.00**	721.11	3038.00	**1670.00**	910.00
1832.00	**1000.00**	537.78	2444.00	**1340.00**	726.67	3056.00	**1680.00**	915.56
1850.00	**1010.00**	543.33	2462.00	**1350.00**	732.22	3074.00	**1690.00**	921.11

(CONTINUED)

CONVERSIONS

TEMPERATURE CONVERSIONS

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º F		º C	º F		º C	º F		º C
3092.00	**1700.00**	926.67	3704.00	**2040.00**	1115.56	4316.00	**2380.00**	1304.44
3110.00	**1710.00**	932.22	3722.00	**2050.00**	1121.11	4334.00	**2390.00**	1310.00
3128.00	**1720.00**	937.78	3740.00	**2060.00**	1126.67	4352.00	**2400.00**	1315.56
3146.00	**1730.00**	943.33	3758.00	**2070.00**	1132.22	4370.00	**2410.00**	1321.11
3164.00	**1740.00**	948.89	3776.00	**2080.00**	1137.78	4388.00	**2420.00**	1326.67
3182.00	**1750.00**	954.44	3794.00	**2090.00**	1143.33	4406.00	**2430.00**	1332.22
3200.00	**1760.00**	960.00	3812.00	**2100.00**	1148.89	4424.00	**2440.00**	1337.78
3218.00	**1770.00**	965.56	3830.00	**2110.00**	1154.44	4442.00	**2450.00**	1343.33
3236.00	**1780.00**	971.11	3848.00	**2120.00**	1160.00	4460.00	**2460.00**	1348.89
3254.00	**1790.00**	976.67	3866.00	**2130.00**	1165.56	4478.00	**2470.00**	1354.44
3272.00	**1800.00**	982.22	3884.00	**2140.00**	1171.11	4496.00	**2480.00**	1360.00
3290.00	**1810.00**	987.78	3902.00	**2150.00**	1176.67	4514.00	**2490.00**	1365.56
3308.00	**1820.00**	993.33	3920.00	**2160.00**	1182.22	4532.00	**2500.00**	1371.11
3326.00	**1830.00**	998.89	3938.00	**2170.00**	1187.78	4550.00	**2510.00**	1376.67
3344.00	**1840.00**	1004.44	3956.00	**2180.00**	1193.33	4568.00	**2520.00**	1382.22
3362.00	**1850.00**	1010.00	3974.00	**2190.00**	1198.89	4586.00	**2530.00**	1387.78
3380.00	**1860.00**	1015.56	3992.00	**2200.00**	1204.44	4604.00	**2540.00**	1393.33
3398.00	**1870.00**	1021.11	4010.00	**2210.00**	1210.00	4622.00	**2550.00**	1398.89
3416.00	**1880.00**	1026.67	4028.00	**2220.00**	1215.56	4640.00	**2560.00**	1404.44
3434.00	**1890.00**	1032.22	4046.00	**2230.00**	1221.11	4658.00	**2570.00**	1410.00
3452.00	**1900.00**	1037.78	4064.00	**2240.00**	1226.67	4676.00	**2580.00**	1415.56
3470.00	**1910.00**	1043.33	4082.00	**2250.00**	1232.22	4694.00	**2590.00**	1421.11
3488.00	**1920.00**	1048.89	4100.00	**2260.00**	1237.78	4712.00	**2600.00**	1426.67
3506.00	**1930.00**	1054.44	4118.00	**2270.00**	1243.33	4730.00	**2610.00**	1432.22
3524.00	**1940.00**	1060.00	4136.00	**2280.00**	1248.89	4748.00	**2620.00**	1437.78
3542.00	**1950.00**	1065.56	4154.00	**2290.00**	1254.44	4766.00	**2630.00**	1443.33
3560.00	**1960.00**	1071.11	4172.00	**2300.00**	1260.00	4784.00	**2640.00**	1448.89
3578.00	**1970.00**	1076.67	4190.00	**2310.00**	1265.56	4802.00	**2650.00**	1454.44
3596.00	**1980.00**	1082.22	4208.00	**2320.00**	1271.11	4820.00	**2660.00**	1460.00
3614.00	**1990.00**	1087.78	4226.00	**2330.00**	1276.67	4838.00	**2670.00**	1465.56
3632.00	**2000.00**	1093.33	4244.00	**2340.00**	1282.22	4856.00	**2680.00**	1471.11
3650.00	**2010.00**	1098.89	4262.00	**2350.00**	1287.78	4874.00	**2690.00**	1476.67
3668.00	**2020.00**	1104.44	4280.00	**2360.00**	1293.33	4892.00	**2700.00**	1482.22
3686.00	**2030.00**	1110.00	4298.00	**2370.00**	1298.89	4910.00	**2710.00**	1487.78

(CONTINUED)

CONVERSIONS

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º F		º C	º F		º C	º F		º C
4928.00	**2720.00**	1493.33	5630.00	**3110.00**	1710.00	7502.00	**4150.00**	2287.78
5036.00	**2780.00**	1526.67	5648.00	**3120.00**	1715.56	7520.00	**4160.00**	2293.33
5054.00	**2790.00**	1532.22	5666.00	**3130.00**	1721.11	7538.00	**4170.00**	2298.89
5072.00	**2800.00**	1537.78	5684.00	**3140.00**	1726.67	7556.00	**4180.00**	2304.44
5090.00	**2810.00**	1543.33	5702.00	**3150.00**	1732.22	7574.00	**4190.00**	2310.00
5108.00	**2820.00**	1548.89	5720.00	**3160.00**	1737.78	7592.00	**4200.00**	2315.56
5126.00	**2830.00**	1554.44	5738.00	**3170.00**	1743.33	7610.00	**4210.00**	2321.11
5144.00	**2840.00**	1560.00	5756.00	**3180.00**	1748.89	7628.00	**4220.00**	2326.67
5162.00	**2850.00**	1565.56	5774.00	**3190.00**	1754.44	7646.00	**4230.00**	2332.22
5180.00	**2860.00**	1571.11	5792.00	**3200.00**	1760.00	7664.00	**4240.00**	2337.78
5198.00	**2870.00**	1576.67	5810.00	**3210.00**	1765.56	7682.00	**4250.00**	2343.33
5216.00	**2880.00**	1582.22	5828.00	**3220.00**	1771.11	7700.00	**4260.00**	2348.89
5234.00	**2890.00**	1587.78	5846.00	**3230.00**	1776.67	7718.00	**4270.00**	2354.44
5252.00	**2900.00**	1593.33	5864.00	**3240.00**	1782.22	7736.00	**4280.00**	2360.00
5270.00	**2910.00**	1598.89	5522.00	**3050.00**	1676.67	7754.00	**4290.00**	2365.56
5288.00	**2920.00**	1604.44	5540.00	**3060.00**	1682.22	7772.00	**4300.00**	2371.11
5306.00	**2930.00**	1610.00	5558.00	**3070.00**	1687.78	7790.00	**4310.00**	2376.67
5324.00	**2940.00**	1615.56	5576.00	**3080.00**	1693.33	7808.00	**4320.00**	2382.22
5342.00	**2950.00**	1621.11	5594.00	**3090.00**	1698.89	7826.00	**4330.00**	2387.78
5360.00	**2960.00**	1626.67	7232.00	**4000.00**	2204.44	7844.00	**4340.00**	2393.33
5378.00	**2970.00**	1632.22	7250.00	**4010.00**	2210.00	7862.00	**4350.00**	2398.89
5396.00	**2980.00**	1637.78	7268.00	**4020.00**	2215.56	7880.00	**4360.00**	2404.44
5414.00	**2990.00**	1643.33	7286.00	**4030.00**	2221.11	7898.00	**4370.00**	2410.00
5432.00	**3000.00**	1648.89	7304.00	**4040.00**	2226.67	7916.00	**4380.00**	2415.56
5450.00	**3010.00**	1654.44	7322.00	**4050.00**	2232.22	7934.00	**4390.00**	2421.11
5468.00	**3020.00**	1660.00	7340.00	**4060.00**	2237.78	7952.00	**4400.00**	2426.67
5486.00	**3030.00**	1665.56	7358.00	**4070.00**	2243.33	7970.00	**4410.00**	2432.22
5504.00	**3040.00**	1671.11	7376.00	**4080.00**	2248.89	7988.00	**4420.00**	2437.78
5522.00	**3050.00**	1676.67	7394.00	**4090.00**	2254.44	8006.00	**4430.00**	2443.33
5540.00	**3060.00**	1682.22	7412.00	**4100.00**	2260.00	8024.00	**4440.00**	2448.89
5558.00	**3070.00**	1687.78	7430.00	**4110.00**	2265.56	8042.00	**4450.00**	2454.44
5576.00	**3080.00**	1693.33	7448.00	**4120.00**	2271.11	8060.00	**4460.00**	2460.00
5594.00	**3090.00**	1698.89	7466.00	**4130.00**	2276.67	8078.00	**4470.00**	2465.56
5612.00	**3100.00**	1704.44	7484.00	**4140.00**	2282.22	8096.00	**4480.00**	2471.11

(CONTINUED)

CONVERSIONS

TEMPERATURE CONVERSIONS

THE MIDDLE COLUMNS OF NUMBERS REFER TO THE TEMPERATURE EITHER IN DEGREES OF CELSIUS OR FAHRENHEIT TO BE CONVERTED. WHEN CONVERTING FROM DEGREES OF FAHRENHEIT TO DEGREES OF CELSIUS, READ THE CELSIUS EQUIVALENT IN THE COLUMN HEADED " º C ". WHEN CONVERTING FROM CELSIUS TO FAHRENHEIT, READ THE FAHRENHEIT EQUIVALENT IN THE COLUMN HEADED " º F ".

º F		º C	º F		º C
8114.00	**4490.00**	2476.67	8726.00	**4830.00**	2665.56
8132.00	**4500.00**	2482.22	8744.00	**4840.00**	2671.11
8150.00	**4510.00**	2487.78	8762.00	**4850.00**	2676.67
8168.00	**4520.00**	2493.33	8780.00	**4860.00**	2682.22
8186.00	**4530.00**	2498.89	8798.00	**4870.00**	2687.78
8204.00	**4540.00**	2504.44	8816.00	**4880.00**	2693.33
8222.00	**4550.00**	2510.00	8834.00	**4890.00**	2698.89
8240.00	**4560.00**	2515.56	8852.00	**4900.00**	2704.44
8258.00	**4570.00**	2521.11	8870.00	**4910.00**	2710.00
8276.00	**4580.00**	2526.67	8888.00	**4920.00**	2715.56
8294.00	**4590.00**	2532.22	8906.00	**4930.00**	2721.11
8312.00	**4600.00**	2537.78	8924.00	**4940.00**	2726.67
8330.00	**4610.00**	2543.33	8942.00	**4950.00**	2732.22
8348.00	**4620.00**	2548.89	8960.00	**4960.00**	2737.78
8366.00	**4630.00**	2554.44	8978.00	**4970.00**	2743.33
8384.00	**4640.00**	2560.00	8996.00	**4980.00**	2748.89
8402.00	**4650.00**	2565.56	9014.00	**4990.00**	2754.44
8420.00	**4660.00**	2571.11	9032.00	**5000.00**	2760.00
8438.00	**4670.00**	2576.67	9122.00	**5050.00**	2787.78
8456.00	**4680.00**	2582.22	9212.00	**5100.00**	2815.56
8474.00	**4690.00**	2587.78	9302.00	**5150.00**	2843.33
8492.00	**4700.00**	2593.33	9392.00	**5200.00**	2871.11
8510.00	**4710.00**	2598.89	9482.00	**5250.00**	2898.89
8528.00	**4720.00**	2604.44	9572.00	**5300.00**	2926.67
8546.00	**4730.00**	2610.00	9662.00	**5350.00**	2954.44
8564.00	**4740.00**	2615.56	9752.00	**5400.00**	2982.22
8582.00	**4750.00**	2621.11	9842.00	**5450.00**	3010.00
8600.00	**4760.00**	2626.67	9932.00	**5500.00**	3037.78
8618.00	**4770.00**	2632.22	10022.00	**5550.00**	3065.56
8636.00	**4780.00**	2637.78	10832.00	**6000.00**	3315.56
8654.00	**4790.00**	2643.33			
8672.00	**4800.00**	2648.89			
8690.00	**4810.00**	2654.44			
8708.00	**4820.00**	2660.00			

CONVERSIONS

CONVERSIONS FOR IMPACT ENERGY VALUES

JOULES	FT. LBS.	JOULES	FT. LBS.	JOULES	FT. LBS.	JOULES	FT. LBS.
1.36	1	37.96	28	74.57	55	111.18	82
2.71	2	39.32	29	75.93	56	112.53	83
4.07	3	40.67	30	77.28	57	113.89	84
5.42	4	42.03	31	78.64	58	115.24	85
6.78	5	43.39	32	79.99	59	116.60	86
8.13	6	44.74	33	81.35	60	117.96	87
9.49	7	46.10	34	82.71	61	119.31	88
10.85	8	47.45	35	84.06	62	120.67	89
12.20	9	48.81	36	85.42	63	122.02	90
13.56	10	50.17	37	86.77	64	123.38	91
14.91	11	51.52	38	88.13	65	124.74	92
16.27	12	52.88	39	89.48	66	126.09	93
17.63	13	54.23	40	90.84	67	126.09	93
18.98	14	55.59	41	92.20	68	127.45	94
20.34	15	56.94	42	93.55	69	128.80	95
21.69	16	58.30	43	94.91	70	130.16	96
23.05	17	59.66	44	96.26	71	131.51	97
24.40	18	61.01	45	97.62	72	132.87	98
25.76	19	62.37	46	98.97	73	134.23	99
27.12	20	63.72	47	100.33	74	135.58	100
28.47	21	65.08	48	101.69	75		
29.83	22	66.44	49	103.04	76		
31.18	23	67.79	50	104.40	77		
32.54	24	69.15	51	105.75	78		
33.90	25	70.50	52	107.11	79		
35.25	26	71.86	53	108.47	80		
36.61	27	73.21	54	109.82	81		

CONVERSIONS

CONVERSION FOR STRESS VALUES KSI TO MPA

THE MIDDLE COLUMN OF FIGURES CONTAINS THE READINGS (IN MPa OR KSI) TO BE CONVERTED. IF CONVERTING FROM KSI TO MPa, READ THE MPa EQUIVALENT IN THE COLUMN HEADED "MPa". IF CONVERTING FROM MPa TO KSI, READ THE EQUIVALENT IN THE COLUMN HEADED "KSI".

KSI		MPA	KSI		MPA	KSI		MPA
0.14504	**1**	6.895	4.4962	**31**	213.737	8.847	**61**	420.580
0.29008	**2**	13.790	4.6412	**32**	220.632	8.992	**62**	427.475
0.43511	**3**	20.684	4.7862	**33**	227.527	9.137	**63**	434.370
0.58015	**4**	27.579	4.9313	**34**	234.422	9.282	**64**	441.264
0.72519	**5**	34.474	5.0763	**35**	241.316	9.427	**65**	448.159
0.87023	**6**	41.369	5.2214	**36**	248.211	9.572	**66**	455.054
1.0153	**7**	48.263	5.3664	**37**	255.106	9.718	**67**	461.949
1.1603	**8**	55.158	5.5114	**38**	262.001	9.863	**68**	468.843
1.3053	**9**	62.053	5.6565	**39**	268.896	10.008	**69**	475.738
1.4504	**10**	68.948	5.8015	**40**	275.790	10.153	**70**	482.633
1.5954	**11**	75.842	5.9465	**41**	282.685	10.298	**71**	489.528
1.7405	**12**	82.737	6.0916	**42**	289.580	10.443	**72**	496.423
1.8855	**13**	89.632	6.2366	**43**	296.475	10.588	**73**	503.317
2.0305	**14**	96.527	6.3817	**44**	303.369	10.733	**74**	510.212
2.1756	**15**	103.421	6.5267	**45**	310.264	10.878	**75**	517.107
2.3206	**16**	110.316	6.6717	**46**	317.159	11.023	**76**	524.002
2.4656	**17**	117.211	6.8168	**47**	324.054	11.168	**77**	530.896
2.6107	**18**	124.106	6.9618	**48**	330.948	11.313	**78**	537.791
2.7557	**19**	131.000	7.1068	**49**	337.843	11.458	**79**	544.686
2.9008	**20**	137.895	7.2519	**50**	344.738	11.603	**80**	551.581
3.0458	**21**	144.790	7.3969	**51**	351.633	11.748	**81**	558.475
3.1908	**22**	151.685	7.5420	**52**	358.527	11.893	**82**	565.370
3.3359	**23**	158.579	7.6870	**53**	365.422	12.038	**83**	572.265
3.4809	**24**	165.474	7.8320	**54**	372.317	12.183	**84**	579.160
3.6259	**25**	172.369	7.9771	**55**	379.212	12.328	**85**	586.054
3.7710	**26**	179.264	8.1221	**56**	386.106	12.473	**86**	592.949
3.9160	**27**	186.158	8.2672	**57**	393.001	12.618	**87**	599.844
4.0611	**28**	193.053	8.4122	**58**	399.896	12.763	**88**	606.739
4.2061	**29**	199.948	8.5572	**59**	406.791	12.908	**89**	613.633
4.3511	**30**	206.843	8.7023	**60**	413.685	13.053	**90**	620.528

(CONTINUED)

CONVERSIONS

CONVERSION FOR STRESS VALUES KSI TO MPA

THE MIDDLE COLUMN OF FIGURES CONTAINS THE READINGS (IN MPa OR KSI) TO BE CONVERTED. IF CONVERTING FROM KSI TO MPa, READ THE MPa EQUIVALENT IN THE COLUMN HEADED "MPa". IF CONVERTING FROM MPa TO KSI, READ THE EQUIVALENT IN THE COLUMN HEADED "KSI".

KSI		MPA	KSI		MPA	KSI		MPA
13.343	**92**	634.318	47.862	**330**	2275.270	91.374	**630**	------
13.489	**93**	641.212	49.313	**340**	2344.217	92.824	**640**	------
13.634	**94**	648.107	50.763	**350**	2413.165	94.275	**650**	------
13.779	**95**	655.002	52.214	**360**	2482.113	95.725	**660**	------
13.924	**96**	661.897	53.664	**370**	2551.060	97.175	**670**	------
14.069	**97**	668.791	55.114	**380**	2620.008	98.626	**680**	------
14.214	**98**	675.686	56.565	**390**	2688.955	100.076	**690**	------
14.504	**100**	689.476	58.015	**400**	2757.903	101.526	**700**	------
15.954	**110**	758.423	59.465	**410**	2826.850	102.977	**710**	------
17.405	**120**	827.371	60.916	**420**	2895.798	104.427	**720**	------
18.855	**130**	896.318	62.366	**430**	2964.746	105.878	**730**	------
20.305	**140**	965.266	63.817	**440**	3033.693	107.328	**740**	------
21.756	**150**	1034.214	65.267	**450**	3102.641	108.778	**750**	------
23.206	**160**	1103.161	66.717	**460**	3171.588	110.229	**760**	------
24.656	**170**	1172.109	68.168	**470**	3240.536	111.679	**770**	------
26.107	**180**	1241.056	69.618	**480**	3309.483	113.129	**780**	------
27.557	**190**	1310.004	71.068	**490**	3378.431	114.580	**790**	------
29.008	**200**	1378.951	72.519	**500**	3447.379	116.030	**800**	------
30.458	**210**	1447.899	73.969	**510**	------	117.481	**810**	------
31.908	**220**	1516.847	75.420	**520**	------	118.931	**820**	------
33.359	**230**	1585.794	76.870	**530**	------	120.381	**830**	------
34.809	**240**	1654.742	78.320	**540**	------	121.832	**840**	------
36.259	**250**	1723.689	79.771	**550**	------	123.282	**850**	------
37.710	**260**	1792.637	81.221	**560**	------	124.732	**860**	------
39.160	**270**	1861.584	82.672	**570**	------	126.183	**870**	------
40.611	**280**	1930.532	84.122	**580**	------	127.633	**880**	------
42.061	**290**	1999.480	85.572	**590**	------	130.534	**900**	------
43.511	**300**	2068.427	87.023	**600**	------	131.984	**910**	------
44.962	**310**	2137.375	88.473	**610**	------	133.435	**920**	------
46.412	**320**	2206.322	89.923	**620**	------	134.885	**930**	------

(CONTINUED)

CONVERSIONS

CONVERSION FOR STRESS VALUES KSI TO MPA

THE MIDDLE COLUMN OF FIGURES CONTAINS THE READINGS (IN MPa OR KSI) TO BE CONVERTED. IF CONVERTING FROM KSI TO MPa, READ THE MPa EQUIVALENT IN THE COLUMN HEADED "MPa". IF CONVERTING FROM MPa TO KSI, READ THE EQUIVALENT IN THE COLUMN HEADED "KSI".

