17

Material Expansion Coefficients

Linear Thermal Expansion Coefficients of Metals and Alloys

Table 17-1 provides the linear thermal expansion coefficients of the most frequently used metals and allows.

Table 17-1. Linear thermal expansison coefficients of metals and alloys

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
ALUMINUM AND ALUMINUM ALLOYS		
Aluminum (99.996%)	23.6	13.1
Wrought Alloys		
EC 1060 and 1100	23.6	13.1
2011 and 2014	23.0	12.8
2024	22.8	12.7
2218	22.3	12.4
3003	23.2	12.9
4032	19.4	10.8
5005, 5050, and 5052	23.8	13.3
5056	24.1	13.4
5083	23.4	13.0
5086	23.9	13.3
5154	23.9	13.3
5357	23.7	13.2
5456	23.9	13.3
6061 and 6063	23.4	13.0
6101 and 6151	23.0	12.8
7075	23.2	12.9
7090 and 7178	23.4	13.0

Table 17-1. Linear thermal expansison coefficients of metals and alloys (Cont.)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
ALUMINUM AND ALUMINUM ALLOYS (Continued)		
Casting Alloys		
A13	20.4	11.4
43 and 108	22.0	12.3
A108	21.5	12.0
A132	19.0	10.6
D132	20.5	11.4
F132	20.7	11.5
138	21.4	11.9
142	22.5	12.5
195	23.0	12.8
B195	22.0	12.3
214	24.0	13.4
220	25.0	13.9
319	21.5	12.0
355	22.0	12.3
356	21.5	12.0
360	21.0	11.7
750	23.1	12.9
40E	24.7	13.8
COPPER AND COPPER ALLOYS		
Wrought Coppers		
Pure Copper	16.5	9.2
Electrolytic Tough Pitch Copper (ETP)	16.8	9.4
Deoxidized Copper, High Residual Phosphorous (DHP)	17.7	9.9
Oxygen-Free Copper	17.7	9.9
Free-Machining Copper 0.5% Te or 1% Pb	17.7	9.9

Table 17-1. Linear thermal expansison coefficients of metals and alloys (Cont.)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
COPPER AND COPPER ALLOYS (Continued)		
Wrought Alloys (Continued)		
Gilding, 95%	18.1	10.1
Commercial Bronze, 90%	18.4	10.3
Jewelry Bronze, 87.5%	18.6	10.4
Red Brass, 85%	18.7	10.4
Low Brass, 80%	19.1	10.6
Cartridge Brass, 70%	19.9	11.1
Yellow Brass	20.3	11.2
Muntz Metal	20.8	11.5
Leaded Commercial Bronze	18.4	10.2
Low-Leaded Brass	20.2	11.3
Medium-Leaded Brass	20.3	11.3
High-Leaded Brass	20.3	11.3
Extra-High-Leaded Brass	20.5	11.4
Free-Cutting Brass	20.5	11.4
Leaded Muntz Metal	20.8	11.6
Forging Brass	20.7	11.5
Architectural Bronze	20.9	11.6
Inhibited Admiralty	20.2	11.3
Naval Brass	21.2	11.8
Leaded Naval Brass	21.2	11.8
Manganese Bronze (A)	21.2	11.8
Phosphorous Bronze, 5% (A)	17.8	9.9
Phosphorous Bronze, 8% (C)	18.2	10.1
Phosphorous Bronze, 10%(D)	18.4	10.3
Phosphorous Bronze, 1.25%	17.8	9.9

