Subpart 2

PHYSICAL PROPERTIES TABLES

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TABLE TE-1
THERMAL EXPANSION FOR FERROUS MATERIALS

Temperature, °F	Coefficients for Carbon and Low Alloy Steels (Group 1) [Note (1)]			Coefficients for Other Low Alloy Steels (Group 2) [Note (2)]			Coefficients for 5Cr–1Mo and 29Cr–7Ni–2Mo–N Steels		
	A	B	C	A	B	C	A	B	C
70	6.4	6.4	0	7.0	7.0	0	6.5	6.4	0
100	6.5	6.5	0.2	7.1	7.1	0.3	6.6	6.5	0.3
150	6.7	6.6	0.6	7.3	7.2	0.7	6.7	6.6	0.7
200	6.9	6.7	1.0	7.5	7.3	1.1	6.8	6.7	1.1
250	7.1	6.8	1.5	7.6	7.3	1.6	6.9	6.8	1.5
300	7.3	6.9	1.9	7.7	7.4	2.1	7.0	6.9	1.9
350	7.5	7.0	2.4	7.9	7.5	2.5	7.2	6.9	2.3
400	7.7	7.1	2.8	8.0	7.6	3.0	7.3	7.0	2.8
450	7.8	7.2	3.3	8.1	7.6	3.5	7.4	7.0	3.2
500	8.0	7.3	3.7	8.3	7.7	4.0	7.4	7.1	3.6
550	8.2	7.3	4.2	8.4	7.8	4.5	7.5	7.1	4.1
600	8.4	7.4	4.7	8.5	7.8	5.0	7.6	7.2	4.6
650	8.5	7.5	5.2	8.6	7.9	5.5	7.7	7.2	5.0
700	8.6	7.6	5.7	8.6	7.9	6.0	7.8	7.2	5.5
750	8.8	7.7	6.3	8.7	8.0	6.5	7.9	7.3	5.9
800	8.9	7.8	6.8	8.8	8.1	7.1	8.0	7.3	6.4
850	9.0	7.9	7.3	8.8	8.1	7.6	8.0	7.4	6.9
900	9.1	7.9	7.9	8.9	8.1	8.1	8.1	7.4	7.4
950	9.2	8.0	8.4	9.0	8.2	8.7	8.2	7.4	7.9
1000	9.3	8.1	9.0	9.0	8.2	9.2	8.2	7.5	8.4
1050	9.4	8.1	9.6	9.0	8.3	9.7	8.3	7.5	8.9
1100	9.5	8.2	10.1	9.1	8.3	10.3	8.3	7.6	9.4
1150	9.5	8.3	10.7	9.1	8.3	10.8	8.4	7.6	9.9
1200	9.6	8.3	11.3	9.1	8.4	11.4	8.5	7.6	10.4
1250	9.6	8.4	11.8	9.1	8.4	11.9	8.5	7.7	10.9
1300	9.6	8.4	12.4	9.1	8.4	12.4	8.5	7.7	11.4
1350	...	...	...	9.1	8.5	13.0	8.6	7.7	11.9
1400	...	...	...	9.1	8.5	13.5	8.6	7.8	12.4
1450	...	...	...	9.1	8.5	14.1	...	...	...
1500	...	...	...	9.1	8.5	14.6	...	...	...

