EARLE M. JORGENSEN COMPANY

REFERENCE BOOK

ALLOY • ALUMINUM • BRASS • BRONZE
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SECTION Q

MISCELLANEOUS DATA

HARDNESS CONVERSION NUMBERS FOR STEEL

BRINELL 3000 kg. Load 10 MM. BALL		ROCKWELL				SHORE	TENSILE STRENGTH
Diameter Millimeters	Hardness Number	A Scale	B Scale	C Scale	15-N Scale	SCHERO-SCOPE	psi (Approx.)
2.25	745	84.1	—	65.3	92.3	91	—
2.30	712	—	—	—	—	—	—
2.35	682	82.2	—	61.7	91.0	84	—
2.40	653	81.2	—	60.0	90.2	81	—
2.45	627	80.5	—	58.7	89.6	79	—
2.50	601	79.8	—	57.3	89.0	77	—
2.55	578	79.1	—	56.0	88.4	75	—
2.60	555	78.4	—	54.7	87.8	73	298000
2.65	534	77.8	—	53.5	87.2	71	288000
2.70	514	76.9	—	52.1	86.5	70	274000
2.75	495	76.3	—	51.0	85.9	68	264000
2.80	477	75.6	—	49.6	85.3	66	252000
2.85	461	74.9	—	48.5	84.7	65	242000
2.90	444	74.2	—	47.1	84.0	63	230000
2.95	429	73.4	—	45.7	83.4	61	219000
3.00	415	72.8	—	44.5	82.8	59	212000
3.05	401	72.0	—	43.1	82.0	58	202000
3.10	388	71.4	—	41.8	81.4	56	193000
3.15	375	70.6	—	40.4	80.6	54	184000
3.20	363	70.0	—	39.1	80.0	52	177000
3.25	352	69.3	110.0	37.9	79.3	51	170000
3.30	341	68.7	109.0	36.6	78.6	50	163000
3.35	331	68.1	108.5	35.5	78.0	48	158000
3.40	321	67.5	108.0	34.3	77.3	47	152000
3.45	311	66.9	107.5	33.1	76.7	46	147000
3.50	302	66.3	107.0	32.1	76.1	45	143000
3.55	293	65.7	106.0	30.9	75.5	43	139000
3.60	285	65.3	105.5	29.9	75.0	—	136000
3.65	277	64.6	104.5	28.8	74.4	41	131000
3.70	269	64.1	104.0	27.6	73.7	40	128000
3.75	262	63.6	103.0	26.6	73.1	39	125000
3.80	255	63.0	102.0	25.4	72.5	38	121000
3.85	248	62.5	101.0	24.2	71.7	37	118000
3.90	241	61.8	100.0	22.8	70.9	36	114000
3.95	235	61.4	99.0	21.7	70.3	35	111000
4.00	229	60.8	98.2	20.5	69.7	34	109000
4.05	223	—	97.3	18.8	—	—	104000
4.10	217	—	96.4	17.5	—	33	103000
4.15	212	—	95.5	16.0	—	—	100000
4.20	207	—	94.6	15.2	—	32	99000
4.25	201	—	93.8	13.8	—	31	97000
4.30	197	—	92.8	12.7	—	30	94000
4.35	192	—	91.9	11.5	—	29	92000
4.40	187	—	90.7	10.0	—	—	90000
4.45	183	—	90.0	9.0	—	28	89000
4.50	179	—	89.0	8.0	—	27	88000
4.55	174	—	87.8	6.4	—	—	86000
4.60	170	—	86.8	5.4	—	26	84000
4.65	167	—	86.0	4.4	—	—	83000
4.70	163	—	85.0	3.3	—	25	82000
4.80	156	—	82.9	0.9	—	—	80000
4.90	149	—	80.8	—	—	23	—
5.00	143	—	78.7	—	—	22	—
5.10	137	—	76.4	—	—	21	—
5.20	131	—	74.0	—	—	—	—
5.30	126	—	72.0	—	—	20	—
5.40	121	—	69.8	—	—	19	—
5.50	116	—	67.6	—	—	18	—
5.60	111	—	65.7	—	—	15	—

HARDNESS CONVERSION NUMBERS FOR STEEL

ROCKWELL						BRINELL
B Scale	F Scale	15-T Scale	30-T Scale	E Scale	H Scale	A Scale	500 kg. Load 10 mm. Ball
74	99.0	—	66.0	—	—	46.0	118
72	98.0	84.0	65.0	—	—	45.0	114
70	97.0	83.5	63.5	99.5	—	44.0	110
68	95.5	—	62.0	98.0	—	43.0	107
66	94.5	82.0	60.5	97.0	—	42.0	104
64	93.5	81.5	59.5	95.5	—	41.5	101
62	92.0	—	58.0	94.5	—	40.5	98
60	91.0	—	56.5	93.0	—	39.5	95
58	90.0	79.5	55.0	92.0	—	38.5	92
56	89.0	79.0	54.0	90.5	—	—	90
54	87.5	—	52.5	89.5	—	37.0	87
52	86.5	77.5	51.0	88.0	—	36.0	85
50	85.5	77.0	49.5	87.0	—	35.0	83
48	84.5	—	48.5	85.5	—	34.5	81
46	83.0	75.5	47.0	84.5	—	33.5	—
44	82.0	75.0	45.5	83.5	—	32.5	78
42	81.0	—	44.0	82.0	—	31.5	76
40	79.5	73.5	43.0	81.0	—	—	—
38	78.5	73.0	41.5	79.5	—	30.0	73
36	77.5	—	40.0	78.5	100.0	29.0	—
34	76.5	71.5	38.5	77.0	99.0	28.0	70
32	75.0	71.0	37.5	76.0	98.5	27.5	—
30	74.0	70.5	36.0	75.0	—	26.5	67
28	73.0	—	34.5	73.5	97.0	25.5	66
26	72.0	69.0	33.0	72.5	—	24.5	65
24	70.5	68.5	32.0	71.0	95.5	24.0	—
22	69.5	—	30.5	70.0	95.0	23.0	—
20	68.5	—	29.0	68.5	—	22.0	—
18	67.0	66.5	27.5	67.5	93.5	—	—
16	66.0	66.0	26.0	66.5	—	20.5	—
14	65.0	—	25.0	65.0	92.0	—	—
12	64.0	64.5	23.5	64.0	91.5	—	—
10	63.0	64.0	22.0	62.5	90.5	—	57
8	61.5	63.5	20.5	61.5	90.0	—	—
6	60.5	—	19.5	60.5	—	—	—
4	59.5	62.0	18.0	59.0	88.5	—	—
2	58.0	61.5	16.5	58.0	—	—	54
0	57.0	—	15.0	57.0	87.0	—	53

ROCKWELL HARDNESS SCALES

Scale	Major Load, Kg	Indenter	Use of Scale
A	60	Diamond cone	Extremely hard material such as tungsten carbide or hard sheet material too thin for heavy load.
B	100	1/16" ball	Materials of B 0 to B 100 hardness.
C	150	Diamond cone	Materials of C 20 to C 70 hardness.
E	100	1/8" ball	Very soft materials such as bearing metals.
F	60	1/16" ball	Very soft materials such as bearing metals.
H	60	1/8" ball	Very soft materials such as bearing metals.

ROCKWELL SUPERFICIAL HARDNESS SCALES

15-N	15	Diamond cone	Materials comparable in hardness of C 20 to C 70.
15-T	15	1/16" ball	Materials comparable in hardness of B 0 to B 100.
30-T	100	1/16" ball	Materials comparable in hardness of B 0 to B 100.

MACHINABILITY
SURFACE CUTTING SPEEDS

Surface cutting speeds given below are approximate and are intended as a guide in calculating the proper speed for the part in hand. The figures are average for the general run of parts and are based on the use of high speed cutting tools. Any extraordinary features in the part to be made should be taken into consideration and speeds altered accordingly.

For the carbon and alloy grades listed, the figures are based on cold drawn bars in the as-drawn condition, except when it is noted that the grade is annealed.

Surface cutting speeds for hot rolled as-rolled bars and hot rolled heat treated bars are not available, since the machining qualities of these bars vary according to hardness, microstructure, condition of the surface, etc.

For the stainless steels and super alloys listed, all grades are annealed or solution annealed except where other wise indicated.