Table 17-1. Linear thermal expansison coefficients of metals and alloys (Cont.)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
COPPER AND COPPER ALLOYS (Continued)		
Wrought Alloys (Continued)		
Free-Cutting Phosphorous Bronze	17.3	9.6
Cupro-Nickel, 30%	16.2	9.0
Cupro-Nickel, 10%	17.1	9.5
Nickel Silver, 65-18	16.2	9 0
Nickel Silver, 55-18	16.7	9.3
Nickel Silver, 65.12	16.2	9.0
High-Silicon Bronze (A)	18.0	10.0
Low-Silicon Bronze (B)	179	10.0
Aluminum Bronze (3)	16.4	9.2
Aluminum-Silicon Bronze	18.0	10.0
Aluminum Bronze	16.8	9.4
Beryllium Copper	17.8	9.9
Casting Alloys		
88 Cu-8 SN-4 Zn	18.0	10.0
88 Cu-11 Sn	18.4	10.3
88 Cu-6 Sn-1.5 Pb-4.5 Zn	18.5	10.3
87 Cu-8 Sn-1 Pb-4 Zn	18.0	10.0
87 Cu-10 Sn-1 Pb-2 Zn	18.0	10.0
80 Cu-10 Sn-10 Pb	18.5	10.3
78 Cu-7 Sn-15 Pb	18.5	10.3
85 Cu-5 Sn-5 Pb-5 Zn	18.1	10.0
72 Cu-1 Sn-3 Pb-24 Zn	20.7	11.5
67 Cu-1 Sn-3 Pb-29 Zn	20.2	11.3
61 Cu-1 Sn-1 Pb-37 Zn	21.6	12.0
Manganese Bronze (60,000 psi)	20.5	11.4

Table 17-1. Linear thermal expansison coefficients of metals and alloys (Cont.)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
COPPER AND COPPER ALLOYS (Continued)		
Casting Alloys (Continued)		
Manganese Bronze (65,000 psi)	21.6	12.0
Manganeze Bronze (110,000 psi)	19.8	11.0
Aluminum Bronze (Alloy 9A)	17.0	9.5
Aluminum Bronze (Alloy 9B)	17.0	9.5
Aluminum Bronze (Alloys 9C & 9D)	16.2	9.0
IRON AND IRON ALLOYS		
Pure Iron	11.7	6.5
Fe-C Alloys		
0.06% C	11.7	6.5
0.22% C	11.7	6.5
0.40% C	11.3	6.3
0.56% C	11.0	6.1
1.08% C	10.8	6.0
1.45% C	10.1	5.6
Invar (36 Ni)	0 to 2	to 1.1
13 Mn-1.2 C	18.0	10.0
13 Cr-0.35 C	10.0	5.6
12.0 Cr-0.4 Ni-0.09 C	9.8	5.5
17.7 Cr-9.6 Ni-0.06 C	16.5	9.2
18. W-4 Cr-1 V	11.2	6.2
Gray Cast Iron	10.5	5.7
Malleable Iron (Pearlitic)	12.0	6.7
LEAD AND LEAD ALLOYS		
Corroding Lead (99.73+% Pb)	29.3	16.3
5-95 Solder	28.7	16.0
20-80 Solder	26.5	14.8
50-50 Solder	23.4	13.0

Table 17-1. Linear thermal expansison coefficients of metals and alloys (Cont.)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
LEAD AND LEAD ALLOYS (Continued)		
1% Antimonial Lead	28.8	16.1
Hard Lead (96 Pb, 4 Sb)	27.8	15.5
Hard Lead (94Pb, 6 Sb)	27.2	15.2
8% Antimonial Lead	26.7	14.9
9% Antimonial Lead	26.4	14.7
Lead-Base Babbitt:		
SAE 14	19.6	10.9
Alloy 8	24.0	13.4
MAGNESIUM AND MAGNESIUM ALLOYS		
Magnesium (99.8%)	25.2	14.1
Casting Alloys		
AM100A	25.2	14.1
AZ63A	26.1	14.6
AZ91A, B, C	26.0	14.5
AZ92A	25.2	14.1
HZ32A	26.7	14.9
ZH42	27.0	15.1
ZH62A	27.1	15.1
AK51A	26.1	14.6
EZ33A	26.1	14.6
EK30A and EK41A	26.1	14.6
Wrought Alloys		
M1A and A3A	26.0	14.5
AZ31B and PE	26.0	14.5
AZ61A and AZ80A	26.0	14.5
ZK60A, B	26.0	14.5
HM31A	26.1	14.6

