SPECIALTY STEEL

VANGUARD STEEL LTD.

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ALLOY STEEL - 3312

AISI / SAE 3312 (UNS G 33106)
3-1/2% NICKEL-CHROMIUM CASE HARDENING STEEL

TYPICAL ANALYSIS

C	Mn	P	S	Si	Ni	Cr
0.08 / 0.13	0.045 / 0.6	0.025 Max	0.025 Max	0.2 / 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 mould, 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

MECHANICAL PROPERTIES

Hardened and tempered - uncarburized tempering temperature - 540º 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	294	285	235

AISI / SAE 3312 (UNS G 33106)
3-1/2% NICKEL-CHROMIUM CASE HARDENING STEEL

MECHANICAL PROPERTIES

Hardened and tempered-carburized single refining tempering 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	341	311	293

THERMAL TREATMENTS	DEGREES IN CELSIUS
Forging	Commence at 1175º / 1230º Finish at 870º / 925º Bury in MICA
Annealing	830º / 855º Cool in Furnace
Normalizing	870º / 925º Air Cool
Hardening & Tempering	(Uncarburized) - 815º / 840º Oil Quench, or 840º / 870º Air Quench. Temper immediately according to strength level required at 200º / 600º.
Case Hardening	(Single Refining Treatment) - After carburizing at 898º / 929º cool to room temperature. Reheat to 770º / 800º Oil Quench and temper at 200º.

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 STEEL - 4130

AISI / SAE 4130 (UNS G 41300)
CHROMIUM MOLYBDENUM STEEL

TYPICAL ANALYSIS

C	Mn	P	S	Si	Mo	Cr
0.28 / 0.33	0.4 / 0.6	0.035 Max	0.04 Max	0.15 / 0.35	0.15 / 0.25	0.8 / 1.10

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

THERMAL TREATMENTS	DEGREES IN CELSIUS
Forging	Commence at 1200º Max. Finish at 950º
Annealing	830º / 855º Cool Slowly in Furnace
Normalizing	870º / 930º Cool in Air
Hardening	840º / 870º Water Quench
	855º / 885º Oil Quench
Tempering	430º / 700º According to Properties Required

AISI / SAE 4130 (UNS G 41300)
CHROMIUM MOLYBDENUM STEEL

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 post-heating are recommended for difficult segments. The grade of welding rod to be used depends upon the thickness of section, design and service requirements, etc.

ALLOY STEEL - 4140

AISI / SAE 4140 (UNS G 41400)
CHROMIUM-MOLYBDENUM STEEL

TYPICAL ANALYSIS

C	Mn	P	S	Si	Mo	Cr
0.38 / 0.43	0.75 / 1.00	0.035 Max	0.04 Max	0.15 / 0.35	0.15 / 0.25	0.8 / 1.10

This chromium-molybdenum alloy steel is oil-hardening steel of relatively high harding ability, and is among the most widely used and versatile machinery steel. The chromium content 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 comparatively 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 540º degrees Celsius and maintains 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 be considerably increased by flame or induction hardening, or alternatively, may be nitride.

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, (%)	23	26	25	21
REDUCTION IN AREA, (%)	54	55	56	59
BRINELL HARDNESS	197	212	202	197

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, (%)	17.1	16	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, (%)	25	28.7	26.7	31
REDUCTION IN AREA, (%)	69	66.7	67	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, (%)	20	18	18	19
REDUCTION IN AREA, (%)	57	55	56	22
BRINELL HARDNESS	311	269	286	277

AISI / SAE 4140 (UNS G 41400)
CHROMIUM-MOLYBDENUM STEEL

THERMAL TREATMENTS	DEGREES IN CELSIUS
Forging	Commence at 1200º Max. Finish at 950º
Annealing	815º / 950º Cool Slowly in Furnace
Normalizing	870º / 900º Cool in Air
Hardening	820º / 870º Oil Quench
Tempering	430º / 700º 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 STEEL - 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	Mo	Ni	Cr
0.42 / 0.49	0.75 / 1.30	0.035 Max	0.04 Max	0.15 / 0.35	0.15 / 0.45	1.00 Max	0.75 / 1.20

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 @ 57º 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" to 7"	7" & Over
TENSILE STRENGTH, (PSI)	145,000	140,000	135,000
YIELD STRENGTH, (PSI) ELONGATION,	125,000	110,000	100,000
(%)	14	14	14
REDUCTION IN AREA, (%)	40 - 50	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 STEEL - 4340

AISI / SAE 4340 (UNS G 43400)
NICKEL-CHROMIUM-MOLYBDENUM STEEL

TYPICAL ANALYSIS

C	Mn	P	S	Si	Mo	Ni	Cr
0.38 / 0.43	0.6 / 0.8	0.035 Max	0.04 Max	0.15 / 0.35	0.2 / 0.3	1.65 / 2	0.7 / 0.9

The "king" of the hardening grades of constructional alloy steels. A rich alloy content, this nickel-chromium-molybdenum steel, possesses much deeper harding ability than 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	23	21	22
REDUCTION IN AREA, (%)	46	49	50	48
BRINELL HARDNESS	229	223	217	217

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	18.2	17.8	14.4
REDUCTION IN AREA, (%)	53	55.8	54.6	40.2

BRINELL HARDNESS	285	321	285 / 311	302 / 311

ALLOY STEEL - 4340

AISI / SAE 4340 (UNS G 43400)
NICKEL-CHROMIUM-MOLYBDENUM STEEL

THERMAL TREATMENTS	DEGREES IN CELSIUS
Forging	Commence at 1200º Max. Finish at 950º
Annealing	835º / 900º Cool Slowly in Furnace
Normalizing	855º / 900º (Due to the air hardening properties of 4340, normalizing is not recommended except when followed by tempering)
	815º / 855º Oil Quench
Hardening	According to Properties Required
Tempering	

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.

