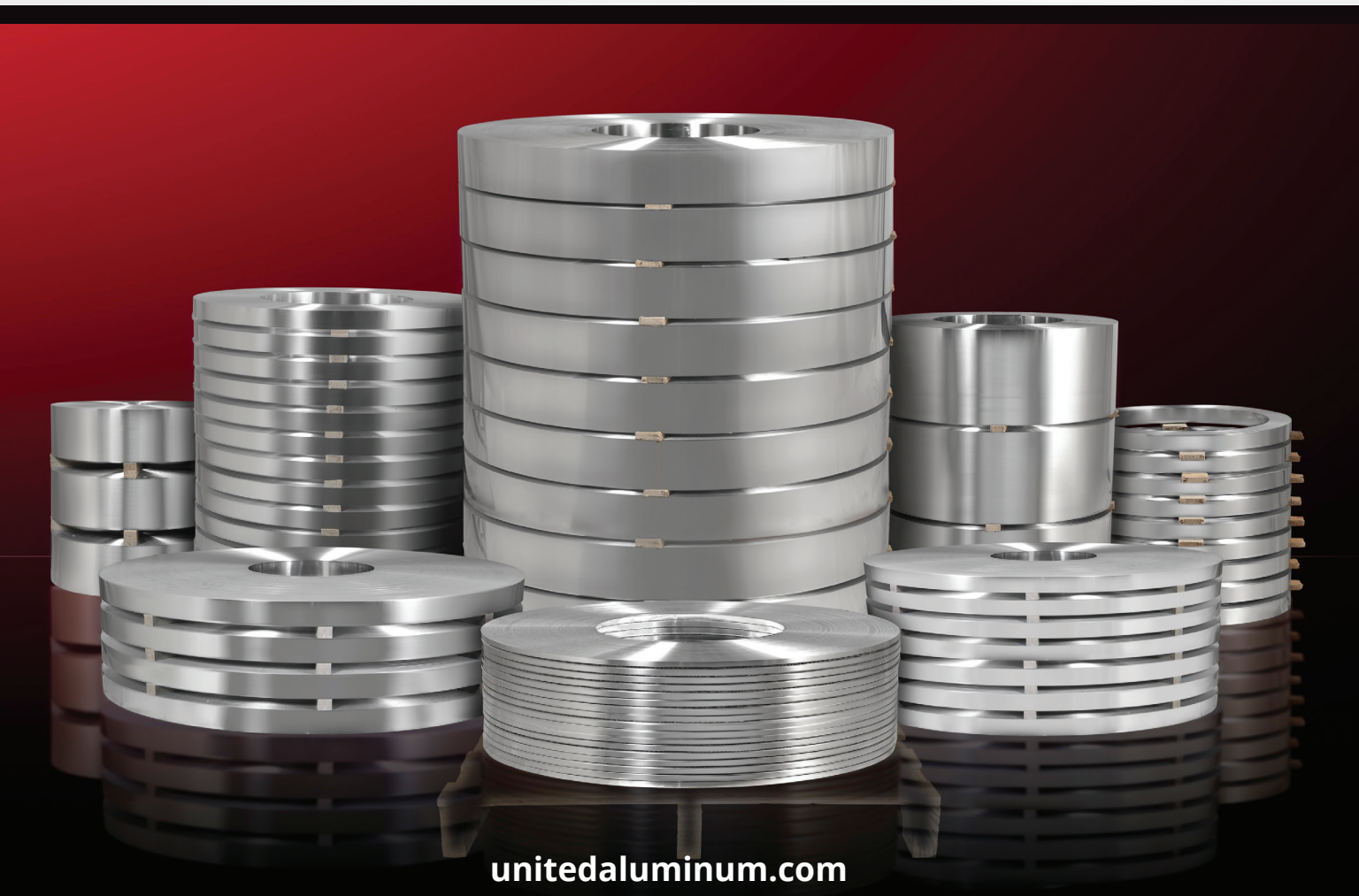
OVER 100 YEARS IN ROLLING

UNITED ALUMINUM®

Technical Manual

Custom Rolled® Aluminum Coil Since 1915



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THE BENEFITS OF ALUMINUM

- Aluminum is a light metal, about one third of the density of steel, copper, and brass.
- Aluminum has good corrosion resistance to common atmospheric and marine atmospheres. Its corrosion resistance and scratch resistance can be enhanced by anodizing.
- Aluminum has high reflectivity and can be used for decorative applications.
- Some aluminum alloys can match or even exceed the strength of common construction steel.
- Aluminum retains its toughness at very low temperatures, without becoming brittle like carbon steels.
- **Aluminum is a good conductor of heat and electricity. When measured by equal cross-sectional area, electrical grade aluminum has conductivity which is approximately 62% of electrical grade annealed copper. However, when compared using equal weight, the conductivity of aluminum is 204% of copper.**
- Aluminum is readily worked and formed using a wide variety of forming processes including deep drawing and roll forming.
- Aluminum is non-toxic and is commonly used in contact with foodstuffs.
- Aluminum can be readily recycled.

ALUMINUM ALLOY DESIGNATIONS

Alloy Designation System for Wrought Sheet Products

Aluminum alloys for sheet products are identified by a four-digit numerical system which is administered by the Aluminum Association. The alloys are conveniently divided into eight groups based on their principal alloying element. The first digit identifies the alloy group as follows:

ALLOY GROUP	PRINCIPAL ALLOYING ELEMENT	
1xxx	Unalloyed Aluminum	Purity of 99.0% or Greater
2xxx	Copper	Heat Treatable Alloys
3xxx	Manganese	
4xxx	Silicon	Low Melting Point Alloys
5xxx	Magnesium	
6xxx	Magnesium and Silicon	Heat Treatable Alloys
7xxx	Zinc	Heat Treatable Alloys
8xxx	Other Elements	

The last two digits in the 1xxx group correspond with the two digits after the decimal which indicate the minimum aluminum content. For example the aluminum content of 1060 is 99.60% minimum, 1100 is 99.00% minimum, 1350 is 99.50% minimum and so on.

The last two digits of the other groups are sequential numbers issued by the Aluminum Association to ensure each alloy is uniquely identified.

The second digit in all the groups indicates a minor modification of the basic alloy. For instance, 5252 is the second modification of 5052 alloy.

ALUMINUM TEMPER DESIGNATIONS

The temper designation follows the alloy code and is separated by a hyphen.

-F	As Fabricated: Applies to products of rolling or forming where there is no special control over the thermal or work-hardening conditions. Since mechanical properties may vary widely, no limits have been assigned. This temper usually applies to sheet products which are at intermediate stages of production.
-H	Strain Hardened: Applies to wrought products which are strengthened by cold rolling or cold working.
-O	Annealed: Applies to wrought products which have been heated above the recrystallization temperature to produce the lowest tensile strength condition of the alloy.