CARBON STEELS

Grade	Surface Feet per Minute	Rating*
1015	120	72%
1018	130	78%
1020	120	72%
1022	130	78%
1030	115	70%
1040	105	64%
1042	105	64%
1050	90	54%
1095	70	42%
1117	150	91%
1137	120	72%
1141	115	70%
1141 Ann.	135	81%
1144	125	76%
1144 Ann.	140	85%
1212	165	100%
1213	225	136%
12L14	280	170%
1215	225	136%
1144 Hi Stress	130	79%
STRESSPROOF®	140	83%
FATIGUE-PROOF®	134	80%
Leaded Grade A	325	193%
Ledloy A, La-Led	325	193%
Leaded Grade AX, AY, AZ	420	250%
Ledloy AZ, La-Led X	420	250%

ALLOY STEELS

Grade	Surface Feet per Minute	Rating*
2355 Ann.	115	70%
4130 Ann.	120	72%
4140 Ann.	110	66%
4142 Ann.	110	66%
41L42 Ann.	127	77%
4150 Ann.	100	60%
4150 Resul. Heat Treat	65	40%
4330 Mod. Ann.	95	59%
4340 Ann.	95	57%
4340 Mod. (300M) Ann.	95	57%
4620	110	66%
4820 Ann.	80	49%
52100 Ann.	65	40%
6150 Ann.	100	60%
8620	110	66%
86L20	127	77%
9310 Ann.	85	51%
D6AC Ann.	50	30%
“e.t.d.” 150®	125	75%
H-11 Ann.	49	29%
HS 220-18 Ann.	85	51%
Nitriding #3 135 Mod. Ann.	76	45%

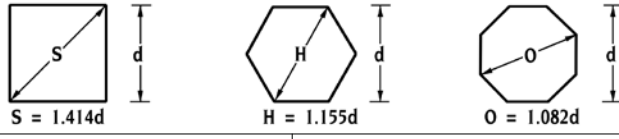
STAINLESS & SUPER ALLOYS

Grade	Surface Feet per Minute	Rating*
302	75	45%
303	130	78%
303MA	135	82%
304	75	45%
304L	75	45%
316	75	45%
321	60	36%
347	60	36%
410	90	54%
416	180	110%
420	75	45%
430	90	54%
430F	150	91%

Grade	Surface Feet per Minute	Rating*
431	75	45%
440A	75	45%
440B&C	65	40%
15-5 Condition A	80	48%
Condition H1150	90	55%
Condition H1150M	125	76%
17-4 Condition A	80	48%
Nitronic 50® (22-13-5)	50	21%
A286 Aged	55	33%
Hastelloy X	32	19%
Maraging 18 Ni 250	50	30%

* “Rating” refers to relative speed, based on 1212 as 100%

DISTANCE ACROSS CORNERS OF SQUARES, HEXAGONS, and OCTAGONS



S = 1.414d H = 1.155d O = 1.082d

d Size in Inches	Distance across corners, Inches S Square	H Hexagon	O Octagon
1/8	.177	.144	.135
3/16	.265	.217	.203
1/4	.354	.289	.271
5/16	.442	.361	.338
3/8	.530	.433	.406
7/16	.619	.505	.474
1/2	.707	.577	.541
9/16	.795	.650	.609
5/8	.884	.722	.677
11/16	.972	.794	.744
3/4	1.061	.866	.812
13/16	1.149	.938	.879
7/8	1.237	1.010	.947
15/16	1.326	1.083	1.015
1	1.414	1.155	1.082
1/16	1.503	1.227	1.150
1/8	1.591	1.299	1.218
3/16	1.679	1.371	1.285
1/4	1.768	1.443	1.353
5/16	1.856	1.516	1.421
3/8	1.945	1.588	1.488
7/16	2.033	1.660	1.556
1/2	2.121	1.732	1.624
9/16	2.210	1.804	1.691
5/8	2.298	1.876	1.759
11/16	2.386	1.949	1.827
3/4	2.475	2.021	1.894
13/16	2.563	2.093	1.962
7/8	2.652	2.165	2.030
15/16	2.740	2.237	2.097

d Size in Inches	Distance across corners, Inches S Square	H Hexagon	O Octagon
2	2.828	2.309	2.165
1/16	2.917	2.382	2.232
1/8	3.005	2.454	2.300
3/16	3.094	2.526	2.368
1/4	3.182	2.598	2.435
5/16	3.270	2.670	2.503
3/8	3.359	2.742	2.571
7/16	3.447	2.815	2.638
1/2	3.536	2.887	2.706
9/16	3.624	2.959	2.774
5/8	3.712	3.031	2.841
11/16	3.801	3.103	2.909
3/4	3.889	3.175	2.977
13/16	3.977	3.248	3.044
7/8	4.066	3.320	3.112
15/16	4.154	3.392	3.180
3	4.243	3.464	3.247
1/8	4.419	3.608	3.383
1/4	4.596	3.753	3.518
3/8	4.773	3.897	3.653
1/2	4.950	4.041	3.788
5/8	5.126	4.186	3.924
3/4	5.303	4.330	4.059
7/8	5.480	4.474	4.194
4	5.657	4.619	4.330
1/4	6.010	4.907	4.600
1/2	6.364	5.196	4.871
3/4	6.717	5.485	5.141
5	7.071	5.774	5.412
1/4	7.425	6.062	5.683
1/2	7.778	6.351	5.953
3/4	8.132	6.640	6.224
6	8.485	6.928	6.494

CIRCUMFERENCES AND AREAS OF CIRCLES

Diameter		Circum-		Dia-	Circum-		Dia-	Circum-	
Frac.	Decimal	ference	Area	meter	ference	Area	meter	ference	Area
1/64	.015625	.04909	.00019	1	3.1416	.78540	64	201.06	3216.99
1/32	.03125	.09818	.00077	2	6.2832	3.1416	65	204.20	3318.31
3/64	.046875	.14726	.00173	3	9.4248	7.0686	66	207.34	3421.19
1/16	.0625	.19635	.00307	4	12.5664	12.5664	67	210.49	3525.65
5/64	.078125	.24545	.00479	5	15.7080	19.635	68	213.63	3631.68
3/32	.09375	.29452	.00690	6	18.850	28.274	69	216.77	3739.28
7/64	.109375	.34363	.00939	7	21.991	38.485	70	219.91	3848.45
1/8	.125	.39270	.01227	8	25.133	50.266	71	223.05	3959.19
9/64	.140625	.44181	.01553	9	28.274	63.617	72	226.19	4071.50
5/32	.15625	.49087	.01917	10	31.416	78.540	73	229.34	4185.39
11/64	.171875	.53999	.02320	11	34.558	95.033	74	232.48	4300.84
3/16	.1875	.58904	.02761	12	37.699	113.10	75	235.62	4417.86
13/64	.203125	.63817	.03241	13	40.841	132.73	76	238.76	4536.46
7/32	.21875	.68722	.03758	14	43.982	153.94	77	241.90	4656.63
15/64	.234375	.73635	.04314	15	47.124	176.72	78	245.04	4778.36
1/4	.25	.78540	.04909	16	50.265	201.06	79	248.19	4901.67
17/64	.265625	.83453	.05542	17	53.407	226.98	80	251.33	5026.55
9/32	.28125	.88357	.06213	18	56.549	254.47	81	254.47	5153.00
19/64	.296875	.93271	.06922	19	59.690	283.53	82	257.61	5281.02
5/16	.3125	.98175	.07670	20	62.832	314.16	83	260.75	5410.61
21/64	.328125	1.0309	.08456	21	65.973	346.36	84	263.89	5541.77
11/32	.34375	1.0799	.09281	22	69.115	380.13	85	267.04	5674.50
23/64	.359375	1.1291	.10144	23	72.257	415.48	86	270.18	5808.80
3/8	.375	1.1781	.11045	24	75.398	452.39	87	273.32	5944.68
25/64	.390625	1.2273	.11984	25	78.540	490.87	88	276.46	6082.12
13/32	.40625	1.2763	.12962	26	81.681	530.93	89	279.60	6221.14
27/64	.421875	1.3254	.13979	27	84.823	572.56	90	282.74	6361.73
7/16	.4375	1.3744	.15033	28	87.965	615.75	91	285.88	6503.88
29/64	.453125	1.4236	.16126	29	91.106	660.52	92	289.03	6647.61
15/32	.46875	1.4726	.17257	30	94.248	706.86	93	292.17	6792.91
31/64	.484375	1.5218	.18427	31	97.389	754.77	94	295.31	6939.78
1/2	.5	1.5708	.19635	32	100.53	804.25	95	298.45	7088.22
33/64	.515625	1.6199	.20880	33	103.67	855.30	96	301.59	7238.23
17/32	.53125	1.6690	.22166	34	106.81	907.92	97	304.73	7339.81
35/64	.546875	1.7181	.23489	35	109.96	962.11	98	307.88	7542.96
9/16	.5625	1.7671	.24850	36	113.10	1017.88	99	311.02	7697.69
37/64	.578125	1.8163	.26248	37	116.24	1075.21	100	314.16	7853.98
19/32	.59375	1.8653	.27688	38	119.38	1134.11	101	317.30	8011.85
39/64	.609375	1.9145	.29164	39	122.52	1194.59	102	320.44	8171.28
5/8	.625	1.9365	.30680	40	125.66	1256.64	103	323.58	8332.29
41/64	.640625	2.0127	.32232	41	128.81	1320.25	104	326.73	8494.87
21/32	.65625	2.0617	.33824	42	131.95	1385.44	105	329.87	8659.01
43/64	.671875	2.1108	.35453	43	135.09	1452.20	106	333.01	8824.73
11/16	.6875	2.1598	.37122	44	138.23	1520.53	107	336.15	8992.02
45/64	.703125	2.2090	.38828	45	141.37	1590.43	108	339.29	9160.88
23/32	.71875	2.2580	.40574	46	144.51	1661.90	109	342.43	9331.32
47/64	.734375	2.3072	.42356	47	147.65	1734.94	110	345.58	9503.32
3/4	.75	2.3562	.44179	48	150.80	1809.56	111	348.72	9676.89
49/64	.765625	2.4054	.45253	49	153.94	1885.74	112	351.86	9852.03
25/32	.78125	2.4544	.47937	50	157.08	1963.50	113	355.00	10028.75
51/64	.796875	2.5036	.49872	51	160.22	2042.82	114	358.14	10207.03
13/16	.8125	2.5525	.51849	52	163.36	2123.72	115	361.28	10386.89
53/64	.828125	2.6017	.53862	53	166.50	2206.18	116	364.42	10568.32
27/32	.84375	2.6507	.55914	54	169.65	2290.22	117	367.57	10751.32
55/64	.859375	2.6999	.58003	55	172.79	2375.83	118	370.71	10935.88
7/8	.875	2.7489	.60132	56	175.93	2463.01	119	373.85	11122.02
57/64	.890625	2.7981	.62298	57	179.07	2551.76	120	376.99	11309.73
29/32	.90625	2.8471	.64504	58	182.21	2642.08	121	380.13	11499.01
59/64	.921875	2.8963	.66746	59	185.35	2733.97	122	383.27	11689.87
15/16	.9375	2.9452	.69029	60	188.50	2827.43	123	386.42	11882.29
61/64	.953125	2.9945	.71349	61	191.64	2922.47	124	389.56	12076.28
31/32	.96875	3.0434	.73708	62	194.78	3019.07	125	392.70	12271.85
63/64	.984375	3.0928	.76097	63	197.92	3117.25	126	395.84	12468.98