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 STEEL - 8620

AISI / SAE 8620 (UNS G 86200)
NICKEL-CHROMIUM-MOLYBDENUM CASE HARDENING STEEL

TYPICAL ANALYSIS

C	Mn	P	S	Si	Mo	Ni	Cr
0.18 / 0.23	0.7 / 0.9	0.035 Max	0.04 Max	0.15 / 0.35	0.15 / 0.25	0.4 / 0.7	0.4 / 0.7

An alloy steel designed for case hardening applications. The nickel imparts 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
REDUCTION IN AREA, (%)	61
BRINELL HARDNESS	186

AISI / SAE 8620 (UNS G 86200)
NICKEL-CHROMIUM-MOLYBDENUM CASE HARDENING STEEL

THERMAL TREATMENTS	DEGREES IN CELSIUS
Forging	Commence at 1200º Max. Finish at 950º
Annealing	856º / 885º Cool Slowly in Furnace
Normalizing	898º / 926º Cool in Air
Hardening & tempering	(Uncarburized) - 815º / 855º Oil or Water Quench, temper at 200º to 650º according to strength level required.

(Carburizing) - Direct Oil Quenching

1.) Oil quench direct from carburizing temperature. Draw at desired temperature for at least 1 to 2 hours per inch of section.

2.) Single Refine - Box cool from pack carburizing or air cool from other media. Reheat to 829º / 842º, oil quench. Draw at desired temperature for minimum 1 to 2 hours per inch of section.
(Provides good case hardness and core properties)

3.) Double refine - Box cool from carburizing media.
Reheat to 829º / 842º, oil quench. Reheat to 760º / 787º, oil quench.
Draw at desired temperature for minimum 1 - 2 hours per Inch of section.
(provides optimum combination of case hardness, core strength and toughness)

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 than 1" or where a weldment Is subject to restraint and is unable to contract freely during cooling. As steel harding ability increases, so should the preheat temperature.

CARBON STEEL - 1018

AISI / SAE 1018 ASTM A 108 (UNS G 10180)

TYPICAL ANALYSIS

C	Mn	P	S
0.15 / 0.20	0.60 / 0.90	0.04 max	0.05 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.)

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.)

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.

AISI / SAE 1018 ASTM A 108 (UNS G 10180)

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" and Under	-0.002"
> 1-1/2" to 2-1/2"	-0.003"
> 2-1/2" to 4"	-0.004"
> 4" to 6"	-0.005"
> 6" to 8"	-0.006"

CARBON STEEL - 12L14

AISI / SAE 12L14 (UNS G 12144)

TYPICAL ANALYSIS

C	Mn	P	S
0.15 Max	0.85 / 1.15	0.04 / 0.09	0.26 / 0.35

C12L14 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

For 1" round

(The following values are average values 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.

CARBON STEEL-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
0.43 / 0.50	0.60 / 0.90	0.04 Max	0.05 Max	0.15 / 0.35

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 centreless 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 unsymmetrically 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)	115,000	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% of AISI B-1112. Average surface cutting speed is 95 to 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 1/4" 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.

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

SIZE TOLERANCE

All tolerances are minus

DIAMETER	TOLERANCES
1-1/2" and Under	-0.001"
> 1-1/2" to 2-1/2"	-0.0015"
> 2-1/2" to 3"	-0.002"
> 3" to 4"	-0.003"
> 4" to 6"	-0.005"
> 6" to 7"	-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
0.43 / 0.50	0.60 / 0.90	0.04 Max	0.05 Max	0.15 / 0.35

The steel used is C1045 / 1050 cold finished shafting to ASTM A-08-90A. Size tolerances are to ASTM standard specifications A29 / A29M 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 centreless 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 coefficient to friction.

CHROME PLATING

Finished thickness of Chrome	0.001" Min 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

SIZE TOLERANCE

(All tolerances are minus)

DIAMETER	TOLERANCES
1-1/2" and Under	-0.0015"
> 1-1/2" to 2-1/2"	-0.002"
> 2-1/2" to 3"	-0.0025"
> 3" to 4"	-0.0035"
> 4"	-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
0.43 / 0.50	0.60 / 0.90	0.04 Max	0.05 Max	0.15 / 0.35

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 50 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	0.050" to 0.090"
CASE HARDNESS	RC 50 Min. Surface Hardness

CHROME PLATING

FINISHED THICKNESS OF CHROME	0.001" Min 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

SIZE TOLERANCE

(All tolerances are minus)

DIAMETER	TOLERANCES
1-1/2" and Under	-0.0015"
> 1-1/2" to 2-1/2"	-0.002"
> 2-1/2" to 3"	-0.0025"
> 3" to 4"	-0.0035"
> 4"	-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
0.38 / 0.43	0.75 / 1.00	0.035 Max	0.04 Max	0.15 / 0.35	0.80 / 1.10	0.15 / 0.25

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 centreless 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" and Under	-0.001"
> 1-1/2" to 2-1/2"	-0.0015"
> 2-1/2" to 3"	-0.002"
> 3" to 4"	-0.003"
> 4"	-0.005"

(Available in metric and imperial sizes)

HOT ROLLED CARBON STEEL - 1020

AISI / SAE 1020, ASTM A576 (UNS G 10200)

TYPICAL ANALYSIS

C	Mn	P	S
0.17 / 0.24	0.25 / 0.60	0.04 Max	0.05 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.