KSI		MPA	KSI		MPA	KSI		MPA
136.335	**940**	------	214.656	**1480**	------	304.579	**2100**	------
137.786	**950**	------	217.557	**1500**	------	307.480	**2120**	------
139.236	**960**	------	220.457	**1520**	------	310.381	**2140**	------
140.687	**970**	------	223.358	**1540**	------	313.282	**2160**	------
142.137	**980**	------	226.259	**1560**	------	316.182	**2180**	------
143.587	**990**	------	229.160	**1580**	------	319.083	**2200**	------
145.038	**1000**	------	232.060	**1600**	------	321.984	**2220**	------
147.938	**1020**	------	234.961	**1620**	------	324.885	**2240**	------
150.839	**1040**	------	237.862	**1640**	------	327.785	**2260**	------
153.740	**1060**	------	243.663	**1680**	------	330.686	**2280**	------
156.641	**1080**	------	246.564	**1700**	------	333.587	**2300**	------
159.542	**1100**	------	249.465	**1720**	------	336.488	**2320**	------
162.442	**1120**	------	252.366	**1740**	------	339.388	**2340**	------
165.343	**1140**	------	255.266	**1760**	------	342.289	**2360**	------
168.244	**1160**	------	258.167	**1780**	------	345.190	**2380**	------
171.145	**1180**	------	261.068	**1800**	------	348.091	**2400**	------
174.045	**1200**	------	263.969	**1820**	------	350.991	**2420**	------
176.946	**1220**	------	266.869	**1840**	------	353.892	**2440**	------
179.847	**1240**	------	269.770	**1860**	------	356.793	**2460**	------
182.748	**1260**	------	272.671	**1880**	------	359.694	**2480**	------
185.648	**1280**	------	275.572	**1900**	------	362.594	**2500**	------
188.549	**1300**	------	278.472	**1920**	------			
191.450	**1320**	------	281.373	**1940**	------			
194.351	**1340**	------	284.274	**1960**	------			
197.251	**1360**	------	287.175	**1980**	------			
200.152	**1380**	------	290.075	**2000**	------			
203.053	**1400**	------	292.976	**2020**	------			
205.954	**1420**	------	295.877	**2040**	------			
208.854	**1440**	------	298.778	**2060**	------			
211.755	**1460**	------	301.679	**2080**	------			

CONVERSIONS

HARDNESS CONVERSIONS

APPROXIMATE RELATIONS BETWEEN BRINELL, ROCKWELL, SHORE, VICKERS AND FIRTH HARDNESS AND THE TENSILE STRENGTHS OF S.A.E. CARBON AND CONSTRUCTIONAL STEELS

BRINELL		VICKERS OR FIRTH	ROCKWELL			
DIA. (MM) 3,000 KG. 10 MM. CARBIDE BALL	HARDNESS NUMBER	DIAMETER PYRAMID (50 KB. BRALE)	C SCALE (150 KG. BRALE)	B. SCALE 100 KG. 1/16" BALL	SHORE	TENSILE STRENGTH (X 1000 PSI)
------	------	940	68	------	97	------
------	------	860	66	------	92	------
2.30	712	800	64	------	88	------
2.35	682	737	62	------	85	------
2.40	653	697	60	------	81	------
2.50	601	677	59	------	80	328
2.55	578	640	57	------	77	309
2.60	555	591	55	120	73	285
2.65	534	579	54	119	71	279
2.70	514	547	52	119	70	263
2.75	495	528	51	117	68	253
2.80	477	508	50	117	67	247
2.85	461	494	49	116	66	237
2.90	444	472	47	115	63	225
2.95	429	455	46	115	61	217
3.00	415	440	45	114	59	212
3.05	401	425	43	113	58	200
3.10	388	410	42	112	56	196
3.15	375	396	40	112	54	186
3.20	363	383	39	110	52	181
3.25	352	372	38	110	51	177
3.30	341	360	37	109	50	174
3.35	331	350	36	109	48	168
3.40	321	339	34	108	47	158
3.45	311	328	33	108	46	154
3.50	302	319	32	107	45	150

(CONTINUED)

CONVERSIONS

HARDNESS CONVERSIONS

APPROXIMATE RELATIONS BETWEEN BRINELL, ROCKWELL, SHORE, VICKERS AND FIRTH HARDNESS AND THE TENSILE STRENGTHS OF S.A.E. CARBON AND CONSTRUCTIONAL STEELS

BRINELL		VICKERS OR FIRTH	ROCKWELL			
DIA. (MM) 3,000 KG. 10 MM. CARBIDE BALL	HARDNESS NUMBER	DIAMETER PYRAMID (50 KB. BRALE)	C SCALE (150 KG. BRALE)	B. SCALE 100 KG. 1/16" BALL	SHORE	TENSILE STRENGTH (X 1000 PSI)
3.55	293	309	31	106	43	146
3.60	285	301	30	105	42	142
3.65	277	292	29	104	41	138
3.70	262	276	27	103	39	131
3.75	255	269	25	102	38	125
3.80	248	261	24	101	37	121
3.85	241	253	23	100	36	119
3.90	235	247	22	99	35	117
4.00	229	241	21	98	34	113
4.05	223	234	18	97	33	110
4.10	217	228	18	96	33	107
4.15	212	222	16	95	32	102
4.20	207	218	15	95	32	100
4.25	202	212	14	94	31	98
4.30	197	207	13	93	30	96
4.35	192	202	12	92	29	94
4.40	187	196	10	91	------	90
4.45	183	192	9	90	28	89
4.50	179	188	8	89	27	87
4.55	174	182	6	88	------	84
4.60	170	178	5	87	26	82
4.65	166	175	4	86	------	80
4.70	163	171	3	85	25	78
4.75	159	167	2	84	------	77
4.80	156	163	1	83	24	76
4.85	153	160	------	82	------	75
4.90	149	156	------	81	23	74

(CONTINUED)

CONVERSIONS

HARDNESS CONVERSIONS

APPROXIMATE RELATIONS BETWEEN BRINELL, ROCKWELL, SHORE, VICKERS AND FIRTH HARDNESS AND THE TENSILE STRENGTHS OF S.A.E. CARBON AND CONSTRUCTIONAL STEELS

BRINELL		VICKERS OR FIRTH	ROCKWELL			
DIA. (MM) 3,000 KG. 10 MM. CARBIDE BALL	HARDNESS NUMBER	DIAMETER PYRAMID (50 KB. BRALE)	C SCALE (150 KG. BRALE)	B. SCALE 100 KG. 1/16" BALL	SHORE	TENSILE STRENGTH (X 1000 PSI)
4.95	146	153	------	80	------	72
5.00	143	150	------	79	22	71
5.05	140	147	------	78	------	70
5.10	137	143	------	76	21	67
5.15	134	140	------	75	------	66
5.20	131	137	------	74	------	65
5.25	128	134	------	73	------	64
5.30	126	132	------	72	20	63
5.35	124	129	------	71	------	62
5.40	121	127	------	70	19	60
5.45	118	124	------	69	------	59
5.50	116	122	------	68	18	58
5.55	114	119	------	67	------	57
5.60	111	117	------	66	15	56
5.65	109	------	------	65	------	------
5.70	107	------	------	64	------	------
5.75	105	------	------	62	------	------
5.80	103	------	------	61	------	------

CONVERSIONS

TENSILE STRENGTH CONVERSION

LBS. PER SQ. IN.	LONG TONS PER SQ. IN.	KG. PER SQ. MM.	LBS. PER SQ. IN.	LONG TONS PER SQ. IN.	KG. PER SQ. MM.
45,000	20.09	31.64	111,000	49.55	78.04
46,000	20.54	32.35	112,000	50.00	78.74
47,000	20.98	33.04	113,000	50.45	79.45
48,000	21.43	33.75	114,000	50.89	80.15
49,000	21.88	34.46	115,000	51.34	80.85
50,000	22.32	35.15	116,000	51.79	81.56
51,000	22.77	35.86	117,000	52.23	82.26
52,000	23.21	36.55	118,000	52.68	82.96
53,000	23.66	37.26	119,000	53.13	83.67
54,000	24.11	37.97	120,000	53.57	84.37
55,000	24.55	38.66	121,000	54.02	85.07
56,000	25.00	39.37	122,000	54.47	85.78
57,000	25.45	40.08	123,000	54.91	86.48
58,000	25.89	40.77	124,000	55.36	87.19
59,000	26.34	41.48	125,000	55.81	87.89
60,000	26.79	42.19	126,000	56.25	88.59
61,000	27.23	42.88	127,000	56.70	89.30
62,000	27.68	43.59	128,000	57.14	89.99
63,000	28.13	44.30	129,000	57.59	90.70
64,000	28.57	44.99	130,000	58.04	91.41
65,000	29.02	45.70	131,000	58.48	92.10
66,000	29.47	46.41	132,000	58.93	92.81
67,000	29.91	47.10	133,000	59.38	93.52
68,000	30.36	47.81	134,000	59.82	94.21
69,000	30.80	48.51	135,000	60.27	94.92
70,000	31.25	49.21	136,000	60.72	95.63
80,000	35.72	56.25	137,000	61.16	96.32
90,000	40.18	63.28	138,000	61.61	97.03
100,000	44.64	70.30	139,000	62.06	97.74
101,000	45.09	71.01	140,000	62.50	98.43
102,000	45.54	71.72	141,000	62.95	99.14
103,000	45.98	72.41	142,000	63.39	99.83
104,000	46.43	73.12	143,000	63.84	100.54
105,000	46.88	73.83	144,000	64.29	101.25
106,000	47.32	74.52	145,000	64.73	101.94
107,000	47.77	75.23	146,000	65.18	102.65
108,000	48.22	75.94	147,000	65.63	103.36
109,000	48.66	76.63	148,000	66.07	104.05
110,000	49.11	77.34	149,000	66.52	104.76

(CONTINUED)

CONVERSIONS

TENSILE STRENGTH CONVERSION

LBS. PER SQ. IN.	LONG TONS PER SQ. IN.	KG. PER SQ. MM.	LBS. PER SQ. IN.	LONG TONS PER SQ. IN.	KG. PER SQ. MM.
150,000	66.97	105.47	189,000	84.38	132.89
151,000	67.41	106.16	190,000	84.82	133.58
152,000	67.86	106.87	191,000	85.27	134.29
153,000	68.31	107.58	192,000	85.72	135.00
154,000	68.75	108.27	193,000	86.16	135.69
155,000	69.20	108.98	194,000	86.61	136.40
156,000	69.64	109.67	195,000	87.06	137.11
157,000	70.09	110.38	196,000	87.50	137.80
158,000	70.54	111.09	197,000	87.95	138.51
159,000	70.98	111.78	198,000	88.40	139.22
160,000	71.43	112.49	199,000	88.84	139.91
161,000	71.88	113.20	200,000	89.29	140.62
162,000	72.32	113.89	201,000	89.73	141.31
163,000	72.77	114.60	202,000	90.18	142.02
164,000	73.22	115.31	203,000	90.63	142.73
165,000	73.66	116.01	204,000	91.07	143.42
166,000	74.11	116.71	205,000	91.52	144.13
167,000	74.56	117.42	206,000	91.97	144.84
168,000	75.00	118.12	207,000	92.41	145.53
169,000	75.45	118.82	208,000	92.86	146.24
170,000	75.89	119.52	209,000	93.31	146.95
171,000	76.34	120.23	210,000	93.75	147.64
172,000	76.79	120.93	211,000	94.20	148.35
173,000	77.23	121.63	212,000	94.65	149.06
174,000	77.68	122.34	213,000	95.09	149.75
175,000	78.13	123.04	214,000	95.54	150.46
176,000	78.57	123.74	215,000	95.98	151.16
177,000	79.02	124.45	216,000	96.43	151.87
178,000	79.47	125.16	217,000	96.88	152.57
179,000	79.91	125.85	218,000	97.32	153.27
180,000	80.36	126.56	219,000	97.77	153.98
181,000	80.81	127.27	220,000	98.22	154.68
182,000	81.25	127.96	221,000	98.66	155.38
183,000	81.70	128.67	222,000	99.11	156.09
184,000	82.14	129.36	223,000	99.56	156.79
185,000	82.59	130.07	224,000	100.00	157.49
186,000	83.04	130.78	225,000	100.45	158.20
187,000	83.48	131.47	226,000	100.90	158.90
188,000	83.93	132.18	227,000	101.34	159.60

(CONTINUED)

CONVERSIONS

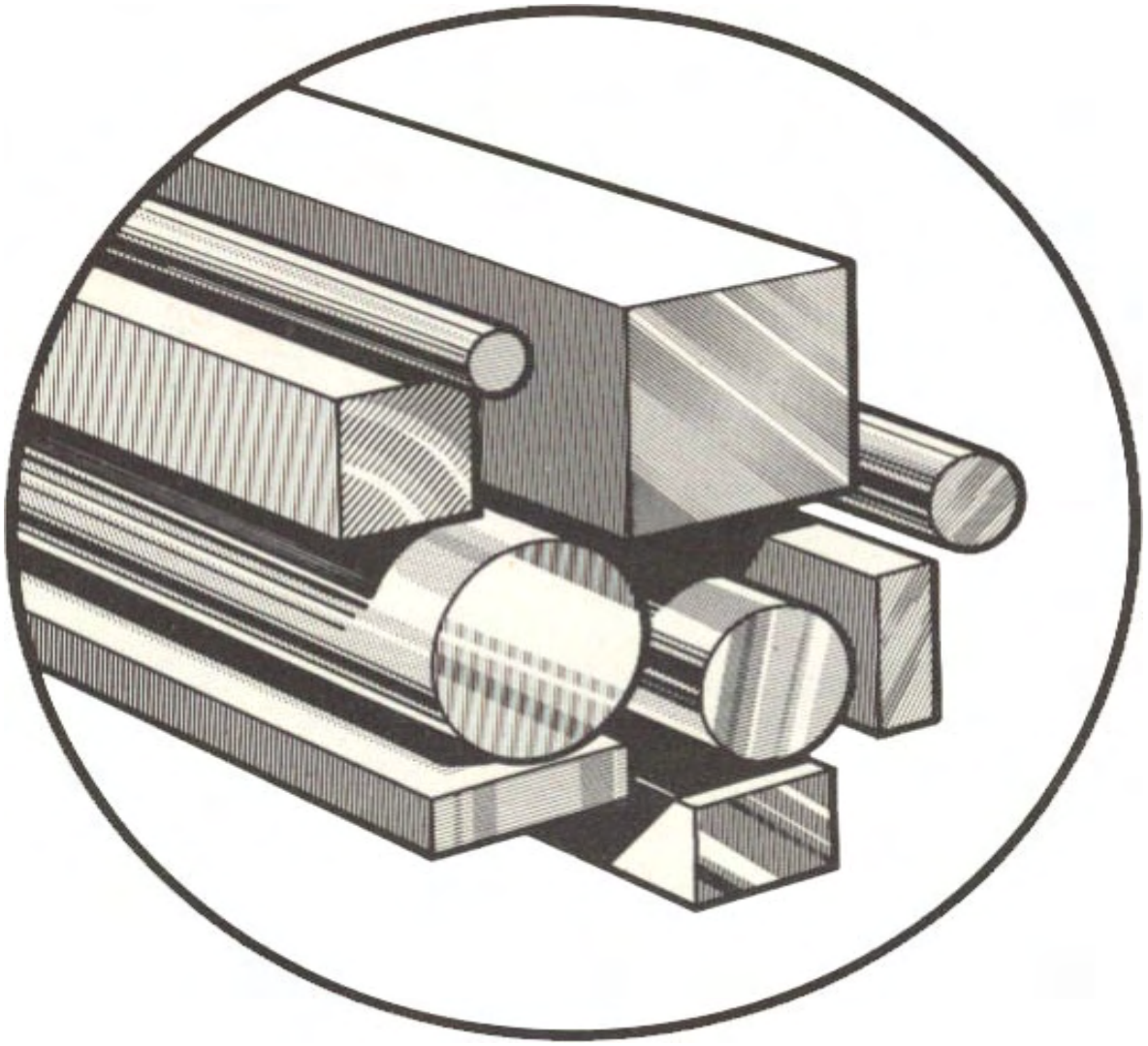
TENSILE STRENGTH CONVERSION

LBS. PER SQ. IN.	LONG TONS PER SQ. IN.	KG. PER SQ. MM.	LBS. PER SQ. IN.	LONG TONS PER SQ. IN.	KG. PER SQ. MM.
228,000	101.79	160.31	264,000	117.86	185.61
229,000	102.23	161.00	265,000	118.31	186.32
230,000	102.68	161.71	266,000	118.75	187.02
231,000	103.13	162.42	267,000	119.20	187.73
232,000	103.57	163.11	268,000	119.65	188.43
230,000	102.68	161.71	269,000	120.09	189.13
231,000	103.13	162.42	270,000	120.54	189.84
232,000	103.57	163.11	271,000	120.99	190.54
233,000	104.02	163.82	272,000	121.43	191.24
234,000	104.47	164.53	273,000	121.88	191.95
235,000	104.91	165.22	274,000	122.32	192.64
236,000	105.36	165.93	275,000	122.77	193.35
237,000	105.81	166.64	276,000	123.22	194.06
238,000	106.25	167.33	277,000	123.66	194.75
239,000	106.70	168.04	278,000	124.11	195.46
240,000	107.15	168.75	279,000	124.56	196.17
241,000	107.59	169.44	280,000	125.00	196.86
242,000	108.04	170.15	281,000	125.45	197.57
243,000	108.48	170.84	282,000	125.90	198.28
244,000	108.93	171.55	283,000	126.34	198.97
245,000	109.38	172.26	284,000	126.79	199.68
246,000	109.82	172.95	285,000	127.24	200.39
247,000	110.27	173.66	286,000	127.68	201.08
248,000	110.72	174.37	287,000	128.13	201.79
249,000	111.16	175.06	288,000	128.57	202.48
250,000	111.61	175.77	289,000	129.02	203.19
251,000	112.06	176.48	290,000	129.47	203.90
252,000	112.50	177.17	291,000	129.91	204.59
253,000	112.95	177.88	292,000	130.36	205.30
254,000	113.40	178.59	293,000	130.81	206.01
255,000	113.84	179.28	294,000	131.25	206.70
256,000	114.29	179.99	295,000	131.70	207.41
257,000	114.74	180.70	296,000	132.15	208.12
258,000	115.18	181.39	297,000	132.59	208.81
259,000	115.63	182.10	298,000	133.04	209.52
260,000	116.07	182.80	299,000	133.49	210.23
261,000	116.52	183.50	300,000	133.93	210.92
262,000	116.97	184.21			
263,000	117.41	184.91			

VANGUARD STEEL LTD.

PRODUCT MANUAL

SECTION 12.
GLOSSARY OF TERMS



GLOSSARY OF TERMS

ABRASION:
THE PROCESS OF RUBBING, GRINDING, OR WEARING AWAY BY FRICTION.

ACID STEEL:
STEEL MELTED IN A FURNACE WITH AN ACID BOTTOM AND LINING AND UNDER A SLAG CONTAINING AN EXCESS OF AN ACID SUBSTANCE THAT IS DOMINANTLY SILICEOUS.

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.

AGE HARDENING:
HARDENING BY AGING, USUALLY AFTER RAPID COOLING OR COLD WORKING. AGE HARDENING INCREASES HARDNESS AND STRENGTH AND ORDINARILY DECREASES DUCTILITY.

AIR-HARDENING STEEL:
A STEEL CONTAINING SUFFICIENT CARBON AND OTHER ALLOYING ELEMENTS TO HARDEN FULLY DURING COOLING IN AIR OR OTHER GASEOUS MEDIUMS FROM A TEMPERATURE ABOVE ITS TRANSFORMATION RANGE. THE TERM SHOULD BE RESTRICTED TO STEELS THAT ARE CAPABLE OF BEING HARDENED BY COOLING IN AIR IN FAIRLY LARGE SECTIONS, ABOUT 2 INCHES OR MORE IN DIAMETER. ALSO CALLED SELF-HARDENING STEEL.

ALLOY STEEL:
STEEL CONTAINING SIGNIFICANT QUANTITIES OF ALLOYING ELEMENTS (OTHER THAN CARBON AND THE COMMONLY ACCEPTED AMOUNTS OF MANGANESE, SILICON, SULFUR AND PHOSPHORUS) ADDED TO EFFECT CHANGES IN THE MECHANICAL OR PHYSICAL PROPERTIES.

ALUMINIZING:
ENRICHMENT OF SURFACE LAYER WITH ALUMINUM BY THERMOCHEMICAL TREATMENT.

