
APPENDIX E8

MISCELLANEOUS MATERIALS AND THEIR PROPERTIES

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TABLE E8.1 Nominal Coefficients of Thermal Expansion for Ferrous Materials

Materials	Coef- ficient	Temperature, °F						
		70	100	150	200	250	300	350
Carbon and low alloy steels								
Material Group A [Note (1)]	A	6.41	6.53	6.73	6.93	7.12	7.30	7.49
	B	...	6.50	6.57	6.67	6.77	6.87	6.98
	C	0	0.0023	0.0063	0.0104	0.0146	0.0190	0.0235
Material Group B [Note (2)]	A	5.60	5.83	6.20	6.55	6.88	7.18	7.47
	B	...	5.73	5.91	6.09	6.27	6.43	6.59
	C	0	0.0021	0.0057	0.0095	0.0135	0.0177	0.0221
Material Group C [Note (3)]	A	5.42	5.65	6.03	6.39	6.73	7.04	7.33
	B	...	5.53	5.71	5.89	6.09	6.26	6.43
	C	0	0.0020	0.0055	0.0092	0.0132	0.0173	0.0216
Material Group D [Note (4)]	A	7.02	7.13	7.29	7.45	7.60	7.74	7.88
	B	...	7.06	7.16	7.25	7.34	7.43	7.50
	C	0	0.0025	0.0069	0.0113	0.0158	0.0205	0.0252
Material Group E [Note (5)]	A	6.20	6.37	6.62	6.85	7.05	7.25	7.43
	B	...	6.27	6.41	6.54	6.65	6.78	6.88
	C	0	0.0023	0.0062	0.0102	0.0144	0.0187	0.0231
2¼Cr-1Mo	A	6.45	6.60	6.80	6.90	7.16	7.35	7.48
	B	...	6.50	6.60	6.70	6.80	6.90	6.98
	C	0	0.0023	0.0063	0.0105	0.0147	0.0190	0.0235
5Cr-½Mo, 5Cr-½Mo-Si, and 5Cr-½Mo-Ti	A	6.52	6.59	6.71	6.83	6.94	7.04	7.15
	B	...	6.50	6.65	6.73	6.80	6.87	6.93
	C	0	0.0026	0.0066	0.0107	0.0149	0.0190	0.0233
7Cr-½Mo and 9Cr-1Mo	A	5.82	5.90	6.03	6.16	6.29	6.41	6.53
	B	...	5.85	5.93	6.02	6.10	6.15	6.23
	C	0	0.0021	0.0057	0.0094	0.0132	0.0170	0.0209
Mn-V	A	6.60	6.79	7.00	7.20	7.40	7.58	7.75
	B	...	6.68	6.80	6.90	7.05	7.15	7.25
	C	0	0.0024	0.0065	0.0108	0.0152	0.0197	0.0244
5Ni-¼Mo	A	6.20	6.34	6.55	6.74	6.90	7.06	7.21
	B	...	6.27	6.41	6.50	6.59	6.68	6.76
	C	0	0.0023	0.0062	0.0101	0.0142	0.0184	0.0227
8Ni and 9Ni	A	5.50	5.70	6.00	6.25	6.45	6.60	6.75
	B	...	5.63	5.80	5.94	6.06	6.17	6.28
	C	0	0.0020	0.0056	0.0093	0.0131	0.0170	0.0211
High chrome steels								
12Cr, 12Cr-1Al, 13Cr, and 13Cr-4Ni	A	5.92	6.03	6.18	6.30	6.41	6.50	6.59
	B	...	5.98	6.08	6.15	6.23	6.30	6.35
	C	0	0.0022	0.0058	0.0096	0.0135	0.0174	0.0213
15Cr and 17Cr	A	5.33	5.41	5.54	5.66	5.77	5.88	5.99
	B	...	5.37	5.45	5.52	5.59	5.65	5.70
	C	0	0.0019	0.0052	0.0086	0.0121	0.0156	0.0192

TABLE E8.1 Nominal Coefficients of Thermal Expansion for Ferrous Materials
(Continued)