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TABLE TE-1 (CONT'D)
THERMAL EXPANSION FOR FERROUS MATERIALS

Temperature, °F	Coefficients for 9Cr–1Mo Steels			Coefficients for 5Ni–$^1/_4$Mo Steels			Coefficients for 8Ni and 9Ni Steels		
	A	B	C	A	B	C	A	B	C
70	5.8	5.8	0	6.2	6.2	0	5.5	5.5	0
100	5.9	5.9	0.2	6.3	6.3	0.2	5.7	5.6	0.2
150	6.0	5.9	0.6	6.6	6.4	0.6	6.0	5.8	0.6
200	6.2	6.0	0.9	6.7	6.5	1.0	6.3	5.9	0.9
250	6.3	6.1	1.3	6.9	6.6	1.4	6.5	6.1	1.3
300	6.4	6.2	1.7	7.1	6.7	1.8	6.6	6.2	1.7
350	6.5	6.2	2.1	7.2	6.8	2.3	6.8	6.3	2.1
400	6.6	6.3	2.5	7.4	6.8	2.7	6.9	6.4	2.5
450	6.8	6.3	2.9	7.5	6.9	3.2	7.0	6.5	3.0
500	6.9	6.4	3.3	7.6	7.0	3.6	7.2	6.6	3.4
550	7.0	6.5	3.7	7.8	7.1	4.1	7.3	6.6	3.8
600	7.1	6.5	4.1	7.9	7.1	4.5	7.4	6.7	4.3
650	7.2	6.6	4.6	8.0	7.2	5.0	7.5	6.7	4.7
700	7.3	6.6	5.0	8.1	7.3	5.5	7.5	6.8	5.1
750	7.4	6.7	5.4	8.2	7.3	6.0	7.6	6.8	5.6
800	7.4	6.7	5.9	8.3	7.4	6.5	7.6	6.9	6.0
850	7.5	6.8	6.3	8.4	7.5	7.0	7.7	6.9	6.5
900	7.6	6.8	6.8	8.5	7.5	7.5	7.7	7.0	6.9
950	7.7	6.9	7.3	8.6	7.6	8.0	7.8	7.0	7.4
1000	7.8	6.9	7.7	8.7	7.6	8.5	7.8	7.0	7.8
1050	7.8	7.0	8.2	8.8	7.7	9.1	...	...	...
1100	7.9	7.0	8.7	8.8	7.8	9.6	...	...	...
1150	8.0	7.1	9.1	8.9	7.8	10.1	...	...	...
1200	8.0	7.1	9.6	9.0	7.9	10.7	...	...	...
1250	8.1	7.1	10.1	...	...	...	...	...	...
1300	8.1	7.2	10.6	...	...	...	...	...	...
1350	...	...	...	...	...	...	...	...	...
1400	...	...	...	...	...	...	...	...	...
1450	...	...	...	...	...	...	...	...	...
1500	...	...	...	...	...	...	...	...	...

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TABLE TE-1 (CONT'D)
THERMAL EXPANSION FOR FERROUS MATERIALS

Temperature, °F	Coefficients for 12Cr, 12Cr–1Al, 13Cr, and 13Cr–4Ni Steels			Coefficients for 15Cr and 17Cr Steels			Coefficients for 27Cr Steels		
	A	B	C	A	B	C	A	B	C
70	5.9	5.9	0	5.3	5.3	0	5.0	5.0	0
100	6.0	6.0	0.2	5.4	5.4	0.2	5.1	5.1	0.2
150	6.2	6.1	0.6	5.5	5.5	0.5	5.1	5.1	0.5
200	6.3	6.2	1.0	5.7	5.5	0.9	5.2	5.2	0.8
250	6.4	6.2	1.4	5.8	5.6	1.2	5.3	5.2	1.1
300	6.5	6.3	1.7	5.9	5.7	1.6	5.4	5.2	1.4
350	6.6	6.4	2.1	6.0	5.7	1.9	5.4	5.3	1.8
400	6.7	6.4	2.5	6.1	5.8	2.3	5.5	5.3	2.1
450	6.7	6.4	2.9	6.2	5.8	2.7	5.6	5.3	2.4
500	6.8	6.5	3.3	6.3	5.9	3.0	5.7	5.4	2.8
550	6.8	6.5	3.8	6.4	5.9	3.4	5.7	5.4	3.1
600	6.9	6.5	4.2	6.5	6.0	3.8	5.8	5.4	3.5
650	6.9	6.6	4.6	6.5	6.0	4.2	5.9	5.5	3.8
700	7.0	6.6	5.0	6.6	6.1	4.6	5.9	5.5	4.2
750	7.1	6.6	5.4	6.7	6.1	5.0	6.0	5.5	4.5
800	7.1	6.7	5.8	6.8	6.1	5.3	6.1	5.6	4.9
850	7.2	6.7	6.3	6.8	6.2	5.8	6.2	5.6	5.3
900	7.2	6.7	6.7	6.9	6.2	6.2	6.2	5.7	5.6
950	7.3	6.8	7.1	7.0	6.3	6.6	6.3	5.7	6.0
1000	7.3	6.8	7.6	7.0	6.3	7.0	6.4	5.7	6.4
1050	7.3	6.8	8.0	7.1	6.3	7.5	6.4	5.8	6.8
1100	7.4	6.8	8.4	7.1	6.4	7.9	6.5	5.8	7.2
1150	7.4	6.9	8.9	7.2	6.4	8.3	6.6	5.8	7.6
1200	7.4	6.9	9.3	7.2	6.4	8.7	6.7	5.9	7.9
1250	7.5	6.9	9.8	7.2	6.5	9.2	6.7	5.9	8.3
1300	7.5	6.9	10.2	7.3	6.5	9.6	6.8	5.9	8.8
1350	7.5	7.0	10.7	7.3	6.5	10.0	6.9	6.0	9.2
1400	7.6	7.0	11.1	7.3	6.6	10.5	6.9	6.0	9.6
1450	7.6	7.0	11.6	7.3	6.6	10.9	7.0	6.0	10.0
1500	7.6	7.0	12.0	7.4	6.6	11.4	7.1	6.1	10.4