(CONTINUED)

GLOSSARY OF TERMS

ANNEALING:
HEATING TO AND HOLDING AT A SUITABLE TEMPERATURE AND THEN COOLING AT A SUITABLE RATE, FOR SUCH PURPOSES AS REDUCING HARDNESS, IMPROVING MACHINABILITY, FACILITATING COLD WORKING, PRODUCING A DESIRED MICROSTRUCTURE, OR OBTAINING DESIRED MECHANICAL, PHYSICAL, OR OTHER PROPERTIES. WHEN APPLICABLE, THE FOLLOWING MORE SPECIFIC TERMS SHOULD BE USED: BLACK ANNEALING, BLUE ANNEALING, BOX ANNEALING, BRIGHT ANNEALING, FLAME ANNEALING, GRAPHITIZING, INTERMEDIATE ANNEALING, ISOTHERMAL ANNEALING, MALLEABLIZING, PROCESS ANNEALING, QUENCH ANNEALING, RECRYSTALLIZATION ANNEALING AND SPHEROIDIZING. WHEN APPLIED TO FERROUS ALLOYS, THE TERM "ANNEALING", WITHOUT QUALIFICATION, IMPLIES FULL ANNEALING. WHEN APPLIED TO NONFERROUS ALLOYS, THE TERM "ANNEALING" IMPLIES A HEAT TREATMENT DESIGNED TO SOFTEN A COLD WORKED STRUCTURE BY RECRYSTALLIZATION OR SUBSEQUENT GRAIN GROWTH OR TO SOFTEN AN AGE-HARDENED ALLOY BY CAUSING A NEARLY COMPLETE PRECIPITATION OF THE SECOND PHASE IN RELATIVELY COARSE FORM. ANY PROCESS OF ANNEALING WILL USUALLY REDUCE STRESSES, BUT IF THE TREATMENT IS APPLIED FOR THE SOLE PURPOSE OF SUCH RELIEF, IT SHOULD BE DESIGNATED "STRESS RELIEVING".

ARTIFICIAL AGING:
AN AGING TREATMENT ABOVE ROOM TEMPERATURE.

AUSTEMPERING:
QUENCHING A FERROUS ALLOY FROM A TEMPERATURE ABOVE THE TRANSFORMATION RANGE, IN A MEDIUM HAVING A RATE OF HEAT ABSTRACTION HIGH ENOUGH TO PREVENT THE FORMATION OF HIGH TEMPERATURE TRANSFORMATION PRODUCTS AND THEN HOLDING THE ALLOY, UNTIL TRANSFORMATION IS COMPLETE, AT A TEMPERATURE BELOW THAT OF PEARLITE FORMATION AND ABOVE THAT OF MARTENSITE FORMATION.

AUSTENITE:
A SOLID SOLUTION OF ONE OR MORE ELEMENTS IN FACE-CENTERED CUBIC IRON.

AUSTENITIZING:
FORMING AUSTENITE BY HEATING A FERROUS ALLOY INTO THE TRANSFORMATION RANGE (COMPLETE AUSTENITIZING). WHEN USED WITHOUT QUALIFICATION, THE TERM IMPLIES COMPLETE AUSTENITIZING.

BAKING:
HEATING TO A LOW TEMPERATURE IN ORDER TO REMOVE GASES.

(CONTINUED)

GLOSSARY OF TERMS

BANDED STRUCTURE:
A SEGREGATED STRUCTURE OF NEARLY PARALLEL BAND ALIGNED IN THE DIRECTION OF WORKING.

BARK:
THE DECARBURIZED LAYER JUST BENEATH THE SCALE THAT RESULTS FROM HEATING STEEL IN AN OXIDIZING ATMOSPHERE.

BASIC STEEL:
STEEL MELTED IN A FURNACE WITH A BASIC BOTTOM AND LINING, AND UNDER A SLAG CONTAINING AN EXCESS OF A BASIC SUBSTANCE.

BEND TESTS:
VARIOUS TESTS USED FOR DETERMINING RELATIVE DUCTILITY OF METAL THAT IS TO BE FORMED, USUALLY SHEET, STRIP, PLATE OR WIRE, AND FOR DETERMINING SOUNDNESS AND TOUGHNESS OF METAL. THE SPECIMEN IS USUALLY BENT OVER A SPECIFIED DIAMETER THROUGH A SPECIFIED DIAMETER THROUGH A SPECIFIED ANGLE FOR A SPECIFIED NUMBER OF CYCLES.

BESSEMER PROCESS:
A PROCESS FOR MAKING STEEL BY BLOWING AIR THROUGH MOLTEN PIG IRON CONTAINED IN A REFRACTORY LINED VESSEL SO AS TO REMOVE BY OXIDATION MOST OF THE CARBON, SILICON, AND MANGANESE.

BILLET:
A SOLID SEMIFINISHED ROUND OR SQUARE PRODUCT THAT HAS BEEN HOT WORKED BY FORGING, ROLLING, OR EXTRUSION. AN IRON OR STEEL BILLET HAS A MINIMUM WIDTH OR THICKNESS OF 1-1/2 INCH AND THE CROSS-SECTIONAL AREA VARIES FROM 2-1/4 TO 36 SQUARE INCH. FOR NONFERROUS METALS, IT MAY ALSO BE A CASTING SUITABLE FOR FINISHED OR SEMIFINISHED ROLLING OR FOR EXTRUSION.

BLANKING:
SHEARING OUT A PIECE OF SHEET METAL IN PREPARATION FOR DEEP DRAWING.

BLANK CARBURIZING: (NITRIDING)
THE CARBURIZING (NITRIDING) HEATING CYCLE APPLIED TO A TEST SPECIMEN BUT CONDUCTED WITHOUT THE CARBURIZING (NITRIDING) MEDIUM.

(CONTINUED)

GLOSSARY OF TERMS

BLANK HARDENING TEST:
HARDENING OF NON-CARBURIZED SPECIMEN FOR ROUGH DETERMINATION OF MECHANICAL PROPERTIES OBTAINABLE IN THE NON-CARBURIZED REGION OF CASE HARDENED WORKPIECES.

BLISTER:
A DEFECT IN METAL, ON OR NEAR THE SURFACE, RESULTING FROM THE EXPANSION OF GAS IN A SUBSURFACE ZONE. VERY SMALL BLISTERS ARE CALLED "PINHEADS" OR "PEPPER BLISTERS".

BLOOM:
A SEMIFINISHED HOT ROLLED PRODUCT, RECTANGULAR IN CROSS-SECTION, PRODUCED ON A BLOOMING MILL. FOR IRON AND STEEL, THE WIDTH IS NOT MORE THAN TWICE THE THICKNESS, AND THE CROSS-SECTIONAL AREA IS USUALLY NOT LESS THAN 36 SQUARE INCHES. IRON AND STEEL BLOOMS ARE SOMETIMES MADE BY FORGING.

BLOWHOLE:
A HOLE PRODUCED IN A CASTING WHEN GAS, ENTRAPPED WHILE THE MOLD IS BEING FILLED, OR EVOLVED DURING THE SOLIDIFICATION OF METAL, FAILS TO ESCAPE AND IS HELD IN POCKETS.

BLUE ANNEALING:
HEATING HOT ROLLED FERROUS SHEETS IN AN OPEN FURNACE TO A TEMPERATURE WITHIN THE TRANSFORMATION RANGE AND THEN COOLING IN AIR, IN ORDER TO SOFTEN THE METAL. THE FORMATION OF A BLUISH OXIDE ON THE SURFACE IS INCIDENTAL.

BLUE BRITTLENESS:
BRITTLENESS EXHIBITED BY SOME STEELS AFTER BEING HEAT TREATED TO SOME TEMPERATURE WITHIN THE RANGE OF 150-340°C, AND MORE ESPECIALLY IF THE STEEL IS WORKED AT AN ELEVATED TEMPERATURE.

BORON TREATMENT:
ENRICHMENT OF SURFACE LAYER WITH BORON BY THERMOCHEMICAL TREATMENT.

(CONTINUED)

GLOSSARY OF TERMS

BOX ANNEALING:
ANNEALING A METAL OR ALLOY IN A SEALED CONTAINER UNDER CONDITIONS THAT MINIMIZE OXIDATION. IN BOX ANNEALING A FERROUS ALLOY, THE CHARGE IS USUALLY HEATED SLOWLY TO A TEMPERATURE BELOW THE TRANSFORMATION RANGE, BUT SOMETIMES ABOVE OR WITHIN IT, AND IS THEN COOLED SLOWLY; THIS PROCESS IS ALSO CALLED "CLOSE ANNEALING" OR "POT ANNEALING".

BRAZING:
JOINING METALS BY FUSION OR NONFERROUS ALLOYS THAT HAVE MELTING POINTS ABOVE 428º C BUT LOWER THAN THOSE OF THE METALS BEING JOINED. THIS MAY BE ACCOMPLISHED BY MEANS OF A TORCH (TORCH BRAZING), IN A FURNACE (FURNACE BRAZING). THE FILLER METAL IS ORDINARILY IN ROD FORM IN TORCH BRAZING; WHEREAS IN FURNACE AND DIP BRAZING THE WORK MATERIAL IS FIRST ASSEMBLED AND THE FILLER METAL MAY THEN BE APPLIED AS WIRE, WASHERS, CLIPS, BANDS, OR MAY BE INTEGRALLY BONDED, AS IN BRAZING SHEET.

BRIGHT ANNEALING:
ANNEALING IN A PROTECTIVE MEDIUM TO PREVENT DISCOLORATION OF THE BRIGHT SURFACE.

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:
FRACTURE WITH LITTLE OR NO PLASTIC DEFORMATION.

BRITTLENESS:
A TENDENCY TO FRACTURE WITHOUT APPRECIABLE DEFORMATION.

BURNING:
1. PERMANENTLY DAMAGING A METAL OR AN 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.

(CONTINUED)

GLOSSARY OF TERMS

CAMBER:
DEVIATION FROM EDGE STRAIGHTNESS, USUALLY REFERRING TO THE GREATEST DEVIATION OF SIDE EDGE FROM A STRAIGHT LINE.

CAPPED STEEL:
SEMIKILLED STEEL CAST IN A BOTTLE-TOP MOLD AND COVERED WITH A CAP FITTING INTO THE NECK OF THE MOLD. THE CAP CAUSES THE TOP METAL TO SOLIDIFY. PRESSURE IS BUILT UP IN THE SEALED-IN MOLTEN METAL AND RESULTS IN A SURFACE CONDITION MUCH LIKE THAT OF RIMMED STEEL.

CARBIDE:
A COMPOUND OF CARBON WITH ONE OR MORE METALLIC ELEMENTS.

CARBON CHARACTERISTIC:
CARBON CONTENT AS A FUNCTION OF DISTANCE TO A REFERENCE POINT.

CARBON POTENTIAL:
A MEASURE OF THE ABILITY OF AN ENVIRONMENT CONTAINING ACTIVE CARBON TO ALTER OR MAINTAIN, UNDER PRESCRIBED CONDITIONS, THE CARBON CONTENT OF THE STEEL EXPOSED TO IT.
NOTE: IN ANY PARTICULAR ENVIRONMENT, THE CARBON LEVEL ATTAINED WILL DEPEND ON SUCH FACTORS AS TEMPERATURE, TIME AND STEEL COMPOSITION.

CARBON RESTORATION:
REPLACING THE CARBON LOST IN THE SURFACE LAYER FROM PREVIOUS PROCESSING BY CARBURIZING THIS LAYER TO THE ORIGINAL CARBON LEVEL.

CARBONITRIDING:
INTRODUCING CARBON AND NITROGEN INTO THE SURFACE OF A STEEL BAR BY HEATING IT IN AN ATMOSPHERE THAT CONTAINS SUITABLE GASES SUCH AS HYDROCARBONS, CARBON MONOXIDE AND AMMONIA. THE CARBONITRIDED ALLOY IS USUALLY QUENCH HARDENED.

CARBON STEEL:
STEEL CONTAINING CARBON UP TO ABOUT 2% AND ONLY RESIDUAL QUANTITIES OF OTHER ELEMENTS EXCEPT THOSE ADDED FOR DEOXIDIZATION, WITH SILICON USUALLY LIMITED TO 0.60 % AND MANGANESE TO ABOUT 1.65 %. ALSO TERMED "PLAIN CARBON STEEL", "ORDINARY STEEL", AND "STRAIGHT CARBON STEEL".

(CONTINUED)

GLOSSARY OF TERMS

CARBURIZING:
A PROCESS THAT INTRODUCES CARBON INTO A SOLID FERROUS ALLOY BY HEATING THE METAL IN CONTACT WITH A CARBONACEOUS MATERIAL IN SOLID, LIQUID, OR GASEOUS FORM. THE PROCESS IS GENERALLY FOLLOWED BY QUENCHING TO PRODUCE A HARDENED CASE.

CASE:
IN A FERROUS ALLOY, THE OUTER PORTION THAT HAS BEEN MADE HARDER THAN THE INNER PORTION OR CORE BY CASE HARDENING.

CASE DEPTH:
DISTANCE FROM THE SURFACE OF A CASE HARDENED PIECE TO THAT POINT AT WHICH THE HARDNESS CORRESPONDS TO A DEFINED LIMITING VALUE.

CASE HARDENING:
A PROCESS OF HARDENING A FERROUS ALLOY SO THAT THE SURFACE LAYER OR CASE IS MADE SUBSTANTIALLY HARDER THAN THE INNER PORTION OR CORE. TYPICAL PROCESSES USED FOR CASE HARDENING ARE CARBURIZING, CYANIDING, CARBONITRIDING NITRIDING, INDUCTION HARDENING AND FLAME HARDENING.

CAST IRON:
AN IRON CONTAINING CARBON IN EXCESS OF THE SOLUBILITY IN THE AUSTENITE THAT EXISTS IN THE ALLOY AT THE EUTECTIC TEMPERATURE.

CAST STEEL:
ANY OBJECT MADE BY POURING MOLTEN STEEL INTO MOLDS.

CEMENTATION:
THE INTRODUCTION OF ONE OR MORE ELEMENTS INTO THE OUTER PORTION OF A METAL OBJECT BY MEANS OF DEFUSION AT HIGH TEMPERATURE.

CEMENTITE:
A COMPOUND OF IRON AND CARBON, KNOWN CHEMICALLY AS IRON CARBIDE AND HAVING THE APPROXIMATE CHEMICAL FORMULA Fe3C. 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.

(CONTINUED)

GLOSSARY OF TERMS

CENTRIFUGAL CASTING:
A CASTING MADE BY POURING METAL INTO A MOLD THAT IS ROTATED OR REVOLVED.

CERAMIC TOOLS:
CUTTING TOOLS MADE FROM FUSED, SINTERED, OR CEMENTED METALLIC OXIDES.

CHAMFER:
1. A BEVELED SURFACE TO ELIMINATE AN OTHERWISE SHARP CORNER.
2. A RELIEVED ANGULAR CUTTING EDGE AT A TOOTH CORNER.

CHARGE:
1. THE LIQUID AND SOLID MATERIALS FED INTO A FURNACE FOR ITS OPERATION.
2. WEIGHTS OF VARIOUS LIQUID AND SOLID MATERIALS PUT INTO A FURNACE DURING ONE FEEDING CYCLE.

CHARPY TEST:
A PENDULUM-TYPE SINGLE-BLOW IMPACT TEST IN WHICH THE SPECIMEN USUALLY NOTCHED, IS SUPPORTED AT BOTH ENDS AS A SIMPLE BEAM AND BROKEN BY A FALLING PENDULUM. THE ENERGY ABSORBED, AS DETERMINED BY THE SUBSEQUENT RISE OF THE PENDULUM, IS A MEASURE OF IMPACT STRENGTH OR NOTCH TOUGHNESS.

CHECK ANALYSIS:
CHEMICAL ANALYSIS MADE OF DRILLINGS TAKEN FROM SEMI-FINISHED OR FINISHED PRODUCTS. THE UNITS ARE SUBJECT TO CERTAIN SPECIFIED VARIATIONS FROM THE LADLE ANALYSIS.

CHEMICAL MILLING:
REMOVING METAL STOCK BY CONTROLLED SELECTIVE CHEMICAL ETCHING.

CHROMIZING:
ENRICHMENT OF SURFACE LAYER WITH CHROMIUM BY THERMOCHEMICAL TREATMENT.

CLINK:
INTERNAL CRACK, USUALLY RESULTING FROM IMPROPER HEATING OF COLD STEEL.

(CONTINUED)

GLOSSARY OF TERMS

CLAD METAL:
A COMPOSITE METAL CONTAINING TWO OR THREE LAYERS THAT HAVE BEEN BONDED TOGETHER. THE BONDING MAY HAVE BEEN ACCOMPANIED BY COROLLING, WELDING, CASTING, HEAVY CHEMICAL DEPOSITION, OR HEAVY ELECTROPLATING.

COIL BREAKS:
CREASES OR RIDGES ACROSS A METAL SHEET TRANSVERSE TO THE DIRECTION OF COILING, OCCASIONALLY OCCURRING WHEN THE METAL HAS BEEN COILED HOT AND UNCOILED COLD.

COLD DRAWING:
THE SIZING OF A PROPERLY PREPARED BAR BY DRAWING IT THROUGH A DIE.

COLD SHORT:
A CONDITION OF BRITTLENESS EXISTING IN SOME METALS AT TEMPERATURES BELOW THE RECRYSTALIZATION TEMPERATURE.

COLD SHUT:
1. A DISCONTINUITY THAT APPEARS ON THE SURFACE OF CAST METAL AS A RESULT OF TWO STREAMS OF LIQUID MEETING AND FAILING TO UNITE.
2. A PORTION OF THE SURFACE OF A FORGING THAT IS SEPARATED, IN PART, FROM THE MAIN BODY OF METAL BY OXIDE.

COLD TREATMENT:
EXPOSING TO SUITABLE SUB-ZERO TEMPERATURES FOR THE PURPOSE OF OBTAINING DESIRED CONDITIONS OR PROPERTIES, SUCH AS DIMENSIONAL OR MICROSTRUCTURAL STABILITY. WHEN THE TREATMENT INVOLVES THE TRANSFORMATION OF RETAINED AUSTENITE, IT IS USUALLY FOLLOWED BY A TEMPERING TREATMENT.

COLD WORK:
PLASTIC DEFORMATION AT SUCH TEMPERATURES AND RATES THAT SUBSTANTIAL INCREASES OCCUR IN THE STRENGTH AND HARDNESS OF THE METAL.

COLD WORKING:
DEFORMING METAL PLASTICALLY AT A TEMPERATURE LOWER THEN THE RECRYSTALLIZATION TEMPERATURE.

(CONTINUED)

GLOSSARY OF TERMS

COLUMNAR STRUCTURE:
A COARSE STRUCTURE OF PARALLEL COLUMNS OF GRAINS, HAVING THE LONG AXIS PERPENDICULAR TO THE CASTING SURFACE.

COMBINED CARBON:
CARBON THAT IS COMBINED WITH IRON OR ALLOYING ELEMENTS TO FORM CARBIDE IN CAST IRON OR STEEL.

COMPRESSIVE STRENGTH:
THE MAXIMUM COMPRESSIVE STRESS THAT A MATERIAL IS CAPABLE OF DEVELOPING, BASED ON AREA OF CROSS-SECTION.

CONDITIONING:
THE REMOVAL OF SURFACE DEFECTS (SEAMS, LAPS, PITS, ETC..) FROM STEEL. CONDITIONING IS USUALLY DONE WHEN THE STEEL IS IN THE SEMIFINISHED CONDITION (BLOOMS, BILLETS, SLABS). IT MAY BE ACCOMPLISHED BY CHIPPING, SCARFING, GRINDING OR MACHINING.

CONTINUOUS CASTING:
A CASTING TECHNIQUE IN WHICH AN INGOT, BILLET, TUBE, OR OTHER SHAPE IS CONTINUOUSLY SOLIDIFIED WHILE IT IS BEING POURED, SO THAT ITS LENGTH IS NOT DETERMINED BY MOLD DIMENSION.

CONTROLLED ATMOSPHERE:
GASEOUS MEDIUM, IN WHICH CONCENTRATION, TEMPERATURE AND PRESSURE OF INDIVIDUAL CONSTITUENTS IS HELD WITHIN GIVE LIMITS, IN ORDER TO BRING ABOUT, LESSEN OR AVOID CERTAIN REACTIONS BETWEEN THE CONSTITUENTS AND THE WORKPIECE BEING TREATED (REDUCTION, OXIDATION, CARBURIZATION, DECARBURIZATION)

CONTROLLED COOLING:
COOLING FROM AN ELEVATED TEMPERATURE IN A PREDETERMINED MANNER, TO AVOID HARDENING, CRACKING, OR INTERNAL DAMAGE, OR TO PRODUCE A DESIRED MICROSTRUCTURE OR MECHANICAL PROPERTIES. THE TERM APPLIES TO COOLING FOLLOWING HOT WORKING.

(CONTINUED)

GLOSSARY OF TERMS

COOLING STRESS:
STRESSES DEVELOPED BY UNEVEN CONTRACTION OR EXTERNAL CONSTRAINT OF METAL DURING COOLING. STRESSES RESULTING FROM LOCALIZED PLASTIC DEFORMATION DURING COOLING, AND RETAINED.