CAPACITIES OF ROUND TANKS

ONE FOOT IN DEPTH

Diam. of Tank	No. U.S. Gallons	Cubic Feet
1′	5.87	.785
1″	6.89	.922
2″	8.00	1.069
3″	9.18	1.227
4″	10.44	1.396
5″	11.79	1.576
6″	13.22	1.767
7″	14.73	1.969
8″	16.32	2.182
9″	17.99	2.405
10″	19.75	2.640
11″	21.58	2.885
2′	23.50	3.142
1″	25.50	3.409
2″	27.58	3.687
3″	29.74	3.976
4″	31.99	4.276
5″	34.31	4.587
6″	36.72	4.909
7″	39.21	5.241
8″	41.78	5.585
9″	44.43	5.940
10″	47.16	6.305
11″	49.98	6.682
3′	52.88	7.069
1″	55.85	7.467
2″	58.92	7.876
3″	62.06	8.296
4″	65.28	8.726
5″	68.59	9.169
6″	71.97	9.621
7″	75.44	10.085
8″	78.99	10.559
9″	82.62	11.045
10″	86.33	11.541
11″	90.13	12.048
4′	94.00	12.566
1″	97.96	13.095
2″	102.00	13.636
3″	106.12	14.186
4″	110.32	14.748
5″	114.61	15.321
6″	118.97	15.904
7″	123.42	16.499
8″	127.95	17.105
9″	132.56	17.721
10″	137.25	18.348
11″	142.03	18.986
5′	146.88	19.635
1″	151.81	20.295
2″	156.84	20.966
3″	161.93	21.648
4″	167.11	22.340
5″	172.38	23.044
6″	177.72	23.758
7″	183.15	24.483
8″	188.66	25.220
9″	194.25	25.967
10″	199.92	26.725
11″	205.67	27.495
6′	211.51	28.274
3″	229.50	30.680
6″	248.23	33.183
9″	267.69	35.785
7′	287.88	38.485
3″	308.81	41.283
6″	330.48	44.179
9″	352.88	47.173
8′	376.01	50.266
3″	399.88	53.456
6″	424.48	56.745
9″	449.82	60.132
9′	475.89	63.617
3″	502.70	67.201
6″	530.23	70.882
9″	558.51	74.662
10′	587.52	78.540
3″	617.26	82.516
6″	647.74	86.590
9″	678.95	90.763
11′	710.90	95.033
3″	743.58	99.402
6″	776.99	103.87
9″	811.14	108.43
12′	846.03	113.10
3″	881.65	117.86
6″	918.00	122.72
9″	955.09	127.68
13′	992.91	132.73
3″	1031.5	137.89
6″	1070.8	143.14
9″	1110.8	148.49
14′	1151.5	153.94
3″	1193.0	159.48
6″	1235.3	165.13
9″	1278.2	170.87
15′	1321.9	176.71
3″	1366.4	182.65
6″	1411.5	188.69
9″	1457.4	194.83
16′	1504.1	201.06
3″	1551.4	207.39
6″	1599.5	213.82
9″	1648.4	220.35
17′	1697.9	226.98
3″	1748.2	233.71
6″	1799.3	240.53
9″	1851.1	247.45
18′	1903.6	254.47
3″	1956.8	261.59
6″	2010.8	268.80
9″	2065.5	276.12
19′	2120.9	283.53
3″	2177.1	291.04
6″	2234.0	298.65
9″	2291.7	306.35
20′	2350.1	314.16
3″	2409.2	322.06
6″	2469.1	330.06
9″	2529.6	338.16
21′	2591.0	346.36
3″	2653.0	354.66
6″	2715.8	363.05
9″	2779.3	371.54
22′	2843.6	380.13
3″	2908.6	388.82
6″	2974.3	397.61
9″	3040.8	406.49
23′	3108.0	415.48
3″	3175.9	424.56
6″	3244.6	433.74
9″	3314.0	443.01
24′	3384.1	452.39
3″	3455.0	461.86
6″	3526.6	471.44
9″	3598.9	481.11

(Above data based on 1 cu. ft. = 7.48055 gal.)

Other Diameters — Capacities for diameters other than those shown can be determined as follows:

Find capacity for 1/2 diameter desired and multiply by 4, or
Find capacity for 1/3 diameter desired and multiply by 9, or
Find capacity for 1/4 diameter desired and multiply by 16, etc.

Barrels — 1 barrel = 31.5 gallons, or 1 gallon = .031746 barrel. Thus to find capacity in barrels, either divide gallons by 31.5 or multiply gallons by .031746.

GEOMETRIC FORMULAS

CIRCLE

Area = Square of Diameter x .7854

or Square of Radius x 3.1416

Circumference = Diameter x 3.1416

Diameter = Circumference x .3183

Doubling diameter increases area four times; tripling diameter increases area nine times, etc.

SQUARE

Area = Square of Side

Diagonal = Side x 1.4142

Side = Diagonal x .7071

SQUARE INSCRIBED IN CIRCLE

Side of Square = Diameter of Circle x .7071

or Circumference of Circle x .2251

Diameter of Circle = Side of Square x 1.4142

Circumference of Circle = Side of Square x 4.4429

SQUARE AND CIRCLE WITH EQUAL AREA

Side of Square = Diameter of Circle x .8862

Diameter of Circle = Side of Square x 1.128

Circumference of Circle = Side of Square x 3.545

RECTANGLE

Area = Length x Width

Diagonal = Square root of sum of squares of Width and Length

TRIANGLE

Area = Base x ½ of Perpendicular Height

HEXAGON (Equal sides and angles)

Area = Square of Distance across Flats x .866

or Square of Side x 2.598

Side = 1/2 of Diagonal

or Distance across Flats x .577

Diagonal = Distance across Flats x 1.155

or Side x 2

OCTAGON (Equal sides and angles)

Area = Square of Distance across Flats x .828

or Square of Side x 4.828

Side = Diagonal x .383

or Distance across Flats x .414

Diagonal = Distance across flats x 1.082

or Side x 2.613

SPHERE

Area of Surface = Square of Diameter x 3.1416

Volume = Cube of Diameter x .5236

CUBE

Area of Surface = Square of Side x 6

Volume = Cube of Side

Diagonal = Side x 1.732

CYLINDER

Area of Curved Surface = Diameter x Length x 3.1416

Volume = Square of Diameter x Length x .7854

CONE

Area of Curved Surface = Diameter of Base x Slant Height x 1.5708

Volume = Diameter of Base Squared x Perpendicular Height x .2618

or Area of Base x 1/3 Perpendicular Height

PYRAMID

Lateral Surface Area (Not incl. base) =

Perimeter of Base x 1/2 of Slant Height

Volume = Area of Base x 1/3 Perpendicular Height

U.S. and METRIC SYSTEM EQUIVALENTS

LENGTH EQUIVALENTS

Unit	Milli-meters	meters	Inches	Centi-Feet	Yards	Meters
1 Millimeter =	1	.1	.03937	.003281	.001094	.001
1 Centimeter =	10	1	.3937	.032808	.010936	.01
1 Inch =	25.4	2.54	1	.083333	.027778	.0254
1 Foot =	304.8	30.48	12	1	.333333	.3048
1 Yard =	914.4	91.44	36	3	1	.9144
1 Meter =	1000	100	39.37	3.28083	1.09361	1

Unit	Feet	Yards	Meters	Rods	Furlongs	Miles (Statute)
1 Rod =	16.5	5.5	5.02920	1	.025 (1/40)	.003125 (1.320)
1 Furlong =	660	220	201.16	40	1	.125 (1/8)
1 Kilometer =	3280.8	1093.6	1000	199	4.971	.62137
1 Mile (statute) =	5280	1760	1609.34	320	8	1

1 Nautical Mile = 6080.2 feet = 1.15155 statute miles = 1/3 league.
1 Light Year = 5.879 trillion miles = 9.46 trillion kilometers.