DESIGNATIONS OF THE –H STRAIN HARDENED TEMPERS

The First Digit

There are three different methods used to achieve the final temper of strain hardened material.

-H1	Strain Hardened Only: Applies to products which are strain hardened to obtain the desired strength level without any subsequent thermal treatment.
-H2	Strain Hardened And Partially Annealed: Applies to products that are strain hardened to a higher strength level than desired, followed by a partial anneal (or "back anneal") which reduces the strength to the desired level.
-H3	Strain Hardened And Stabilized: This designation only applies to magnesium-containing alloys which gradually age-soften at room temperature after strain hardening. A low temperature anneal is applied which stabilizes the properties.

The Second Digit

The amount of strain hardening, and hence the strength level, is indicated by a second digit.

-Hx2	Quarter hard
-Hx4	Half hard
-Hx6	Three quarter
-Hx8	Full hard
-Hx9	Extra hard (the minimum tensile strength exceeds that of the Hx8 temper by 2 ksi or more)

Hx1, Hx3, Hx5 and Hx7 tempers are intermediate between those defined above.
The mechanical property limits that correspond to each temper designation can be found by referring to an appropriate aluminum standard such as the *Aluminum Association Standards and Data* or ASTM B 209.

The Third Digit

A third digit is sometimes used to indicate a variation of the basic two-digit temper.

HEAT TREATMENT TEMPERS

Alloys in the 2xxx, 6xxx and 7xxx groups can be strengthened by a heat treatment process. The aluminum is heat treated by carrying out a solution treatment process in which the metal is heated to an elevated temperature followed by rapid cooling, then a precipitation hardening process (or "aging" process). The tempers are designated by –T followed by a digit. Some common –T tempers are as follows:

-T3	Solution heat-treated, cold worked, and naturally aged: Applies to products that are cold-worked to improve strength after solution heat-treatment, or which the effect of flattening or straightening is recognized in mechanical property limits.
-T4	Solution heat-treated and naturally aged: Applies to product that are allowed to age harden at room temperature following a solution treatment.
-T6	Solution heat-treated and artificially aged: Applies to products that are reheated to a low temperature following a solution treatment. This allows the metal to achieve its highest heat-treated strength level.

CHEMICAL COMPOSITION LIMITS FOR ALUMINUM ALLOYS

Composition in percent by weight according to The Aluminum Association. The values indicate maximum limits unless shown as a range or a minimum.

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti		OTHERS EACH	OTHERS TOTAL	Al MIN.
1050	0.25	0.40	0.05	0.05	0.05	—	0.05	0.03		0.03	—	99.50
1060	0.25	0.35	0.05	0.03	0.03	—	0.05	0.03		0.03	–	99.60
1070	0.20	0.25	0.04	0.03	0.03	—	0.04	0.03		0.03	—	99.70
1100	0.95 Si + Fe		0.05-0.20	0.05	—	—	0.10	—		0.05	0.15	99.00
1145	0.55 Si + Fe		0.05	0.05	0.05	—	0.05	0.03		0.03	—	99.45
1350	0.10	0.40	0.05	0.01	—	0.01	0.05	—	0.05 B, 0.02 V+Ti	0.03	0.10	99.50
2024	0.50	0.50	3.8-4.9	0.30-0.9	1.2-1.8	0.10	0.25	0.15		0.05	0.15	Rem.
3003	0.6	0.7	0.05-0.20	1.0-1.5	—	—	0.10	—		0.05	0.15	Rem.
3104	0.6	0.8	0.05-0.25	0.8-1.4	0.8-1.3	—	0.25	0.10		0.05	0.15	Rem.
3004	0.30	0.7	0.25	1.0-1.5	0.8-1.3	—	0.25	—		0.05	0.15	Rem.
3005	0.6	0.7	0.30	1.0-1.5	0.20-0.6	0.10	0.25	0.10		0.05	0.15	Rem.
3105	0.6	0.7	0.30	0.30-0.8	0.20-0.8	0.20	0.40	0.10		0.05	0.15	Rem.
4004	9.0-10.5	0.8	0.25	0.10	1.0-2.0	—	0.20	—		0.05	0.15	Rem.
4104	9.0-10.5	0.8	0.25	0.10	1.0-2.0	—	0.20	—	0.02-0.20 Bi	0.05	0.15	Rem.
4043	4.5-6.0	0.8	0.30	0.05	0.05	—	0.10	0.20		0.05	0.15	Rem.
4045	9.0-11.0	0.8	0.30	0.05	0.05	—	0.10	0.20		0.05	0.15	Rem.
5005	0.30	0.7	0.20	0.20	0.50-1.1	0.10	0.25	—		0.05	0.15	Rem.
5050	0.40	0.7	0.20	0.10	1.1-1.8	0.10	0.25	—		0.05	0.15	Rem.
5052	0.25	0.40	0.10	0.10	2.2-2.8	0.15-0.35	0.10	—		0.05	0.15	Rem.
5252	0.08	0.10	0.10	0.10	2.2-2.8	—	0.05	—		0.03	0.10	Rem.
5754	0.40	0.40	0.10	0.50	2.6-3.6	0.30	0.20	0.15	0.10-0.6 Mn+Cr	0.05	0.15	Rem.
5056	0.30	0.40	0.10	0.05-0.20	4.5-5.6	0.05-0.20	0.10	—		0.05	0.15	Rem.
5657	0.08	0.10	0.10	0.03	0.6-1.0	—	0.05	—		0.02	0.05	Rem.
5182	0.20	0.35	0.15	0.20-0.50	4.0-5.0	0.10	0.25	0.10		0.05	0.15	Rem.
6061	0.40-0.8	0.7	0.15-0.40	0.15	0.8-1.2	0.04-0.35	0.25	0.15		0.05	0.15	Rem.
7075	0.40	0.50	1.2-2.0	0.30	2.1-2.9	0.18-0.28	5.1-6.1	0.20		0.05	0.15	Rem.
8111	0.30-1.1	0.40-1.0	0.10	0.10	0.05	0.05	0.10	0.08		0.05	0.15	Rem.

Rem.=Remainder

ALUMINUM SHEET & COIL PUBLISHED DIMENSIONAL TOLERANCES

Thickness Tolerances for Aluminum Sheet

Specified Thickness (Inches)		Thickness Tolerance for widths up to 39.37″
Over	Thru	Inches plus and minus
0.0059	0.016	0.0010
0.016	0.025	0.0015
0.025	0.039	0.0020
0.039	0.047	0.0025
0.047	0.063	0.0030
0.063	0.098	0.0035
0.098	0.126	0.0045
0.126	0.158	0.0055
0.158	0.197	0.0070

The above are the published thickness tolerances in ANSI-H35.2 for all sheet alloys not included in the Aerospace Alloys Table or specified for aerospace applications.