CORE:
IN A CASE HARDENED OR SURFACE HARDENED FERROUS ALLOY, THE INNER PORTION THAT IS SOFTER THAN THE OUTSIDE PORTION OR CASE.

CORE HARDENING:
HARDENING OF A WORKPIECE WHICH HAS BEEN CARBURIZED AND SUBSEQUENTLY COOLED BELOW Ac1 OF THE CORE, FROM THE HARDENING TEMPERATURE OF THE CORE.

CORROSION:
A GRADUAL CHEMICAL OR ELECTROCHEMICAL ATTACK ON A METAL BY ATMOSPHERE, MOISTURE, OR OTHER AGENTS.

CORROSION EMBRITTLEMENT:
THE SEVERE LOSS OF DUCTILITY OF A METAL RESULTING FROM CORROSIVE ATTACK, USUALLY INTERGRANULAR AND OFTEN NOT VISUALLY APPARENT.

CORROSION FATIGUE:
EFFECT OF THE APPLICATION OF REPEATED OR FLUCTUATING STRESSES IN A CORROSIVE ENVIRONMENT CHARACTERIZED BY SHORTER LIFE THAN WOULD BE ENCOUNTERED AS A RESULT OF EITHER THE REPEATED OR FLUCTUATING STRESSES ALONE OR THE CORROSIVE ENVIRONMENT ALONE.

CREEP:
THE FLOW OR PLASTIC DEFORMATION OF METALS HELD FOR A LONG PERIOD OF TIME AT STRESSES LOWER THAN THE NORMAL YIELD STRENGTH.

CREEP LIMIT:
1. THE MAXIMUM STRESS THAT WILL CAUSE LESS THAN A SPECIFIED QUANTITY OF CREEP IN A GIVEN TIME.
2. THE MAXIMUM NOMINAL STRESS UNDER WHICH THE CREEP STRAIN RATE DECREASES CONTINUOUSLY WITH TIME UNDER CONSTANT LOAD AND AT CONSTANT TEMPERATURE. SOMETIMES USED SYNONYMOUSLY WITH CREEP STRENGTH.

(CONTINUED)

GLOSSARY OF TERMS

CREEP STRENGTH:
1. THE CONSTANT NOMINAL STRESS THAT WILL CAUSE A SPECIFIED QUANTITY OF CREEP IN A GIVEN TIME AT CONSTANT TEMPERATURE.
2. THE CONSTANT NOMINAL STRESS THAT WILL CAUSE A SPECIFIED CREEP RATE AT A CONSTANT TEMPERATURE.

CRITICAL COOLING RATE:
THE MINIMUM RATE OF CONTINUOUS COOLING TO PREVENT UNDESIRABLE TRANSFORMATIONS. FOR STEEL IT IS THE MINIMUM RATE AT WHICH AUSTENITE MUST BE CONTINUOUSLY COOLED TO SUPPRESS TRANSFORMATIONS ABOVE THE Ms TEMPERATURE.

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 AND PRESSURE, OR COMBINATIONS THEREOF, AT WHICH THE PHASES OF A HETEROGENEOUS SYSTEMS ARE IN EQUILIBRIUM.

CRITICAL STRAIN:
THE PERCENTAGE STRAIN AT WHICH, OR IMMEDIATELY HIGHER THEN WHICH, LARGE GRAIN GROWTH OCCURS DURING HEATING.

CROSS ROLLING:
THE ROLLING OF SHEET SO THAT THE DIRECTION OF ROLLING IS CHANGED ABOUT 90º FROM THE DIRECTION OF THE PREVIOUS ROLLING.

CROWN:
A CONTOUR ON A SHEET OR ROLL WHERE THE THICKNESS OR DIAMETER INCREASES FROM EDGE TO CENTER.

CRYSTAL:
A PHYSICALLY HOMOGENEOUS SOLID IN WHICH THE ATOMS, IONS OR MOLECULES ARE ARRANGED IN A THREE DIMENSIONAL REPETITIVE PATTERN.

CUP FRACTURE (CUP AND CONE FRACTURE)
FRACTURE, FREQUENTLY SEEN IN TENSILE TEST PIECES OF A DUCTILE MATERIAL, IN WHICH THE SURFACE OF FAILURE ON ONE PORTION SHOWS A CENTRAL FLAT AREA OF FAILURE IN TENSION, WITH AN EXTERIOR EXTENDED RIM OF FAILURE IN SHEAR.

(CONTINUED)

GLOSSARY OF TERMS

CUTTING SPEED:
THE LINEAR OR PERIPHERAL SPEED OF RELATIVE MOTION BETWEEN THE TOOL AND WORKPIECE IN THE PRINCIPLE DIRECTION OF CUTTING.

CYANIDING:
A CASE HARDENING PROCESS IN WHICH A FERROUS MATERIAL IS HEATED ABOVE THE LOWER TRANSFORMATION RANGE IN 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.

CYCLE ANNEALING:
AN ANNEALING PROCESS EMPLOYING A PREDETERMINED AND CLOSELY CONTROLLED TIME-TEMPERATURE CYCLE TO PRODUCE SPECIFIC PROPERTIES OR MICROSTRUCTURE.

DECARBURIZATION:
THE LOSS OF CARBON FROM THE SURFACE OF A FERROUS ALLOY AS A RESULT OF HEATING IN A MEDIUM THAT REACTS WITH THE CARBON .

DEFECT:
INTERNAL OR EXTERNAL FLAW OR BLEMISH. HARMFUL DEFECTS CAN RENDER MATERIAL UNSUITABLE FOR SPECIFIC END USE.

DEOXIDATION:
ELIMINATION OF OXYGEN IN LIQUID STEEL, USUALLY BY INTRODUCTION OF ALUMINUM OR SILICON OR OTHER SUITABLE ELEMENT. THIS TERM IS ALSO USED TO DENOTE REDUCTION OF SURFACE SCALE (IRON OXIDE).

DESCALING:
REMOVING THE LAYER OF OXIDES FORMED ON SOME METALS AT ELEVATED TEMPERATURES. DESCALING IS DONE BY EITHER PICKLING OR MECHANICAL DESCALING. PICKLING IS DONE IN A SOLUTION OF SULPHURIC ACID. MECHANICAL DESCALING IS DONE WITH THE AID OF AN ABRASIVE MATERIAL. THE ABRASIVE SHOT IS IMPELLED TOWARD THE HOT ROLLED SURFACE AND THUS EFFECTIVELY REMOVING THE OXIDE LAYER.

(CONTINUED)

GLOSSARY OF TERMS

DIFFERENTIAL HEATING:
HEATING THAT INTENTIONALLY PRODUCES A TEMPERATURE GRADIENT WITHIN AN OBJECT SUCH THAT, AFTER COOLING, A DESIRED STRESS DISTRIBUTION OR VARIATION IN PROPERTIES IS PRESENT WITHIN THE OBJECT.

DIFFUSION ANNEALING:
ANNEALING IMMEDIATELY BELOW SOLIDUS TEMPERATURE AND EXTENDED HOLDING AT THAT TEMPERATURE TO REDUCE LOCAL DEVIATIONS IN CHEMICAL COMPOSITION.

DIFFUSION COATING:
ANY PROCESS WHEREBY A BASIS METAL OR ALLOY IS EITHER:
1. COATED WITH ANOTHER METAL AND HEATED TO A SUFFICIENT TEMPERATURE IN SUITABLE ENVIRONMENT.
2. EXPOSED TO A GASEOUS OR LIQUID MEDIUM CONTAINING THE OTHER METAL OR ALLOY, CAUSING DIFFUSION OF THE COATING OR OF THE OTHER METAL OR ALLOY INTO THE BASIS METAL WITH RESULTANT CHANGE IN THE COMPOSITION AND PROPERTIES OF ITS SURFACE.

DIRECT CHILL (DC) CASTING:
A CONTINUOS METHOD OF MAKING INGOTS OR BILLETS FOR SHEET OR EXTRUSION BY POURING THE METAL INTO A SHORT MOLD. THE BASE OF THE MOLD IS A PLATFORM THAT IS GRADUALLY LOWERED WHILE THE METAL SOLIDIFIES, THE FROZEN SHELL OF METAL ACTING AS A RETAINER FOR THE LIQUID METAL BELOW THE WALL OF THE MOLD. THE INGOT IS USUALLY COOLED BY THE IMPINGEMENT OF WATER DIRECTLY ON THE MOLD OR ON THE WALLS OF THE SOLID METAL AS IT IS LOWERED. THE LENGTH OF THE INGOT IS LIMITED BY THE DEPTH TO WHICH THE PLATFORM CAN BE LOWERED; THEREFORE, IT IS OFTEN CALLED SEMICONTINUOUS CASTING.

DIRECT QUENCHING:
QUENCHING CARBURIZED PARTS DIRECTLY FROM THE CARBURIZING OPERATION.

DOUBLE AGING:
EMPLOYMENT OF TWO DIFFERENT AGING TREATMENTS TO CONTROL THE TYPE OF PRECIPITATE FORMED FROM A SUPER-SATURATED ALLOY MATRIX IN ORDER TO OBTAIN THE DESIRED PROPERTIES.

(CONTINUED)

GLOSSARY OF TERMS

DOUBLE QUENCHING:
QUENCHING A CARBURIZED WORKPIECE TWICE. THE FIRST QUENCHING IS CARRIED OUT DIRECTLY AFTER CARBURIZING FROM THE HARDENING TEMPERATURE OF THE CORE; THE SECOND ONE FROM THE HARDENING TEMPERATURE OF THE SURFACE LAYER.

DOUBLE TEMPERING:
A TREATMENT IN WHICH QUENCH HARDENED STEEL IS GIVEN TWO COMPLETE TEMPERING CYCLES AT SUBSTANTIALLY THE SAME TEMPERATURE FOR THE PURPOSE OF ASSURING COMPLETION OF THE TEMPERING REACTION AND PROMOTING STABILITY OF THE RESULTING MICROSTRUCTURE.

DROP FORGING:
A FORGING MADE WITH A DROP HAMMER.

DROP HAMMER:
A FORGING HAMMER THAT DEPENDS ON GRAVITY FOR ITS FORCE.

DUCTILE CRACK PROPAGATION:
SLOW CRACK PROPAGATION THAT IS ACCOMPANIED BY NOTICEABLE PLASTIC DEFORMATION AND REQUIRES ENERGY TO BE SUPPLIED FROM OUTSIDE THE BODY.

DUCTILITY:
THE ABILITY OF A MATERIAL TO BE DEFORMED PLASTICALLY WITHOUT FRACTURING, BEING MEASURED BY ELONGATION OF REDUCTION OF AREA IN A TENSILE TEST.

EARING:
THE FORMATION OF SCALLOPS (EARS) AROUND THE TOP EDGE OF A DRAWN PART CAUSED BY DIFFERENCES IN THE DIRECTIONAL PROPERTIES OF SHEET METAL USED.

ELASTIC LIMIT:
THE MAXIMUM STRESS TO WHICH A MATERIAL MAY BE SUBJECTED WITHOUT ANY PERMANENT STRAIN REMAINING UPON COMPLETE RELEASE OF STRESS.

ELONGATION:
IN TENSILE TESTING, THE INCREASE IN THE GAUGE LENGTH, MEASURED AFTER FRACTURE OF THE SPECIMEN WITHIN THE GAUGE LENGTH, USUALLY EXPRESSED AS A PERCENTAGE OF THE ORIGINAL GAUGE LENGTH.

(CONTINUED)

GLOSSARY OF TERMS

ENDURANCE LIMIT:
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.

END QUENCH TEST:
METHOD OF TESTING HARDENABILITY BY QUENCHING THE END FACE OF A SPECIMEN OF A GIVEN DIMENSIONS UNDER DEFINED CONDITIONS, THUS ESTABLISHING DIFFERENT COOLING RATES OVER THE LENGTH OF THE SPECIMEN AND HENCE PRODUCE A HARDENING CURVE WHICH IS CHARACTERISTIC OF THE TRANSFORMATION BEHAVIOR. (JOMINY TEST)

ERICHSEN TEST:
A CUPPING TEST IN WHICH A PIECE OF SHEET METAL, RESTRAINED EXCEPT AT THE CENTER, IS DEFORMED BY A CONE-SHAPED SPHERICAL-END PLUNGER UNTIL FRACTURE OCCURS. THE HEIGHT OF THE CUP IN MILLIMETERS AT FRACTURE IS A MEASURE OF THE DUCTILITY.

EXTRUSION:
CONVERSION OF A BILLET INTO LENGTHS OF UNIFORM CROSS-SECTION BY FORCING THE PLASTIC METAL THROUGH A DIE ORIFICE OF THE DESIRED CROSS-SECTIONAL OUTLINE. IN DIRECT EXTRUSION, THE DIE AND RAM ARE AT OPPOSITE ENDS OF THE BILLET, AND THE PRODUCT AND RAM TRAVEL IN THE SAME DIRECTION. A STEPPED EXTRUSION IS A SINGLE PRODUCT WITH ONE OR MORE ABRUPT CROSS-SECTION CHANGES AND IS OBTAINED BY INTERRUPTING THE EXTRUSION BY DIE CHANGES. IMPACT EXTRUSION (COLD EXTRUSION) IS THE PROCESS OR RESULTANT PRODUCT OF A PUNCH STRIKING AN UNHEATED SLUG IN A CONFORMING DIE. THE METAL FLOW MAY BE EITHER BETWEEN THE PUNCH AND DIE OR THROUGH ANOTHER OPENING. HOT EXTRUSION IS SIMILAR TO COLD EXTRUSION EXCEPT THAT A PREHEATED SLUG IS USED AND THE PRESSURE APPLICATION IS SLOWER.

FATIGUE:
THE TENDENCY LEADING TO A FRACTURE UNDER REPEATED OR FLUCTUATING STRESSES HAVING A MAXIMUM VALUE LESS THEN THE TENSILE STRENGTH OF THE MATERIAL.

FATIGUE CRACK OR FAILURE:
FATIGUE FRACTURES ARE PROGRESSIVE BEGINNING AS MINUTE CRACKS THAT GROW UNDER THE ACTION OF THE FLUCTUATING STRESS.

(CONTINUED)

GLOSSARY OF TERMS

FATIGUE LIFE:
THE NUMBER OF CYCLES OF STRESS THAT CAN BE SUSTAINED PRIOR TO FAILURE FOR A STATED TEST CONDITION.

FATIGUE LIMIT:
THE MAXIMUM STRESS BELOW WHICH A MATERIAL CAN PRESUMABLY ENDURE AN 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 SHOULD BE STATED.

FATIGUE RATIO:
THE RATIO OF THE FATIGUE LIMIT FOR CYCLES OF REVERSED FLEXURAL STRESS TO THE TENSILE STRENGTH.

FATIGUE STRENGTH:
THE MAXIMUM STRESS THAT CAN BE SUSTAINED FOR A SPECIFIED NUMBER OF CYCLES WITHOUT FAILURE, THE STRESS BEING COMPLETELY REVERSED WITHIN EACH CYCLE UNLESS OTHERWISE STATED.

FERRITE:
A SOLID SOLUTION OF ONE OR MORE ELEMENTS IN BODY-CENTERED CUBIC IRON. UNLESS OTHERWISE DESIGNATED (FOR INSTANCE, AS A CHROMIUM FERRITE), THE SOLUTE IS GENERALLY ASSUMED TO BE CARBON. ON SOME EQUILIBRIUM DIAGRAMS THERE ARE TWO FERRITE REGIONS SEPARATED BY AN AUSTENITE AREA. THE LOWER AREA IS ALPHA FERRITE; THE UPPER, DELTA FERRITE. IF THERE IS NO DESIGNATION, ALPHA FERRITE IS ASSUMED.

FERRITIC STAINLESS STEEL:
STEEL HAVING THE MICROSTRUCTURE SUBSTANTIALLY WHOLLY FERRITIC AT NORMAL TEMPERATURE; USUALLY A STEEL OF THE CHROMIUM TYPE.

FERRO-ALLOY:
AN ALLOY OF IRON THAT CONTAINS A SUFFICIENT AMOUNT OF ONE OR MORE CHEMICAL ELEMENTS, SUCH AS MANGANESE, CHROMIUM OR SILICON, TO BE USEFUL AS AN AGENT FOR INTRODUCING THESE ELEMENTS INTO STEEL BY ADMIXTURE WITH MOLTEN STEEL.

FILLET:
A CONCAVE JUNCTION OF TWO (USUALLY PERPENDICULAR) SURFACES.

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GLOSSARY OF TERMS

FINISHED STEEL:
STEEL THAT IS READY FOR THE MARKET WITHOUT FURTHER WORK OR TREATMENT. BLOOMS, BILLETS, SLABS, SHEET BARS, AND WIRE RODS ARE TERMED "SEMI-FINISHED".

FINISHING TEMPERATURE:
THE TEMPERATURE AT WHICH HOT MECHANICAL WORKING OF A METAL IS COMPLETED.

FISH EYES:
AREAS ON A FRACTURED STEEL SURFACE HAVING A CHARACTERISTIC WHITE CRYSTALLINE APPEARANCE.

FISH TAIL:
AN OVERLAPPING AT THE BACK END OF ROLLED SHEET OR BAR.

FLAKES:
SHORT DISCONTINUOUS INTERNAL FISSURES IN FERROUS METALS ATTRIBUTED TO STRESSES PRODUCED BY LOCALIZED TRANSFORMATION AND DECREASED SOLUBILITY OF HYDROGEN DURING COOLING AFTER HOT WORKING. IN A FRACTURED SURFACE THEY APPEAR AS SHORT DISCONTINUOUS CRACKS. ALSO CALLED "SHATTER CRACKS" AND "SNOW FLAKES".

FLAME ANNEALING:
ANNEALING IN WHICH THE HEAT IS APPLIED DIRECTLY BY A FLAME.

FLAME HARDENING:
A SURFACE HARDENING PROCESS IN WHICH ONLY THE SURFACE LAYER OF A SUITABLE WORKPIECE IS HEATED BY A SUITABLY INTENSE FLAME TO ABOVE THE UPPER TRANSFORMATION TEMPERATURE AND IMMEDIATELY QUENCHED.

FLANGE:
1. A PROJECTION OF METAL ON FORMED OBJECTS.
2. THE PARTS OF A CHANNEL AT RIGHT ANGLES TO THE CENTRAL SECTION OR WEB.

FLASH:
A THIN FIN OF METAL METAL FORMED AT THE SIDES OR WELD WHEN AN EXCESS PORTION OF METAL IS FORCED OUT BETWEEN THE EDGES OF THE FORGING OR WELDING DIES.

(CONTINUED)

GLOSSARY OF TERMS

FLATNESS:
A TERM FOR THE MEASURE OF DEVIATION OF FLAT ROLLED MATERIAL FROM A PLANE SURFACE; USUALLY DETERMINED AS THE HEIGHT OF RIPPLES OF WAVES ABOVE A HORIZONTAL LEVEL SURFACE.

FLUTING:
BREAKING OR KINKING CAUSED BY CURVING A METAL STRIP ON A RADIUS SO SMALL, IN RELATION TO THE THICKNESS, AS TO STRETCH THE OUTER SURFACE WELL BEYOND ITS ELASTIC LIMIT.

FORGING:
PLASTICALLY DEFORMING METAL, USUALLY HOT, INTO DESIRED SHAPES WITH COMPRESSIVE FORCE, WITH OR WITHOUT DIES.

FRACTURE TEST:
BREAKING A SPECIMEN AND EXAMINING THE FRACTURED SURFACE TO DETERMINE COMPOSITION, GRAIN SIZE, CASE DEPTH, SOUNDNESS, AND PRESENCE OF DEFECTS.

FREE MACHINING:
PERTAINS TO THE MACHINING CHARACTERISTICS OF AN ANALYSIS TO WHICH AN INGREDIENT HAS BEEN INTRODUCED TO GIVE SMALL BROKEN CHIPS, LOWER POWER CONSUMPTION, BETTER SURFACE FINISH, AND LONGER TOOL LIFE; AMONG SUCH ADDITIONS ARE SULFUR OR LEAD TO STEEL, LEAD TO BRASS, LEAD AND BISMUTH TO ALUMINUM, AND SULFUR OR SELENIUM TO STAINLESS STEEL.

FULL ANNEALING:
HEATING TO AND HOLDING AT SOME TEMPERATURE ABOVE THE TRANSFORMATION RANGE, FOLLOWED BY COOLING SLOWLY THROUGH THE TRANSFORMATION RANGE.

FULL HARDENING:
HARDENING OVER THE WHOLE CROSS-SECTION OF A WORK PIECE.

GRAIN GROWTH:
AN INCREASE IN THE AVERAGE SIZE OF THE GRAINS IN POLYCRYSTALLINE METAL, USUALLY AS A RESULT OF HEATING AT ELEVATED TEMPERATURES

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GLOSSARY OF TERMS

GRAIN MODIFICATION:
HEATING TO A LITTLE ABOVE Ac3 (Ac1 IN THE CASE OF HYPEREUTECTOID STEELS) WITHOUT PROLONGED HOLDING AND COOLING AT AN APPROPRIATE RATE TO ACHIEVE A MORE UNIFORM GRAIN.