HOT ROLLED CARBON STEEL - 1040 - 1045

AISI / SAE 1040-1045, ASTM A576 (UNS G 10400-G, 10450)

TYPICAL ANALYSIS

	C	Mn	P	S
1040	0.37 / 0.40	0.60 / 0.90	0.04 Max	0.05 Max
1045	0.43 / 0.50	0.60 / 0.90	0.04 Max	0.05 Max

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

THERMAL TREATMENTS	DEGREES (Celsius)
FORGING	Commencing at 1150º Max Finish at 950º
ANNEALING	800º / 830º Surface Cool
NORMALIZING	870º / 920º Cool in Air
HARDENING	840º / 870º Water Quench 855º / 885º Oil Quench
TEMPERING	430º / 700º 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.

AISI / SAE 1040-1045, ASTM A576 (UNS G 10400-G, 10450)

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.

TOOL STEEL AISI O-1

AISI O-1UNS T 31501
THIS 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 (Celsius)
FORGING	1050º - 850º
ANNEALING	740º - 760º Tensile Strength as Annealed (41 - 48 Tons per Sq. Inch) 191 - 219 BHN
HARDENING	780º - 820º in Oil or Hot Bath (200º - 230º) Min. Soak 10 Minutes
TEMPERING (Maximum Wear)	150º - 205º
TEMPERING (Maximum Toughness)	230º - 315º
QUENCHING MEDIUM	OIL
OBTAINABLE HARDNESS - (HRC)	63 - 66
WEAR RESISTANCE	MEDIUM
TOUGHNESS	MEDIUM
DISTORTION IN HEAT TREATING	VERY LOW
MACHINABILITY	HIGH
RED HARDNESS	LOW

TOOL STEEL - 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, planing, 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 (Celsius)
FORGING	1050º - 900º
ANNEALING	840º - 870º Tensile Strength as Annealed (44 - 51 Tons per Sq. Inch) 204 - 234 BHN
HARDENING	950º - 980º in Air or Oil
TEMPERING (Maximum Wear)	175º - 205º
TEMPERING (Maximum Toughness)	Double Temper at 480º
QUENCHING MEDIUM	AIR
OBTAINABLE HARDNESS - (HRC)	63 - 66
WEAR RESISTANCE	HIGH
TOUGHNESS	MEDIUM
DISTORTION IN HEAT TREATING	LOWEST
MACHINABILITY	MEDIUM
RED HARDNESS	HIGH

TOOL STEEL - 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 mould, etc.

THERMAL TREATMENTS	DEGREES (Celsius)
FORGING	1050º - 850º
ANNEALING	800º - 850º Tensile Strength as Annealed (44 - 51 Tons per Sq. Inch) 204 - 234 BHN
HARDENING	Furnace Cooling to 600º at about 10º per Hour
TEMPERING (Maximum Wear)	175º - 205º
TEMPERING (Maximum Toughness)	Double Temper at 480º
QUENCHING MEDIUM	AIR
OBTAINABLE HARDNESS - (HRC)	63 - 65
WEAR RESISTANCE	VERY HIGH
TOUGHNESS	LOW
DISTORTION IN HEAT TREATING	LOWEST
MACHINABILITY	LOW
RED HARDNESS	HIGH

TOOL STEEL - 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 (Celsius)
FORGING	1100º - 900º
ANNEALING	800º - 840º Tensile Strength as Annealed (44 - 51 Tons per Sq. Inch) 204 - 234 BHN
HARDENING	1040º - 1080º
TEMPERING	600º - 650º
NITRIDING	500º - 520º Gas or Salt Bath
QUENCHING MEDIUM	AIR OIL
OBTAINABLE HARDNESS - (HRC)	63 - 66 52 - 56
WEAR RESISTANCE	MEDIUM
TOUGHNESS	VERY HIGH
DISTORTION IN HEAT TREATING	VERY LOW
MACHINABILITY	HIGH
RED HARDNESS	HIGH

TOOL STEEL - 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 (Celsius)
FORGING	1120º - 950º
ANNEALING	815º - 840º Tensile Strength as Annealed (45 - 52 Tons per Sq. Inch) 187 - 223 BHN
HARDENING	925º - 950º
TEMPERING (Maximum Wear)	205º - 260º
TEMPERING (Maximum Toughness)	480º - 540º
QUENCHING MEDIUM	AIR (Section 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

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, jewellers 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 per Sq. Inch
BRINELL HARDNESS	174 - 207

THERMAL TREATMENTS	**AISI W-1 DEGREES (Celsius)**	**AISI O-1 DEGREES (Celsius)**
HOT FORMING	1000º - 800º	1050º - 850º
ANNEALING	690º - 710º	740º - 760º
HARDENING	760º - 780º In Water	790º - 830º In Oil
TEMPERING	As Required	100º - 300º
OBTAINABLE HARDNESS - HRC	64 - 66	64 - 66

TOLERANCES	**PLUS or MINUS**
Up To 0.124"	0.0003"
0.125" To 0.499"	0.0005"
0.500" To 2.000"	0.0010"

(AVAILABLE IN METRIC AND IMPERIAL SIZES)

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 (Celsius)	AISI A-2 DEGREES (Celsius)
ANNEALING	760º - 785º Slow Cool in Furnace; Hardness as Annealed 190 - 220 BH	830º - 860º Slow Cool in Furnace; Hardness as Annealed 204 - 234 BH
STRESS RELIEVING	Preheat 650º - 705º High Heat 775º - 815º	Preheat 650º - 705º High Heat 940º - 980º
QUENCH	In Oil	In Air or Salt at 540º - 595º
TEMPERING	This operation should follow hardening immediately, according to properties required. 150º -205º	This operation should follow hardening immediately, according to properties required. 175º -205º
(Maximum Wear)	230º - 315º	Double Temper at 480º
(Maximum Toughness)	63 - 65 RC	63 - 65 RC
OBTAINABLE HARDNESS		