Thickness Tolerances for Aerospace Alloys

Specified Thickness (Inches)		Thickness Tolerance for widths up to 39.37″
Over	Thru	Inches plus and minus
0.0059	0.010	0.0010
0.010	0.039	0.0015
0.039	0.079	0.0020
0.079	0.098	0.0025
0.098	0.126	0.0035
0.126	0.158	0.0040
0.158	0.197	0.0055

The above are the published thickness tolerances in ANSI-H35.2 for aerospace alloys 2024 and 7075.

Width Tolerances for Slit Coil

Specified Thickness (Inches)	Specified Width (inches)			
	Up Thru 6	Over 6 Thru 12	Over 12 Thru 24	Over 24 Thru 48
0.006-0.125	0.010	1/64	1/32	3/64
0.126-0.186	0.012	1/32	1/32	1/16

ANSI-H35.2

Lateral Bow (or “Camber”) Limits for Slit Coil

Allowable deviation of an edge from a 6ft. straight line

Specified Thickness (Inches)	Specified Width (inches)				
	½ Thru 1	Over 1 Thru 2	Over 2 Thru 4	Over 4 Thru 10	Over 10
0.006-0.064	3/4	9/16	3/8	1/4	3/16
0.065-0.125	–	–	3/8	1/4	3/16

ANSI-H35.2

TYPICAL MECHANICAL PROPERTIES

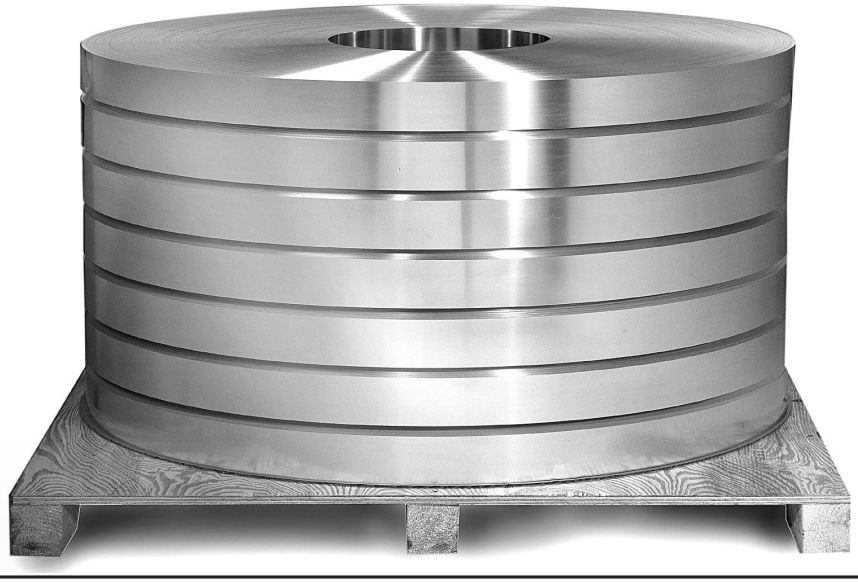
The following typical properties are not guaranteed since in most cases they are averages for various sizes and methods of manufacture and may not be exactly representative of any particular product or size. The data is intended for comparing alloys and tempers and should not be used for design purposes.

		Tensile Strength	Yield Strength	Elongation (%) for the following gauge ranges:		Tensile Strength	Yield Strength	Elongation (%) for the following gauge ranges:	
Alloy	Temper	(ksi)	(ksi)	0.010-0.050˝	0.051-.125˝	(MPa)	(MPa)	0.25-1.25mm	1.26-3.0mm
1100	O	13	5	30	32	89.6	34.5	30	6
	H12	16	15	4	12	110.3	103.4	4	12
	H14	18	17	3	10	124.1	117.2	3	10
	H16	21	20	2	8	144.8	137.9	2	8
	H18	24	22	2	6	165.5	151.7	2	6
1350	O	12	4	34	42	82.7	27.6	34	42
	H12	14	12	5	12	96.5	82.7	5	12
	H14	16	14	3	9	110.3	96.5	3	9
	H16	18	16	3	8	124.1	110.3	3	8
	H19	27	24	2	6	186.2	165.5	2	6
2024	O	27	11	18	20	186.2	75.8	18	20
	T3	70	50	16	18	482.6	344.7	16	18
	T4	68	47	20	19	468.8	324.1	20	19
3003	O	16	6	30	33	110.3	41.4	30	33
	H12	19	18	9	11	131.0	124.1	9	11
	H14	22	21	3	7	151.7	144.8	3	7
	H16	26	25	3	5	179.3	172.4	3	5
	H18	29	27	3	5	199.9	186.2	3	5
3004	O	26	10	19	23	179.3	68.9	19	23
	H32	31	25	6	15	213.7	172.4	6	15
	H34	35	29	5	10	241.3	199.9	5	10
	H36	38	33	5	8	262.0	227.5	5	8
	H38	41	36	4	6	282.7	248.2	4	6
3005	O	20	8	22	23	137.9	55.2	22	23
	H12	26	24	5	13	179.3	165.5	5	13
	H14	29	28	4	9	199.9	193.1	4	9
	H16	31	30	3	5	213.7	206.8	3	5
	H18	37	36	2	3	255.1	248.2	2	3
5005	O	18	6	22	25	124.1	41.4	22	25
	H12	20	19	5	9	137.9	131.0	5	9
	H14	23	22	4	7	158.6	151.7	4	7
	H16	26	25	3	5	179.3	172.4	3	5
	H18	29	28	2	2	199.9	193.1	2	2
	H32	20	17	8	9	137.9	117.2	8	9
	H34	23	20	6	8	158.6	137.9	6	8
	H36	26	24	5	6	179.3	165.5	5	6
	H38	29	27	3	4	199.9	186.2	3	4
5050	O	21	8	20	25	144.8	55.2	20	25
	H32	25	21	9	13	172.4	144.8	9	13
	H34	28	24	5	10	193.1	165.5	5	10
	H36	30	26	4	7	206.8	179.3	4	7
	H38	32	29	2	4	220.6	199.9	2	4
5052	O	28	13	20	21	193.1	89.6	20	21
	H32	33	28	7	10	227.5	193.1	7	10
	H34	38	31	6	8	262.0	213.7	6	8
	H36	40	35	4	5	275.8	241.3	4	5
	H38	42	37	3	4	289.6	255.1	3	4
5056	O	42	22	23	24	289.6	151.7	23	24
	H38	60	50	6	13	413.7	344.7	6	13
5182	O	40	21	21	25	275.8	144.8	21	25
	H32	41	22	20	21	282.7	151.7	20	21
	H34	48	37	11	14	330.9	255.1	11	14
	H36	51	42	9	11	351.6	289.6	9	11
	H38	54	47	6	7	372.3	324.1	6	7
6061	O	18	8	25	26	124.1	55.2	25	26
	T4	35	21	22	24	241.3	144.8	22	24
	T6	45	40	12	17	310.3	275.8	12	17
7075	O	33	15	16	18	227.5	103.4	16	18
	T6	83	73	11	12	572.3	503.3	11	12