GRAIN REFINER:
ANY MATERIAL ADDED TO A LIQUID METAL FOR THE PURPOSE OF PRODUCING A FINER GRAIN SIZE IN THE SUBSEQUENT CASTING, OR OF RETAINING FINE GRAINS DURING THE HEAT TREATMENT OF WROUGHT STRUCTURES.

GRAINS:
INDIVIDUAL CRYSTALS IN METAL.

GRANULAR FRACTURE:
A TYPE OF IRREGULAR SURFACE PRODUCED WHEN METAL IS BROKEN, THAT IS CHARACTERIZED BY A ROUGH, GRAINLIKE APPEARANCE AS DIFFERENTIATED FROM A SMOOTH SILKY, OR FIBROUS TYPE. IT CAN BE SUBCLASSIFIED INTO TRANSGRANULAR AND INTERGRANULAR FORMS. THIS TYPE OF FRACTURE IS FREQUENTLY CALLED CRYSTALLINE FRACTURE, BUT THE INFERENCE THAT THE METAL HAS CRYSTALLIZED IS NOT JUSTIFIED.

GRAPHITIZING:
ANNEALING A FERROUS ALLOY IN SUCH A WAY THAT SOME OR ALL OF THE CARBON IS PRECIPITATED 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 CRACKS:
SHALLOW CRACKS FORMED IN THE SURFACE OF RELATIVELY HARD MATERIALS BECAUSE OF EXCESSIVE GRINDING HEAT OR THE HIGH SENSITIVITY OF THE MATERIAL.

GUN DRILLING:
A DRILL, USUALLY WITH ONE OR MORE FLUTES AND WITH COOLANT PASSAGES THROUGH THE DRILL BODY, USED FOR DEEP HOLE DRILLING.

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GLOSSARY OF TERMS

HAMMER FORGING:
FORGING IN WHICH THE WORK IS DEFORMED BY REPEATED BLOWS. COMPARE WITH PRESS FORGING.

HARD CHROMIUM:
CHROMIUM DEPOSITED FOR ENGINEERING PURPOSES, SUCH AS INCREASING THE WEAR RESISTANCE OF SLIDING METAL SURFACES, RATHER THAN AS A DECORATIVE COATING. IT IS USUALLY APPLIED DIRECTLY TO BASIC METAL AND IS CUSTOMARILY THICKER THAN A DECORATIVE DEPOSIT.

HARDENABILITY:
IN A FERROUS ALLOY, THE PROPERTY THAT DETERMINES THE DEPTH AND DISTRIBUTION OF HARDNESS INDUCED BY QUENCHING.

HARDENING:
INCREASING THE HARDNESS BY SUITABLE TREATMENT, USUALLY INVOLVING HEATING AND COOLING.

HARDENING AND TEMPERING:
HARDENING AND SUBSEQUENTLY TEMPERING TO IMPROVE TENSILE STRENGTH OR-IN SOME CASES-HARDNESS WITHOUT LOSS IN TOUGHNESS.

HARDENING CRACK SENSITIVITY:
TENDENCY OF A WORKPIECE TO DEVELOP CRACKS DURING OR AFTER HARDENING.

HARDENING FROM HOT FORMING TEMPERATURE.
HARDENING IMMEDIATELY AFTER HOT FORMING WITHOUT COOLING BELOW Ar1.

HARDENING TEMPERATURE:
TEMPERATURE FROM WHICH A WORKPIECE IS COOLED DURING HARDENING.

HARDNESS:
DEFINED IN TERMS OF THE METHOD OF MEASUREMENT, THE RESISTANCE TO INDENTATION, STIFFNESS OR TEMPER OF WROUGHT PRODUCTS OR MACHINABILITY CHARACTERISTICS.

HARDNESS PENETRATION DEPTH:
DISTANCE FROM THE SURFACE OF A HARDENED WORKPIECE TO THAT POINT AT WHICH THE HARDNESS CORRESPONDS TO A DEFINED LIMITING VALUE.

(CONTINUED)

GLOSSARY OF TERMS

HARDNESS TESTS:

(1) BRINELL HARDNESS- A HARDNESS TEST PERFORMED ON A BRINELL HARDNESS TESTING MACHINE. THE SMOOTH SURFACE OF A SPECIMEN IS INDENTED WITH A SPHERICAL-SHAPED HARDENED STEEL BALL OF KNOWN DIAMETER BY MEANS OF A PREDETERMINED LOAD APPLIED TO THE BALL. THE DIAMETER OF THE IMPRESSION IS MEASURED IN MILLIMETERS WITH A MICROMETER MICROSCOPE, AND THE READING IS COMPARED WITH A CHART TO DETERMINE THE BRINELL HARDNESS NUMBER (BHN).

(2) ROCKWELL HARDNESS- A HARDNESS TEST PERFORMED ON A ROCKWELL HARDNESS TESTING MACHINE. THE HARDNESS IS DETERMINED BY A DIAL READING WHICH INDICATES THE DEPTH OF PENETRATION OF A STEEL BALL OR DIAMOND CONE WHEN A LOAD IS APPLIED.

(3) SCLEROSCOPE OR SHORE HARDNESS- A HARDNESS TEST PERFORMED ON A SHORE SCLEROSCOPE HARDNESS TESTER. THE HARDNESS IS DETERMINED BY THE REBOUND OF A DIAMOND POINTED HAMMER (OR TUP) WHEN IT STRIKES THE SURFACE OF A SPECIMEN. THE HAMMER (OR TUP) IS ENCLOSED IN A GLASS TUBE AND THE HEIGHT OF THE REBOUND IS READ EITHER AGAINST A GRADUATED SCALE INSCRIBED ON THE TUBE, OR DIAL, DEPENDING ON THE MODEL INSTRUMENT USED.

HEAT-AFFECTED ZONE:

THAT PORTION OF THE BASE METAL WHICH WAS NOT MELTED DURING BRAZING, CUTTING, OR WELDING, BUT WHOSE MICROSTRUCTURE AND PHYSICAL PROPERTIES WERE ALTERED BY THE HEAT.

HEAT ANALYSIS:

AN ANALYSIS OF EACH HEAT OR CAST OF STEEL FOR ELEMENTS SPECIFIED OR RESTRICTED BY THE APPLICABLE SPECIFICATIONS. THIS ANALYSIS IS MADE FROM A TEST INGOT TAKEN DURING THE POURING OF THE HEAT. (LEAD IS NOT DETERMINABLE SINCE LEAD IS ADDED WHILE EACH INGOT IS POURED. HENCE THE PERCENTAGE OF LEAD IS REPORTED AS 0.15 TO 0.35%.

HEAT TREATMENT:

HEATING AND COOLING A SOLID METAL OR ALLOY IN SUCH A WAY AS TO PRODUCE DESIRED CONDITIONS OR PROPERTIES. HEATING FOR THE SOLE PURPOSE OF HOT WORKING IS EXCLUDED FROM THE MEANING OF THIS DEFENITION.

(CONTINUED)

GLOSSARY OF TERMS

HEAT TREATMENT DIAMETER:
REFERENCE DIAMETER OF A CYLINDRICAL WORKPIECE USED FOR COMPARING DIFFERENT CROSS-SECTIONAL SHAPES, IN PARTICULAR WITH REGARD TO THEIR COOLING CHARACTERISTIC.

HEATING:
INCREASING THE TEMPERATURE OF A WORKPIECE.

HEATING TEMPERATURE:
TEMPERATURE OF A WORKPIECE AT THE END OF HEATING.

HEATING TIME:
TIME ELAPSING FROM BEGINNING TO END OF HEATING CYCLE.

HOMOGENIZING:
HOLDING AT HIGH TEMPERATURE TO REDUCE OR ELIMINATE CHEMICAL SEGREGATION.

HOT-COLD WORKING:
MECHANICAL DEFORMATION OF AUSTENITIC AND PRECIPITATION HARDENING ALLOYS AT A TEMPERATURE JUST BELOW THE CRYSTALLIZATION RANGE TO INCREASE THE YIELD STRENGTH AND HARDNESS BY EITHER PLASTIC DEFORMATION OR PRECIPITATION HARDENING EFFECTS INDUCED BY PLASTIC DEFORMATION OR BOTH.

HOT FORMING:
WORKING OPERATIONS PERFORMED ON METAL HEATED TO TEMPERATURES ABOVE ROOM TEMPERATURE.

HOT SHORTNESS:
BRITTLENESS IN METAL IN THE HOT FORMING RANGE.

HOT TOP:
A RESERVOIR, THERMALLY INSULATED OR HEATED, TO HOLD MOLTEN METAL ON TOP OF A MOLD TO FEED THE INGOT OR CASTING AS IT CONTRACTS ON SOLIDIFYING TO AVOID HAVING "PIPE" OR VOIDS.

HOT QUENCHING:
AN IMPRECISE TERM USED TO COVER A VARIETY OF QUENCHING PROCEDURES IN WHICH A QUENCHING MEDIUM IS MAINTAINED AT A PRESCRIBED TEMPERATURE ABOVE 71º C.

(CONTINUED)

GLOSSARY OF TERMS

HYDROGEN EMBRITTLEMENT:
A CONDITION OF LOW DUCTILITY IN METALS RESULTING FROM THE ABSORPTION OF HYDROGEN.

IMPACT ENERGY (IMPACT VALUE):
THE AMOUNT OF ENERGY REQUIRED TO FRACTURE A MATERIAL, USUALLY MEASURED BY MEANS OF AN IZOD OR CHARPY TEST. THE TYPE OF SPECIMEN AND TESTING CONDITIONS AFFECT THE VALUES AND THEREFORE SHOULD BE SPECIFIED.

IMPACT TEST:
A TEST TO DETERMINE THE 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 THE CHARPY OR IZOD TESTS.

IMPULSE HARDENING:
HARDENING WITH VERY SHORT AUSTENIZING AT A TEMPERATURE HIGHER THAN THE NORMAL AUSTENITIZING TEMPERATURE.

IMPULSE TEMPERING:
SHORT-DURATION TEMPERING AT A TEMPERATURE HIGHER THAN THE NORMAL TEMPERING TEMPERATURE.

INCLUSIONS:
NONMETALLIC MATERIALS IN A SOLID METALLIC MATRIX.

INDUCTION HARDENING:
QUENCH HARDENING IN WHICH THE HEAT IS GENERATED BY ELECTRICAL INDUCTION.

INGOT:
A CASTING INTENDED FOR SUBSEQUENT ROLLING OR FORGING.

INTERGRANULAR CORROSION:
A TYPE OF ELECTROCHEMICAL CORROSION THAT PROGRESSES ALONG THE GRAIN BOUNDARIES OF AN ALLOY, USUALLY BECAUSE THE GRAIN BOUNDARY REGIONS CONTAIN MATERIAL ANODIC TO THE CENTRAL REGIONS OF THE GRAINS.

(CONTINUED)

GLOSSARY OF TERMS

INTERRUPTED QUENCHING:
A QUENCHING PROCEDURE IN WHICH THE WORKPIECE IS REMOVED FROM THE FIRST QUENCH AT A TEMPERATURE SUBSTANTIALLY HIGHER THAN THAT OF THE QUENCHENT AND IS THEN SUBJECTED TO A SECOND QUENCHING SYSTEM HAVING A DIFFERENT COOLING RATE THAN THE FIRST.

ISOTHERMAL ANNEALING:
AUSTENITIZING A FERROUS ALLOY ANT THEN COOLING TO AND HOLDING AT A TEMPERATURE AT WHICH AUSTENITE TRANSFORMS TO A RELATIVELY SOFT FERRITE-CARBIDE AGGREGATE.

ISOTHERMAL TRANSFORMATION:
A CHANGE IN PHASE AT ANY CONSTANT TEMPERATURE.

IZOD TEST:
A PENDULUM TYPE OF SINGLE-BLOW IMPACT TEST IN WHICH THE SPECIMEN, USUALLY NOTCHED, IS FIXED AT ONE END AND BROKEN BY A FALLING PENDULUM. THE ENERGY ABSORBED, AS MEASURED BY THE SUBSEQUENT RISE OF THE PENDULUM, IS A MEASURE OF IMPACT STRENGTH OR NOTCH TOUGHNESS.

KILLED STEEL:
STEEL DEOXIDIZED 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.

LADLE ANALYSIS:
CHEMICAL ANALYSIS MADE FROM SAMPLES OBTAINED DURING ORIGINAL CASTING OF INGOTS, TO CONTROL ANALYSIS TO SATISFY THE SPECIFICATIONS.

LAMINATIONS:
DEFECTS RESULTING FROM THE PRESENCE OF BLISTER, SEAMS OR FOREIGN INCLUSIONS ALIGNED PARALLEL TO THE WORKED SURFACE OF A METAL.

LAP:
A SURFACE DEFECT, APPEARING AS A SEAM, CAUSED BY FOLDING OVER HOT METAL, FINS, OR SHARP CORNERS AND THEN ROLLING OR FORGING THEM INTO THE SURFACE, BUT NOT WELDING THEM.

(CONTINUED)

GLOSSARY OF TERMS

LONGITUDINAL DIRECTION:
THE PRINCIPLE DIRECTION OF FLOW IN A WORKED METAL.

MACHINABILITY:
THE RELATIVE EASE OF MACHINING A METAL.

MACHINABILITY INDEX:
A RELATIVE MEASURE OF THE MACHINABILITY OF AN ENGINEERING MATERIAL UNDER SPECIFIED STANDARD CONDITIONS.

MACROSCOPIC:
VISIBLE EITHER BY THE UNAIDED EYE OR UNDER MAGNIFICATION (AS GREAT AS TEN DIAMETERS).

MACROSTRUCTURE:
THE STRUCTURE OF METALS AS REVEALED BY MACROSCOPIC EXAMINATION.

MALLEABILITY:
THE PROPERTY THAT DETERMINES THE EASE OF DEFORMING A METAL WHEN THE METAL IS SUBJECTED TO ROLLING OR HAMMERING.

MALLEABILIZING:
ANNEALING WHITE CAST IRON IN SUCH A WAY THAT SOME OR ALL OF THE COMBINED CARBON IS TRANSFORMED TO A GRAPHITE OR, IN SOME INSTANCES, PART OF THE CARBON IS REMOVED COMPLETELY.

MARTEMPERING:
QUENCHING AN AUSTENITIZED FERROUS ALLOY IN A MEDIUM AT A TEMPERATURE IN THE UPPER PART OF THE MARTENSITE RANGE, OR SLIGHTLY ABOVE THAT RANGE, AND HOLDING IT IN THE MEDIUM UNTIL THE TEMPERATURE THROUGHOUT THE ALLOY IS SUBSTANTIALLY UNIFORM. THE ALLOY IS THEN ALLOWED TO COOL IN AIR THROUGH THE MARTENSITE RANGE.

MARTENSITE:
THE HARD CONSTITUENT PRODUCED WHEN A STEEL IS COOLED FROM THE HARDENING TEMPERATURE AT A SPEED GREATER THAN ITS CRITICAL COOLING RATE.

(CONTINUED)

GLOSSARY OF TERMS

MECHANICAL PROPERTIES:
THE PROPERTIES OF A MATERIAL THAT REVEAL ITS ELASTIC AND INELASTIC BEHAVIOR WHERE FORCE IS APPLIED, THEREBY INDICATING ITS SUSCEPTIBILITY FOR MECHANICAL APPLICATIONS; FOR EXAMPLE, MODULUS OF ELASTICITY, TENSILE STRENGTH, ELONGATION, HARDNESS AND FATIGUE LIMIT.

MODULUS OF ELASTICITY:
A MEASURE OF THE RIGIDITY OF METAL. RATIO OF STRESS, WITHIN PROPORTIONAL LIMIT, TO CORRESPONDING STRAIN. SPECIFICALLY, THE MODULUS OBTAINED IN TENSION OR COMPRESSION IS YOUNG'S MODULUS, STRETCH MODULUS OR MODULUS OF EXTENSIBILITY; THE MODULUS OBTAINED IN TORSION OR SHEAR IS MODULUS OF RIGIDITY, SHEAR MODULUS OR MODULUS OF TORSION; THE MODULUS COVERING THE RATIO OF THE MEAN NORMAL STRESS TO THE CHANGE IN VOLUME PER UNIT VOLUME IS THE BULK MODULUS. THE TANGENT MODULUS AND SECANT MODULUS ARE NOT RESTRICTED WITHIN THE PROPORTIONAL LIMIT; THE FORMER IS THE SLOPE OF THE STRESS-STRAIN CURVE AT A SPECIFIED POINT; THE LATTER IS THE SLOPE OF A LINE FROM THE ORIGIN TO A SPECIFIED POINT ON THE STRESS-STRAIN CURVE. ALSO CALLED "ELASTIC MODULUS" AND " COEFFICIENT OF ELASTICITY".

NITRIDING:
A CASE HARDENING PROCESS IN WHICH A FERROUS-BASE MATERIAL IS HEATED TO APPROXIMATELY THE IRON-NITROGEN EUTECTOID TEMPERATURE IN EITHER A GASEOUS OR A LIQUID MEDIUM CONTAINING ACTIVE NITROGEN, THUS CAUSING ABSORPTION OF NITROGEN AT THE SURFACE AND, BY DIFFUSION, CREATING A CONCENTRATION GRADIENT. WITHIN THE CAPABILITIES OF THE PARTICULAR MATERIAL, SLOW COOLING PRODUCES FULL. HARDNESS OF THE CASE. IN CONVENTIONAL NITRIDING A HARDENED AND TEMPERED ALLOY STEEL OR TOOLSTEEL IS TREATED FOR SUFFICIENT TIME TO PRODUCE HIGHLY SATURATED NITRIDES IN THE CASE. IN AN IMPORTANT VARIATION OF THE PROCESS, SOME-TIMES CALLED DUCTILE NITRIDING, APPLIED TO ANY FERROUS BASE MATERIAL, THE AMOUNT OF ACTIVE NITROGEN AND THE TIME OF EXPOSURE ARE SO CONTROLLED AS TO PRODUCE A CASE OF LOWER NITROGEN CONTENT WHICH, WITHIN THE CAPABILITIES OF THE MATERIAL, IS FULLY HARD ON A MICRO SCALE BUT LOWER IN HARDNESS ON A MACRO SCALE AND RELATIVELY DUCTILE. DEPENDENT ON THE TYPE OF NITRIDING AGENT USED, DISTINCTION IS MADE BETWEEN GAS, SALT BATH, POWDER AND PLASMA NITRIDING.

NON-SCALLOPING QUALITY:
STEEL SPECIALLY MADE TO BE SUBSTANTIALLY FREE FROM SCALLOPS OR EARS DURING PRESSING AND DRAWING.

(CONTINUED)

GLOSSARY OF TERMS

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 BRITTLENESS IN AREAS CONTAINING A GROOVE, SCRATCH, SHARP FILLET OR NOTCH.

OPEN-HEARTH FURNACE:
A REVERBERATORY MELTING FURNACE WITH A SHALLOW HEARTH AND A LOW ROOF. THE FLAME PASSES OVER THE CHARGE IN THE HEARTH, CAUSING THE CHARGE TO BE HEATED BOTH BY DIRECT FLAME AND RADIATION FROM THE ROOF AND SIDEWALLS OF THE FURNACE.

ORANGE PEEL:
A PEBBLE-GRAIN SURFACE WHICH DEVELOPS IN FORMING OF METALS HAVING COARSE GRAINS.

OVERAGING:
AGING UNDER CONDITIONS OF TIME AND TEMPERATURE GREATER THAN THOSE REQUIRED TO OBTAIN MAXIMUM CHANGE IN A CERTAIN PROPERTY, SO THAT THE PROPERTY IS ALTERED IN THE DIRECTION OF THE INITIAL VALUE. SEE AGING.

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.

OVERTIMING:
HOLDING FOR SUCH A LONG TIME THAT, ASSUMING NORMAL TEMPERATURES, UNDESIRABLE GRAIN COARSENING OCCURS WHICH CAN HOWEVER BE REVERSED BY FURTHER HEAT TREATMENT OR FORMING OPERATION.

PEARLITE:
A LAMELLAR AGGREGATE OF FERRITE AND CEMENTITE, OFTEN OCCURRING IN STEEL AND CAST IRON.

(CONTINUED)

GLOSSARY OF TERMS

PEENING:
MECHANICAL WORKING OF METAL BY HAMMER BLOWS OR SHOT IMPINGEMENT.

PHYSICAL PROPERTIES:
THE PROPERTIES, OTHER THAN MECHANICAL PROPERTIES, THAT PERTAIN TO THE PHYSICS OF A MATERIAL; FOR EXAMPLE, DENSITY, ELECTRICAL CONDUCTIVITY, HEAT CONDUCTIVITY, THERMAL EXPANSION.