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 (Inches)	MINIMUM MACHINING ALLOWANCE PER SIDE (Inches)
0" TO 5/8"	0.016"
> 5/8" TO 7/8"	0.021"
> 7/8" TO 1"	0.023"
> 1" TO 1-1/8"	0.025"
> 1-1/8" TO 1-1/4"	0.028"
> 1-1/4" TO 1-3/8"	0.030"
> 1-3/8" TO 1-1/2"	0.033"
> 1-1/2" TO 2"	0.042"
> 2" TO 2-1/2"	0.052"
> 2-1/2" TO 3-1/2"	0.072"
> 3-1/2" TO 4-1/2"	0.090"
> 4-1/2" TO 5-1/2"	0.110"
> 5-1/2" TO 6-1/2"	0.125"
> 6-1/2" TO 8-1/4"	0.155"
> 8-1/4" TO 9-1/2"	0.203"

ROUGH TURNED BARS

10" TO 14"	0.1250"
> 14"	0.1875"

Removal for aircraft quality alloys subject to magnetic particle inspection will require approx. Twice the above machining allowance in accordance with AISI standards.

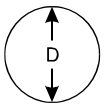
THEORETICAL WEIGHTS

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 !

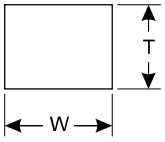
WEIGHT FORMULAS

Steel bar weights are based on (0.2836 Lbs. per Cubic Inch). Aluminum weights are based on (0.098 Lbs. per Cubic Inch (1100 Alloy)). SEE NEXT PAGE FOR CONVERSION FACTORS FOR OTHER ALLOYS.

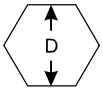


ROUND			D = INCHES
STEEL	Lbs. per Lineal Foot	=	2.67290 X D X D
	Lbs. per Lineal Inch	=	0.22274 X D X D
ALUMINUM	Lbs. per Lineal Foot	=	0.92400 X D X D

SQUARE			D = INCHES
STEEL	Lbs. per Lineal Foot	=	3.4032 X D X D
	Lbs. per Lineal Inch	=	0.2836 X D X D
ALUMINUM	Lbs. per Lineal Foot	=	1.1800 X D X D



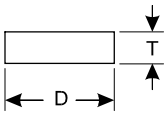
FLATS			T = INCHES, W = INCHES
STEEL	Lbs. per Lineal Foot	=	3.4032 X D X D
	Lbs. per Lineal Inch	=	0.2836 X D X D
ALUMINUM	Lbs. per Lineal Foot	=	1.1800 X D X D



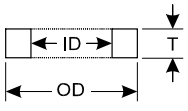
HEXAGON			D = INCHES
STEEL	Lbs. per Lineal Foot	=	2.9473 X D X D
	Lbs. per Lineal Inch	=	0.2456 X D X D
ALUMINUM	Lbs. per Lineal Foot	=	1.0200 X D X D

OCTAGON			D = INCHES
STEEL	Lbs. per Lineal Foot	=	2.81930 X D X D
	Lbs. per Lineal Inch	=	0.23494 X D X D
ALUMINUM	Lbs. per Lineal Foot	=	0.97400 X D X D

TUBING			OD = INCHES, W = INCHES
STEEL	Lbs. per Lineal Foot	=	10.68 X (OD-W)XW
	Lbs. per Lineal Inch	=	0.890 X (OD-W)XW
ALUMINUM	Lbs. per Lineal Foot	=	3.700 X (OD-W)XW



CIRCLE		D = INCHES, T = INCHES
STEEL		0.222274 X T X D X D
ALUMINUM		0.077000 X T X D X D



RINGS		OD = INCHES, ID = INCHES, T = INCHES
STEEL		0.222274 X (OD X OD - ID X ID)
ALUMINUM		0.077000 X (OD X OD - ID X ID)

WEIGHT CONVERSION FACTORS

CONVERSION (To obtain weight of:)	DENSITY (Lbs. per Cubic Inch)	FACTOR (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
BERYLLIUM	0.067	0.236
BRASS	0.307	1.084
CAST IRON	0.258	0.911
COLUMBIUM	0.310	1.095
COPPER	0.324	1.144
GOLD	0.698	2.446
LEAD	0.410	1.448
MAGNESIUM	0.065	0.229
MOLYBDENUM	0.369	1.303
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
SILVER	0.379	1.339
STAINLESS		
300 Series	0.286	1.010
400 Series	0.283	1.000
TANTALUM	0.600	2.120
TITANIUM	0.163	0.575
TUNGSTEN	0.697	2.462
ZINC	0.258	0.911
ZIRCONIUM	0.230	0.812