WEIGHT EQUIVALENTS

Unit	Grains	Grams	Ounces (Troy)	Ounces (Avoir.)	Pounds (Troy)	Pounds (Avoir.)	Kilo-grams
1 Grain =	1	.064799	.002083	.002286	.000174	.000143	.000065
1 Gram =	15.4324	1	.032151	.035274	.002679	.002205	.001
1 Ounce (Troy) =	480	31.1035	1	1.09714	.083333	.068571	.031104
1 Ounce (Avoir.) =	437.5	28.3495	.911458	1	.075955	.0625	.028350
1 Pound (Troy) =	5760	373.242	12	13.1657	1	.822857	.373242
1 Pound (Avoir.) =	7000	453.592	14.5833	16	1.21528	1	.453592
1 Kilogram =	15432.4	1000	32.1507	35.2740	2.67923	2.20462	1

Unit	Kilograms	Pounds (Troy)	Pounds (Avoir.)	Metric Tons	Net (Short) Tons	Gross (Long) Tons
1 Metric Ton =	1000	2679.23	2204.62	1	1.10231	.984206
1 Net (Short) Ton =	907.185	2430.56	2000	.907185	1	.892857
1 Gross (Long) Ton =	1016.05	2722.22	2240	1.01605	1.12	1

VOLUME AND CAPACITY EQUIVALENTS

Unit	Cubic Centi-meters	Cubic Inches	Liters	Quarts (Liquid)	Quarts (Dry)	Gals. (Liquid)	Gals. (Dry)	Cubic Feet
1 Cu. Centimeter =	1	.06102	.001	.00106	.00091	.00026	.00023	.00004
1 Cu. Inch =	16.387	1	.01639	.01732	.01488	.00433	.00372	.00058
1 Gill =	118.29	7.2188	.11829	.125	.10742	.03125	.02686	.00418
1 Pint (Liquid) =	473.18	28.875	.47318	.5	.42968	.125	.10742	.01671
1 Pint (Dry) =	550.62	33.600	.55062	.58182	.5	.14546	.125	.01945
1 Liter =	1000	61.023	1	1.0567	.90808	.26417	.22702	.03531
1 Quart (liquid) =	946.36	57.75	.94636	1	.85937	.25	.21484	.03342
1 Quart (dry) =	1101.2	67.201	1.1012	1.1637	1	.29091	.25	.03889
1 Gallon (liquid) =	3785.4	231	3.7854	4	3.4375	1	.85937	.13368
1 Gallon (dry) =	4404.9	268.80	4.4049	4.6546	4	1.1636	1	.15556
1 Peck =	8809.8	537.61	8.8098	9.3092	8	2.3273	2	.31111
1 Cu. Foot =	28317.0	1728	28.317	29.922	25.714	7.4805	6.4285	1
1 Bushel =	35239.3	2150.4	35.239	37.237	32	9.3092	8	1.2445
1 Barrel =	119241.2	7276.5	119.24	126	108.28	31.5	27.070	4.2109
1 Cu. Yard =	764559.4	46656	764.56	807.90	694.28	201.97	173.57	27
1 Cu. Meter =	1000000	61023.4	1000	1056.7	908.08	264.17	227.02	35.314

AREA EQUIVALENTS

Unit	Square Inches	Square Feet	Square Yards	Square Meters
1 Square Foot =	144	1	.1111	.09290
1 Square Yard =	1296	9	1	.83613
1 Square Meter =	1550	10.7639	1.19599	1
1 Square Rod =	39204	272.25	30.25	25.293
1 Are =	155000	1076.39	119.599	100
1 Acre =	6272640	43560	4840	4046.85
1 Square Mile (640 Acres) =	—	27878400	3097600	8589984
1 Square Kilometer =	—	10763867	1195985	1000000

METRIC SYSTEM

LENGTH

1 meter (m)	=	10 decimeters (dm) 100 centimeters (cm) 1,000 millimeters (mm)
1 dekameter (dkm)	=	10 meters (m)
1 hectometer (hm)	=	100 meters (m)
1 kilometer (km)	=	1,000 meters (m)

WEIGHT

1 gram (g)	=	10 decigrams (dg) 100 centigrams (cg) 1,000 milligrams (mg)
1 dekagram (dkg)	=	10 grams (g)
1 hectogram (hg)	=	100 grams (g)
1 kilogram (kg)	=	1,000 grams (g)
1 metric ton	=	1,000 kilograms (kg) 1,000,000 grams (g)

VOLUME & CAPACITY

1 liter (l)	=	1 cubic decimeter (dm^3) 10 deciliters (dl) 100 centiliters (cl) 1,000 milliliters (ml) 1,000 cubic centimeters (cm^3 or cc)
1 dekaliter (dkl)	=	10 liters (l)
1 hectoliter (hl)	=	100 liters (l)
1 kiloliter (kl)	=	1 cubic meter (m^3) 1 stere (s) 1,000 liters (l)

AREA

1 centare (ca)	=	1 square meter (m3) 100 square decimeters (dm^2) 10,000 square centimeters (cm^2) 1,000,000 square millimeters (mm^2)
1 are (a)	=	1 square dekameter (dkm^2) 100 square meters (m^2)
1 hectare (ha)	=	100 are (a) 10,000 square meters (m^2)
1 square kilometer (km^2)	=	1,000,000 square meters (m^2)

PRESSURE

1 Megapascual (MPa) = 145.0377 Pounds per Square Inch (psi)

Other prefixes occasionally used:

micro — one millionth
deca — 10 times (same as deka)
myria — 10,000 times
mega — 1,000,000 times

APPROXIMATE STOCK REQUIRED TO PRODUCE 1000 PIECES

Length of Finished Piece Plus Cut-Off in Inches	Number of Feet Per 1000 Pieces	Length of Finished Piece Plus Cut-Off in Inches	Number of Feet Per 1000 Pieces	Length of Finished Piece Plus Cut-Off in Inches	Number of Feet Per 1000 Pieces	Length of Finished Piece Plus Cut-Off in Inches	Number of Feet Per 1000 Pieces
3/32	7.8	1	83.3	2	166.7	3	250.0
7/64	9.1	1/64	84.6	1/64	168.0	1/64	251.3
1/8	10.4	1/32	85.9	1/32	169.3	1/32	252.6
9/64	11.7	3/64	87.2	3/64	170.6	3/64	253.9
5/32	13.0	1/16	88.5	1/16	171.9	1/16	255.2
11/64	14.3	5/64	89.8	5/64	173.2	5/64	256.5
3/16	15.6	3/32	91.1	3/32	174.5	3/32	257.8
13/64	16.9	7/64	92.4	7/64	175.8	7/64	259.1
7/32	18.2	1/8	93.8	1/8	177.1	1/8	260.4
15/64	19.5	9/64	95.1	9/64	178.4	9/64	261.7
1/4	20.8	5/32	96.4	5/32	179.7	5/32	263.0
17/64	22.1	11/64	97.7	11/64	181.0	11/64	264.3
9/32	23.4	3/16	99.0	3/16	182.3	3/16	265.6
19/64	24.7	13/64	100.3	13/64	183.6	13/64	266.9
5/16	26.0	7/32	101.6	7/32	184.9	7/32	268.2
21/64	27.3	15/64	102.9	15/64	186.2	15/64	269.5
11/32	28.6	1/4	104.2	1/4	187.5	1/4	270.8
23/64	29.9	17/64	105.5	17/64	188.8	17/64	272.1
3/8	31.3	9/32	106.8	9/32	190.1	9/32	273.4
25/64	32.6	19/64	108.1	19/64	191.4	19/64	274.7
13/32	33.9	5/16	109.4	5/16	192.7	5/16	276.0
27/64	35.2	21/64	110.7	21/64	194.0	21/64	277.3
7/16	36.5	11/32	112.0	11/32	195.3	11/32	278.6
29/64	37.8	23/64	113.3	23/64	196.6	23/64	279.9
15/32	39.1	3/8	114.6	3/8	197.9	3/8	281.3
31/64	40.4	25/64	115.9	25/64	199.2	25/64	282.6
1/2	41.7	13/32	117.2	13/32	200.5	13/32	283.9
33/64	43.0	27/64	118.5	27/64	201.8	27/64	285.2
17/32	44.3	7/16	119.8	7/16	203.1	7/16	286.5
35/64	45.6	29/64	121.1	29/64	204.4	29/64	287.8
9/16	46.9	15/32	122.4	15/32	205.7	15/32	289.1
37/64	48.2	31/64	123.7	31/64	207.0	31/64	290.4
19/32	49.5	1/2	125.0	1/2	208.3	1/2	291.7
39/64	50.8	33/64	126.3	33/64	209.6	33/64	293.0
5/8	52.1	17/32	127.6	17/32	210.9	17/32	294.3
41/64	53.4	35/64	128.9	35/64	212.2	35/64	295.6
21/32	54.7	9/16	130.2	9/16	213.5	9/16	296.9
43/64	56.0	37/64	131.5	37/64	214.8	37/64	298.2
11/16	57.3	19/32	132.8	19/32	216.1	19/32	299.5
45/64	58.6	39/64	134.1	39/64	217.4	39/64	300.8
23/32	59.9	5/8	135.4	5/8	218.8	5/8	302.1
47/64	61.2	41/64	136.7	41/64	220.1	41/64	303.4
3/4	62.5	21/32	138.0	21/32	221.4	21/32	304.7
49/64	63.8	43/64	139.3	43/64	222.7	43/64	306.0
25/32	65.1	11/16	140.6	11/16	224.0	11/16	307.3
51/64	66.4	45/64	141.9	45/64	225.3	45/64	308.6
13/16	67.7	23/32	143.2	23/32	226.6	23/32	309.9
53/64	69.0	47/64	144.5	47/64	227.9	47/64	311.2
27/32	70.3	3/4	145.8	3/4	229.2	3/4	312.5
55/64	71.6	49/64	147.1	49/64	230.5	25/32	314.1
7/8	72.9	25/32	148.4	25/32	231.8	13/16	316.7
57/64	74.2	51/64	149.7	51/64	233.1	7/8	322.9
29/32	75.5	13/16	151.0	13/16	234.4	15/16	328.1
59/64	76.8	53/64	152.3	53/64	235.7	4	333.3
15/16	78.1	27/32	153.6	27/32	237.0		
61/64	79.4	55/64	154.9	55/64	238.3		
31/32	80.7	7/8	156.3	7/8	239.6		
63/64	82.0	57/64	157.6	57/64	240.9		
		29/32	158.9	29/32	242.2		
		59/64	160.2	59/64	243.5		
		15/16	161.5	15/16	244.8		
		61/64	162.8	61/64	246.1		
		31/32	164.1	31/32	247.4		
		63/64	165.4	63/64	248.7		

Based on 12′ 0″ bars, the losses in bar ends are:

1″ bar end — 0.7%
2″ bar end — 1.38%
3″ bar end — 2.08%
4″ bar end — 2.80%

DEFINITIONS OF TERMS USED IN THE METALS INDUSTRY

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 such as silica.