PICKLING:
REMOVING SURFACE OXIDES FROM METALS BY CHEMICAL OR ELECTROCHEMICAL REACTION.

PIG IRON:
HIGH-CARBON IRON MADE BY REDUCTION OF IRON ORE IN THE BLAST FURNACE.

PINHOLE POROSITY:
VERY SMALL HOLES SCATTERED THROUGH A CASTING, POSSIBLY BY MICROSHRINKAGE OR GAS EVOLUTION DURING SOLIDIFICATION.

PIPE:
CAVITY FORMED BY CONTRACTION IN METAL (ESPECIALLY INGOTS) DURING SOLIDIFICATION OF THE LAST PORTION OF LIQUID METAL.

PIT:
A SHARP DEPRESSION IN THE SURFACE OF THE METAL.

PITTING:
FORMING SMALL SHARP CAVITIES IN A METAL SURFACE BY NONUNIFORM ELECTRO-DEPOSITION OR BY CORROSION.

PLANISHING:
PRODUCING A SMOOTH SURFACE FINISH ON METAL BY RAPID SUCCESSION OF BLOWS DELIVERED BY HIGHLY POLISHED DIES OR BY A HAMMER DESIGNED FOR THE PURPOSE, OR BY ROLLING IN A PLANISHING MILL.

PLASTIC DEFORMATION:
PERMANENT DISTORTION OF A MATERIAL UNDER THE ACTION OF APPLIED STRESS.

(CONTINUED)

GLOSSARY OF TERMS

PLASTICITY:
THE ABILITY OF A METAL TO BE DEFORMED EXTENSIVELY WITHOUT RUPTURE.

POROSITY:
UNSOUNDNESS CAUSED IN CAST METALS BY THE PRESENCE OF BLOWHOLES AND SHRINKAGE CAVITIES.

POSTHEATING:
HEATING WELDMENTS IMMEDIATELY AFTER WELDING, FOR TEMPERING, FOR STRESS RELIEVING, OR FOR PROVIDING A CONTROLLED RATE OF COOLING TO PREVENT FORMATION OF A HARD OR BRITTLE STRUCTURE.

PRECIPITATION HARDENING:
HARDENING CAUSED BY THE PRECIPITATION OF A CONSTITUENT FROM A SUPERSATURATED SOLID SOLUTION. SEE ALSO AGE HARDENING AND AGING.

PREFERRED HARDENING:
IN A POLYCRYSTALLINE STRUCTURE, A DEPARTURE FROM CRYSTALLOGRAPHIC RANDOMNESS.

PREHEATING:
HEATING BEFORE SOME FURTHER THERMAL OR MECHANICAL TREATMENT. FOR TOOL STEEL, HEATING TO AN INTERMEDIATE TEMPERATURE IMMEDIATELY BEFORE FINAL AUSTENITIZING. FOR SOME NONFERROUS ALLOYS, HEATING TO A HIGH TEMPERATURE FOR A LONG TIME IN ORDER TO HOMOGENIZE THE STRUCTURE BEFORE WORKING.

PRESS FORGING:
FORGING METAL, USUALLY HOT, BETWEEN DIES IN A PRESS.

PROCESS ANNEALING:
IN THE SHEET AND WIRE INDUSTRIES, HEATING A FERROUS ALLOY TO A TEMPERATURE CLOSE TO, BUT BELOW, THE LOWER LIMIT OF THE TRANSFORMATION RANGE AND THEN COOLING, IN ORDER TO SOFTEN THE ALLOY FOR FURTHER COLD WORKING.

PRODUCT ANALYSIS:
AN ANALYSIS OF THE METAL AFTER IT HAS BEEN ROLLED OR FORGED INTO SEMI-FINISHED OR FINISHED FORMS.

(CONTINUED)

GLOSSARY OF TERMS

PROOF STRESS:
1. THE STRESS THAT WILL CAUSE A SPECIFIED SMALL PERMANENT SET IN A MATERIAL.
2. A SPECIFIED STRESS TO BE APPLIED TO A MEMBER OR STRUCTURE TO INDICATE ITS ABILITY TO WITHSTAND SERVICE LOADS.

PROPORTIONAL LIMIT:
THE MAXIMUM STRESS AT WHICH STRAIN REMAINS DIRECTLY PROPORTIONAL TO STRESS.

QUENCH AGING:
AGING INDUCED BY RAPID COOLING AFTER SOLUTION HEAT TREATMENT.

QUENCH ANNEALING:
ANNEALING AN AUSTENITIC FERROUS ALLOY BY SOLUTION HEAT TREATMENT.

QUENCH HARDENING:
HARDENING A SUITABLE FERROUS ALLOY BY AUSTENITIZING AND THEN COOLING AT SUCH A RATE THAT A SUBSTANTIAL AMOUNT OF AUSTENITE TRANSFORMS TO MARTENSITE.

QUENCHANT:
MEDIUM USED FOR HARDENING OR QUENCHING OPERATION.

QUENCHING:
RAPID COOLING FROM AN ELEVATED TEMPERATURE BY CONTACT WITH LIQUIDS, GASES OR SOLIDS.

QUENCHING CRACK:
FRACTURE RESULTING FROM THERMAL STRESSES INDUCED DURING RAPID COOLING OR QUENCHING; FREQUENTLY ENCOUNTERED IN ALLOYS THAT HAVE BEEN OVERHEATED AND LIQUATED.

RECARBURIZATION:
CARBURIZING OF DECARBURIZED WORKPIECE TO APPROXIMATELY THE SAME CARBON CONTENT IT SHOWED.

RECRYSTALLIZATION:
1. THE CHANGE FROM ONE CRYSTAL STRUCTURE TO ANOTHER, AS OCCURS ON HEATING OR COOLING THROUGH A TRANSFORMATION TEMPERATURE.
2. THE FORMATION OF A NEW, STRAIN-FREE GRAIN STRUCTURE FROM THAT EXISTING IN COLD WORKED METAL, USUALLY ACCOMPLISHED BY HEATING

(CONTINUED)

GLOSSARY OF TERMS

RECRYSTALLIZATION ANNEALING:
ANNEALING COLD WORKED METAL TO PRODUCE A NEW GRAIN STRUCTURE WITHOUT PHASE CHANGE.

RECRYSTALLIZATION TEMPERATURE:
THE APPROXIMATE MINIMUM TEMPERATURE AT WHICH COMPLETE RECRYSTALLIZATION OF A COLD WORKED METAL OCCURS WITHIN A SPECIFIED TIME.

RED SHORTNESS:
BRITTLENESS IN STEEL WHEN IT IS RED HOT.

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 THE SPECIMEN.

REFINING TEMPERATURE:
TEMPERATURE USUALLY JUST HIGHER THAN THE TRANSFORMATION RANGE, EMPLOYED IN THE HEAT TREATMENT OF STEEL TO REFINE THE STRUCTURE, IN PARTICULAR, THE GRAIN SIZE.

RESIDUAL STRESS:
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 THE INGOT HAVE VERY GOOD SURFACE QUALITY.

ROCKWELL HARDNESS TEST:
A TEST FOR DETERMINING THE HARDNESS OF A MATERIAL BASED UPON THE DEPTH OF PENETRATION OF A SPECIFIED PENETRATION INTO THE SPECIMEN UNDER CERTAIN ARBITRARILY FIXED CONDITIONS OF TEST.

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GLOSSARY OF TERMS

ROLLER LEVELING:
LEVELING BY PASSING FLAT STOCK THROUGH A MACHINE HAVING A SERIES OF SMALL-DIAMETER STAGGERED ROLLS.

ROLLING:
REDUCING THE CROSS-SECTIONAL AREA OF METAL STOCK, OR OTHERWISE SHAPING METAL PRODUCTS, TROUGH THE USE OF ROTATING ROLLS.

ROUGH MACHINING:
MACHINING WITHOUT REGARD TO FINISH, USUALLY TO BE FOLLOWED BY A SUBSEQUENT OPERATION.

SCAB:
A DEFECT CONSISTING OF A FLAT VOLUME OF METAL JOINED TO A CASTING THROUGH A SMALL AREA. IT IS USUALLY SET IN A DEPRESSION, A FLAT SIDE BEING SEPARATED FROM THE METAL OF THE CASTING PROPER BY A THIN LAYER OF SAND.

SCALING:
FORMING A THICK LAYER OF OXIDATION PRODUCTS ON METALS AT HIGH TEMPERATURES.

SCARFING:
CUTTING SURFACE AREAS OF METAL OBJECTS, ORDINARILY BY USING A GAS TORCH. THE OPERATION PERMITS SURFACE DEFECTS TO BE CUT FROM INGOTS, BILLETS, OR THE EDGES OF PLATE THAT IS TO BE BEVELED FOR BUTT WELDING.

SCLEROSCOPE TEST:
A HARDNESS TEST WHERE 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.

SEAM:
ON THE SURFACE OF METAL, AN UNWELDED FOLD OR LAP WHICH APPEARS AS A CRACK, USUALLY RESULTING FROM A DEFECT OBTAINED IN CASTING OR IN WORKING.

SEGREGATION:
NON-UNIFORM DISTRIBUTION OF ALLOYING ELEMENTS, IMPURITIES OR MICROPHASES.

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GLOSSARY OF TERMS

SEMIKILLED STEEL:
STEEL THAT IS INCOMPLETELY DEOXIDIZED AND CONTAINS SUFFICIENT DISSOLVED OXYGEN TO REACT WITH THE CARBON TO FORM CARBON MONOXIDE TO OFFSET SOLIDIFICATION SHRINKAGE.

SHEAR STRENGTH:
THE STRESS REQUIRED TO PRODUCE FRACTURE IN THE PLANT OF CROSS SECTION, THE CONDITIONS OF LOADING BEING SUCH THAT THE DIRECTION OF FORCE AND RESISTANCE ARE PARALLEL AND OPPOSITE ALTHOUGH THEIR PATHS ARE OFFSET A SPECIFIED MINIMUM AMOUNT.

SHEARED EDGE:
A SHEARED EDGE IS OBTAINED IS OBTAINED WHEN ROLLED EDGE IS REMOVED BY A ROTARY SLITTER OR A MECHANICAL SHEAR.

SHORTNESS:
A FORM OF BRITTLENESS IN METAL. IT IS DESIGNATED AS "COLD", "HOT" AND "RED" TO INDICATE THE TEMPERING RANGE IN WHICH THE BRITTLENESS OCCUR.

SILICONIZING:
ENRICHMENT IN SURFACE LAYER WITH SILICON BY THERMOCHEMICAL TREATMENT.

SINGLE QUENCHING:
SINGLE HARDENING OPERATION FOLLOWING CARBURIZING WITH COOLING TO A TEMPERATURE BELOW Ac1.

SINTERING:
1. THE BONDING OF ADJACENT SURFACES OF PARTICLES IN A MASS OF METAL POWDERS OR A COMPACT, BY HEATING.
2. A SHAPED BODY COMPOSED OF METAL POWDERS AND PRODUCED BY SINTERING WITH OR WITHOUT PRIOR COMPACTING.

SKELP:
A PIECE OR STRIP OF METAL PRODUCED TO A SUITABLE THICKNESS, WIDTH, AND EDGE CONFIGURATION, FROM WHICH PIPE OR TUBING IS MADE.

(CONTINUED)

GLOSSARY OF TERMS

SKIN:
A THIN SURFACE LAYER THAT IS DIFFERENT FROM THE MAIN MASS OF A METAL OBJECT, IN COMPOSITION, STRUCTURE OR OTHER CHARACTERISTIC.

SLACK QUENCHING:
THE INCOMPLETE HARDENING OF STEEL DUE TO QUENCHING FROM THE AUSTENITIZING TEMPERATURE AT A RATE SLOWER THAN THE CRITICAL COOLING RATE FOR THE PARTICULAR STEEL, RESULTING IN THE FORMATION OF ONE OR MORE TRANSFORMATION PRODUCTS IN ADDITION TO MARTENSITE.

SLAG:
A NONMETALLIC PRODUCT RESULTING FROM THE MUTUAL DISSOLUTION OF FLUX AND NON-METALLIC IMPURITIES IN SMELTING AND REFINING 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.

SPECIAL BAR QUALITY:
A QUALITY SUITABLE FORGING, HEAT TREATING, COLD DRAWING, TURNING, ETC. THESE APPLICATIONS REQUIRE SPECIAL MANUFACTURING CONTROL FOR CHEMICAL COMPOSITION, DEOXIDATION, MOLD PRACTICE, POURING, DISCARD, SURFACE PREPARATION, HEATING, ROLLING, COOLING, TESTING AND INSPECTION.

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 Ae1.
2. HEATING AND COOLING ALTERNATIVELY BETWEEN TEMPERATURES THAT ARE JUST ABOVE AND JUST BELOW Ae1.
3. HEATING TO A TEMPERATURE ABOVE Ae1 OR Ae3 AND THEN COOLING VERY SLOWLY IN THE FURNACE OR HOLDING AT A TEMPERATURE JUST BELOW Ae1.
4. COOLING AT A SUITABLE RATE FROM THE MINIMUM TEMPERATURE AT WHICH ALL CARBIDE IS DISSOLVED, TO PREVENT THE RE-FORMATION OF A CARBIDE NETWORK AND THEN RE-HEATING IN ACCORDANCE WITH METHOD 1 OR 2 ABOVE. (APPLICABLE TO HYPEREUTECTOID STEEL CONTAINING A CARBIDE NETWORK).

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GLOSSARY OF TERMS

STABILIZING TREATMENT:

A TREATMENT APPLIED FOR THE PURPOSE OF STABILIZING THE DIMENSIONS OF A WORK-PIECE OR THE STRUCTURE OF A MATERIAL SUCH AS:
1. BEFORE FINISHING TO FINAL DIMENSIONS, HEATING A WORKPIECE TO OR SOMEWHAT BEYOND ITS OPERATING TEMPERATURE AND THEN COOLING TO ROOM TEMPERATURE A SUFFICIENT NUMBER OF TIMES TO INSURE STABILITY OF DIMENSION IN SERVICE.
2. TRANSFORMING RETAINED AUSTENITE IN THOSE MATERIALS WHICH RETAIN SUBSTANTIAL AMOUNTS WHEN QUENCH HARDENED (SEE COLD TREATMENT).
3. HEATING A SOLUTION TREATED AUSTENITIC STAINLESS STEEL THAT CONTAINS AMOUNTS OF TITANIUM OR COLUMBIUM PLUS TANTALUM TO A TEMPERATURE BELOW THE SOLUTION HEAT TREATING TEMPERATURE TO CAUSE PRECIPITATION OF FINELY DIVIDED, UNIFORMLY DISTRIBUTED CARBIDES OF THOSE ELEMENTS, THEREBY SUBSTANTIALLY REDUCING THE AMOUNT OF CARBON AVAILABLE FOR THE FORMATION OF CHROMIUM CARBIDES IN THE GRAIN BOUNDARIES UPON SUBSEQUENT EXPOSURE TO TEMPERATURES IN THE SENSITIZING RANGE.

STEEL:

AN IRON-BASE ALLOY, MALLEABLE IN SOME TEMPERATURE RANGE AS INITIALLY CAST, CONTAINING MANGANESE, USUALLY CARBON, AND OFTEN OTHER ALLOYING ELEMENTS. IN CARBON STEEL AND LOW-ALLOY STEEL, THE MAXIMUM CARBON IS ABOUT 2.0%; IN HIGH-ALLOY STEEL, ABOUT 2.5%. THE DIVIDING LINE BETWEEN LOW-ALLOY AND HIGH-ALLOY STEELS IS GENERALLY REGARDED AS BEING AT ABOUT 5% METALLIC ALLOYING ELEMENTS. STEEL IS TO BE DIFFERENTIATED FROM TWO GENERAL CLASSES OF "IRONS": THE CAST IRONS, ON THE HIGH-CARBON SIDE, AND THE RELATIVELY PURE IRONS SUCH AS INGOT IRON CARBONYL IRON, AND ELECTROLYTIC IRON, ON THE LOW-CARBON SIDE. IN SOME STEELS CONTAINING EXTREMELY LOW CARBON, THE MANGANESE CONTENT IS THE PRINCIPAL DIFFERENTIATING FACTOR, STEEL USUALLY CONTAINING AT LEAST 0.25% INGOT IRON CONTAINS CONSIDERABLY LESS.

STRAIN:

A MEASURE OF THE CHANGE IN THE SIZE OR SHAPE OF A BODY, REFERRED TO ITS ORIGINAL SIZE OR SHAPE. "LINEAR STRAIN" IS THE CHANGE PER UNIT LENGTH OF A 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 GAUGE LENGTH. "CONVENTIONAL STRAIN" IS THE LINEAR STRAIN REFERRED TO THE ORIGINAL GAUGE 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 THE APPLIED STRESS.

(CONTINUED)

GLOSSARY OF TERMS

STRAIN AGING:
AGING INDUCED BY COLD WORKING. SEE AGING.

STRAIN HARDENING OF AUSTENITE:
AUSTENITIZING FOLLOWED BY COOLING TO A TEMPERATURE RANGE WITH LOW TENDENCY OF TRANSFORMATION, SHAPING WITH AVOIDANCE OF RECRYSTALLIZATION AND SUBSEQUENT FURTHER COOLING TO ACHIEVE HARDENING.

STRESS:
LOAD PER UNIT OF AREA. ORDINARILY STRESS-STRAIN CURVES DO NOT SHOW THE TRUE STRESS (LOAD DIVIDED BY AREA AT THAT MOMENT) BUT A FICTITIOUS VALUE OBTAINED BY USING THE ORIGINAL AREA.

STRESS-CORROSION CRACKING:
FAILURE BY CRACKING UNDER COMBINED ACTION OR CORROSION AND STRESS, EITHER EXTERNAL (APPLIED) OR INTERNAL (RESIDUAL). CRACKING MAY BE EITHER INTERGRANULAR OR TRANSGRANULAR, DEPENDING ON METAL AND CORROSIVE MEDIUM.

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.

STRETCHER LEVELING:
LEVELING WHERE A PIECE OF METAL IS GRIPPED AT EACH END AND SUBJECTED TO A STRESS HIGHER THAN ITS YIELD STRENGTH TO REMOVE WARP AND DISTORTION. SOMETIMES CALLED PATENT LEVELING.

STRETCHER STRAINS:
ELONGATED MARKINGS THAT APPEAR ON THE SURFACE OF SOME MATERIALS WHEN DEFORMED JUST PAST THE YIELD POINT. THESE MARKINGS LIE APPROXIMATELY PARALLEL TO THE DIRECTION OF MAXIMUM SHEAR STRESS AND ARE THE RESULT OF LOCALIZED YIELDING. SAME AS LUDERS LINES.

SWEEP:
CURVATURE IN STRUCTURAL AND OTHER SIMILAR SHAPES NORMAL TO THE PLANE OF THE WEB.

(CONTINUED)

GLOSSARY OF TERMS

TEMPER:
1. IN HEAT TREATMENT, REHEATING HARDENED STEEL OR HARDENED CAST IRON TO SOME TEMPERATURE BELOW THE EUTECTOID TEMPERATURE FOR THE PURPOSE OF DECREASING THE HARDNESS AND INCREASING THE TOUGHNESS. THE PROCESS IS SOMETIMES APPLIED TO NORMALIZED STEEL.
2. IN TOOL STEELS "TEMPER" IS SOMETIMES USED, BUT INADVISEDLY, TO DENOTE THE 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 TEMPERATURE BELOW THE TRANSFORMATION RANGE. THE BRITTLENESS IS REVEALED BY NOTCHED-BAR IMPACT TESTS AT OR BELOW ROOM TEMPERATURE.

TEMPERING:
REHEATING A QUENCH-HARDENED OR NORMALIZED FERROUS ALLOY TO A TEMPERATURE BELOW THE TRANSFORMATION RANGE AND THEN COOLING AT ANY RATE DESIRED.

TENSILE STRENGTH:
THE VALUE OBTAINED BY DIVIDING THE MAXIMUM LOAD OBSERVED DURING TENSILE STRAINING UNTIL BREAKAGE OCCURS, BY THE SPECIMEN CROSS-SECTIONAL AREA BEFORE STRAINING. ALSO CALLED "ULTIMATE STRENGTH".

THERMAL FATIGUE:
FRACTURE RESULTING FROM THE PRESENCE OF TEMPERATURE GRADIENTS WHICH VARY WITH TIME IN SUCH A MANNER AS TO PRODUCE CYCLIC STRESSES IN A STRUCTURE.

TOLERANCES:
ALLOWABLE VARIATIONS FROM SPECIFIED DIMENSIONS..

TORSION:
A TWISTING ACTION RESULTING IN SHEAR STRESSES AND STRAINS.

(CONTINUED)

GLOSSARY OF TERMS

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 STRESS-STRAIN CURVE IN TENSILE TESTING IS ALSO A MEASURE OF TOUGHNESS.