TYPICAL PHYSICAL PROPERTIES

Alloy	Average[1] Coeffecient of Thermal Expansion 68° to 212°F (°F)$^{-1}$	Melting Range [2,3] Approximately (°F)	Density (lb/in^3)	Thermal Conductivity (English Units[4])	Electrical Conductivity at 68°F (Percent of International Annealed Copper Standard)		Electrical Resistivity at 68°F (Ohms-Cir. Mil/Foot)
					Equal Volume	Equal Weight	
1100	13.1	1190-1215	0.098	1520	59	194	18
1350	13.2	1195-1215	0.0975	1625	62	204	17
2024-O	12.9	935-1180[5]	0.100	1340	50	160	21
2024-T3,T4	12.9	935-1180[5]	0.100	840	30	96	35
2024-T6	12.9	935-1180[5]	0.100	1050	38	122	27
3003	12.9	1190-1210	0.099	1200	48	156	22
3004	13.3	1165-1210	0.098	1100	41	134	25
3005	13.1	1175-1210	0.098	1190	45	148	23
5005	13.2	1170-1210	0.098	1390	52	172	20
5050	13.2	1155-1205	0.097	1340	50	165	21
5052	13.2	1125-1200	0.097	960	35	116	30
5056	13.4	1055-1180	0.096	790	28	95	37
5182	13.4	1055-1180	0.096	790	28	95	37
5657	13.2	1180-1215	0.097	960	35	116	30
6061-O	13.1	1080-1205[6]	0.098	1250	47	155	22
6061-T4	13.1	1080-1205[6]	0.098	1070	40	132	26
6061-T6	13.1	1080-1205[6]	0.098	1160	43	142	24

[1] Coefficient to be multiplied by 10^{-6}. Example $12.2 \times 10^{-6} = 0.0000122$.
[2] Melting ranges shown apply to wrought products of ¼ inch thickness or greater.
[3] Based on typical composition of the indicated alloys.
[4] English units = btu-in/ft^{2}hr °F.
[5] Eutectic melting is not eliminated by homogenization.
[6] Eutectic melting can be completely eliminated by homogenization



SELECTION GUIDE FOR ALUMINUM ALLOYS AND TEMPERS

ALLOY	TEMPER	RESISTANCE TO CORROSION		Workability (Cold)	Machinability	Brazeability	WELDABILITY		
		General	Stress-Corrosion Cracking				Gas	Arc	Resistance Spot and Seam
1100	O	A	A	A	E	A	A	A	B
	H12	A	A	A	E	A	A	A	A
	H14	A	A	A	D	A	A	A	A
	H16	A	A	B	D	A	A	A	A
	H18	A	A	C	D	A	A	A	A
1350	O	A	A	A	E	A	A	A	B
	H18	A	A	B	D	A	A	A	A
2024	O	–	–	–	D	D	D	D	D
	T3, T4	D	C	C	B	D	C	B	B
	T6	D	D	C	B	D	D	C	B
3003	O	A	A	A	E	A	A	A	A
	H12	A	A	A	E	A	A	A	A
	H14	A	A	B	D	A	A	A	A
	H16	A	A	C	D	A	A	A	A
	H18	A	A	C	D	A	A	A	A
	H25	A	A	B	D	A	A	A	A
3004	O	A	A	A	D	B	B	A	B
	H32	A	A	B	D	B	B	A	A
	H34	A	A	B	C	B	B	A	A
	H36	A	A	C	C	B	B	A	A
	H38	A	A	C	C	B	B	A	A
3005	O	A	A	A	D	B	A	A	B
	H12	A	A	B	D	B	A	A	A
	H14	A	A	B	C	B	A	A	A
	H16	A	A	C	C	B	A	A	A
	H18	A	A	C	C	B	A	A	A
5005	O	A	A	A	E	B	A	A	B
	H12	A	A	A	E	B	A	A	A
	H14	A	A	B	D	B	A	A	A
	H16	A	A	C	D	B	A	A	A
	H18	A	A	C	D	B	A	A	A
	H32	A	A	A	E	B	A	A	A
	H34	A	A	B	D	B	A	A	A
	H36	A	A	C	D	B	A	A	A
	H38	A	A	C	D	B	A	A	A

SELECTION GUIDE FOR ALUMINUM ALLOYS AND TEMPERS

ALLOY	TEMPER	RESISTANCE TO CORROSION		Workability (Cold)	Machinability	Brazeability	WELDABILITY		
		General	Stress-Corrosion Cracking				Gas	Arc	Resistance Spot and Seam
5050	**O**	A	A	A	E	B	A	A	B
	H32	A	A	A	D	B	A	A	A
	H34	A	A	B	D	B	A	A	A
	H36	A	A	C	C	B	A	A	A
	H38	A	A	C	C	B	A	A	A
5052	**O**	A	A	A	D	C	A	A	B
	H32	A	A	B	D	C	A	A	A
	H34	A	A	B	C	C	A	A	A
	H36	A	A	C	C	C	A	A	A
	H38	A	A	C	C	C	A	A	A
5056 & 5182	**O**	A	B	A	D	D	C	A	B
	H12, H32	A	B	B	D	D	C	A	A
	H14, H34	A	B	B	C	D	C	A	A
	H16, H36	A	B-C	B-C	C	D	C	A	A
	H18, H38	A	C	C	C	D	C	A	A
5657	**H241**	A	A	A	D	B	A	A	A
	H25	A	A	B	D	B	A	A	A
	H26	A	A	B	D	B	A	A	A
	H28	A	A	C	D	B	A	A	A
6061	**O**	B	A	A	D	A	A	A	B
	T4	B	B	B	C	A	A	A	A
	T6	B	A	C	C	A	A	A	A
7075	**O**	–	–	–	D	D	D	D	B
	T6	C	C	D	B	D	D	D	B

Corrosion ratings A through E are relative ratings in decreasing order of merit, based on exposures to sodium chloride solution by intermittent spraying or immersion. Alloys with A and B ratings can be used in industrial and seacoast atmospheres without protection. Alloys with C, D and E ratings generally should be protected at least on faying surfaces.

Stress-corrosion cracking ratings are based on service experience and on laboratory tests of specimens exposed to the 3.5% sodium chloride alternate immersion test.