Temperature, °F								
400	450	500	550	600	650	700	750	800
Carbon and low alloy steels								
7.66	7.84	8.03	8.21	8.35	8.51	8.64	8.78	8.90
7.07	7.15	7.25	7.34	7.42	7.52	7.59	7.68	7.76
0.0280	0.0326	0.0374	0.0423	0.0472	0.0523	0.0574	0.0627	0.0680
7.73	7.97	8.18	8.38	8.55	8.70	8.83	8.94	9.02
6.74	6.89	7.06	7.18	7.28	7.40	7.51	7.61	7.71
0.0267	0.0314	0.0364	0.0414	0.0463	0.0515	0.0568	0.0621	0.0675
7.60	7.85	8.07	8.28	8.46	8.62	8.75	8.87	8.96
6.61	6.77	6.91	7.06	7.17	7.30	7.41	7.50	7.59
0.0262	0.0309	0.0357	0.0407	0.0456	0.0508	0.0560	0.0612	0.0665
8.01	8.13	8.25	8.36	8.46	8.55	8.63	8.71	8.78
7.58	7.63	7.70	7.77	7.83	7.90	7.94	8.00	8.05
0.0300	0.0348	0.0397	0.0448	0.0498	0.0550	0.0600	0.0653	0.0706
7.59	7.75	7.90	8.04	8.16	8.28	8.39	8.49	8.57
6.98	7.07	7.16	7.24	7.32	7.41	7.47	7.55	7.61
0.0276	0.0322	0.0369	0.0417	0.0466	0.0516	0.0565	0.0616	0.0667
7.65	7.76	7.90	7.99	8.10	8.17	8.25	8.32	8.40
7.07	7.15	7.23	7.31	7.38	7.45	7.50	7.56	7.62
0.0280	0.0326	0.0373	0.0421	0.0469	0.0519	0.0567	0.0617	0.0668
7.25	7.35	7.44	7.53	7.62	7.71	7.79	7.87	7.95
6.97	7.00	7.05	7.10	7.15	7.19	7.24	7.28	7.32
0.0276	0.0319	0.0364	0.0409	0.0455	0.0500	0.0547	0.0594	0.0641
6.64	6.75	6.87	6.97	7.07	7.17	7.27	7.36	7.44
6.29	6.34	6.40	6.46	6.51	6.57	6.62	6.66	6.71
0.0249	0.0289	0.0330	0.0372	0.0414	0.0457	0.0500	0.0544	0.0588
7.90	8.05	8.17	8.30	8.40	8.50	8.60	8.70	8.78
7.33	7.40	7.50	7.58	7.65	7.74	7.80	7.87	7.93
0.0290	0.0337	0.0388	0.0437	0.0486	0.0539	0.0590	0.0642	0.0695
7.35	7.50	7.63	7.76	7.89	8.00	8.12	8.23	8.33
6.84	6.92	6.99	7.06	7.14	7.21	7.27	7.34	7.40
0.0271	0.0315	0.0361	0.0407	0.0454	0.0501	0.0549	0.0599	0.0649
6.90	7.04	7.16	7.27	7.37	7.45	7.52	7.57	7.64
6.39	6.47	6.56	6.63	6.70	6.72	6.78	6.84	6.89
0.0253	0.0295	0.0338	0.0382	0.0426	0.0468	0.0513	0.0558	0.0604
High chrome steels								
6.66	6.72	6.77	6.83	6.88	6.94	6.99	7.05	7.11
6.40	6.44	6.48	6.51	6.53	6.57	6.60	6.64	6.67
0.0253	0.0294	0.0334	0.0375	0.0415	0.0457	0.0499	0.0542	0.0584
6.09	6.19	6.28	6.37	6.46	6.54	6.62	6.70	6.77
5.75	5.80	5.85	5.90	5.95	6.00	6.05	6.09	6.13
0.0228	0.0264	0.0302	0.0340	0.0378	0.0418	0.0457	0.0497	0.0537

TABLE E8.1 Nominal Coefficients of Thermal Expansion for Ferrous Materials
(Continued)