TRANSFORMATION RANGE: (TRANSFORMATION TEMPERATURE RANGE)

THOSE RANGES OF TEMPERATURE WITHIN WHICH AUSTENITE 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. THE TERM IS SOMETIMES USED TO DENOTE THE LIMITING TEMPERATURE OF A TRANSFORMATION RANGE. THE FOLLOWING SYMBOLS ARE USED FOR IRON AND STEELS:

Accm. IN HYPEREUTECTOID STEEL, THE TEMPERATURE AT WHICH THE SOLUTION OF CEMENTITE IN AUSTENITE IS COMPLETED DURING HEATING.

Ac1. THE TEMPERATURE AT WHICH AUSTENITE BEGINS TO FORM DURING HEATING.

Ac3. THE TEMPERATURE AT WHICH TRANSFORMATION OF FERRITE TO AUSTENITE IS COMPLETED DURING HEATING.

Ac4. THE TEMPERATURE AT WHICH AUSTENITE TRANSFORMS TO DELTA FERRITE DURING HEATING.

Aecm. Ae1,Ae3,Ae4. THE TEMPERATURE OF PHASE CHANGES AT EQUILIBRIUM.

Arcm. IN HYPEREUTECTOID STEEL, THE TEMPERATURE AT WHICH PRECIPITATION OF CEMENTITE STARTS DURING COOLING.

Ar1. THE TEMPERATURE AT WHICH TRANSFORMATION OF AUSTENITE TO FERRITE OR TO FERRITE PLUS CEMENTITE IS COMPLETED DURING COOLING.

Ar3. THE TEMPERATURE AT WHICH AUSTENITE BEGINS TO TRANSFORM TO FERRITE DURING COOLING.

Ar4. THE TEMPERATURE AT WHICH DELTA FERRITE TRANSFORMS TO AUSTENITE DURING COOLING.

Ms (OR "Ar"). THE TEMPERATURE AT WHICH TRANSFORMATION OF AUSTENITE TO MARTENSITE STARTS DURING COOLING.

Mf. THE TEMPERATURE AT WHICH MARTENSITE FORMATION FINISHES DURING COOLING.

NOTE: ALL THESE CHANGES EXCEPT THE FORMATION OF MARTENSITE OCCUR AT LOWER TEMPERATURES DURING COOLING THAN DURING HEATING, AND DEPEND ON THE RATE OF CHANGE OF TEMPERATURE.

(CONTINUED)

GLOSSARY OF TERMS

TRANSVERSE:
LITERALLY, "ACROSS", USUALLY SIGNIFYING A DIRECTION OR PLANE PERPENDICULAR TO THE DIRECTION OF WORKING.

ULTIMATE STRENGTH:
THE MAXIMUM CONVENTIONAL STRESS, TENSILE , COMPRESSIVE, OR SHEAR, THAT A MATERIAL CAN WITHSTAND.

UNIVERSAL MILL:
A ROLLING MILL IN WHICH ROLLS WITH A VERTICAL AXIS ROLL THE EDGES OF THE METAL STOCK BETWEEN SOME OF THE PASSES THROUGH THE HORIZONTAL ROLLS.

VACUUM MELTING:
MELTING IN A VACUUM TO PREVENT CONTAMINATION FROM AIR, AS WELL AS TO REMOVE GASES ALREADY DISSOLVED IN THE METAL; THE SOLIDIFICATION MAY ALSO BE CARRIED OUT IN A VACUUM OR AT LOW PRESSURE.

YIELD POINT:
THE FIRST STRESS IN A MATERIAL, USUALLY LESS THEN THE MAXIMUM ATTAINABLE STRESS, AT WHICH AN INCREASE IN STRAIN OCCURS WITHOUT AN INCREASE IN STRESS. ONLY CERTAIN METALS EXHIBIT A YIELD POINT. IF THERE IS A DECREASE IN STRESS AFTER YIELDING, A DISTINCTION MAY BE MADE BETWEEN UPPER AND LOWER YIELD POINTS.

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.

YOUNG'S MODULUS:
THE MODULUS OF ELASTICITY IN TENSION OR COMPRESSION.

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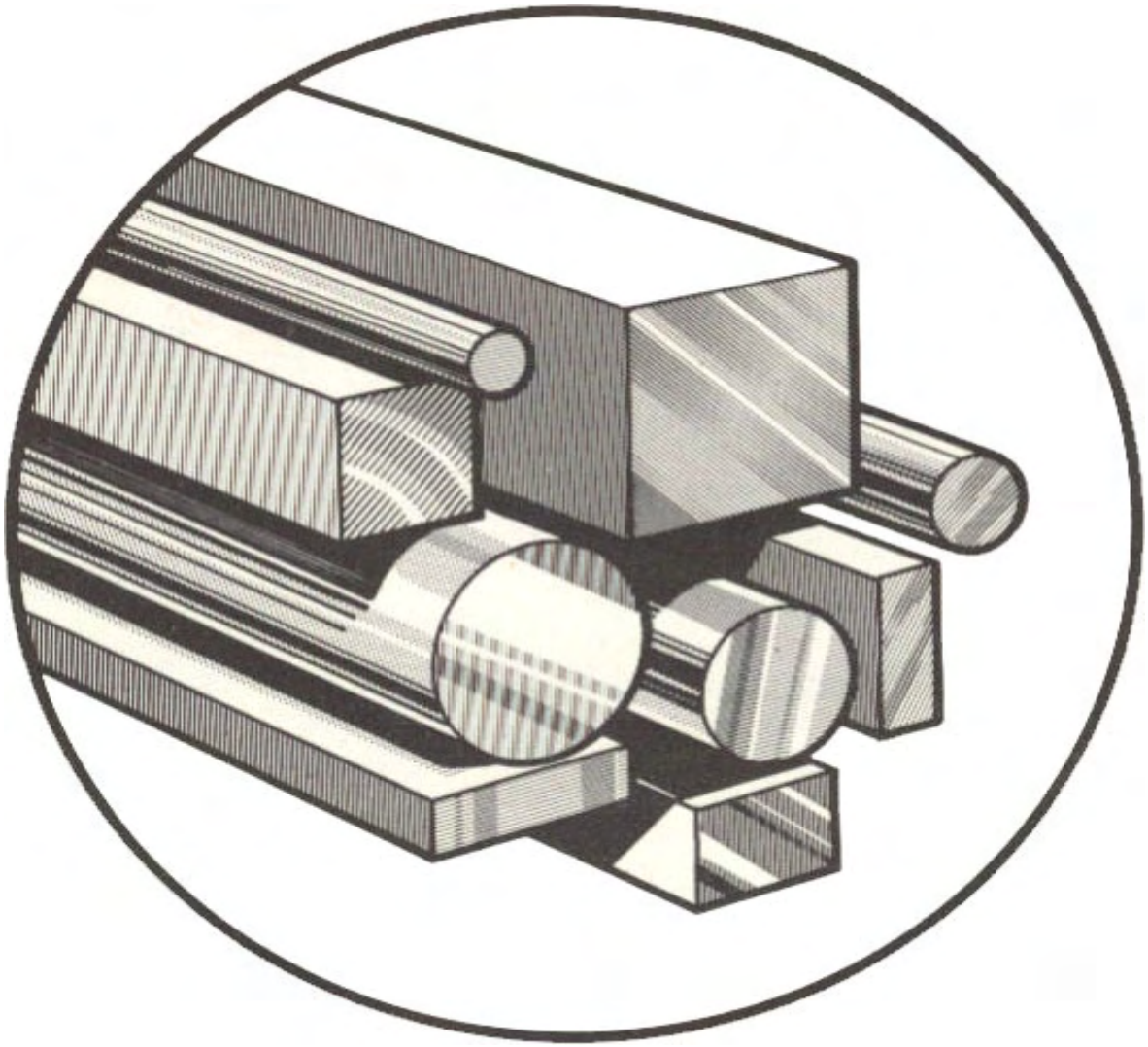
PRODUCT MANUAL

SECTION 13.
COLOR CODES



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PRODUCT MANUAL

COLOR CODE

THE STEEL INDUSTRY DOES NOT HAVE A STANDARD COLOR CODE.

THE FOLLOWING COLORS AS USED BY **VANGUARD STEEL LTD - B.C.**
ARE TO IDENTIFY GRADES FOR CHEMISTRY AND PHYSICAL PROPERTIES.

ALLOY STEEL

AISI 4130 HTSR	GREEN/RED
AISI 4140 HRA	SOLID GREEN
AISI 4140 HTSR	SOLID YELLOW
AISI 4140 HT PRECISION GROUND	FIBRE TUBED WITH YELLOW ENDS
AISI 4145 HTSR	SOLID PINK
AISI 4340 HRA	SOLID BLUE
AISI 4340 HTSR	SOLID RED
AISI 8620 NORMALIZED	SOLID BROWN
AISI 3312	SOLID ORANGE
AISI EN 30 B	RED/WHITE

CARBON STEEL

AISI 1018 C.F.	SOLID SILVER
AISI 1020 HR.	SOLID WHITE
AISI 1040 HR	WHITE/BLUE
AISI 1045 T & G	FIBRE TUBED WITH BLACK ENDS
AISI 12L14 C.F.	SOLID GOLD
60-45-12 DUCTILE	YELLOW/BLACK

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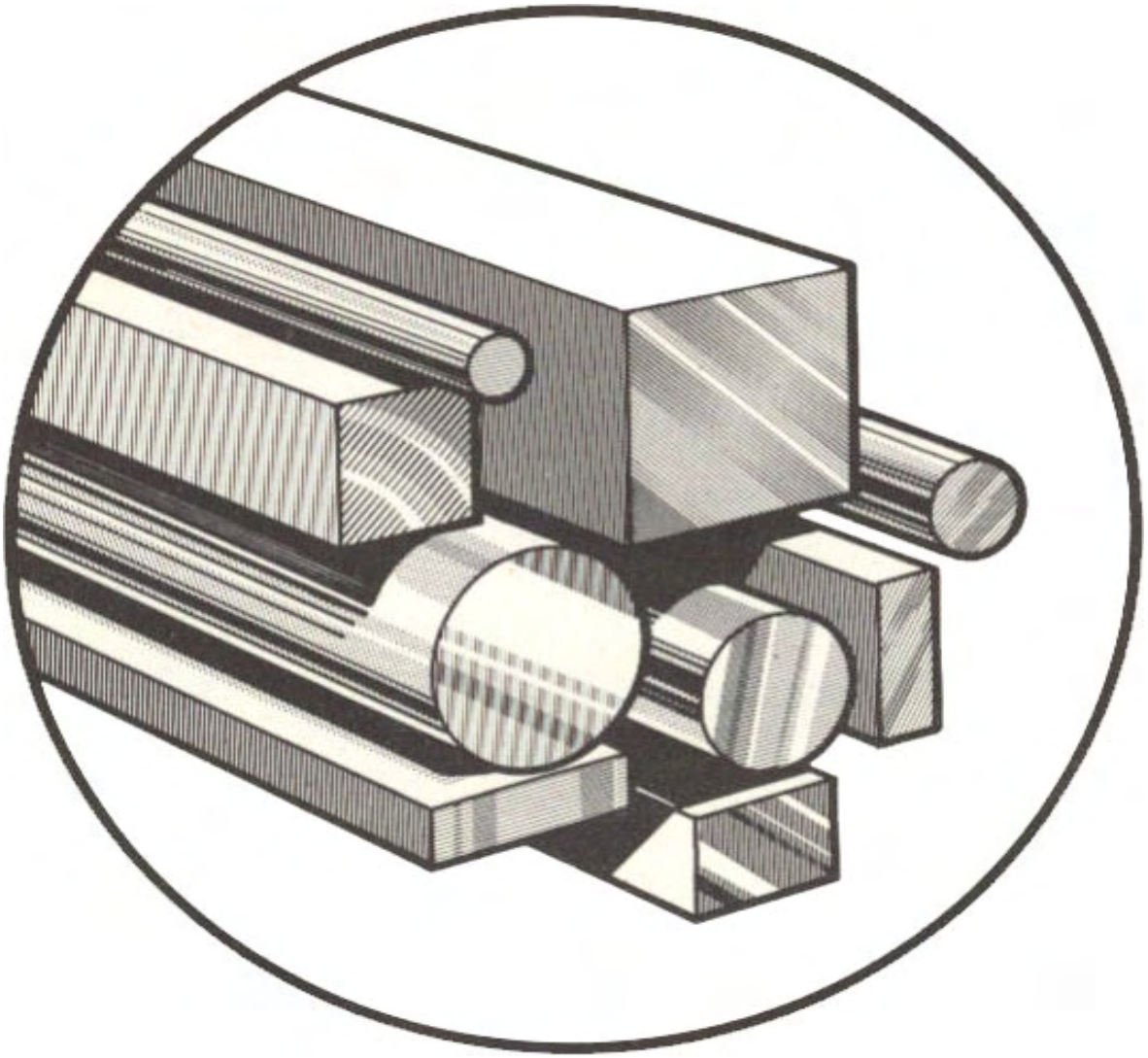
PRODUCT MANUAL

SECTION 14.
MATERIAL SAFETY DATA SHEETS



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PRODUCT MANUAL

MATERIAL SAFETY DATA SHEETS.

GLOSSARY

ACGIH	AMERICAN CONFERENCE OF GOVERNMENT INDUSTRIAL HYGIENISTS
CAS	CHEMICAL ABSTRACTS SERVICE REGISTRY NUMBER
MSDS	MATERIAL SAFETY DATA SHEETS
NIOSH	NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
OSHA	OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
PEL	PERMISSIBLE EXPOSURE LIMIT
PPM	PARTS PER MILLION
TDG	TRANSPORTATION OF DANGEROUS GOODS
TLV	8 HOUR AVERAGE THRESHOLD LIMIT VALUE
WHMIS	WORKPLACE HAZARDOUS MATERIAL INFORMATION SYSTEM

LD50 OF MATERIAL

LD = LETHAL DOSE; THE DOSE OF THE MATERIAL THAT CAUSES DEATH OF 50% OF A GROUP OF TEST ANIMALS WHEN GIVEN A SINGLE DOSE. THE LD50 CAN BE MEASURED FOR ANY ROUTE OF EXPOSURE BUT THE DERMAL (SKIN APPLICATION) AND THE ORAL VALUES ARE MOST RELEVANT TO THE WORK PLACE.

LC50 OF MATERIAL

LC = LETHAL CONCENTRATION; THE CONCENTRATION OF A MATERIAL IN AIR WHICH CAUSES THE DEATH OF 50% OF A GROUP OF TEST ANIMALS WHEN GIVEN OVER A SET PERIOD OF TIME, USUALLY 1 TO 4 HOURS. THE LC50 APPLIES TO MATERIALS THAT CAN BE INHALED.

DISCLAIMER

THE INFORMATION IN THESE MSDS WERE OBTAINED FROM SOURCES WHICH WE BELIEVE ARE RELIABLE, HOWEVER, THE INFORMATION IS PROVIDED WITHOUT ANY REPRESENTATION OR WARRANTY EXPRESS OR IMPLIED REGARDING THE ACCURACY OR CORRECTNESS.

THE CONDITIONS OR METHODS OF HANDLING, STORAGE, USE AND DISPOSAL OF THE PRODUCT ARE BEYOND OUR KNOWLEDGE. FOR THIS AND OTHER REASONS, WE DO NOT ASSUME RESPONSIBILITY AND EXPRESSLY DISCLAIM LIABILITY FOR LOSS, DAMAGE OR EXPENSE ARISING OUT OF OR IN ANY WAY CONNECTED WITH THE HANDLING, STORAGE, USE OR DISPOSAL OF THE PRODUCT

VANGUARD STEEL LTD.

PRODUCT MANUAL

MATERIAL SAFETY DATA SHEETS.

SECTION I - MATERIAL IDENTIFICATION AND USE

MATERIAL NAME:	HR & CF CARBON STEELS HR & CF ALLOY STEELS
CARBON AND ALLOY STEEL BAR, HOLLOW BAR & PLATE	

SECTION I I - HAZARDOUS INGREDIENTS

INGREDIENTS	CAS NUMBER	% WEIGHT	EXPOSURE LIMITS		LD50/LC50
			OSHA PEL (MG/M3)	ACGIH TVL (MG/M3)	ROUTE
IRON (FE)	7439-89-6	95-99	10 AS OXIDE FUME	5 AS IRON OXIDE	NOT APPLICABLE
ALLOYING ELEMENTS					
ALUMINUM (AL)	7429-90-5	< 2	15 DUST	10 (DUST)	NOT APPLICABLE
CARBON (C)	7440-44-0	< 2	NONE LISTED	NONE LISTED	NOT APPLICABLE
CHROMIUM (CR)	7440-47-3	< 2	1.0 AS CHROME	.5 METAL	NOT APPLICABLE
COBALT (CO)	7440-48-4	8 MAX.	0.1	.05 AS FUME	NOT APPLICABLE
COPPER (CU)	7440-50-8	< 1	0.2	1 AS DUST AND MIST	NOT APPLICABLE
LEAD (PB)	7439-92-1	< .35	0.05	.15 DUST AND FUME	NOT APPLICABLE
MANGANESE (MN)	7439-96-5	< 2.5	5 MANGANESE	5 AS DUST; 1 AS FUME	LD50 9MG/KG
MOLYBDENUM (MO)	7439-98-7	< 2	15 AS INSOLUBLE COMPDS.	10 AS INSOLUBLE COMPD	NOT APPLICABLE
NICKEL (NI)	7440-02-0	< 1	1	1	NOT APPLICABLE
PHOSPHORUS (P)	7723-14-0	0.15 MAX.	0.1 AS PHOSPHOR	0.1 AS PHOSPHOR	NOT APPLICABLE
SILICON (SI)	7440-21-3	< 2.3	15 AS DUST	10 AS DUST	NOT APPLICABLE
SULFUR (S)	7704-34-9	< 1	13 SULFUR DIOXIDE	5 SULFUR DIOXIDE	NOT APPLICABLE
TUNGSTEN (W).	7440-33-7	0-18	NONE LISTED	5 INSOLUBLE COMPDS	NOT APPLICABLE
VANADIUM (V)	1314-62-1	< 1	0.5 DUST; 0.1 FUME	0.05 DUST AND FUME	NOT APPLICABLE
ZINC (ZN) COATING	1314-13-2	10 MAX.	5.0 AS FUME	5.0 AS FUME	NOT APPLICABLE

NOTE: THE ABOVE LISTING IS A SUMMARY OF ELEMENTS USED IN ALLOYING STEEL. VARIOUS GRADES OF STEEL WILL CONTAIN DIFFERENT COMBINATIONS OF THESE ELEMENTS. TRACE ELEMENTS MAY ALSO BE PRESENT IN MINUTE AMOUNTS. NO PERMISSIBLE EXPOSURE LIMITS (PEL) OR THRESH OLDS LIMIT (TVL) EXIST FOR STEEL.

SECTION I I I - PHYSICAL DATA

PHYSICAL STATE	ODOR AND APPEARANCE		ODOR THRESHOLD (PPM)	SPECIFIC GRAVITY
GAS [ ]LIQUID[ ]SOLID [X]	SILVER / GRAY METALLIC	NOT APPLICABLE	NOT APPLICABLE	7.6-7.8
VAPOR PRESSURE (MM)	**VAPOR DENSITY (AIR = 1)**	**EVAPORATION RATE**	**BOILING POINT (°C)**	**FREEZING POINT (°C)**
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	MELTING PT 1530ºC
SOLUBILITY IN WATER (20°C)	**% VOLATILE (BY VOLUME)**	**pH**	**COEFFICIENT OF WATER/OIL DISTRIBUTION**	
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	

SECTION I V FIRE AND EXPLOSION DATA

FLAMMABILITY	IF YES, UNDER	MEANS OF EXTINCTION
YES: [ ] NO: [X]	WHICH CONDITION:	NOT APPLICABLE

SPECIAL PROCEDURES	FLASHPOINT (°C) AND METHOD	UPPER EXPLOSION LIMIT (% BY VOLUME)
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
LOWER EXPLOSION LIMIT (% BY VOLUME)	**AUTO IGNITION TEMPERATURE (°C)**	**HAZARDOUS COMBUSTION PRODUCTS**
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE

EXPLOSION DATA SENSITIVITY TO CHEMICAL IMPACT	RATE OF BURNING	EXPLOSIVE POWER	SENSITIVITY TO STATIC DISCHARGE
NO	NOT APPLICABLE	NOT APPLICABLE	NO

SECTION V - REACTIVITY DATA

CHEMICAL STABILITY	IF NO, UNDER
YES: [X] NO: [ ]	WHICH CONDITION

INCOMPATIBILITY TO OTHER SUBSTANCES	IF SO, WHICH ONES ?
YES: [X] NO: [ ]	CONTACT WITH MINERAL ACIDS WILL RELEASE HYDROGEN GAS

REACTIVITY AND UNDER WHAT CONDITIONS	HAZARDOUS DECOMPOSITION PRODUCTS
NOT APPLICABLE	NOT APPLICABLE

MATERIAL SAFETY DATA SHEETS.