A = No known instance of failure in service or in laboratory tests.
B = No known instance of failure in service; limited failures in laboratory tests of short transverse specimens.
C = Service failures with sustained tension stress acting in short transverse direction relative to grain structure; limited failures in laboratory tests of long transverse specimens.
D = Limited service failures with sustained longitudinal or long transverse stress.

Ratings A through D for Workability (cold) and A through E for Machinability are relative ratings in decreasing order of merit.

Ratings A through D for Weldability and Brazeability are relative ratings defined as follows:

A = Generally weldable by all commercial procedures and methods.
B = Weldable with special techniques or for specific applications which justify preliminary trials or testing to develop welding procedure and weld performance.
C = Limited Weldability because of crack sensitivity or loss in resistance to corrosion and mechanical properties.
D = No commonly used welding methods have been developed.

RECOMMENDED MINIMUM BEND RADII FOR 90-DEGREE COLD FORMING OF SHEET

The radii listed are the minimum recommended for bending sheets and plates without fracturing in a standard press brake with air bend dies. Other types of bending operations may require larger radii or permit smaller radii. The minimum permissible radii will also vary with the design and condition of the tooling.

ALLOY	TEMPER	RADII FOR VARIOUS THICKNESSES EXPRESSED IN TERMS OF THICKNESS "t"			
		1/64 in.	1/32 in.	1/16 in.	1/8 in.
1100	O	0	0	0	0
	H12	0	0	0	½t
	H14	0	0	0	1t
	H16	0	½t	1t	1½t
	H18	1t	1t	1½t	2½t
2024	O	0	0	0	½t
	T3	2½t	3t	4t	5t
	T361	3t	4t	5t	6t
	T4	2½t	3t	4t	5t
	T81	4½t	5½t	6t	7½t
	T861	5t	6t	7t	8½t
3003	O	0	0	0	0
	H12	0	0	0	½t
	H14	0	0	0	1t
	H16	½t	1t	1t	1½t
	H18	1t	1½t	2t	2½t
3004	O	0	0	0	½t
	H32	0	0	½t	1t
	H34	0	1t	1t	1½t
	H36	1t	1t	1½t	2½t
	H38	1t	1½t	2½t	3t
3005	O	0	0	0	0
	H12	0	0	0	½t
	H14	0	½t	½t	1½t
	H16	½t	1t	1t	2t
	H18	1t	1½t	2t	2½t

ALLOY	TEMPER	RADII FOR VARIOUS THICKNESSES EXPRESSED IN TERMS OF THICKNESS "t"			
		1/64 in.	1/32 in.	1/16 in.	1/8 in.
5005	O	0	0	0	0
	H12	0	0	0	½t
	H14	0	0	0	1t
	H16	½t	1t	1t	1½t
	H18	1t	1½t	2t	2½t
	H32	0	0	0	½t
	H34	0	0	0	1t
	H36	½t	1t	1t	1½t
	H38	1t	1½t	2t	2½t
5050	O	0	0	0	½t
	H32	0	0	0	1t
	H34	0	0	1t	1½t
	H36	1t	1t	1½t	2t
	H38	1t	1½t	2½t	3t
5052	O	0	0	0	½t
	H32	0	0	1t	1½t
	H34	0	1t	1½t	2t
	H36	1t	1t	1½t	2½t
	H38	1t	1½t	2½t	3t
5657	H25	0	0	0	1t
	H27	1t	1½t	2½t	3t
6061	O	0	0	0	1t
	T4	0	0	1t	1½t
	T6	1t	1t	1½t	2½t
7075	O	0	0t	1t	1t
	T6	3t	4t	5t	6t

WATERSTAIN AND ITS PREVENTION

What is Waterstain?

Sometimes, when a coil of aluminum is unwound, some patches of white, chalky stains can be seen on the surface — this is a sure indication that the coil has been exposed to moisture at some point in time. Although usually white, the colors of the stains can also be brown, black, or even show iridescent colors.

How does the staining occur?

Aluminum reacts with oxygen in the air to form a very tenacious oxide coating. It is this coating that gives aluminum its excellent corrosion resistance. Under most conditions aluminum will not react with water at all, but aluminum is very prone to waterstaining when water is trapped between mating surfaces, such as when it is in the form of a tightly wound coil or in a stack of flat sheet.

Because oxygen from the air is prevented from reaching much of the aluminum surface, a chemical reaction occurs between the entrapped water and the aluminum, which results in a white hydroxide film forming instead of the usual transparent oxide film. The stains have no significant effect on the mechanical strength, but they can be unsightly and are often objectionable for esthetic reasons. They may cause processing problems where additional surface finishing or fabrication is to be performed.

Where does the water come from?

Obviously aluminum coils should not be stored in an area where they would be exposed to rain, or to water from a leaking roof or a leaking water pipe, or be exposed to any water splashes from nearby processing equipment. However, waterstain can still occur in an apparently dry storage area. This is because the most common source of water is condensation.

Air contains water in the form of water vapor. Warm air can hold more moisture than cold and so, if the air is chilled, it releases its moisture in the form of dew. A familiar example is the condensation of water that forms on the outside of a glass of cold liquid.

There is a risk of water condensing on an aluminum coil whenever the metal temperature is allowed to fall much below the surrounding air temperature or, in technical terms, water will condense on aluminum if the temperature of the metal falls below the dew-point. Some examples of how this may occur:

- Moving cold metal from a cold truck directly into a warm storage area can result in condensation, especially on a humid day. Instead, the unopened package of cold metal should be placed in a cooler area, free from drafts, and allowed to warm up slowly.
- Moving metal from cold a warehouse to a warm factory floor. Again, the metal should be allowed to warm up slowly.
- Leaving a warehouse door open, allowing cold air to enter and cool the metal. If the air temperature suddenly rises as the day gets hotter then water may condense on the coil.

How does the water get in between the wraps?

It is often a source of amazement that waterstaining can occur all the way across a wide strip despite only the edges of a coil getting wet. However the water is forced into the wraps of the coil by a strong force called capillary action (the very tiny gaps between the wraps of the coil cause it to behave like a sponge soaking up water).

If there is evidence that the package has been exposed to moisture when you receive the metal, then this should be noted on the receiving papers and you should notify United Aluminum immediately.

If water is already in contact with the metal, the only sure way to avoid waterstain is to process the metal immediately. If this is not practical then remove the water as quickly as possible by using fans to blow air over the metal. Do not use hot air as this can cause further condensation to occur.

United Aluminum hopes that this information has provided a better understanding of waterstain. The value of the aluminum and assured production schedules justify the extra precautions.

ALUMINUM COIL SIZE CALCULATOR

The following data can be used in two ways:
(1) If the arbor, or inner diameter, size is known to a specified pounds per inch of coil width (PIW), the outside diameter can be read below.
(2) If the ID and OD are known, the PIW is in the left column. To calculate the weight of the coil in pounds, multiply the PIW by the width.