Activation — The changing of the passive surface of a metal to a chemically active state. Contrast with passivation.

Aging — In a metal or alloys, a change in properties that generally occurs slowly at room temperature and more rapidly at higher temperatures.

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 in. or more in diameter. Same as self-hardening steel.

Alclad — Composite sheet produced by bonding either corrosion-resistant aluminum alloy or aluminum of high purity to base metal of structurally stronger aluminum alloy.

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

Aluminizing — Forming an aluminum or aluminum alloy coating on a metal by hot dipping, hot spraying, or diffusion.

Anisotropy — The characteristic of exhibiting different values of a property in different directions with respect to a fixed reference system in the material.

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 of 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.

Atomic-Hydrogen Welding — Arc welding with heat from an arc between two tungsten or other suitable electrodes in a hydrogen atmosphere. The use of pressure and filler metal is optional.

Attenuation — The fractional decrease of the intensity of an energy flux, including the reduction of intensity resulting from geometrical spreading, absorption, and scattering.

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.

Austentite — 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 (partial austenitizing) or above the transformation range (complete austenitizing).

Autofrettage — Prestressing a hollow metal cylinder by the use of momentary internal pressure exceeding the yield strength.

Bainite — A decomposition product of austenite consisting of an aggregate of ferrite and carbide. In general, it forms at temperatures lower than those where very fine pearlite forms and higher than that where martensite begins to form on cooling. Its appearance is feathery if formed in the upper part of the temperature range; acicular, resembling tempered martensite, if formed in the lower part.

Banded Structure — A segregated structure of nearly parallel bands 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 such as magnesia or lime.

Bearing Load — A compressive load supported by a member, usually a tube or collar, along a line where contact is made with a pin, rivet, axle, or shaft.

Bearing Strength — The maximum bearing load at failure divided by the effective bearing area. In a pinned or riveted joint, the effective area is calculated as the product of the diameter of the hole and the thickness of the bearing member.

Bend Radius — The inside radius of a bent section.

Bend Test — A test 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 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 in. and the cross-sectional area varies from 2 1/4 to 36 sq. in. For nonferrous metals, it may also be a casting suitable for finished or semifinished rolling or for extrusion.

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 sq. in. Iron and steel blooms are sometimes made by forging.

Blue Annealing — Heating hot rolled ferrous sheet 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 heated to some temperature within the range of 300º to 650ºF, and more especially if the steel is worked at the elevated temperature. Killed steels are virtually free of this kind of brittleness.

Bluing — Subjecting the scale-free surface of a ferrous alloy to the action of air, steam, or other agents at a suitable temperature, thus forming a thin blue film of oxide and improving the appearance and resistance to corrosion. NOTE: this term is ordinarily applied to sheet, strip, or finished parts. It is used also to denote the heating of springs after fabrication in order to improve their properties.

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”.

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.

Brittle Fracture — Fracture with little or no plastic deformation.

Burning — (1) Permanently damaging a metal or alloy by heating to cause either incipient melting or intergranular oxidation. See overheating. (2) In grinding getting the work hot enough to cause discoloration or to change the microstructure by tempering or hardening.

Burnishing — Smoothing surfaces through frictional contact between the work and some hard pieces of material such as hardened metal balls.

Camber — (1) Deviation from edge straightness usually referring to the greatest deviation of side edge from a straight line. (2) Sometimes used to denote crown in rolls where the center diameter has been increased to compensate for deflection caused by the rolling pressure.

Canning — A dished distortion in a flat or nearly flat surface, sometimes referred to as "oil canning".

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.

Carbonitriding — Introducing carbon and nitrogen into a solid ferrous alloy by holding above Ac_1 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 deoxidation, with silicon usually limited to 0.60% and manganese to about 1.65%. Also termed "plain carbon steel", "ordinary steel", and "straight carbon steel".

Carburizing — Introducing carbon into a solid ferrous alloy by holding above Ac_1 in contact with a suitable carbonaceous material, which may be a solid, liquid, or gas. The carburized alloy is usually quench hardened.

Case Hardening — Hardening a ferrous alloy so that the outer portion, 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.

Cavitation — The formation and instantaneous collapse of innumerable tiny voids or cavities within a liquid subjected to rapid and intense pressure changes. Cavitation produced by ultrasonic radiation is sometimes used to give violent localized agitation. Severe turbulent flow often leads to cavitation damage.

Cavitation Damage — Wearing away of metal through the formation and collapse of cavities in a liquid.

Cementite — A compound of iron and carbon, known chemically as iron carbide and having the approximate chemical formula Fe_3C. It is characterized by an orthorhombic crystal structure. When it occurs as a phase in steel, the chemical composition will be altered by the presence of manganese and other carbide-forming elements.

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.

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.

Chemical Milling — Removing metal stock by controlled selective chemical etching.

Chromadizing (Chromodizing, Chromatizing) — Forming an acid surface to improve paint adhesion on aluminum or aluminum alloys, mainly aircraft skins, by treatment with a solution of chromic acid.

Chromizing — A surface treatment at elevated temperature, generally carried out in pack, vapor, or salt bath, in which an alloy is formed by the inward diffusion of chromium into the base metal.

Clad Metal — A composite metal containing two or three layers that have been bonded together. The bonding may have been accomplished 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 Short — A condition of brittleness existing in some metals at temperatures below the recrystallization 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 Work — Permanent strain produced by an external force in a metal below its recrystallization temperature.

Columnar Structure — A coarse structure of parallel columns of grains, having the long axis perpendicular to the casting surface.

Compressive Strength — The maximum compressive stress that a material is capable of developing, based on original area of cross section. In the case of a material which fails in compression by a shattering fracture, the compressive strength has a very definite value. In the case of materials which do not fail in compression by a shattering fracture, the value obtained for compressive strength is an arbitrary value depending upon the degree of distortion that is regarded as indicating complete failure of the material.

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

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.

Covered Electrode — A filler-metal electrode, used in arc welding, consisting of a metal core wire with a relatively thick covering which provides protection for the molten metal from the atmosphere, improves the properties of the weld metal and stabilizes the arc. The covering is usually mineral or metal powders mixed with cellulose or other binder.

Creep — Time-dependent strain occurring under stress. The creep strain occurring at a diminishing rate is called primary creep; that occurring at a minimum and almost constant rate, secondary creep; that occurring at an accelerating rate, tertiary creep.

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.

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

Crevice Erosion — A type of concentration-cell corrosion; corrosion of a metal that is caused by the concentration of dissolved salts, metal ions, oxygen, or other gases, and such, in crevices or pockets remote from the principal fluid stream, with a resultant building up of differential cells that ultimately cause deep pitting.

Critical Cooling Rate — The minimum rate of continuous cooling just sufficient to prevent undesired transformations. For steel, the slowest rate at which it can be cooled from above the upper critical temperature to prevent the decomposition of austenite at any temperature above the M_s.

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.

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.

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.

Cutting Speed — The linear or peripheral speed of relative motion between the tool and workpiece in the principal direction of cutting.

Cyaniding — Introducing carbon and nitrogen into a solid ferrous alloy by holding above Ac_1 in contact with molten cyanide of suitable composition. The cyanided alloy is usually quench hardened.

DC (Direct Chill) Casting — A continuous 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.

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 at the surface.

Dendrite — A crystal that has a tree-like branching pattern, being most evident in cast metals slowly cooled through the solidification range.

Drawing — (1) Forming recessed parts by forcing the plastic flow of metal in dies. (2) Reducing the cross section of wire or tubing by pulling it through a die. (3) A misnomer for tempering.

Drop Forging — A forging made with a drop hammer.

Drop Hammer — A forging hammer than 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 deform plastically without fracturing, being measured by elongation or reduction of area in a tensile test, by height of cupping in an Erichsen test or by other means.

Duralumin (obsolete) — a term formerly applied to the class of age-hardenable aluminum-copper alloys containing manganese, magnesium, or silicon.

Earing — The formation of scallops (ears) around the top edge of a drawn part caused by differences in the directional properties of the sheet metal used.

Eddy-Current Testing — Nondestructive testing method in which eddy-current flow is induced in the test object. Changes in the flow caused by variations in the object are reflected into a nearby coil or coils for subsequent analysis by suitable instrumentation and techniques.

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.

Endurance Limit — Same as fatigue limit.

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.

Exfoliation — A type of corrosion that progresses approximately parallel to the outer surface of the metal, causing layers of the metal to be elevated by the formation of corrosion product.

Fatigue — The phenomenon leading to fracture under repeated or fluctuating stresses having a maximum value less than the tensile strength of the material. Fatigue fractures are progressive, beginning as minute cracks that grow under the action of the fluctuating stress.

Fatigue 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 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 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.

Ferrite Banding — Parallel bands of free ferrite aligned in the direction of working. Sometimes referred to a ferrite streaks.

Fiber Stress — Local stress through a small area (a point or line) on a section where the stress is not uniform, as in a beam under a bending load.

Fish Eyes — Areas on a fractured steel surface having a characteristic white crystalline appearance.

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, flakes appear as bright silvery areas; on an etched surface they appear as short discontinuous cracks. Also called "shatter cracks" and "snowflakes".