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TABLE TE-1 (CONT'D)
THERMAL EXPANSION FOR FERROUS MATERIALS

Temperature, °F	Coefficients for Austenitic Stainless Steels (Group 3) [Note (3)]			Coefficients for Other Austenitic Stainless Steels (Group 4) [Note (4)]			Coefficients for Ductile Cast Iron		
	A	B	C	A	B	C	A	B	C
70	8.5	8.5	0	8.7	8.2	0	...	5.7	0
100	8.7	8.6	0.3	8.8	8.2	0.3	...	5.8	0.2
150	9.0	8.8	0.8	8.9	8.4	0.8	...	5.9	0.6
200	9.3	8.9	1.4	9.0	8.5	1.3	...	6.0	0.9
250	9.6	9.1	2.0	9.1	8.6	1.8	...	6.1	1.3
300	9.8	9.2	2.5	9.1	8.8	2.4	...	6.3	1.7
350	10.0	9.3	3.2	9.2	8.8	3.0	...	6.4	2.1
400	10.2	9.5	3.7	9.2	8.9	3.5	...	6.5	2.6
450	10.3	9.6	4.3	9.2	9.0	4.1	...	6.7	3.0
500	10.4	9.7	5.0	9.3	9.1	4.7	...	6.9	3.5
550	10.6	9.8	5.6	9.3	9.1	5.3	...	6.9	4.0
600	10.7	9.8	6.3	9.4	9.2	5.8	...	7.0	4.4
650	10.8	9.9	6.9	9.4	9.2	6.4	...	7.0	4.9
700	10.9	10.0	7.6	9.4	9.3	7.0	...	7.1	5.4
750	11.0	10.0	8.2	9.5	9.3	7.6	...	7.2	5.9
800	11.1	10.1	8.8	9.5	9.4	8.2	...	7.3	6.4
850	11.1	10.1	9.5	9.6	9.4	8.8	...	7.3	6.9
900	11.2	10.2	10.2	9.6	9.5	9.5	...	7.4	7.4
950	11.3	10.3	10.8	9.7	9.6	10.1	...	7.4	7.9
1000	11.4	10.3	11.5	9.7	9.6	10.7	...	7.5	8.4
1050	11.5	10.4	12.2	9.8	9.7	11.4	...	...	...
1100	11.6	10.5	12.9	9.8	9.7	12.0	...	...	...
1150	11.6	10.5	13.6	9.9	9.8	12.7	...	...	...
1200	11.7	10.6	14.3	9.9	9.8	13.3	...	...	...
1250	11.8	10.6	15.0	9.9	9.9	14.0	...	...	...
1300	11.9	10.7	15.7	10.0	9.9	14.7	...	...	...
1350	11.9	10.7	16.4	10.0	10.0	15.3	...	...	...
1400	12.0	10.8	17.2	10.1	10.1	16.0	...	...	...
1450	12.1	10.8	17.9	10.2	10.1	16.7	...	...	...
1500	12.1	10.8	18.6	10.2	10.2	17.5	...	...	...