THEORETICAL WEIGHTS - ROUNDS

SIZE (Inch)	WEIGHT IN POUNDS Per Foot	Per Inch
1/16	0.010	0.0009
1/8	0.042	0.0035
3/16	0.094	0.0078
1/4	0.167	0.0139
5/16	0.261	0.0218
3/8	0.376	0.0313
7/16	0.512	0.0426
1/2	0.668	0.0557
9/16	0.846	0.0705
5/8	1.044	0.0870
11/16	1.263	0.1053
3/4	1.504	0.1253
13/16	1.765	0.1470
7/8	2.046	0.1705
15/16	2.349	0.1958
1	2.673	0.2228
1-1/16	3.017	0.2515
1-1/8	3.383	0.2819
1-3/16	3.769	0.3141
1-1/4	4.176	0.3480
1-5/16	4.604	0.3837
1-3/8	5.053	0.4211
1-7/16	5.523	0.4603
1-1/2	6.014	0.5012
1-9/16	6.526	0.5438
1-5/8	7.058	0.5882
1-11/16	7.612	0.6343
1-3/4	8.186	0.6821
1-13/16	8.781	0.7317
1-7/8	9.397	0.7831
1-15/16	10.034	0.8362
2	10.690	0.8908
2-1/16	11.370	0.9475
2-1/8	12.070	1.0058
2-3/16	12.790	1.0659
2-1/4	13.532	1.1276
2-5/16	14.294	1.1911
2-3/8	15.077	1.2564
2-7/16	15.881	1.3234
2-1/2	16.706	1.3921
2-9/16	17.551	1.4626
2-5/8	18.418	1.5348
2-11/16	19.305	1.6088
2-3/4	20.214	1.6845
2-13/16	21.143	1.7619
2-7/8	22.093	1.8411
2-15/16	23.064	1.9220
3	24.060	2.0050
3-1/16	25.069	2.0891
3-1/8	26.103	2.1752
3-3/16	27.157	2.2631
3-1/4	28.233	2.3527
3-5/16	29.329	2.4441
3-3/8	30.446	2.5372
3-7/16	31.284	2.6320
3-1/2	32.743	2.7286
3-9/16	33.923	2.8269
3-5/8	35.124	2.9270
3-11/16	36.345	3.0288
3-3/4	37.588	3.1323
3-13/16	38.851	3.2376
3-7/8	40.135	3.3446
3-15/16	41.440	3.4534
4	42.770	3.5642
4-1/16	44.113	3.6761
4-1/8	45.481	3.7901
4-3/16	46.870	3.9058
4-1/4	48.279	4.0233
4-5/16	49.710	4.1425
4-3/8	51.161	4.2634
4-7/16	52.633	4.3861
4-1/2	54.126	4.5105
4-9/16	55.640	4.6367
4-5/8	57.175	4.7646
4-11/16	58.731	4.8942
4-3/4	60.307	5.0256
4-13/16	61.905	5.1587
4-7/8	63.523	5.2936
4-15/16	65.162	5.4302
5	66.820	5.5683
5-1/16	68.504	5.7086
5-1/8	70.205	5.8504
5-3/16	71.928	5.9940
5-1/4	73.672	6.1393
5-5/16	75.436	6.2864
5-3/8	77.222	6.4351
5-7/16	79.028	6.5857
5-1/2	80.855	6.7379
5-9/16	82.703	6.8919
5-5/8	84.572	7.0477
5-11/16	86.462	7.2052
5-3/4	88.373	7.3644
5-13/16	90.304	7.5254
5-7/8	92.257	7.6881
5-15/16	94.230	7.8525

THEORETICAL WEIGHTS - ROUNDS

SIZE (Inch)	WEIGHT IN POUNDS Per Foot	Per Inch
6	96.220	8.0183
6-1/16	98.240	8.1866
6-1/8	100.276	8.3563
6-3/16	102.332	8.5277
6-1/4	104.410	8.7008
6-5/16	106.509	8.8757
6-3/8	108.628	9.0524
6-7/16	110.769	9.2307
6-1/2	112.930	9.4108
6-9/16	115.112	9.5927
6-5/8	117.315	9.7763
6-11/16	119.539	9.9616
6-3/4	121.784	10.1487
6-13/16	124.050	10.3375
6-7/8	126.336	10.5280
6-15/16	128.644	10.7203
7	131.000	10.9167
7-1/16	133.321	11.1101
7-1/8	135.691	11.3076
7-3/16	138.082	11.5069
7-1/4	140.494	11.7079
7-5/16	142.927	11.9106
7-3/8	145.381	12.1151
7-7/16	147.855	12.3213
7-1/2	150.351	12.5292
7-9/16	152.867	12.7389
7-5/8	155.404	12.9503
7-11/16	157.962	13.1635
7-3/4	160.541	13.3784
7-13/16	163.141	13.5951
7-7/8	165.762	13.8135
7-15/16	168.403	14.0336
8	171.100	14.2583
8-1/16	173.749	14.4791
8-1/8	176.453	14.7044
8-3/16	179.178	14.9315
8-1/4	181.924	15.1604
8-5/16	184.691	15.3909
8-3/8	187.479	15.6232
8-7/16	190.288	15.8573
8-1/2	193.117	16.0931
8-9/16	195.967	16.3306
8-5/8	198.839	16.5699
8-11/16	201.731	16.8109
8-3/4	204.644	17.0537
8-13/16	207.578	17.2982
8-7/8	210.533	17.5444
8-15/16	213.508	17.7924