Table 17-1. Linear thermal expansison coefficients of metals and alloys (Cont.)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
NICKEL AND NICKEL ALLOYS		
Nickel (99.95% Ni-+Co)	13.3	7.4
Duranickel	13.0	7.2
Monel	14.0	7.8
Monel (cast)	12.9	7.2
Inconel	11.5	6.4
Ni-o-nel	12.9	7.2
Hastelloy B	10.0	5.6
Hastelloy C	11.3	6.3
Hastelloy D	11.0	6.1
Hastelloy F	14.2	7.9
Hastelloy N	10.4	5.8
Hastelloy W	11.3	6.3
Hastelloy X	13.8	7.7
Illium G	12.19	6.8
Illium R	12.0	26.7
80 Ni-20 Cr	17.3	9.6
60 Ni-24 Fe-16Cr	17.0	9.5
35 Ni-45 Fe-20 Cr	15.8	8.8
Constantan	18.8	10.5
STAINLESS STEELS		
301	16.9	9.4
302	17.3	9.6
302B	16.2	9.0
303	17.3	9.6
304	17.3	9.6
305	17.3	9.6
308	17.3	9.6

Table 17-1. Linear thermal expansison coefficients of metals and alloys (Cont.)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
STAINLESS STEELS (Continued)		
309	14.9	8.3
310	14.4	8.0
314	15.1	8.4
316	16.0	8.9
317	16.0	8.9
321	16.7	9.3
347	16.7	9.3
501	11.15	6.2
502	11.15	6.2
403	9.9	5.5
405	10.8	6.0
410	11.0	6.1
416	9.9	5.5
420	10.25	5.7
430	10.45	5.8
430F	10.45	5.8
431	11.7	6.5
440A	10.1	5.6
440B	10.1	5.6
440C	10.1	5.6
446	10.6	5.9
TITANIUM AND TITANIUM ALLOYS		
99.9% Ti	8.41	4.7
99.0% Ti	8.55	4.76
Ti-5 A1-2.5 Sn	9.36	5.2
Ti-8 Mn	8.64	4.8

Table 17-1. Linear thermal expansison coefficients of metals and alloys (Cont.)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
ZINC AND ZINC ALLOYS		
Pure Zinc	39.7	22.1
AG40A Alloy	27.4	15.3
AC41A Alloy	27.4	15.3
Commercial Rolled Zinc:		
0.08 Pb	32.5	18.1
03 Pb, 0.3 Cd	33.9*	18.9
Rolled Zinc Allow (1Cu, 0.010 Mg)	34.8**	19.4
An-Cu-Ti Alloy (0.8 Cu, 0.15 Ti)	24.9***	13.9
*With the grain; 23.4 across the grain ** With the grain; 21.1 across the grain ***With the grain; 19.4 across the grain		
PURE METALS		
Beryllium	11.6	6.5
Cadmium	29.8	16.6
Calcium	22.3	12.4
Chromium	6.2	3.5
Cobalt	13.8	7.7
Gold	14.2	7.9
Iridium	6.8	3.8
Lithium	56.0	31.0
Manganese	22.0	12.3
Palladium	11.76	6.6
Platinum	8.9	5.0
Rhenium	6.7	3.7
Rhodium	8.3	4.6
Ruthenium	9.1	5.1
Silicon	5.0	2.8

Table 17-1. Linear thermal expansison coefficients of metals and alloys (Cont.)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
PURE METALS (Continued)		
Silver	19.68	11.0
Tungsten	4.6	2.7
Vanadium	8.3	4.6
Zirconium	5.85	3.3

Linear Thermal Expansion Coefficients of Metals and Alloys

Printed in U.S.A. 07/02
This is a chapter from the manual titled:
Laser and Optics User's Manual
For complete manual, order:
Paper version: p/n 05517-90045
CD version: p/n 05517-90063
This chapter is p/n 05517-90143