Flame Annealing — Annealing in which the heat is applied directly by a flame.

Flame Hardening — Quench hardening in which the heat is applied directly by a flame.

Flare Test — A test applied to tubing, involving a tapered expansion over a cone. Similar to pin expansion test.

Flash — (1) In forging, the excess metal forced between the upper and lower dies. (2) In die casting, the fin of metal which results from leakage between the mating die surfaces. (3) In resistance butt welding, a fin formed perpendicular to the direction of applied pressure.

Flash Welding — A resistance butt welding process in which the weld is produced over the entire abutting surface by pressure and heat, the heat being produced by electric arcs between the members being welded.

Foil — Metal in sheet form less than 0.006 in. in thickness.

Forging — Plastically deforming metal, usually hot, into desired shapes with compressive force, with or without dies.

Fractography — Descriptive treatment of fracture, especially in metals, with specific reference to photographs of the fracture surface. Macrofractography involves photographs at low magnification; microfractography, at high magnification.

Fracture Test — Breaking a specimen and examining the fractured surface with the unaided eye or with a low-power microscope to determine such things as composition, grain size, case depth, soundness, and presence of defects.

Free Machining — Pertains to the machining characteristics of an alloy 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 sulphur or lead to steel, lead to brass, lead and bismuth to aluminum, and sulphur or selenium to stainless steel.

Fretting (Fretting Corrosion) — Action that results in surface damage, especially in a corrosive environment, when there is relative motion between solid surfaces in contact under pressure.

Full Annealing — Annealing a ferrous alloy by austenitizing and then cooling slowly through the transformation range. The austenitizing temperature to hypoeutectoid steel is usually above Ac_3; and for hypereutectoid steel, usually between Ac_1 and Ac_{cm}.

Galling — Developing a condition on the rubbing surface of one or both mating parts where excessive friction between high spots results in localized welding with substantial spalling and a further roughening of the surface.

Galvanic Corrosion — Corrosion associated with the current of a galvanic cell consisting of two dissimilar conductors in an electrolyte or two similar conductors in dissimilar electrolytes. Where the two dissimilar metals are in contact, the resulting action is referred to as "couple action".

Grain Size — (1) For metals, a measure of the areas or volumes of grains in a polycrystalline material, usually expressed as an average when the individual sizes are fairly uniform. Grain sizes are reported in terms of grains per unit area or volume, average diameter, or as a grain-size number derived from area measurements.

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 Drill — A drill, usually with one or more flutes and with coolant passages through the drill body, used for deep hole drilling.

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 basis 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.

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.

Homogenizing — Holding at high temperature to eliminate or decrease chemical segregation by diffusion.

Honing — Removing stock generally on the internal cylindrical surface of a workpiece with an abrasive stick mounted in a holder.

Hot Shortness — Brittleness in metal in the hot forming range.

Hot Top — (1) 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.

Hydrogen Embrittlement — A condition of low ductility in metals resulting from the absorption of hydrogen.

Immersed Scanning — In ultrasonics, a planned, systematic movement of the beam relative to the object being inspected, the search unit being coupled to this object through a column of liquid. In most cases the object and the search unit are submerged in water.

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 speciment 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.

Inclusions — Nonmetallic materials in a solid metallic matrix.

Induction Hardening — Quench hardening in which the heat is generated by electrical induction.

Inert-Gas Shielded-Arc Welding — Arc welding in an inert gas such as argon or helium.

Ingot Iron — Commercially pure open-hearth iron.

interrupted Quenching — Quenching in which the metal object being quenched is removed from the quenching medium while the object is at a temperature substantially higher than that of the quenching medium.

Investment Casting — (1) Casting metal into a mold produced by surrounding (investing) an expendable pattern with a refractory slurry that sets at room temperature after which the wax, plastic, or frozen mercury pattern is removed through the use of heat. Also called precision casting, or lost-wax process. (2) A casting made by the process.

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.

Kip — A load of 1000 lb.

Laminations — Metal defects with separation or weakness generally aligned parallel to the worked surface of the metal. May be the result of pipe, blisters, seams, inclusions, or segregation elongated and made directional by working. Lamination defects may also occur in metal-powder compacts.

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.

Light Metal — One of the low-density metals such as aluminum, magnesium, titanium, beryllium, or their alloys.

Longitudinal Direction — The principal direction of flow in a worked metal.

Low-Hydrogen Electrode — A covered arc-welding electrode that provides an atmosphere around the arc and molten weld metal which is low in hydrogen.

Machinability — The relative ease of machining a metal.

Machinability Index — A relative measure of the machinability of an engineering material under specified standard conditions.

Macro-Etch — Etching of a metal surface for accentuation of gross structural details and defects for observation by the unaided eye or at magnifications not exceeding ten diameters.

Macrostructure — The structure of metals as revealed by examination of the etched surface of a polished specimen at a magnification not exceeding ten diameters.

Magnetic-Particle Inspection — A nondestructive method of inspection for determining the existence and extent of possible defects in ferromagnetic materials. Finely divided magnetic particles, applied to the magnetized part, are attracted to and outline the pattern of any magnetic-leakage fields created by discontinuities.

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 — (1) In an alloy, a metastable transitional structure intermediate between two allotropic modifications whose abilities to dissolve a given solute differ considerably, the high-temperature phase having the greater solubility. The amount of the high-temperature phase transformed to martensite depends to a large extent upon the temperature attained in cooling, there being a rather distinct beginning temperature. (2) A metastable phase of steel, formed by a transformation of austenite below the M_s (or Ar") temperature. It is an interstitial supersaturated solid solution of carbon in iron having a body-centered tetragonal lattice. Its microstructure is characterized by an acicular, or needle-like, pattern.

Mechanical Properties — The properties of a material that reveal its elastic and inelastic behavior where force is applied, thereby indicating its suitability 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 — Introducing nitrogen into a solid ferrous alloy by holding at a suitable temperature (below Ac_1 for ferritic steels) in contact with a nitrogenous material, usually ammonia of molten cyanide of appropriate composition. Quenching is not required to produce a hard case.

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.

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 in the hearth, causing the charge to be heated both by direct flame and radiation from the roof and sidewalls of the furnace. In ferrous industry, the furnace is regenerative.

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 combination of working and heat treating, the overheating is known as burning.

Oxygen-Free Copper — Electrolytic copper free from cuprous oxide, produced without the use of residual metallic or metalloidal deoxidizers.

Pack Rolling — Hot rolling a pack of two or more sheets of metal; scale prevents their being welded together.

Pancake Forging — A rough forged shape which may be obtained quickly with a minimum of tooling. It usually requires considerable machining to attain the finish size.

Passivation — The changing of the chemically active surface of a metal to a much less reactive state. Contrast with activation.

Pearlite — A lamellar aggregate of ferrite and cementite, often occurring in steel and case iron.

Peening — Mechanical working of metal by hammer blows or shot impingement.

Penetrant Inspection — A method of non-destructive testing for determining the existence and extent of discontinuities that are open to the surface in the part being inspected. The indications are made visible through the use of a dye or fluorescent chemical in the liquid employed as the inspection medium.

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 — (1) High-carbon iron made by reduction of iron ore in the blast furnace. (2) Cast iron in the form of pigs.

Pin Expansion Test — A test for determining the ability of tubes to be expanded or for revealing the presence of cracks or other longitudinal weaknesses, made by forcing a tapered pin into the open end of a tube.

Pipe — (1) The central cavity formed by contraction in metal, especially ingots, during solidification. (2) The defect in wrought or cast products resulting from such a cavity. (3) An extrusion defect due to the oxidized surface of the billet flowing toward the center of the rod at the back end. (4) A tubular metal product, cast or wrought.

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.

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.

Preheating — Heating before some further thermal or mechanical treatment. For tool steel, heating to an intermediate temperature immediately before 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.

Primes — Metal products, principally sheet and plate, of the highest quality and free from visible defects.

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.

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.

Pulse-Echo Method — A nondestructive test in which pulses of energy are directed into a part, and the time for the echo to return from one or more reflecting surfaces is measured.

Quench Hardening — Hardening a ferrous alloy by austenitizing and then cooling rapidly enough so that some or all of the austenite transforms to martensite. The austenitizing temperature for hypoeutectoid steels is usually above Ac_3 and for hypereutectoid steels usually between Ac_1 and and Ac_{cm}.

Recrystallization — (1) The change from one crystal structure to another, as occurs on heating or cooling through a critical temperature. (2) The formation of a new, strain-free grain structure from that existing in cold worked metal, usually accomplished by heating.

Recrystallization Temperature — The approximate minimum temperature at which complete recrystallization of a cold worked metal occurs within a specified time.

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.

Refractory Metal — A metal having an extremely high melting point. In the broad sense, it refers to metals having melting points above the range of iron, cobalt, and nickel.

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.

Roller Leveling — Leveling by passing flat stock through a machine having a series of small-diameter staggered 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.

Scalped Extrusion Ingot — A cast, solid, or hollow extrusion ingot which as been machined on the outside surface.

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.

Secondary Hardening — Tempering certain alloy steels at certain temperatures so that the resulting hardness is greater than that obtained by tempering the same steel at some lower temperature for the same time.

Segregation — Nonuniform distribution of alloying elements, impurities or microphases.

Semikilled Steel — Steel that is completely deoxided and contains sufficient dissolved oxygen to react with the carbon to form carbon monoxide to offset solidification shrinkage.