POUNDS PER INCH OF COIL WIDTH	INSIDE DIAMETER (ID) OF COIL (INCHES)								
	3	6	8	10	12	16	20	22	24
	OUTSIDE DIAMETER (OD) OF COIL (INCHES)								
10	11.8	12.9	13.9	15.2	16.6	19.6	23.0	24.8	26.6
15	14.3	15.2	16.1	17.2	18.4	21.2	24.4	26.1	27.8
20	16.4	17.2	18.0	19.0	20.1	22.7	25.7	27.3	28.9
25	18.3	19.0	19.7	20.6	21.7	24.1	26.9	28.4	30.0
30	20.0	20.6	21.3	22.1	23.1	25.4	28.1	29.6	31.1
35	21.5	22.2	22.8	23.6	24.5	26.7	29.2	30.6	32.1
40	23.0	23.6	24.2	24.9	25.8	27.9	30.3	31.7	33.1
45	24.4	24.9	25.5	26.2	27.0	29.0	31.4	32.7	34.1
50	25.7	26.2	26.7	27.4	28.2	30.1	32.4	33.7	35.0
55	26.9	27.4	27.9	28.5	29.3	31.2	33.4	34.6	35.9
60	28.1	28.6	29.0	29.7	30.4	32.2	34.3	35.5	36.8
65	29.2	29.7	30.1	30.7	31.4	33.2	35.3	36.4	37.7
70	30.3	30.7	31.2	31.8	32.5	34.1	36.2	37.3	38.5
75	31.4	31.8	32.2	32.8	33.4	35.1	37.1	38.2	39.4
80	32.4	32.8	33.2	33.8	34.4	36.0	37.9	39.0	40.2
85	33.4	33.8	34.2	34.7	35.3	36.9	38.8	39.9	41.0
90	34.3	34.7	35.1	35.6	36.2	37.8	39.6	40.7	41.8
95	35.3	35.6	36.0	36.5	37.1	38.6	40.4	41.5	42.5
100	36.2	36.5	36.9	37.4	38.0	39.4	41.2	42.2	43.3
110	37.9	38.3	38.6	39.1	39.7	41.1	42.8	43.7	44.8
120	39.6	39.9	40.3	40.7	41.3	42.6	44.3	45.2	46.2
130	41.2	41.5	41.9	42.3	42.8	44.1	45.7	46.6	47.6
140	42.8	43.1	43.4	43.8	44.3	45.6	47.1	48.0	48.9
150	44.2	44.6	44.9	45.3	45.7	47.0	48.5	49.3	50.2
160	45.7	46.0	46.3	46.7	47.1	48.3	49.8	50.6	51.5
170	47.1	47.4	47.7	48.0	48.5	49.6	51.1	51.9	52.8
180	48.5	48.7	49.0	49.4	49.8	50.9	52.3	53.1	54.0
190	49.8	50.0	50.3	50.7	51.1	52.2	53.6	54.3	55.2
200	51.1	51.3	51.6	51.9	52.4	53.4	54.8	55.5	56.3
210	52.3	52.6	52.8	53.2	53.6	54.6	55.9	56.7	57.5
220	53.5	53.8	54.1	54.4	54.8	55.8	57.1	57.8	58.6
230	54.7	55.0	55.2	55.6	56.0	57.0	58.2	58.9	59.7
240	55.9	56.2	56.4	56.7	57.1	58.1	59.3	60.0	60.8
250	57.1	57.3	57.6	57.9	58.2	59.2	60.4	61.1	61.8
260	58.2	58.4	58.7	59.0	59.3	60.3	61.5	62.1	62.9
270	59.3	59.5	59.8	60.1	60.4	61.4	62.5	63.2	63.9
280	60.4	60.6	60.8	61.1	61.5	62.4	63.5	64.2	64.9
290	61.5	61.7	61.9	62.2	62.5	63.4	64.6	65.2	65.9
300	62.5	62.7	62.9	63.2	63.6	64.4	65.6	66.2	66.9
310	63.5	63.7	64.0	64.2	64.6	65.4	66.5	67.2	67.8
320	64.5	64.8	65.0	65.2	65.6	66.4	67.5	68.1	68.8
330	65.5	65.8	66.0	66.2	66.6	67.4	68.5	69.1	69.7
340	66.5	66.7	66.9	67.2	67.5	68.4	69.4	70.0	70.7
350	67.5	67.7	67.9	68.2	68.5	69.3	70.3	70.9	71.6
360	68.5	68.7	68.9	69.1	69.4	70.2	71.3	71.8	72.5
370	69.4	69.6	69.8	70.1	70.4	71.2	72.2	72.7	73.4
380	70.3	70.5	70.7	71.0	71.3	72.1	73.1	73.6	74.2
390	71.2	71.4	71.6	71.9	72.2	73.0	73.9	74.5	75.1
400	72.2	72.3	72.5	72.8	73.1	73.8	74.8	75.4	76.0
410	73.0	73.2	73.4	73.7	74.0	74.7	75.7	76.2	76.8
420	73.9	74.1	74.3	74.5	74.8	75.6	76.5	77.1	77.7
430	74.8	75.0	75.2	75.4	75.7	76.4	77.4	77.9	78.5
440	75.7	75.8	76.0	76.3	76.6	77.3	78.2	78.7	79.3

ALUMINUM COIL LENGTH CALCULATOR

The coil length, in feet, can be estimated from this chart if the PIW and gauge are known. This chart can be used in conjunction with the preceding chart to include OD and ID criteria.