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TABLE TE-1 (CONT'D)
THERMAL EXPANSION FOR FERROUS MATERIALS

Temperature, °F	Coefficients for Precipitation Hardened 17Cr–4Ni–4Cu Stainless Steels [Note (5)]		
	A	B	C
70	5.9	5.9	0
100	5.9	5.9	0.2
150	5.9	5.9	0.6
200	5.9	5.9	0.9
250	5.9	5.9	1.3
300	5.9	5.9	1.6
350	5.9	5.9	2.0
400	5.9	5.9	2.3
450	5.9	5.9	2.7
500	5.9	5.9	3.1
550	5.9	5.9	3.4
600	6.0	5.9	3.8
650	6.0	5.9	4.1
700	6.0	5.9	4.5
750	6.1	6.0	4.9
800	6.1	6.0	5.2

Notes appear on following page.

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NOTES TO TABLE TE-1

GENERAL NOTES:

(a) Coefficient A is the instantaneous coefficient of thermal expansion × 10^{-6} (in./in./°F). Coefficient B is the mean coefficient of thermal expansion × 10^{-6} (in./in./°F) in going from 70°F to indicated temperature. Coefficient C is the linear thermal expansion (in./100 ft) in going from 70°F to indicated temperature.

(b) For SI units, multiply coefficients A and B by 1.8 to convert to mm/mm/°C and divide coefficient C by 2.16 to convert to mm/(m•°C).

(c) See Table SI-1 for the conversion of temperatures to degrees Celsius.

NOTES:

(1) Group 1 alloys (by nominal composition):

Carbon steels (C, C–Mn, C–Si, and C–Mn–Si)	1¼Cr–½Mo–Si	¾Ni–1Mo–¾Cr
C–¼Mo	1¾Cr–½Mo–Cu	1Ni–½Cr–½Mo
C–½Mo	1¾Cr–½Mo–Ti	1¼Ni–1Cr–½Mo
½Cr–⅕Mo–V	2Cr–½Mo	1¾Ni–¾Cr–¼Mo
½Cr–¼Mo–Si	2¼Cr–1Mo	2Ni–¾Cr–¼Mo
½Cr–½Mo	3Cr–1Mo	2Ni–¾Cr–⅓Mo
¾Cr–½Ni–Cu	½Ni–½Cr–¼Mo	2Ni–1½Cr–¼Mo–V
¾Cr–¾Ni–Cu–Al	½Ni–½Cr–¼Mo–V	2½Ni
1Cr–⅕Mo	½Ni–½Mo–V	2¾Ni–1½Cr–½Mo–V
1Cr–⅕Mo–Si	¾Ni–½Cr–½Mo–V	3½Ni
1Cr–½Mo	¾Ni–½Cu–Mo	3½Ni–1¾Cr–½Mo–V
1Cr–½Mo–V	¾Ni–½Mo–⅓Cr–V	4Ni–1½Cr–½Mo–V
1¼Cr–½Mo	¾Ni–½Mo–Cr–V	

(2) Group 2 alloys (by nominal composition):

Mn–¼Mo	Mn–½Mo–¾Ni	22Cr–5Ni–3Mo–N
Mn–½Mo	Mn–V	23Cr–4Ni–Mo–Cu
Mn–½Mo–¼Ni	18Cr–5Ni–3Mo–N	25Cr–7Ni–4Mo–N
Mn–½Mo–½Ni		