SIZE (Inch)	WEIGHT IN POUNDS Per Foot	Per Inch
9	216.500	18.0417
9-1/16	219.522	18.2935
9-1/8	222.561	18.5467
9-3/16	225.620	18.8017
9-1/4	228.700	19.0583
9-5/16	231.801	19.3167
9-3/8	234.923	19.5769
9-7/16	238.066	19.8388
9-1/2	241.229	20.1024
9-9/16	244.414	20.3678
9-5/8	247.619	20.6349
9-11/16	250.845	20.9038
9-3/4	254.093	21.1744
9-13/16	257.361	21.4467
9-7/8	260.650	21.7208
9-15/16	263.959	21.9966
10	267.300	22.2750
10-1/16	270.642	22.5535
10-1/8	274.014	22.8345
10-3/16	277.407	23.1173
10-1/4	280.822	23.4018
10-5/16	284.257	23.6881
10-3/8	287.713	23.9761
10-7/16	291.189	24.2658
10-1/2	294.687	24.5573
10-9/16	298.206	24.8505
10-5/8	301.745	25.1454
10-11/16	305.306	25.4421
10-3/4	308.887	25.7406
10-13/16	312.489	26.0408
10-7/8	316.112	26.3427
10-15/16	319.756	26.6463
11	323.400	26.9500
11-1/16	327.107	27.2589
11-1/8	330.813	27.5678
11-3/16	334.541	27.8784
11-1/4	338.289	28.1907
11-5/16	342.058	28.5048
11-3/8	345.848	28.8207
11-7/16	349.659	29.1383
11-1/2	353.491	29.4576
11-9/16	357.344	29.7786
11-5/8	361.217	30.1014
11-11/16	365.112	30.4260
11-3/4	369.027	30.7523
11-13/16	372.964	31.0803
11-7/8	376.921	31.4101
11-15/16	380.899	31.7416

THEORETICAL WEIGHTS - ROUNDS

SIZE (Inch)	WEIGHT IN POUNDS Per Foot	Per Inch
12	384.900	32.0750
12-1/4	401.102	33.4252
12-1/2	417.641	34.8034
12-3/4	434.513	36.2094
13	451.700	37.6417
13-1/4	469.261	39.1051
13-1/2	487.136	40.5947
13-3/4	505.345	42.1121
14	523.888	43.6570
14-1/4	542.766	45.2301
14-1/2	561.977	46.8311
14-3/4	581.523	48.4599
15	601.400	50.1167
15-1/4	621.616	51.8014
15-1/2	642.164	53.5137
15-3/4	663.046	55.2539
16	684.262	50.1167
16-1/4	705.813	58.8177
16-1/2	727.697	60.6414
16-3/4	749.916	62.4930
17	772.500	64.3750
17-1/4	795.355	66.2796
17-1/2	818.576	68.2146
17-3/4	842.131	70.1775
18	866.000	72.1667
18-1/4	890.243	74.1869
18-1/2	914.800	76.2333
18-3/4	939.691	78.3076
19	964.900	80.4083
19-1/4	990.477	82.5397
19-1/2	1016.370	84.6975
19-3/4	1042.598	86.8832
20	1069.000	89.0833
20-1/4	1096.056	91.3380
20-1/2	1123.286	93.6072
20-3/4	1150.851	95.9042
21	1179.000	98.2500
21-1/4	1206.981	100.5818
21-1/2	1235.548	102.9623
21-3/4	1264.449	105.3707
22	1294.000	107.8333
22-1/4	1323.253	110.2710
22-1/2	1353.156	112.7630
22-3/4	1383.393	115.2827
23	1413.964	117.8303
23-1/4	1444.870	120.4058
23-1/2	1476.109	123.0091
23-3/4	1507.683	125.6402
24	1539.590	128.2992
24-1/4	1571.832	130.9860
24-1/2	1604.408	133.7007
24-3/4	1637.318	136.4432
25	1670.563	139.2135
25-1/4	1704.141	142.0117
25-1/2	1738.053	144.8378
25-3/4	1772.300	147.6916
26	1806.880	150.5734
26-1/4	1841.795	153.4829
26-1/2	1877.044	156.4203
26-3/4	1912.627	159.3856
27	1948.544	162.3787
27-1/4	1984.795	165.3996
27-1/2	2021.381	168.4484
27-3/4	2058.300	171.5250
28	2095.554	174.6295
28-1/4	2133.141	177.7618
28-1/2	2171.063	180.9219
28-3/4	2209.319	184.1099
29	2247.909	187.3257
29-1/4	2286.833	190.5694
29-1/2	2326.091	193.8409
29-3/4	2365.684	197.1403

THEORETICAL WEIGHTS - SQUARES

SIZE (Inch)	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
1-1/8	4.307	0.3589
1-3/16	4.799	0.3999
1-1/4	5.318	0.4431
1-5/16	5.863	0.4885
1-3/8	6.434	0.5362
1-7/16	7.032	0.5860
1-1/2	7.657	0.6381
1-9/16	8.309	0.6924
1-5/8	8.987	0.7489
1-11/16	9.691	0.8076
1-3/4	10.422	0.8685
1-13/16	11.180	0.9317
1-7/8	11.964	0.9970
1-15/16	12.775	1.0646
2	13.613	1.1344
2-1/8	15.368	1.2806
2-3/16	16.285	1.3571
2-1/4	17.229	1.4357
2-5/16	18.199	1.5166
2-3/8	19.196	1.5997
2-7/16	20.220	1.6850
2-1/2	21.270	1.7725
2-9/16	22.347	1.8622
2-5/8	23.450	1.9542
2-11/16	24.580	2.0483
2-3/4	25.737	2.1447
2-13/16	26.920	2.2433
2-7/8	28.130	2.3441
2-15/16	29.366	2.4472

SIZE (Inch)	WEIGHT IN POUNDS Per Foot	Per Inch
3	30.629	2.552
3-1/4	35.946	2.996
3-1/2	41.689	3.474
3-3/4	47.858	3.988
4	54.451	4.538
4-1/4	61.470	5.123
4-1/2	68.915	5.743
4-3/4	76.785	6.399
5	85.080	7.090
5-1/2	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	983.252	81.960
18	1102.637	91.886