POUNDS PER INCH OF COIL WIDTH	THICKNESS (INCHES)															
	0.005	0.010	0.015	0.020	0.025	0.030	0.035	0.040	0.045	0.050	0.060	0.070	0.080	0.090	0.100	0.125
	COIL LENGTH (FEET)															
10	1701	850	567	425	340	283	243	213	189	170	142	121	106	94	85	68
15	2551	1276	850	638	510	425	364	319	283	255	213	182	159	142	128	102
20	3401	1701	1134	850	680	567	486	425	378	340	283	243	213	189	170	136
25	4252	2126	1417	1063	850	709	607	531	472	425	354	304	266	236	213	170
30	5102	2551	1701	1276	1020	850	729	638	567	510	425	364	319	283	255	204
35	5952	2976	1984	1488	1190	992	850	744	661	595	496	425	372	331	298	238
40	6803	3401	2268	1701	1361	1134	972	850	756	680	567	486	425	378	340	272
45	7653	3827	2551	1913	1531	1276	1093	957	850	765	638	547	478	425	383	306
50	8503	4252	2834	2126	1701	1417	1215	1063	945	850	709	607	531	472	425	340
55	9354	4677	3118	2338	1871	1559	1336	1169	1039	935	779	668	585	520	468	374
60	10204	5102	3401	2551	2041	1701	1458	1276	1134	1020	850	729	638	567	510	408
65	11054	5527	3685	2764	2211	1842	1579	1382	1228	1105	921	790	691	614	553	442
70	11905	5952	3968	2976	2381	1984	1701	1488	1323	1190	992	850	744	661	595	476
75	12755	6378	4252	3189	2551	2126	1822	1594	1417	1276	1063	911	797	709	638	510
80	13605	6803	4535	3401	2721	2268	1944	1701	1512	1361	1134	972	850	756	680	544
85	14456	7228	4819	3614	2891	2409	2065	1807	1606	1446	1205	1033	903	803	723	578
90	15306	7653	5102	3827	3061	2551	2187	1913	1701	1531	1276	1093	957	850	765	612
95	16156	8078	5385	4039	3231	2693	2308	2020	1795	1616	1346	1154	1010	898	808	646
100	17007	8503	5669	4252	3401	2834	2430	2126	1890	1701	1417	1215	1063	945	850	680
110	18707	9354	6236	4677	3741	3118	2672	2338	2079	1871	1559	1336	1169	1039	935	748
120	20408	10204	6803	5102	4082	3401	2915	2551	2268	2041	1701	1458	1276	1134	1020	816
130	22109	11054	7370	5527	4422	3685	3158	2764	2457	2211	1842	1579	1382	1228	1105	884
140	23810	11905	7937	5952	4762	3968	3401	2976	2646	2381	1984	1701	1488	1323	1190	952
150	25510	12755	8503	6378	5102	4252	3644	3189	2834	2551	2126	1822	1594	1417	1276	1020
160	27211	13605	9070	6803	5442	4535	3887	3401	3023	2721	2268	1944	1701	1512	1361	1088
170	28912	14456	9637	7228	5782	4819	4130	3614	3212	2891	2409	2065	1807	1606	1446	1156
180	30612	15306	10204	7653	6122	5102	4373	3827	3401	3061	2551	2187	1913	1701	1531	1224
190	32313	16156	10771	8078	6463	5385	4616	4039	3590	3231	2693	2308	2020	1795	1616	1293
200	34014	17007	11338	8503	6803	5669	4859	4252	3779	3401	2834	2430	2126	1890	1701	1361
210	35714	17857	11905	8929	7143	5952	5102	4464	3968	3571	2976	2551	2232	1984	1786	1429
220	37415	18707	12472	9354	7483	6236	5345	4677	4157	3741	3118	2672	2338	2079	1871	1497
230	39116	19558	13039	9779	7823	6519	5588	4889	4346	3912	3260	2794	2445	2173	1956	1565
240	40816	20408	13605	10204	8163	6803	5831	5102	4535	4082	3401	2915	2551	2268	2041	1633
250	42517	21259	14172	10629	8503	7086	6074	5315	4724	4252	3543	3037	2657	2362	2126	1701
260	44218	22109	14739	11054	8844	7370	6317	5527	4913	4422	3685	3158	2764	2457	2211	1769
270	45918	22959	15306	11480	9184	7653	6560	5740	5102	4592	3827	3280	2870	2551	2296	1837
280	47619	23810	15873	11905	9524	7937	6803	5952	5291	4762	3968	3401	2976	2646	2381	1905
290	49320	24660	16440	12330	9864	8220	7046	6165	5480	4932	4110	3523	3082	2740	2466	1973
300	51020	25510	17007	12755	10204	8503	7289	6378	5669	5102	4252	3644	3189	2834	2551	2041
310	52721	26361	17574	13180	10544	8787	7532	6590	5858	5272	4393	3766	3295	2929	2636	2109
320	54422	27211	18141	13605	10884	9070	7775	6803	6047	5442	4535	3887	3401	3023	2721	2177
330	56122	28061	18707	14031	11224	9354	8017	7015	6236	5612	4677	4009	3508	3118	2806	2245
340	57823	28912	19274	14456	11565	9637	8260	7228	6425	5782	4819	4130	3614	3212	2891	2313
350	59524	29762	19841	14881	11905	9921	8503	7440	6614	5952	4960	4252	3720	3307	2976	2381
360	61224	30612	20408	15306	12245	10204	8746	7653	6803	6122	5102	4373	3827	3401	3061	2449
370	62925	31463	20975	15731	12585	10488	8989	7866	6992	6293	5244	4495	3933	3496	3146	2517
380	64626	32313	21542	16156	12925	10771	9232	8078	7181	6463	5385	4616	4039	3590	3231	2585
390	66327	33163	22109	16582	13265	11054	9475	8291	7370	6633	5527	4738	4145	3685	3316	2653
400	68027	34014	22676	17007	13605	11338	9718	8503	7559	6803	5669	4859	4252	3779	3401	2721

IMPERIAL-METRIC CONVERSION

TENSILE STRENGTH

TO CONVERT FROM	TO	MULTIPLY BY
kgf/mm^2	N/mm^2 or MPa	9.80665
kgf/mm^2	ksi	1.422335
N/mm^2 or MPa	kgf/mm^2	0.0101972
N/mm^2 or MPa	ksi	0.145038
ksi	kgf/mm^2	0.703069
ksi	N/mm^2 or MPa	6.894752

Tensile strength and yield stress are measured in Metric and Imperial as a force per unit area. The most common are:
- Pound per square inch (psi)
- Kilopounds per square inch (ksi)
- Kilograms-force per square millimeter (kgf/mm^2)
- Newtons per square millimeter (N/mm^2), also known as a MegaPascal (MPa)

LENGTH AND AREA

1 inch = 25.4 mm exactly	1 mm = 0.03937 inch
1 microinch = 0.0254 microns	1 micron = 39.3701 microinch
1 foot = 0.3048 meter	1 meter = 3.28084 feet
1 yard = 0.9144 meter	1 meter = 1.09361 yards
1 mile = 1.609344 kilometers	1 kilometer = 0.62137 mile
1 square inch = 645.16 square millimeters	1 square millimeter = 0.00155 square inch
1 square foot = 0.092903 square meter	1 square meter = 10.7639 square feet
1 square yard = 0.836127 square meter	1 square meter = 1.19599 square yards
1 square mile = 2.58999 square kilometers	1 square kilometer = 0.38610 square mile

MASS

1 lb. = 16 oz. = 453.59237 g (exactly)	1 gram = 0.035274 ounce
1 pound = 0.45359237 kilogram (exactly)	1 kilogram = 2.204622 pounds

VOLUME

1 cubic inch = 16.3871 cubic centimeters	1 cubic centimeter = 0.0610124 cubic inch
1 cubic foot = 0.028317 cubic meter	1 cubic meter = 35.31467 cubic feet
1 cubic yard = 0.764555 cubic meter	1 cubic meter = 1.30795 cubic yards