(3) Group 3 alloys (by nominal composition):

16Cr–12Ni–2Mo	18Cr–8Ni–N	18Cr–13Ni–3Mo
16Cr–12Ni–2Mo–N	18Cr–10Ni–Cb	18Cr–18Ni–2Si
16Cr–12Ni–2Mo–Ti	18Cr–10Ni–Ti	19Cr–9Ni–Mo–W
18Cr–8Ni	18Cr–11Ni	21Cr–11Ni–N

(4) Group 4 alloys (by nominal composition):

29Ni–20Cr–3Cu–2Mo	23Cr–12Ni	25Cr–20Ni–2Mo
20Cr–18Ni–6Mo	25Cr–12Ni	31Ni–31Fe–29Cr–Mo
22Cr–13Ni–5Mn	25Cr–20Ni	44Fe–25Ni–21Cr–Mo

(5) These thermal expansion values are representative of solution annealed material. Subsequent precipitation hardening treatments may affect thermal expansion behavior.

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TABLE TE-2
THERMAL EXPANSION FOR ALUMINUM ALLOYS

Temperature, °F	Coefficients for Aluminum Alloys		
	A	B	C
70	12.1	12.1	0
100	12.5	12.4	0.5
150	12.9	12.7	1.2
200	13.3	13.0	2.0
250	13.6	13.1	2.8
300	13.9	13.3	3.7
350	14.2	13.4	4.5
400	14.6	13.6	5.4
450	14.8	13.8	6.3
500	14.9	13.9	7.2
550	15.2	14.1	8.1
600	15.3	14.2	9.0

GENERAL NOTES:

(a) Aluminum alloys represented by these thermal expansion coefficients include:

A03560	A93003	A95254
A24430	A93004	A95454
A91060	A95052	A95456
A91100	A95083	A95652
A92014	A95086	A96061
A92024	A95154	A96063

(b) 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./100 ft) in going from 70°F to indicated temperature.

(c) For SI units, multiply coefficients A and B by 1.8 to convert to mm/mm/°C and divide coefficient C by 2.16 to convert to mm/(m•°C).

(d) See Table SI-1 for the conversion of temperatures to degrees Celsius.

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TABLE TE-3
THERMAL EXPANSION FOR COPPER ALLOYS

Temperature, °F	Coefficients for Copper Alloys, C1XXXX Series			Coefficients for Bronze Alloys			Coefficients for Brass Alloys			Coefficients for Copper–Nickel (70Cu–30Ni)			Coefficients for Copper–Nickel (90Cu–10Ni)		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
70	...	9.3	0	...	9.6	0	...	9.3	0	...	8.1	0	...	...	...
100	...	9.4	0.3	...	9.7	0.4	...	9.4	0.4	...	8.2	0.3	...	...	...
150	...	9.5	0.9	...	9.9	1.0	...	9.6	1.0	...	8.4	0.9	...	...	...
200	...	9.6	1.5	...	10.0	1.6	...	9.8	1.5	...	8.5	1.3	...	...	...
250	...	9.6	2.1	...	10.1	2.3	...	9.9	2.2	...	8.6	1.9	...	...	...
300	...	9.7	2.7	...	10.1	2.8	...	10.0	2.8	...	8.7	2.4	...	...	...
350	...	9.8	3.2	...	10.2	3.5	...	10.1	3.4	...	8.8	3.0	...	...	...
400	...	9.8	3.8	...	10.2	4.1	...	10.2	4.1	...	8.9	3.5	...	...	...
450	...	9.9	4.5	...	10.3	4.8	...	10.4	4.7	...	9.0	4.1	...	...	...
500	...	9.9	5.1	...	10.3	5.3	...	10.5	5.4	...	9.1	4.7	...	...	...
550	...	10.0	5.6	...	10.4	6.0	...	10.6	6.1	...	9.1	5.2	...	9.5	5.5
600	...	10.0	6.1	...	10.4	6.6	...	10.7	6.8	...	9.2	5.9	...	...	...
650	...	...	...	...	10.5	7.3	...	10.8	7.5	...	9.2	6.4	...	...	...
700	...	...	...	...	10.5	8.0	...	10.9	8.3	...	9.2	7.0	...	...	...
750	...	...	...	...	10.6	8.6	...	11.0	9.0	...	...	...	...	...	...
800	...	...	...	...	10.6	9.3	...	11.2	9.8	...	...	...	...	...	...