Materials	Coef- ficient	Temperature, °F						
		70	100	150	200	250	300	350
High chrome steels (<i>Cont'd</i>)								
27Cr	A	5.02	5.07	5.14	5.22	5.29	5.36	5.44
	B	...	5.06	5.12	5.15	5.20	5.23	5.26
	C	0	0.0018	0.0049	0.0080	0.0112	0.0144	0.0177
High alloy steels								
18Cr-13Ni-3Mo and 16Cr-12Ni- 2Mo [Note (6)]	A	8.42	8.59	8.84	9.09	9.33	9.56	9.76
	B	...	8.54	8.64	8.76	8.88	8.97	9.11
	C	0	0.0031	0.0083	0.0137	0.0192	0.0248	0.0306
17Cr-4Ni-4Cu	A	5.89	5.89	5.89	5.90	5.90	5.90	5.91
	B	...	5.89	5.89	5.90	5.90	5.90	5.91
	C	0	0.0021	0.0057	0.0092	0.0127	0.0163	0.0199
18Cr-5Ni-3Mo	A	7.94	8.06	8.26	8.43	8.61	8.78	8.94
	B	...	8.03	8.17	8.25	8.35	8.45	8.54
	C	0	0.0029	0.0078	0.0129	0.0180	0.0233	0.0287
18Cr-8Ni [Note (6)] and 18Cr-11Ni	A	8.46	8.63	8.87	9.08	9.27	9.46	9.64
	B	...	8.55	8.67	8.79	8.90	9.00	9.10
	C	0	0.0031	0.0083	0.0137	0.0192	0.0248	0.0306
18Cr-10Ni-Ti	A	8.97	9.03	9.13	9.23	9.33	9.41	9.49
	B	...	9.02	9.10	9.16	9.22	9.26	9.30
	C	0	0.0033	0.0088	0.0143	0.0199	0.0256	0.0312
18Cr-10Ni-Cb	A	8.53	8.70	9.00	9.29	9.55	9.78	9.98
	B	...	8.62	8.75	8.92	9.07	9.22	9.32
	C	0	0.0031	0.0084	0.0139	0.0196	0.0254	0.0313
19Cr-9Ni-Mo-W	A	9.10	9.21	9.38	9.54	9.70	9.85	9.99
	B	...	9.17	9.27	9.37	9.46	9.54	9.63
	C	0	0.0033	0.0089	0.0146	0.0204	0.0263	0.0324
22Cr-13Ni-5Mn	A	8.24	8.35	8.51	8.67	8.81	8.95	9.08
	B	...	8.30	8.40	8.48	8.57	8.65	8.73
	C	0	0.0030	0.0081	0.0132	0.0185	0.0239	0.0293
25Cr-12Ni, 23Cr-12Ni, and 25Cr-20Ni	A	8.81	8.89	8.99	9.06	9.11	9.17	9.22
	B	...	8.87	8.95	9.02	9.06	9.10	9.12
	C	0	0.0032	0.0086	0.0141	0.0196	0.0251	0.0306
25Ni-15Cr-2Ti	A	8.22	8.31	8.46	8.61	8.75	8.89	9.02
	B	...	8.24	8.32	8.39	8.47	8.54	8.62
	C	0	0.0030	0.0080	0.0131	0.0183	0.0236	0.0290
28Ni-19Cr-Cu-Mo	A	8.72	8.84	8.93	9.02	9.11	9.20	9.29
	B	...	8.75	8.85	8.90	8.99	9.04	9.09
	C	0	0.0032	0.0085	0.0139	0.0194	0.0250	0.0305

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GENERAL NOTE:

Coefficient A is the instantaneous coefficient of thermal expansion $\times 10^{-6}$ (in./in./°F). Coefficient B is the mean coefficient of thermal expansion $\times 10^{-6}$ (in./in./°F) in going from 70°F to indicated temperature. Coefficient C is the linear thermal expansion (in./ft) in going from 70°F to indicated temperature.