Sendzimir Mill — A mill having two works rolls of 1 to $2\frac{1}{2}$-in. diam. each, backed up by two rolls twice that diameter and each of these backed up by bearings on a shaft mounted eccentrically so that rotating it increases the pressure between bearings and backup rolls.

Shear Strength — The stress required to produce fracture in the plane of cross section, the conditions of loading being such that the directions of force and of resistance are parallel and opposite although their paths are offset a specified minimum amount.

Shell Molding — Forming a mold from thermosetting resin-bonded sand mixtures brought in contact with preheated (300º to 500ºF) metal patterns, resulting in a firm shell with a cavity corresponding to the outline of the pattern. Also called “Croning process”.

Shielded-Arc Welding — Arc welding in which the arc and the weld metal are protected by a gaseous atmosphere, the products of decomposition of the electrode covering, or a blanket of fusible flux.

Shore Hardness Test — Same as scleroscope test.

Shortness — A form of brittleness in metal. It is designed as “cold”, “hot”, and “red”, to indicate the temperature range in which the brittleness occurs.

Siliconizing — Diffusing silicon into solid metal, usually steel, at an elevated temperature.

Skelp — A piece or strip of metal produced to a suitable thickness, width, and edge configuration, from which pipe or tubing is made.

Skull — A layer of solidified metal or dross on the wall of a pouring vessel after the metal has been poured.

Slack Quenching — The process of hardening steel by quenching from the austenitizing temperature at a rate slower than the critical cooling rate for the particular steel, resulting in incomplete hardening and the formation of one or more transformation products in addition to or instead of martensite.

Solid Solution — A single solid homogeneous crystalline phase containing two or more chemical species.

Solution Heat Treatment — Heating an alloy to a suitable temperature, holding at that temperature long enough to allow one or more constituents to enter into solid solution, and then cooling rapidly enough to hold the constituents in solution. The alloy is left in a supersaturated, unstable state, and may subsequently exhibit quench aging.

Sorbite (obsolete) — A fine mixture of ferrite and cementite produced either by regulating the rate of cooling of steel or tempering steel after hardening. The first type is very fine pearlite difficult to resolve under the microscope; the second type is tempered martensite.

Spalling — The cracking and flaking of particles out of a surface.

Spheroidizing — Heating and cooling to produce a spheroidal or globular form of carbide in steel. Spheroidizing methods frequently used are:

1 Prolonged holding at a temperature just below Ae_1.
2 Heating and cooling alternately between temperatures that are just below Ae_1.
3 Heating to a temperature above Ae_1 or Ae_3 and then cooling very slowly in the furnace or holding at a temperature just below Ae_1.
4 Cooling at a suitable rate from the minimum temperature at which all carbide is dissolved, to prevent the reformation of a carbide network, and then reheating in accordance with methods 1 or 2 above. (Applicable to hypereutectoid steel containing a carbide network.)

Spot Welding — Welding of lapped parts in which fusion is confined to a relatively small circular area. It is generally resistance welding, but may also be gas-shielded tungsten-arc, gas-shielded metal-arc, or submerged-arc welding.

Stabilizing Treatment — Any treatment intended to stabilize the structure of an alloy of the dimensions of a part. (1) Heating austenitic stainless steels that contain titanium, columbium, or tantalum to a suitable temperature below that of a full anneal in order to inactivate the maximum amount of carbon by precipitation as a carbide of titanium, columbium, or tantalum. (2) Transforming retained austenite in parts made from tool steel. (3) Precipitating a constituent from a nonferrous solid solution to improve the workability, to decrease the tendency of certain alloys to age harden at room temperature, or to obtain dimensional stability.

Standard Gold — A legally adopted alloy for coinage of gold. In the United States the alloy contains 10% Cu.

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.

Sterling Silver — A silver alloy containing at least 95.2% Ag, the remainder being unspecified but usually copper.

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.

Stress — Force per unit area, often thought of as force acting through a small area within a plane. It can be divided into components, normal and parallel to the plane, called "normal stress" and "shear stress", respectively. "True stress" denotes the stress where force and area are measured at the same time. "Conventional stress", as applied to tension and compression tests, is force by the original area. "Nominal stress" is the stress computed by simple elasticity formulas, ignoring stress raisers and disregarding plastic flow; in a notch bend test, for example, it is bending moment divided by minimum section modulus.

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.

Stress-Rupture Test — A tension test performed at constant temperature, the load being held at such a level as to cause rupture. Also known as "Creep-rupture test".

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 Straightening — A process for straightening rod, tubing, and shapes by the application of tension at the ends of the stock. The products are elongated a definite amount to remove warpage.

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.

Superalloy — An alloy developed for very high temperature service where relatively high stresses (tensile, thermal, vibratory, and shock) are encountered and where oxidation resistance is frequently required.

Superficial Rockwell Hardness Test — Form of Rockwell hardness test using relatively light loads which produce minimum penetration. Used for determining surface hardness or hardness of thin sections or small parts, or where large hardness impression might be harmful.

Tack Welds — Small scattered welds made to hold parts of a weldment in proper alignment while the final welds are being made.

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 also 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 — In tensile testing, the ratio of maximum load to original cross-sectional area. Also called ultimate strength.

Tong Hold — The portion of a forging billet, usually on one end, that is gripped by the operator's tongs. It is removed from the part at the end of the forging operation. Common to drop-hammer and press-type forging.

Torsion — A twisting action resulting in sheer stresses and strains.

Toughness — Ability of a metal to absorb energy and deform plastically before fracturing. It is usually measured by the energy absorbed in a notch impact test, but the area under the stress-strain curve in tensile testing is also a measure of toughness.

Transformation Ranges (Transformation Temperature Ranges) — 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 irons and steels:

Ac_{cm}. In hypereutectoid steel the temperature at which the solution of cementite in austenite is completed during heating.

Ac_1. The temperature at which austenite begins to form during heating.

Ac_3. The temperature at which transformation of ferrite to austenite is completed during heating.

Ac_4. The temperature at which austenite transforms to delta ferrite during heating.

Ae_{cm}, Ae_1, Ae_3, Ae_4. The temperature of phase changes at equilibrium.

Ar_{cm}. In hypereutectoid steel, the temperature at which precipitation of cementite starts during cooling.

Ar_1. The temperature at which transformation of austenite to ferrite or to ferrite plus cementite is completed during cooling.

Ar_3. The temperature at which austenite begins to transform to ferrite during cooling.

Ar_4. The temperature at which delta ferrite transforms to austenite during cooling.

M_s (or Ar"). The temperature at which transformation of austenite to martensite starts during cooling.

M_f. 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.

Transition Temperature — (1) An arbitrarily defined temperature within the temperature range in which metal fracture characteristics determined usually by notched tests are changing rapidly such as a primarily fibrous (shear) to primarily crystalline (cleavage) fracture. Commonly used definitions are "transition temperature for 50% cleavage fracture", "10-ft-lb transition temperature", and "transition temperature for half maximum energy". (2) Sometimes also used to denote the arbitrarily defined temperature in a range in which the ductility changes rapidly with temperature.

Transverse — Literally, "across", usually signifying a direction or plane perpendicular to the direction of working.

Trepanning — A type of boring where an annular cut is made into a solid material with the coincidental formation of a plug or solid cylinder.

Troosite (obsolete) — A previously unresolvable rapidly etching fine aggregate of carbide and ferrite produced either by tempering martensite at low temperature or by quenching a steel at a rate slower than the critical cooling rate. Preferred terminology for the first product is tempered martensite; for the latter fine pearlite.

Ultimate Strength — The maximum conventional stress, tensile, compressive, or shear, that a material can withstand.

Ultrasonic Frequency — A frequency, associated with elastic waves, that is greater than the highest audible frequency, generally regarded as being higher than 15 kc per sec.

Ultrasonic Waves — Waves of ultrasonic frequency. They include longitudinal, transverse, surface, and standing waves.

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.

Wetting — A phenomenon involving a solid and a liquid in such intimate contact that the adhesive force between the two phases is greater than the cohesive force within the liquid. Thus a solid that is wetted, on being removed from the liquid bath, will have a thin continuous layer of liquid adhering to it. Foreign substances such as grease may prevent wetting. Addition agents, such as detergents, may induce wetting by lowering the surface tension of the liquid.

Widmanstatten Structure — A structure characterized by a geometrical pattern resulting from the formation of a new phase along certain crystallographic planes of the parent solid solution. The orientation of the lattice in the new phase is related crystallographically to the orientation of the lattice in the parent phase. The structure was originally observed in meteorites but is readily produced in many other alloys with certain heat treatment.

Wrought Iron — A commercial iron consisting of slag (iron silicate) fibers entrained in a ferrite matrix.

Yield Point — The first stress in a material, usually less than 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 — See modulus of elasticity.