GENERAL NOTES:

(a) Coefficient A is the instantaneous coefficient of thermal expansion × 10^{-6} (in./in./°F). Coefficient B is the mean coefficient of thermal expansion × 10^{-6} (in./in./°F) in going from 70°F to indicated temperature. Coefficient C is the linear thermal expansion (in./100 ft) in going from 70°F to indicated temperature.

(b) For SI units, multiply coefficients A and B by 1.8 to convert to mm/mm/°C and divide coefficient C by 2.16 to convert to mm/(m•°C).

(c) See Table SI-1 for the conversion of temperatures to degrees Celsius.

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TABLE TE-4
THERMAL EXPANSION FOR NICKEL ALLOYS

Temperature, °F	Coefficients for N02200 and N02201			Coefficients for N04400 and N04405			Coefficients for N06002		
	A	B	C	A	B	C	A	B	C
70	6.6	6.6	0	7.7	7.7	0	7.3	7.3	0
100	6.8	6.8	0.2	7.8	7.8	0.3	7.4	7.4	0.3
150	7.1	7.0	0.7	8.0	7.9	0.8	7.5	7.4	0.7
200	7.3	7.2	1.1	8.2	8.1	1.3	7.6	7.5	1.2
250	7.5	7.4	1.6	8.4	8.2	1.8	7.7	7.6	1.6
300	7.7	7.5	2.1	8.5	8.3	2.3	7.8	7.6	2.1
350	7.8	7.6	2.6	8.7	8.4	2.8	7.9	7.7	2.6
400	8.1	7.7	3.1	8.8	8.5	3.4	7.9	7.7	3.1
450	8.3	7.8	3.6	8.9	8.6	3.9	8.0	7.8	3.5
500	8.4	7.9	4.1	9.0	8.7	4.5	8.1	7.8	4.0
550	8.6	8.0	4.6	9.1	8.8	5.1	8.2	7.9	4.5
600	8.7	8.1	5.1	9.2	8.8	5.6	8.3	7.9	5.0
650	8.8	8.1	5.6	9.3	8.9	6.2	8.4	8.0	5.6
700	8.9	8.2	6.2	9.3	8.9	6.7	8.6	8.0	6.1
750	9.0	8.2	6.7	9.4	8.9	7.3	8.8	8.1	6.6
800	9.1	8.3	7.2	9.4	8.9	7.8	9.1	8.2	7.2
850	...	8.4	7.8	...	8.9	8.4	...	8.3	7.8
900	...	8.4	8.4	...	9.0	8.9	...	8.4	8.3
950	...	8.5	8.9	...	9.0	9.5	...	8.4	8.9
1000	...	8.5	9.5	...	9.1	10.1	...	8.5	9.5
1050	...	8.6	10.1	...	9.1	10.7	...	8.6	10.1
1100	...	8.6	10.6	...	9.1	11.3	...	8.6	10.7
1150	...	8.7	11.2	...	9.1	11.8	...	8.7	11.3
1200	...	8.7	11.8	...	9.2	12.4	...	8.8	11.9
1250	...	8.8	12.4	...	9.2	13.0	...	8.8	12.5
1300	...	8.8	13.0	...	9.2	13.6	...	8.9	13.1
1350	...	8.9	13.6	...	9.2	14.2	...	9.0	13.8
1400	...	8.9	14.2	...	9.3	14.8	...	9.0	14.4
1450	...	...	...	...	9.3	15.4	...	9.1	15.1
1500	...	...	...	...	9.3	16.0	...	9.2	15.7