TABLE E8.1 Nominal Coefficients of Thermal Expansion for Ferrous Materials
(Continued)

Temperature, °F								
400	450	500	550	600	650	700	750	800
High chrome steels (Cont'd)								
5.51	5.58	5.66	5.73	5.80	5.88	5.94	6.02	6.09
5.30	5.33	5.37	5.40	5.43	5.47	5.50	5.54	5.57
0.0210	0.0243	0.0277	0.0311	0.0345	0.0381	0.0416	0.0452	0.0488
High alloy steels								
9.95	10.10	10.25	10.38	10.51	10.64	10.76	10.87	10.98
9.21	9.32	9.42	9.50	9.60	9.69	9.76	9.81	9.90
0.0365	0.0425	0.0486	0.0547	0.0611	0.0674	0.0738	0.0800	0.0867
5.91	5.91	5.91	5.93	5.96	5.99	6.03	6.08	6.14
5.91	5.91	5.91	5.93	5.93	5.93	5.94	5.95	5.96
0.0234	0.0269	0.0305	0.0342	0.0377	0.0413	0.0449	0.0486	0.0522
9.09	9.24	9.38	9.52	9.64	9.76	9.87	9.96	10.06
8.61	8.69	8.76	8.83	8.90	8.97	9.04	9.10	9.16
0.0341	0.0396	0.0452	0.0509	0.0566	0.0624	0.0683	0.0743	0.0802
9.80	9.95	10.10	10.25	10.38	10.50	10.60	10.70	10.79
9.19	9.28	9.37	9.45	9.53	9.61	9.69	9.76	9.82
0.0364	0.0423	0.0483	0.0544	0.0606	0.0669	0.0733	0.0796	0.0860
9.57	9.64	9.72	9.78	9.85	9.92	9.98	10.04	10.10
9.34	9.38	9.42	9.45	9.48	9.52	9.55	9.58	9.61
0.0370	0.0427	0.0486	0.0545	0.0602	0.0662	0.0722	0.0787	0.0842
10.16	10.30	10.44	10.55	10.66	10.76	10.86	10.96	11.05
9.45	9.55	9.65	9.75	9.83	9.90	9.97	10.03	10.08
0.0374	0.0435	0.0498	0.0562	0.0625	0.0689	0.0754	0.0818	0.0883
10.13	10.26	10.38	10.50	10.61	10.72	10.81	10.91	10.99
9.69	9.76	9.83	9.89	9.95	10.01	10.07	10.13	10.18
0.0384	0.0445	0.0507	0.0570	0.0633	0.0697	0.0761	0.0827	0.0892
9.21	9.33	9.44	9.54	9.64	9.73	9.82	9.89	9.97
8.79	8.86	8.92	8.98	9.03	9.09	9.15	9.20	9.25
0.0348	0.0404	0.0460	0.0517	0.0574	0.0633	0.0692	0.0751	0.0810
9.27	9.29	9.33	9.37	9.39	9.44	9.47	9.52	9.56
9.14	9.16	9.18	9.20	9.21	9.23	9.25	9.27	9.28
0.0362	0.0418	0.0474	0.0530	0.0586	0.0642	0.0699	0.0756	0.0813
9.14	9.26	9.37	9.48	9.58	9.68	9.77	9.85	9.93
8.69	8.76	8.82	8.88	8.94	9.00	9.06	9.11	9.17
0.0344	0.0399	0.0455	0.0512	0.0569	0.0627	0.0685	0.0744	0.0803
9.38	9.48	9.57	9.66	9.76	9.86	9.95	10.04	10.14
9.14	9.18	9.22	9.26	9.30	9.35	9.39	9.44	9.48
0.0362	0.0419	0.0476	0.0533	0.0591	0.0651	0.0710	0.0770	0.0830

Notes continue on next page.