THEORETICAL WEIGHTS - HEXAGONS

SIZE (Inch)	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
1-3/16	4.156	0.3463
1-1/4	4.605	0.3838
1-5/16	5.077	0.4231
1-3/8	5.572	0.4644
1-7/16	6.090	0.5075
1-1/2	6.631	0.5526
1-9/16	7.196	0.5996
1-5/8	7.783	0.6486
1-11/16	8.393	0.6994
1-3/4	9.026	0.7522
1-13/16	9.682	0.8069
1-7/8	10.362	0.8635
1-15/16	11.064	0.9220
2	11.789	0.9824
2-3/16	14.103	1.1753
2-1/4	14.921	1.2434
2-5/16	15.761	1.3134
2-3/8	16.625	1.3854
2-7/16	17.511	1.4593
2-1/2	18.421	1.5351
2-9/16	19.353	1.6128
2-5/8	20.309	1.6924
2-11/16	21.287	1.7739
2-3/4	22.289	1.8574
2-13/16	23.314	1.9428
2-7/8	24.361	2.0301
2-15/16	25.432	2.1193

SIZE (Inch)	WEIGHT IN POUNDS Per Foot	Per Inch
3	26.526	2.2105
3-1/4	31.131	2.5942
3-1/2	36.104	3.0087
3-3/4	41.446	3.4539
4	47.157	3.9297

THEORETICAL WEIGHTS - OCTAGONS

SIZE (Inch)	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
1-3/16	3.976	0.3313
1-1/4	4.405	0.3671
1-5/16	4.857	0.4047
1-3/8	5.330	0.4442
1-7/16	5.826	0.4855
1-1/2	6.343	0.5286
1-9/16	6.883	0.5736
1-5/8	7.445	0.6204
1-11/16	8.028	0.7195
1-3/4	8.634	0.7718
1-13/16	9.262	0.8260
1-7/8	9.912	0.8816
1-15/16	10.583	0.9398
2	11.277	1.1242
2-3/16	13.491	1.1894
2-1/4	14.273	1.2564
2-5/16	15.077	1.3252
2-3/8	15.903	1.3959
2-7/16	16.751	1.4684
2-1/2	17.621	1.5427
2-9/16	18.513	1.6189
2-5/8	19.427	1.6969
2-11/16	20.363	1.7767
2-3/4	21.321	1.8584
2-13/16	22.301	1.9419
2-7/8	23.303	2.0273
2-15/16	24.327	

SIZE (Inch)	WEIGHT IN POUNDS Per Foot	Per Inch
3	25.374	2.1145
3-1/4	29.779	2.4816
3-1/2	34.536	2.8780
3-3/4	39.646	3.3039
4	45.109	3.7591

THEORETICAL WEIGHTS - FLATS

SIZE (Inch)	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

SIZE (Inch)	WEIGHT IN POUNDS Per Foot	Per Inch
(1/8 X __)		
2	0.851	0.0709
2-1/4	0.957	0.0798
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	0.5254
(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

SIZE (Inch)	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
1-1/2	1.595	0.1329
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	0.588	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
3-1/2	4.467	0.3722

SIZE (Inch)	WEIGHT IN POUNDS Per Foot	Per Inch
(3/8 X __)		
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

SIZE (Inch)	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	2.925	0.2437
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

SIZE (Inch)	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	10.210	0.8508
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
2-3/4	8.189	0.6514
3	8.933	0.6824
3-1/2	10.422	0.7445
4	11.911	0.8685
4-3/4	14.145	0.9926
5	14.889	1.1787
6	17.867	1.2408
7	20.845	1.4889
8	23.822	1.7371
12	35.734	1.9852
(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

SIZE (Inch)	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

SIZE (Inch)	WEIGHT IN POUNDS Per Foot	Per Inch
(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

SIZE (Inch)	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	39.778	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
(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

SIZE (Inch)	WEIGHT IN POUNDS Per Foot	Per Inch

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 favourable 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; favours insensibility to ageing. Added in small amounts, it helps fine grain formation. Since it combines with nitrogen to form very hard nitride, it is a favourable 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 sulphur, rarely used for steel alloys.

BORON (B)

Added in amounts of 0.0005 to 0.03% it significantly increases the harden ability of steel. This effect on harden ability 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 harden ability 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 harden ability. It makes the steel apt for oil or air hardening. It reduces the critical cooling rate required for martensite formation, increases harden ability 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.

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 favours 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 favourably with sulphur to improve forging ability and surface quality as it converts sulphur to manganese sulphide, thereby, reducing the risk of hot shortness, or susceptibility to cracking and tearing, at rolling temperatures. Manganese increases tensile strength, hardness, harden ability, 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 coefficient 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 harden ability, 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.

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 shortness, 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 steel-making 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 resulphurized steel.

SULPHUR (S)

Of all companion elements in steel, sulphur shows the strongest tendency to segregate. Iron sulphide 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 sulphur has a particularly good affinity to manganese, it can be fixed in the form of manganese sulphide which are the least dangerous of all inclusions, being finely dispersed in steel and having a high melting point. Sulphur is used as an alloying addition in free-cutting steels; the finely dispersed sulphide inclusion interrupt the continuity of metal structure, thus producing short chips in machining. Sulphur 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 harden ability of medium-carbon steels ; larger additions appear to reduce the harden ability 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 favourite alloying element in high speed and hot work steels, high temperature steels and super hard steels.