SECTION V I - TOXICOLOGICAL PROPERTIES OF PRODUCTS

ROUTE OF ENTRY [ ] SKIN CONTACT [X] SKIN ABSORPTION [ ] EYE CONTACT [X] INHALATION ACUTE [X] INHALATION CHRONIC [X] INGESTION

STEEL PRODUCTS IN A NORMAL STATE POSE NO INHALATION, INGESTION OR CONTACT HAZARD, HOWEVER THESE MAY OCCUR WITH BURNING, WELDING OR GRINDING OPERATIONS, PROLONGED CONTACT WITH COATING MATERIALS MAY CAUSE SKIN IRRITATION AND/OR DERMATITIS.

EFFECTS OF ACUTE EXPOSURE TO PRODUCT

NONE TO SHIPPED PRODUCT, WELDING OR BURNING OF MATERIAL WILL GENERATE METAL FUMES, INHALATION OVER EXPOSURE TO FUMES MAY CAUSE FLU-LIKE SYMPTOMS (I.E. CHILLS, FEVER) CALLED METAL FUME FEVER, EYE, NOSE OR THROAT IRRITATION. EYE IRRITATION AS A RESULT OF CONTACT WITH LIME COATING.

EFFECTS OF CHRONIC EXPOSURE TO PRODUCT

NONE TO SHIPPED PRODUCT, WELDING, BURNING, GRINDING GENERATES METAL FUME OR OXIDE DUST. PROLONGED INHALATION OVEREXPOSURE TO DUST OR FUME (IRON OXIDE) MAY RESULT IN THE ACCUMULATION OF IRON OXIDE DUST IN THE LUNGS; A CONDITION KNOWN AS SIDEROSIS, WITH FEW OR NO SYMPTOMS. CERTAIN NICKEL AND CHROMIUM COMPOUNDS HAVE BEEN LISTED WITH (ARC AS NASAL) AND LUNG CARCINOGENS, PROLONGED SKIN CONTACT MAY CAUSE DERMATITIS IN SENSITIVE INDIVIDUALS (FROM NICKEL, CHROMIUM & COBALT CONTENT IN STEEL). PROLONGED OVEREXPOSURE TO COBALT DUST MAY RESULT IN AN ASTHMA-LIKE CONDITION (COUGH, SHORTNESS OF BREATH).

LD50 OF PRODUCT (SPECIES AND ROUTE)	IRRITANCY OF PRODUCT	EXPOSURE LIMITS OF PRODUCT
9 MG/KG (ORAL-RAT)	NOT APPLICABLE	SEE SECTION I I
LC50 OF PRODUCT (SPECIFY SPECIES)	**SENSITIZATION TO PRODUCT**	**SYNERGISTIC MATERIALS**
NOT AVAILABLE	NO KNOWN EFFECTS	NO KNOWN EFFECTS

CARCINOGENICITY [X]	REPRODUCTIVE EFFECTS [ ]	TERATOGENICITY [ ]	MUTAGENICITY [ ]
SEE ABOVE	NO KNOWN EFFECTS	NO KNOWN EFFECTS	NO KNOWN EFFECTS

SECTION V I I - PREVENTIVE MEASURES

PERSONAL PROTECTIVE EQUIPMENT

DEPENDS ON THE PROCESS BEING PERFORMED ON THE MATERIAL. EACH OPERATION MUST BE ASSESSED FOR SUITABLE PROTECTIVE EQUIPMENT.

GLOVES (SPECIFY)	RESPIRATORY (SPECIFY)	EYE (SPECIFY)	FOOTWEAR (SPECIFY)
LEATHER FACED OR EQUIVALENT	SEE BELOW	SAFETY GLASSES OR FACE SHIELD AS REQUIRED	SAFETY SHOES/BOOTS AS REQUIRED
CLOTHING (SPECIFY)	**OTHER (SPECIFY)**		
NOT APPLICABLE	RESPIRATORY-NIOSH APPROVED AIR PURIFYING FOR DUST MIST OR FUME WHERE REQUIRED		

ENGINEERING CONTROLS (E.G. VENTILATION, ENCLOSED PROCESS, SPECIFY)

GENERAL OR LOCAL VENTILATION DURING WELDING, BURNING, OR GRINDING.

LEAK AND SPILL PROCEDURE	WASTE DISPOSAL	HANDLING PROCEDURES AND EQUIPMENT
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
STORAGE REQUIREMENT	**SPECIAL SHIPPING INFORMATION**	
NOT APPLICABLE	NOT APPLICABLE	

SECTION V I I I - FIRST AID MEASURES

SKIN	WASH AFFECTED AREA WITH SOAP AND WATER. SEEK MEDICAL ATTENTION IF IRRITATION PERSISTS
EYE	FOR IRRITATION FROM COATING MATERIALS, FLUSH EYES WITH PLENTY OF WATER WHILE HOLDING EYE LIDS OPEN. SEEK MEDICAL ATTENTION IF IRRITATION PERSISTS
INHALATION	FOR 0VEREXPOSURE TO METAL FUMES, REMOVE TO FRESH AIR. SEEK MEDICAL ATTENTION.
INGESTION	NOT APPLICABLE
GENERAL ADVISE	SOME OF THE STEEL GRADES MAY HAVE AN OIL COATING APPLIED FOR RUST PREVENTION PURPOSES OR A LIME COATING. THE OIL IS 95-98% PETROLEUM OIL. USE IMPERVIOUS GLOVES WHEN HANDLING TO PREVENT SKIN IRRITATION

SECTION I X

PREPARED BY	PHONE NUMBER	DATE
VANGUARD STEEL LTD	(905) 821-1100	September 2006

VANGUARD STEEL LTD.

PRODUCT MANUAL

MATERIAL SAFETY DATA SHEETS.

SECTION I - MATERIAL IDENTIFICATION AND USE

MATERIAL NAME:	**HOT ROLLED TOOL STEELS**
ALLOY TOOL STEELS	**GROUND TOOL STEELS**
BAR, HOLLOW BAR & PLATE	

SECTION I I - HAZARDOUS INGREDIENTS

INGREDIENTS	CAS NUMBER	% WEIGHT	EXPOSURE LIMITS		LD50/LC50
			OSHA PEL (MG/M3)	ACGIH TVL (MG/M3)	ROUTE
IRON (FE)	7439-89-6	95-99	10 (OXIDE FUME)	5 (AS IRON OXIDE)	NOT APPLICABLE
ALLOYING ELEMENTS					
CHROMIUM (CR)	7440-47-3	25	1 METAL	.5 METAL	NOT APPLICABLE
COBALT (CO)	7440-48-4	8	0.1	0.05	NOT APPLICABLE
MANGANESE (MN)	7439-96-5	15	C 5 DUST	C 5 AS DUST; 1 AS FUME	LD50 9MG/KG
MOLYBDENUM (MO)	7439-98-7	5	15	10	NOT APPLICABLE
NICKEL (NI)	7440-02-0	5	1 METAL	1 METAL	NOT APPLICABLE
SILICON (SI)	7440-21-3	2.5	5	10	NOT APPLICABLE
VANADIUM (V)	1314-62-1	5	C .5	C .05	NOT APPLICABLE

NOTE: THE ABOVE LISTING IS A SUMMARY OF ELEMENTS USED IN ALLOYING STEEL. VARIOUS GRADES OF STEEL WILL CONTAIN DIFFERENT COMBINATIONS OF THESE ELEMENTS. TRACE ELEMENTS MAY ALSO BE PRESENT IN MINUTE AMOUNTS. NO PERMISSIBLE EXPOSURE LIMITS (PEL) OR THRESH OLDS LIMIT (TVL) EXIST FOR STEEL.

SECTION I I I - PHYSICAL DATA

PHYSICAL STATE	ODOR AND APPEARANCE		ODOR THRESHOLD (PPM)	SPECIFIC GRAVITY
GAS [ ]LIQUID[ ]SOLID [X]	SILVER / GRAY METALLIC	NOT APPLICABLE	NOT APPLICABLE	7.6-7.8
VAPOR PRESSURE (MM)	**VAPOR DENSITY (AIR = 1)**	**EVAPORATION RATE**	**BOILING POINT (°C)**	**FREEZING POINT (°C)**
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	MELTING PT 1530 ºC
SOLUBILITY IN WATER (20°C)	**% VOLATILE (BY VOLUME)**	**pH**	**COEFFICIENT OF WATER/OIL DISTRIBUTION**	
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	

SECTION I V FIRE AND EXPLOSION DATA

FLAMMABILITY	IF YES, UNDER	MEANS OF EXTINCTION
YES: [ ] NO: [X]	WHICH CONDITION:	NOT APPLICABLE

SPECIAL PROCEDURES	FLASHPOINT (°C) AND METHOD	UPPER EXPLOSION LIMIT (% BY VOLUME)
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
LOWER EXPLOSION LIMIT (% BY VOLUME)	**AUTO IGNITION TEMPERATURE (°C)**	**HAZARDOUS COMBUSTION PRODUCTS**
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE

EXPLOSION DATA SENSITIVITY TO CHEMICAL IMPACT	RATE OF BURNING	EXPLOSIVE POWER	SENSITIVITY TO STATIC DISCHARGE
NO	NOT APPLICABLE	NOT APPLICABLE	NO

SECTION V - REACTIVITY DATA

CHEMICAL STABILITY	IF NO, UNDER
YES: [X] NO: [ ]	WHICH CONDITION

INCOMPATIBILITY TO OTHER SUBSTANCES	IF SO, WHICH ONES ?
YES: [X] NO: [ ]	CONTACT WITH MINERAL ACIDS WILL RELEASE HYDROGEN GAS

REACTIVITY AND UNDER WHAT CONDITIONS	HAZARDOUS DECOMPOSITION PRODUCTS
NOT APPLICABLE	NOT APPLICABLE

VANGUARD STEEL LTD.

PRODUCT MANUAL

MATERIAL SAFETY DATA SHEETS.

SECTION V I - TOXICOLOGICAL PROPERTIES OF PRODUCTS

ROUTE OF ENTRY [ ] SKIN CONTACT [X] SKIN ABSORPTION [ ] EYE CONTACT [X] INHALATION ACUTE [X] INHALATION CHRONIC [X] INGESTION

STEEL PRODUCTS IN A NORMAL STATE POSE NO INHALATION, INGESTION OR CONTACT HAZARD, HOWEVER THESE MAY OCCUR WITH BURNING, WELDING OR GRINDING OPERATIONS, PROLONGED CONTACT WITH COATING MATERIALS MAY CAUSE SKIN IRRITATION AND/OR DERMATITIS.

EFFECTS OF ACUTE EXPOSURE TO PRODUCT

NONE TO SHIPPED PRODUCT, WELDING OR BURNING OF MATERIAL WILL GENERATE METAL FUMES, INHALATION OVER EXPOSURE TO FUMES MAY CAUSE FLU-LIKE SYMPTOMS (I.E. CHILLS, FEVER) CALLED METAL FUME FEVER, EYE, NOSE OR THROAT IRRITATION. EYE IRRITATION AS A RESULT OF CONTACT WITH LIME COATING.

EFFECTS OF CHRONIC EXPOSURE TO PRODUCT

NONE TO SHIPPED PRODUCT, WELDING, BURNING, GRINDING GENERATES METAL FUME OR OXIDE DUST. PROLONGED INHALATION OVEREXPOSURE TO DUST OR FUME (IRON OXIDE) MAY RESULT IN THE ACCUMULATION OF IRON OXIDE DUST IN THE LUNGS; A CONDITION KNOWN AS SIDEROSIS, WITH FEW OR NO SYMPTOMS. CERTAIN NICKEL AND CHROMIUM COMPOUNDS HAVE BEEN LISTED WITH (ARC AS NASAL) AND LUNG CARCINOGENS, PROLONGED SKIN CONTACT MAY CAUSE DERMATITIS IN SENSITIVE INDIVIDUALS (FROM NICKEL, CHROMIUM & COBALT CONTENT IN STEEL). PROLONGED OVEREXPOSURE TO COBALT DUST MAY RESULT IN AN ASTHMA-LIKE CONDITION (COUGH, SHORTNESS OF BREATH).

LD50 OF PRODUCT (SPECIES AND ROUTE)	IRRITANCY OF PRODUCT	EXPOSURE LIMITS OF PRODUCT
9 MG/KG (ORAL-RAT)	NOT APPLICABLE	SEE SECTION I I
LC50 OF PRODUCT (SPECIFY SPECIES)	**SENSITIZATION TO PRODUCT**	**SYNERGISTIC MATERIALS**
NOT AVAILABLE	NO KNOWN EFFECTS	NO KNOWN EFFECTS

CARCINOGENICITY [X]	REPRODUCTIVE EFFECTS [ ]	TERATOGENICITY [ ]	MUTAGENICITY [ ]
SEE ABOVE	NO KNOWN EFFECTS	NO KNOWN EFFECTS	NO KNOWN EFFECTS

SECTION V I I - PREVENTIVE MEASURES

PERSONAL PROTECTIVE EQUIPMENT

DEPENDS ON THE PROCESS BEING PERFORMED ON THE MATERIAL. EACH OPERATION MUST BE ASSESSED FOR SUITABLE PROTECTIVE EQUIPMENT.

GLOVES (SPECIFY)	RESPIRATORY (SPECIFY)	EYE (SPECIFY)	FOOTWEAR (SPECIFY)
LEATHER FACED OR EQUIVALENT	SEE BELOW	SAFETY GLASSES OR FACE SHIELD AS REQUIRED	SAFETY SHOES/BOOTS AS REQUIRED

CLOTHING (SPECIFY)	OTHER (SPECIFY)
NOT APPLICABLE	RESPIRATORY-NIOSH APPROVED AIR PURIFYING FOR DUST MIST OR FUME WHERE REQUIRED

ENGINEERING CONTROLS (E.G. VENTILATION, ENCLOSED PROCESS, SPECIFY)

GENERAL OR LOCAL VENTILATION DURING WELDING, BURNING, OR GRINDING.

LEAK AND SPILL PROCEDURE	WASTE DISPOSAL	HANDLING PROCEDURES AND EQUIPMENT
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE

STORAGE REQUIREMENT	SPECIAL SHIPPING INFORMATION
NOT APPLICABLE	NOT APPLICABLE

SECTION V I I I - FIRST AID MEASURES

SKIN	WASH AFFECTED AREA WITH SOAP AND WATER. SEEK MEDICAL ATTENTION IF IRRITATION PERSISTS
EYE	FOR IRRITATION FROM COATING MATERIALS, FLUSH EYES WITH PLENTY OF WATER WHILE HOLDING EYE LIDS OPEN. SEEK MEDICAL ATTENTION IF IRRITATION PERSISTS
INHALATION	FOR 0VEREXPOSURE TO METAL FUMES, REMOVE TO FRESH AIR. SEEK MEDICAL ATTENTION.
INGESTION	NOT APPLICABLE
GENERAL ADVISE	SOME OF THE STEEL GRADES MAY HAVE AN OIL COATING APPLIED FOR RUST PREVENTION PURPOSES OR A LIME COATING. THE OIL IS 95-98% PETROLEUM OIL. USE IMPERVIOUS GLOVES WHEN HANDLING TO PREVENT SKIN IRRITATION

SECTION I X

PREPARED BY	PHONE NUMBER	DATE
VANGUARD STEEL LTD	(905) 821-1100	September 2006

VANGUARD STEEL LTD.

PRODUCT MANUAL

MATERIAL SAFETY DATA SHEETS.

SECTION I - MATERIAL IDENTIFICATION AND USE

MATERIAL NAME:	CHROME PLATED 1045, 1050
CHROME PLATED - CARBON STEEL	

SECTION I I - HAZARDOUS INGREDIENTS

INGREDIENTS	CAS NUMBER	% WEIGHT	EXPOSURE LIMITS		LD50/LC50
			OSHA PEL (MG/M3)	ACGIH TVL (MG/M3)	ROUTE
IRON (FE)	7439-89-6	95-99	10 AS OXIDE FUME	5 AS IRON OXIDE	NOT APPLICABLE
ALLOYING ELEMENTS					
ALUMINUM (AL)	7429-90-5	< 2	15 DUST	10 (DUST)	NOT APPLICABLE
CARBON (C)	7440-44-0	< 2	NONE LISTED	3.5 AS CARBON BLACK	NOT APPLICABLE
CHROMIUM (CR.)	7440-47-3	< 1	1 (CR. & INSOL. SALT)	.5 METAL	NOT APPLICABLE
COBALT (CO)	7440-48-4	< 1	0.1	.05 AS FUME	NOT APPLICABLE
COPPER (CU)	7440-50-8	< 1	0.2	1 AS DUST AND MIST	NOT APPLICABLE
BISMUTH (BL)	7440-69-9	< 1	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
MANGANESE (MN)	7439-96-5	< 2	5	5 AS DUST; 1 AS FUME	LD50 9MG/KG
MOLYBDENUM (MO)	7439-98-7	< 1	5	10 (INSOL. SALTS)	NOT APPLICABLE
NICKEL (NI)	7440-02-0	< 1	1.0	1.0	NOT APPLICABLE
PHOSPHORUS (P)	7723-14-0	< 1	0.1	0.1	NOT APPLICABLE
SILICON (SI)	7440-21-3	< 1	15 DUST	10 TOTAL DUST	NOT APPLICABLE
SULFUR (S)	7704-34-9	< 1	13 SULFUR DIOXIDE	5 SULFUR DIOXIDE	NOT APPLICABLE
VANADIUM (V)	7440-62-2	< 1	0.5 DUST; 0.1 FUME	0.05 DUST	NOT APPLICABLE
METAL COATING					
CHROMIUM (CR.)	7440-47-3	> 98	1 (CR. & INSOL. SALTS)	0.5	NOT APPLICABLE

NOTE: THE ABOVE LISTING IS A SUMMARY OF ELEMENTS USED IN ALLOYING STEEL. VARIOUS GRADES OF STEEL WILL CONTAIN DIFFERENT COMBINATIONS OF THESE ELEMENTS. TRACE ELEMENTS MAY ALSO BE PRESENT IN MINUTE AMOUNTS. NO PERMISSIBLE EXPOSURE LIMITS (PEL) OR THRESH OLDS LIMIT (TVL) EXIST FOR STEEL.

SECTION I I I - PHYSICAL DATA

PHYSICAL STATE	ODOR AND APPEARANCE		ODOR THRESHOLD (PPM)	SPECIFIC GRAVITY
GAS [ ]LIQUID[ ]SOLID [X]	SILVER / GRAY METALLIC	NOT APPLICABLE	NOT APPLICABLE	7.6-7.8
VAPOR PRESSURE (MM)	**VAPOR DENSITY (AIR = 1)**	**EVAPORATION RATE**	**BOILING POINT (°C)**	**FREEZING POINT (°C)**
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	MELTING PT 1530ºC
SOLUBILITY IN WATER (20°C)	**% VOLATILE (BY VOLUME)**	**pH**	**COEFFICIENT OF WATER/OIL DISTRIBUTION**	
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	

SECTION I V FIRE AND EXPLOSION DATA

FLAMMABILITY	IF YES, UNDER	MEANS OF EXTINCTION
YES: [ ] NO: [X]	WHICH CONDITION:	NOT APPLICABLE

SPECIAL PROCEDURES	FLASHPOINT (°C) AND METHOD	UPPER EXPLOSION LIMIT (% BY VOLUME)
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
LOWER EXPLOSION LIMIT (% BY VOLUME)	**AUTO IGNITION TEMPERATURE (°C)**	**HAZARDOUS COMBUSTION PRODUCTS**
NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE

EXPLOSION DATA SENSITIVITY TO CHEMICAL IMPACT	RATE OF BURNING	EXPLOSIVE POWER	SENSITIVITY TO STATIC DISCHARGE
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SECTION V - REACTIVITY DATA

CHEMICAL STABILITY	IF NO, UNDER
YES: [X] NO: [ ]	WHICH CONDITION

INCOMPATIBILITY TO OTHER SUBSTANCES	IF SO, WHICH ONES ?
YES: [X] NO: [ ]	CONTACT WITH MINERAL ACIDS WILL RELEASE HYDROGEN GAS

REACTIVITY AND UNDER WHAT CONDITIONS	HAZARDOUS DECOMPOSITION PRODUCTS
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MATERIAL SAFETY DATA SHEETS.

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LEATHER FACED OR EQUIVALENT	SEE BELOW	SAFETY GLASSES OR FACE SHIELD AS REQUIRED	SAFETY SHOES/BOOTS AS REQUIRED

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STORAGE REQUIREMENT	SPECIAL SHIPPING INFORMATION
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SECTION I X

PREPARED BY	PHONE NUMBER	DATE
VANGUARD STEEL LTD	(905) 821-1100	September 2006