TABLE E8.1 Nominal Coefficients of Thermal Expansion for Ferrous Materials
(Continued)

Notes:

(1) Material Group A consists of:		
Plain carbon steels	$\frac{3}{4}\text{Ni}-\frac{1}{2}\text{Mo}-\frac{1}{8}\text{Cr}-\text{V}$	$\frac{1}{2}\text{Ni}-\frac{1}{2}\text{Cr}-\frac{1}{4}\text{Mo}-\text{V}$
Carbon-manganese steel	$\frac{3}{4}\text{Ni}-1\text{Mo}-\frac{3}{4}\text{Cr}$	$\frac{3}{4}\text{Ni}-\frac{1}{2}\text{Cu}-\text{Mo}$
$\frac{1}{2}\text{Ni}-\frac{1}{2}\text{Mo}-\text{V}$	$\frac{3}{4}\text{Ni}-\frac{1}{2}\text{Cr}-\frac{1}{2}\text{Mo}-\text{V}$	$\frac{3}{4}\text{Cr}-\frac{3}{4}\text{Ni}-\text{Cu}-\text{Al}$
$\frac{3}{4}\text{Ni}-\frac{1}{2}\text{Mo}-\text{Cr}-\text{V}$	$1\text{Ni}-\frac{1}{2}\text{Cr}-\frac{1}{2}\text{Mo}$	$\frac{3}{4}\text{Cr}-\frac{1}{2}\text{Ni}-\text{Cu}$
(2) Material Group B consists of:		
Carbon-silicon steels	$\frac{1}{2}\text{Cr}-\frac{1}{2}\text{Mo}$	$1\text{Cr}-\frac{1}{8}\text{Mo}$
$\text{C}-\frac{1}{2}\text{Mo}$	$\frac{1}{2}\text{Cr}-\frac{1}{8}\text{Mo}-\text{V}$	$1\text{Cr}-\frac{1}{8}\text{Mo}-\text{Si}$
$\frac{1}{2}\text{Cr}-\frac{1}{2}\text{Ni}-\frac{1}{8}\text{Mo}$	$1\text{Cr}-\frac{1}{2}\text{Mo}$	$1\frac{3}{4}\text{Cr}-\frac{1}{2}\text{Mo}-\text{Cu}$
(3) Material Group C consists of:		
$\text{C}-\text{Mn}-\text{Si}$ steels	$\frac{1}{4}\text{Cr}-\frac{1}{2}\text{Mo}$	$3\text{Cr}-1\text{Mo}$
$\frac{1}{2}\text{Cr}-\frac{1}{4}\text{Mo}-\text{Si}$	$1\frac{1}{4}\text{Cr}-\frac{1}{2}\text{Mo}-\text{Si}$	
$1\text{Cr}-\frac{1}{2}\text{Mo}-\text{V}$	$2\text{Cr}-\frac{1}{2}\text{Mo}$	
(4) Material Group D consists of:		
$\text{Mn}-\frac{1}{4}\text{Mo}$	$\text{Mn}-\frac{1}{2}\text{Mo}-\frac{1}{4}\text{Ni}$	$\text{Mn}-\frac{1}{2}\text{Mo}-\frac{3}{4}\text{Ni}$
$\text{Mn}-\frac{1}{2}\text{Mo}$	$\text{Mn}-\frac{1}{2}\text{Mo}-\frac{1}{2}\text{Ni}$	
(5) Material Group E consists of:		
$1\frac{1}{4}\text{Ni}-1\text{Cr}-\frac{1}{2}\text{Mo}$	$2\text{Ni}-\frac{3}{4}\text{Cr}-\frac{1}{8}\text{Mo}$	$3\frac{1}{2}\text{Ni}-1\frac{3}{4}\text{Cr}-\frac{1}{2}\text{Mo}-\text{V}$
$1\frac{3}{4}\text{Ni}-\frac{3}{4}\text{Cr}-\frac{1}{4}\text{Mo}$	$2\text{Ni}-1\text{Cu}$	
$2\text{Ni}-\frac{3}{4}\text{Cr}-\frac{1}{4}\text{Mo}$	$2\frac{1}{2}\text{Ni}$ and $3\frac{1}{2}\text{Ni}$	
(6) Includes N grades also		