MEASURE OF CAPACITY

1 fluid ounce = 28.413 milliliters	1 milliliter = 0.0351951 fluid ounces
1 US pint = 0.832681 Imperial pint	1 Imperial pint = 1.20094 US pints
1 US gallon = 0.832681 Imperial gallon	1 Imperial gallon = 1.20094 US gallon
1 US pint = 0.47318 liter	1 liter = 2.11336 US pint
1 US gallon = 3.78541 liters	1 liter = 0.26417 US gallon
1 Imperial pint = 0.56826 liter	1 liter = 1.75978 Imperial pint
1 Imperial gallon = 4.54609 liters	1 liter = 0.219969 Imperial gallon

PRESSURE

1 pound/sq. inch = 0.068948 Bar	1 Bar = 14.5038 pound/sq. inch
1 atmosphere (standard) = 1.013250 Bar	1 Bar = 0.9869232 atmosphere (standard)

ADDITIONAL CONVERSION FACTORS

1 nautical mile = 1.852 kilometers	1 kilometer = 0.539957 nautical miles
1 knot = 1.85318 kilometer per hour	1 kilometer per hour = 0.539613 knots
1 acre = 0.404686 hectare	1 hectare = 2.47105 acres
1 ohm circular-mil per foot = 1.662426×10^{-9} ohm meter	1 ohm meter = 6.01531×10^{-8} ohm circular-mil per foot
1 pound/cubic inch = 2.767990×10^{-4} kg/m^3	1 kg/m^3 = 3.6127×10^{-5} pound/cubic inch
1 Btu-in/ft^2hr°F = 1.730735 W/m.K	1 W/m.K = 0.5777892 Btu-in/ft^2hr°F
1 horsepower = 745.7 watts	1 watt = 0.001341 horsepower

TEMPERATURE CONVERSION

Locate the temperature you wish to convert in the center column. The equivalent Fahrenheit temperature is shown in the right-hand column, while the equivalent centigrade (or Celsius) temperature is shown in the left-hand column.

$$°C = \frac{5}{9}(°F - 32) \qquad °F = \frac{9}{5}°C + 32$$

C		F
–34.4	**–30**	–22.0
–31.7	**–25**	–13.0
–28.9	**–20**	–4.0
–26.1	**–15**	5.0
–23.3	**–10**	14.0
–20.6	**–5**	23.0
–17.8	**0**	32.0
–15.0	**5**	41.0
–12.2	**10**	50.0
–9.4	**15**	59.0
–6.7	**20**	68.0
–3.9	**25**	77.0
–1.1	**30**	86.0
1.7	**35**	95.0
4.4	**40**	104.0
7.2	**45**	113.0
10.0	**50**	122.0
12.8	**55**	131.0
15.6	**60**	140.0
18.3	**65**	149.0
21.1	**70**	158.0
23.9	**75**	167.0
26.7	**80**	176.0
29.4	**85**	185.0
32.2	**90**	194.0
35.0	**95**	203.0
37.8	**100**	212.0
40.6	**105**	221.0
43.3	**110**	230.0
46.1	**115**	239.0
48.9	**120**	248.0
51.7	**125**	257.0
54.4	**130**	266.0
57.2	**135**	275.0
60.0	**140**	284.0
62.8	**145**	293.0
65.6	**150**	302.0
68.3	**155**	311.0
71.1	**160**	320.0
73.9	**165**	329.0
76.7	**170**	338.0
79.4	**175**	347.0
82.2	**180**	356.0
85.0	**185**	365.0
87.8	**190**	374.0
90.6	**195**	383.0
93.3	**200**	392.0

C		F
98.9	**210**	410.0
104.4	**220**	428.0
110.0	**230**	446.0
115.6	**240**	464.0
121.1	**250**	482.0
126.7	**260**	500.0
132.2	**270**	518.0
137.8	**280**	536.0
143.3	**290**	554.0
148.9	**300**	572.0
154.4	**310**	590.0
160.0	**320**	608.0
165.6	**330**	626.0
171.1	**340**	644.0
176.7	**350**	662.0
182.2	**360**	680.0
187.8	**370**	698.0
193.3	**380**	716.0
198.9	**390**	734.0
204.4	**400**	752.0
210.0	**410**	770.0
215.6	**420**	788.0
221.1	**430**	806.0
226.7	**440**	824.0
232.2	**450**	842.0
237.8	**460**	860.0
243.3	**470**	878.0
248.9	**480**	896.0
254.4	**490**	914.0
260.0	**500**	932.0
265.6	**510**	950.0
271.1	**520**	968.0
276.7	**530**	986.0
282.2	**540**	1004.0
287.8	**550**	1022.0
293.3	**560**	1040.0
298.9	**570**	1058.0
304.4	**580**	1076.0
310.0	**590**	1094.0
315.6	**600**	1112.0
321.1	**610**	1130.0
326.7	**620**	1148.0
332.2	**630**	1166.0
337.8	**640**	1184.0
343.3	**650**	1202.0
348.9	**660**	1220.0
354.4	**670**	1238.0

C		F
360.0	**680**	1256.0
365.6	**690**	1274.0
371.1	**700**	1292.0
376.7	**710**	1310.0
382.2	**720**	1328.0
387.8	***730***	1346.0
393.3	**740**	1364.0
398.9	**750**	1382.0
404.4	**760**	1400.0
410.0	**770**	1418.0
415.6	**780**	1436.0
421.1	**790**	1454.0
426.7	**800**	1472.0
432.2	**810**	1490.0
437.8	**820**	1508.0
443.3	**830**	1526.0
448.9	**840**	1544.0
454.4	**850**	1562.0
460.0	**860**	1580.0
465.6	**870**	1598.0
471.1	**880**	1616.0
476.7	**890**	1634.0
482.2	**900**	1652.0
487.8	**910**	1670.0
493.3	**920**	1688.0
498.9	**930**	1706.0
504.4	**940**	1724.0
510.0	**950**	1742.0
515.6	**960**	1760.0
521.1	**970**	1778.0
526.7	**980**	1796.0
532.2	**990**	1814.0
537.8	**1000**	1832.0
543.3	**1010**	1850.0
548.9	**1020**	1868.0
554.4	**1030**	1886.0
560.0	**1040**	1904.0
565.6	**1050**	1922.0
571.1	**1060**	1940.0
576.7	**1070**	1958.0
582.2	**1080**	1976.0
587.8	**1090**	1994.0
593.3	**1100**	2012.0
598.9	**1110**	2030.0
604.4	**1120**	2048.0
610.0	**1130**	2066.0
615.6	**1140**	2084.0

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