WIRE GAUGES

Decimal Inch Equivalents

GAUGE NUMBER	BIRMINGHAM WIRE GAUGE (BWG) (Stubs Iron Gauge)	STEEL WIRE GAUGE (Washburn & Moen)	AMERICAN WIRE GAUGE (Brown & Sharpe)
40		.0070	.00314
39		.0075	.00353
38		.0080	.00396
37		.0085	.00445
36	.004	.0090	.00500
35	.005	.0095	.00561
34	.007	.0104	.00630
33	.008	.0118	.00708
32	.009	.0128	.00795
31	.010	.0132	.00893
30	.012	.0140	.0100
29	.013	.0150	.0113
28	.014	.0162	.0126
27	.016	.0173	.0142
26	.018	.0181	.0159
25	.020	.0204	.0179
24	.022	.0230	.0201
23	.025	.0258	.0226
22	.028	.0286	.0253
21	.032	.0317	.0285
20	.035	.0348	.0320
19	.042	.0410	.0359
18	.049	.0475	.0403
17	.058	.0540	.0453
16	.065	.0625	.0508
15	.072	.0720	.0571
14	.083	.0800	.0641
13	.095	.0915	.0720
12	.109	.1055	.0808
11	.120	.1205	.0907
10	.134	.1350	.1019
9	.148	.1483	.1144
8	.165	.1620	.1285
7	.180	.1770	.1443
6	.203	.1920	.1620
5	.220	.2070	.1819
4	.238	.2253	.2043
3	.259	.2437	.2294
2	.284	.2625	.2576
1	.300	.2830	.2893
0	.340	.3065	.3249
2-0's	.380	.3310	.3648
3-0's	.425	.3625	.4096
4-0's	.454	.3938	.4600
5-0's	.500	.4305	.5165
6-0's		.4615	.5800
7-0's		.4900	

NOTES

Birmingham Wire Gauge (also known as **Stubs Iron Gauge**) is practically obsolete insofar as wire is concerned. It is, however, still used for tubing wall thicknesses and certain strip and spring steel products.

Steel Wire Gauge (also know as **Washburn & Moen**) is used by virtually all manufacturers of steel wire in the United States.

American Wire Gauge (also known as **Brown & Sharpe**) is used for copper, brass, aluminum, and other non-ferrous metals, but not for steel.

SHEET GAUGES

(See next page for explanation fo the respective systems.)

Gauge No.	STEEL SHEETS		GALVANIZED SHEETS		STAINLESS STEEL SHEETS			ALUMINUM SHEETS	
					Wt., Lbs. per Sq. Ft.				
	Weight Lbs. per Square Foor	Thick-ness in Inches	Weight Lbs. per Square Foot	Thick-ness in Inches	Straight Chromium (400) Series	Chromium Nickel (300 Series)	Approx. Thick-ness in Inches	Weight Lbs. per Sq. Ft. (1000)	Thick-ness in Inches
38	.25000	.0060						.0558	.00396
37	.26562	.0064						.0627	.00445
36	.28125	.0067						.0705	.00500
35	.31250	.0075						.0791	.00561
34	.34375	.0082						.0888	.00630
33	.37500	.0090						.0998	.00708
32	.40625	.0097	.56250	.0134	.3708	.3780	.010	.1121	.00795
31	.43750	.0105	.59375	.0142	.4506	.4594	.011	.1259	.00893
30	.50000	.0120	.65625	.0157	.5150	.5250	.013	.1410	.0100
29	.56250	.0135	.71875	.0172	.5794	.5906	.014	.1593	.0113
28	.62500	.0149	.78125	.0187	.6438	.6562	.016	.1777	.0126
27	.68750	.0164	.84375	.0202	.7081	.7218	.017	.2002	.0142
26	.75000	.0179	.90625	.0217	.7725	.7875	.019	.2242	.0159
25	.87500	.0209	1.03125	.0247	.9013	.9187	.022	.2524	.0179
24	1.0000	.0239	1.15625	.0276	1.0300	1.0500	.025	.2834	.0201
23	1.1250	.0269	1.28125	.0306	1.1587	1.1813	.028	.3187	.0226
22	1.2500	.0299	1.40625	.0336	1.2875	1.3125	.031	.3567	.0253
21	1.3750	.0329	1.53125	.0366	1.4160	1.4437	.034	.4019	.0285
20	1.5000	.0359	1.65625	.0396	1.5450	1.5750	.038	.4512	.0320
19	1.7500	.0418	1.90625	.0456	1.8025	1.8375	.044	.5062	.0359
18	2.0000	.0478	2.15625	.0516	2.0600	2.1000	.050	.5682	.0403
17	2.2500	.0538	2.40625	.0575	2.3175	2.3625	.056	.6387	.0453
16	2.5000	.0598	2.65625	.0635	2.5750	2.6250	.063	.7163	.0508
15	2.8125	.0673	2.96875	.0710	2.8968	2.9531	.070	.8051	.0571
14	3.1250	.0747	3.28125	.0785	3.2187	3.2812	.078	.9038	.0641
13	3.7500	.0897	3.90625	.0934	3.8625	3.9375	.094	1.015	.0720
12	4.3750	.1046	4.53125	.1084	4.5063	4.5937	.109	1.139	.0808
11	5.0000	.1196	5.15625	.1233	5.1500	5.2500	.125	1.279	.0907
10	5.6250	.1345	5.78125	.1382	5.7937	5.9062	.141	1.437	.1019
9	6.2500	.1495	6.40625	.1532	6.4375	6.5625	.156	1.613	.1144
8	6.8750	.1644	7.03125	.1681	7.0813	7.2187	.172	1.812	.1285
7	7.5000	.1793						2.035	.1443
6	8.1250	.1943						2.284	.1620
5	8.7500	.2092						2.565	.1819
4	9.3750	.2242						2.881	.2043
3	10.000	.2391						3.235	.2294

EXPLANATION OF SHEET GAUGES
Shown on Preceding Page

STEEL SHEETS
(Including Hot Rolled, Cold Rolled, High Strength
Abrasion Resisting, and Paintlok Sheets)

Considerable confusion exists as to the distinction between the U.S. Standard Gauge and the Manufactures' Standard Gauge Systems. Essentially, the difference is as follows: The U.S. Standard Gauge is a **weight** gauge wherein certain weights per square foot are assigned to the respective gauge numbers. Equivalent thicknesses in this system, however, are based on the weight of **wrought iron**, which is lighter than steel. For this reason, steel manufacturers have established the Manufacturers' Standard Gauge, in which the thicknesses are based on the weight of **steel** sheets.

The U.S. Standard Gauge and Manufacturers' Standard Gauge are identical insofar as **weights** are concerned; the essential difference between the two systems is that the former does not provide for thicknesses of **steel** sheets, whereas the latter does.

Therefore, with respect to the weights and thicknesses of STEEL SHEETS in the table on Page 30 of this section, the weights are those of both the U.S. Standard and the Manufacturers' Standard Gauges. The **thicknesses**, however, are those of the Manufacturers' Standard Gauge, since, as stated above, the U.S. Standard Gauge does not provide for thicknesses of steel sheets.

The following more detailed explanation is quoted from the Steel Products Manual of the American Iron & Steel Institute:

United States Standard Gauge for Sheet and Plate Iron and Steel

In 1893, Congress passed an Act establishing a standard gauge for sheet and plate iron and steel, this Act being for the purpose of securing uniformity, particularly in connection in determining import duties levied by the government on sheets and plates. The basis of each gauge number is the weight per square foot in ounces; consequently, the U.S. Standard Gauge is a weight gauge. This gauge system designates that a section of iron or steel one foot square and one inch thick should weigh 640 ounces. On this basis, each U.S. Gauge Number represents a certain number of ounces in weight and a corresponding multiple of 640ths of an inch in approximate thickness. Approximate thicknesses are derived from the weights per square foot, based on the weight of wrought iron, which is two per cent lighter than steel. Therefore, these approximate thicknesses in the U.S. Standard Gauge Table are not correct for steel. In that table, the density of wrought iron is taken at 480 pounds per cubic foot.

Manufacturers' Standard Gauge for Steel Sheets

Due to the inconsistencies encountered in the U.S. Standard Gauge Table in converting from weight to thickness, a gauge table, known as the Manufacturers' Standard Gauge for Steel Sheets, is used, having a definite thickness equivalent for each gauge number. In that standard gauge, the density of steel is taken as 489.6 pounds per cubic foot, 0.2833 pounds per cubic inch, or 40.80 pounds per square foot per inch thick. However, since

sheet weights are calculated on the basis of the specified width and length, with all shearing on the over side, and also since sheets are somewhat thicker at the center than they are at the edges, a further adjustment must be made in order to obtain a closer approximation for interchangeability between weight and thickness. Over a long period of time, this value for sheets has been found to be close to 2.5 percent heavier than 40.80 pounds per square foot per inch thick, or 41.820 pounds per square foot per inch thick. This figure of 41.820 pounds per square foot per inch thick is the one commonly used to express the relationship between weight and thickness.

GALVANIZED SHEETS

Galvanized sheets are produced to weights per unit of area of coated sheet or to decimal thickness. The Galvanized Sheet Gauge, established by custom, is based on the Manufacturers' Standard Gauge for Steel Sheets. The weight corresponding to each Galvanized Sheet Gauge Number is 2.5 oz. per sq. ft. heavier or .0037" thicker than the weight or thickness corresponding to the same Manufacturers' Standard Gauge Number, regardless of coating weights. For example, the tabular unit weight of a 26-gauge galvanized sheet is 14.5 oz. per sq. ft. regardless of the weight of the coating.

STAINLESS SHEETS

The thicknesses shown on Page 30 of this section for stainless sheets were derived from the original U.S. Standard Gauge (wherein weights were converted to thicknesses on the basis of material one inch thick weighing 40 pounds per square foot, as explained on the preceding page). However, the weights of the U.S. Standard Gauge do not apply for Stainless Sheets. Instead, approximate weights are determined according to the following factors:

Chromium Nickel Types (300 series) —
42.0 lbs. per square foot per inch of thickness.

Straight Chromium Types (400 series) —
41.2 lbs. per square foot per inch of thickness.

ALUMINUM SHEETS

Aluminum sheets are produced to the thicknesses established by the American Wire Gauge (also known as the Brown & Sharpe Gauge). This gauge is used for copper, brass, aluminum, and other nonferrous metals, but not for steel. However, aluminum sheets are generally ordered to decimal thickness and not to gauge.

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