TABLE E8.2 Moduli of Elasticity E of Ferrous Materials for Given Temperatures

Materials	Modulus of Elasticity $E = \text{Value Given} \times 10^6$ psi, for Temp., °F, of											
	-325	-200	-100	70o	200	300	400	500	600	700	800	900
Carbon steels with C \leq 0.30%	31.4	30.8	30.2	29.5	28.8	28.3	27.7	27.3	26.7	25.5	24.2	22.4
Carbon steels with C > 0.30%	31.2	30.6	30.0	29.3	28.6	28.1	27.5	27.1	26.5	25.3	24.0	22.3
Material Group A ¹	31.1	30.5	29.9	29.2	28.5	28.0	27.4	27.0	26.4	25.3	23.9	22.2
Material Group B ²	29.6	29.1	28.5	27.8	27.1	26.7	26.1	25.7	25.2	24.6	23.0	...
Material Group C ³	31.6	31.0	30.4	29.7	29.0	28.5	27.9	27.5	26.9	26.3	25.5	24.8
Material Group D ⁴	32.6	32.0	31.4	30.6	29.8	29.4	28.8	28.3	27.7	27.1	26.3	25.6
Material Group E ⁵	32.9	32.3	31.7	30.9	30.1	29.7	29.0	28.6	28.0	27.3	26.1	24.7
Material Group F ⁶	31.2	30.7	30.1	29.2	28.5	27.9	27.3	26.7	26.1	25.6	24.7	23.2
Material Group G ⁷	30.3	29.7	29.1	28.3	27.6	27.0	26.5	25.8	25.3	24.8	24.1	23.5

Notes:

(1) Material Group A consists of the following carbon-molybdenum steels:

C- $\frac{1}{2}$ Mo	Mn- $\frac{1}{4}$ Mo
Mn- $\frac{1}{2}$ Mo	Mn-V

(2) Material Group B consists of the following Ni steels:

$\frac{3}{4}$ Ni- $\frac{1}{2}$ Mo-Cr-V	1Ni- $\frac{1}{2}$ Cr- $\frac{1}{2}$ Mo
$\frac{1}{2}$ Ni- $\frac{1}{2}$ Mo-V	$\frac{3}{4}$ Ni-1Mo- $\frac{3}{4}$ Cr
$\frac{3}{4}$ Ni- $\frac{1}{2}$ Mo- $\frac{1}{3}$ Cr-V	$\frac{1}{2}$ Ni- $\frac{1}{2}$ Cr- $\frac{1}{4}$ Mo-V
$\frac{3}{4}$ Cr- $\frac{3}{4}$ Ni-Cu-Al	2Ni-1Cu
$\frac{3}{4}$ Cr- $\frac{1}{2}$ Ni-Cu	2 $\frac{1}{2}$ Ni
$\frac{3}{4}$ Ni- $\frac{1}{2}$ Cu-Mo	3 $\frac{1}{2}$ Ni

(3) Material Group C consists of the following $\frac{1}{2}$ -2Cr steels:

$\frac{1}{2}$ Cr- $\frac{1}{2}$ Mo
1Cr- $\frac{1}{2}$ Mo
1 $\frac{1}{4}$ Cr- $\frac{1}{2}$ Mo-Si
1 $\frac{1}{4}$ Cr- $\frac{1}{2}$ Mo
2Cr- $\frac{1}{2}$ Mo

(4) Material Group D consists of the following 2 $\frac{1}{4}$ -3Cr steels:

2 $\frac{1}{4}$ Cr-1Mo
3Cr-1Mo

(5) Material Group E consists of the following 5-9Cr steels:

5Cr- $\frac{1}{2}$ Mo
5Cr- $\frac{1}{2}$ Mo-Si
5Cr- $\frac{1}{2}$ Mo-Ti
7Cr- $\frac{1}{2}$ Mo
9Cr-Mo

(6) Material Group F consists of the following chromium steels:

12Cr-Al
13Cr
15Cr
17Cr

(7) Material Group G consists of the following austenitic steels:

18Cr-8Ni	18Cr-10Ni-Cb
18Cr-8Ni-N	18Cr-18Ni-2Si
16Cr-12Ni	20Cr-6Ni-9Mn
18Cr-13Ni-3Mo	22Cr-13Ni-5Mn
16Cr-12Ni-2Mo-N	23Cr-12Ni
18Cr-3Ni-13Mn	25Cr-20Ni
18Cr-10Ni-Ti	

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