CONVERSIONS

Linear Measure			
1 mi. 1 yd. 1 ft. 1 in. 1 in.	1.6093 km 0.9144 m 0.3048 m 2.540 cm 25.40 mm	1 km 1 m 1 m 1 m 1 cm 1 mm	0.6214 mi. 1.0936 yd. 3.2808 ft. 39.370 in. 0.3937 in. 0.03937 in.
Square Measure			
1 sq. in. 1 sq. ft. 1 sq. yd. 1 sq. mi.	6.4513 cm^2 0.0929 m^2 0.8361 m^2 3.5899 km^2	1 cm^2 1 m^2 1 m^2 1 km^2	0.155 sq. in. 10.7643 sq. ft. 1.196 sq. yd. 0.386 sq. mi
Cubic Measure			
1 cu. in. 1 cu. ft. 1 cu. yd.	16.3862 cm^3 0.0283 m^3 0.7646 m^3	1 cm^3 1 m^3 1 m^3	0.0610 cu. in. 35.3145 cu. ft. 1.308 cu. yd.
Weight			
1 oz. 1 lb. 1 short ton (2,000 lbs.) 1 long ton (2,240 lbs.)	28.349 g 0.454 kg 0.907 metric tons 1.016 metric tons	1 g 1 kg 1 metric ton 1 metric ton	0.035 oz. 2.2046 lbs. 1.102 short tons 0.984 long tons
Pressure / Capacity			
lbs. / sq. in. lbs. / sq. ft. lbs. / cu. in. lbs. / cu. ft. lbs / cu. yd. lbs / ft. run lbs. / yd. run	0.0703 kg / cm^2 4.882 kg / m^2 0.02728 kg / m^3 16.019 kg / m^3 0.5933 kg / m^3 1.488 kg / m 0.496 kg / m	kg / cm^2 kg / m^2 kg / m^3 kg / m^3 kg / m^3 kg / meter run kg / meter run	14.223 lbs. / sq. in. 0.2048 lbs. / sq. ft. 36.1253 lbs. / cu. in. 0.06242 lbs. / cu. ft. 1.68546 lbs. / cu. yd. 0.672 lbs. / ft. 2.016 lbs. / yd.
Temperature			
Fahrenheit (Fº)	(Fº - 32) ¸1.8 = Cº	Celcius (Cº)	(1.8 x Cº) ´ 32 = Fº

IMPERIAL TO METRIC CONVERSION

Inch Fraction	Inch Decimal	Millimeter	Inch Fraction	Inch Decimal	Millimeter
1/64	0.015625	0.3969	33/64	0.515625	13.0969
1/32	0.031250	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	3.1750	5/8	0.625	15.8750
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	6.3500	3/4	0.75	19.0500
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	9.5250	7/8	0.875	22.2250
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	12.7000	1	1.0	25.4

CONVERSIONS

TEMPERATURE CONVERSION TABLE											
º C		º F	º C		º F	º C		º F	º C		º F
-79	-110	-166	127	260			730			1190	
-73	-100	-148	132	270			740			1200	
-68	-90	-130	138	280			750			1210	
-62	-80	-112	143	290			760			1220	
-57	-70	-94	149	300			770			1230	
-51	-60	-76	154	310			780			1240	
-46	-50	-58	160	320			790			1250	
-40	-40	-40	165	330			800			1260	
-34	-30	-22	171	340			810			1270	
-29	-20	-4	177	350			820			1280	
-23	-10	14	182	360			830			1290	
-17.7	0	32	188	370			840			1300	
-17.2	1	33.8	193	380			850			1310	
-16.6	2	35.6	199	390			860			1320	
-16.1	3	37.4	204	400			870			1330	
-15.5	4	39.2	210	410			880			1340	
-15.0	5	41.0	215	420			890			1350	
-14.4	6	42.8	221	430			900			1360	
-13.9	7	44.6	226	450			910			1370	
-13.3	8	46.4	232	460			920			1380	
-12.7	9	48.2	238	470			930			1390	
-12.2	10	50.0	243	480			940			1400	
-6.6	20	68.0	249	490			950			1410	
-1.1	30	86.0	254	500			960			1420	
4.4	40	104.0	260	510			970			1430	
9.9	50	122.0	265	520			980			1440	
15.6	60	140.0		530			990			1450	
21.0	70	158.0		540			1000			1460	
26.8	80	176.0		550			1010			1470	
32.1	90	194.0		560			1020			1480	
37.7	100	212.0		570			1030			1490	
43	110	230		580			1040			1500	
49	120	248		590			1050			1510	
54	130	266		600			1060			1520	
60	140	284		610			1070			1530	
65	150	302		620			1080			1540	
71	160	320		630			1090			1550	
76	170	338		640			1100			1560	
83	180	356		650			1110			1570	
88	190	374		660			1120			1580	
93	200	392		670			1130			1590	
99	210	410		680			1140			1600	
104	220	428		690			1150			1650	
110	230	446		700			1160			1700	
115	240	464		710			1170			1750	
121	250	482		720			1180			1800	

TOOL STEEL - VPM M-4

AISI M-4
HIGH SPEED TOOL STEEL

TYPICAL ANALYSIS

C	Mn	Si	Cr	W	V	Mo
1.30			4.25	5.40	4.10	4.75

A powder metal high speed steel with extremely high wear resistance and high impact toughness. The fine grain size, small carbides, and superior cleanliness are the result of powder metallurgy microstructure.

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 mould, etc.

THERMAL TREATMENTS	DEGREES (Celsius)
FORGING	1050º - 850º
ANNEALING	800º - 850º Tensile Strength as Annealed (44 - 51 Tons per Sq. Inch) 204 - 234 BHN
HARDENING	Furnace Cooling to 600º at about 10º per Hour
TEMPERING (Maximum Wear)	175º - 205º
TEMPERING (Maximum Toughness)	Double Temper at 480º
QUENCHING MEDIUM	AIR
OBTAINABLE HARDNESS - (HRC)	63 - 65
WEAR RESISTANCE	VERY HIGH
TOUGHNESS	LOW
DISTORTION IN HEAT TREATING	LOWEST
MACHINABILITY	LOW
RED HARDNESS	HIGH