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TABLE TE-4 (CONT'D)
THERMAL EXPANSION FOR NICKEL ALLOYS

Temperature, °F	Coefficients for N06007			Coefficients for N06455			Coefficients for N06600		
	A	B	C	A	B	C	A	B	C
70	7.4	7.4	0	5.8	5.8	0	6.8	6.8	0
100	7.4	7.4	0.3	6.0	5.9	0.2	6.9	6.9	0.3
150	7.5	7.5	0.7	6.3	6.0	0.6	7.2	7.0	0.7
200	7.6	7.5	1.2	6.5	6.2	1.0	7.5	7.1	1.1
250	7.7	7.5	1.6	6.8	6.3	1.4	7.7	7.2	1.6
300	7.8	7.6	2.1	7.0	6.4	1.8	7.9	7.3	2.0
350	7.9	7.6	2.6	7.1	6.5	2.2	8.1	7.4	2.5
400	8.0	7.7	3.0	7.3	6.7	2.6	8.2	7.5	3.0
450	8.1	7.7	3.5	7.4	6.8	3.1	8.3	7.6	3.4
500	8.2	7.8	4.0	7.5	6.9	3.5	8.4	7.6	3.9
550	8.4	7.8	4.5	7.6	6.9	4.0	8.5	7.7	4.4
600	8.6	7.9	5.0	7.7	7.0	4.5	8.5	7.8	5.0
650	8.8	8.0	5.6	7.7	7.1	4.9	8.6	7.8	5.5
700	9.1	8.1	6.1	7.8	7.1	5.4	8.7	7.9	6.0
750	9.4	8.2	6.7	7.8	7.2	5.9	8.7	8.0	6.5
800	9.7	8.3	7.3	7.8	7.2	6.3	8.8	8.1	7.1
850	...	8.4	7.9	...	7.3	6.8	...	8.1	7.6
900	...	8.5	8.5	...	7.3	7.3	...	8.2	8.1
950	...	8.6	9.1	...	7.4	7.8	...	8.2	8.7
1000	...	8.7	9.7	...	7.4	8.3	...	8.3	9.3
1050	...	8.7	10.3	...	7.4	8.7	...	8.4	9.8
1100	...	8.8	10.9	...	7.5	9.2	...	8.4	10.4
1150	...	8.9	11.5	...	7.5	9.7	...	8.5	11.0
1200	...	9.0	12.2	...	7.5	10.2	...	8.6	11.6
1250	...	9.1	12.8	...	7.5	10.7	...	8.6	12.2
1300	...	9.1	13.5	...	7.6	11.1	...	8.7	12.9
1350	...	9.2	14.1	...	7.6	11.6	...	8.8	13.5
1400	...	9.2	14.8	...	7.6	12.1	...	8.9	14.2
1450	...	9.3	15.4	...	7.6	12.6	...	9.0	14.8
1500	...	9.4	16.1	...	7.6	13.1	...	9.0	15.5

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TABLE TE-4 (CONT'D)
THERMAL EXPANSION FOR NICKEL ALLOYS

Temperature, °F	Coefficients for N06625			Coefficients for N06690			Coefficients for N07718		
	A	B	C	A	B	C	A	B	C
70	6.7	6.7	0	7.7	7.7	0	7.1	7.1	0
100	6.8	6.8	0.3	7.8	7.8	0.3	7.1	7.1	0.3
150	7.0	7.0	0.7	7.9	7.8	0.8	7.3	7.2	0.7
200	7.2	7.1	1.1	8.0	7.9	1.2	7.4	7.2	1.1
250	7.2	7.2	1.6	8.0	7.9	1.7	7.5	7.3	1.6
300	7.3	7.2	2.0	8.1	7.9	2.2	7.6	7.3	2.0
350	7.3	7.3	2.4	8.2	8.0	2.7	7.7	7.4	2.5
400	7.3	7.3	2.9	8.3	8.0	3.2	7.8	7.5	3.0
450	7.4	7.3	3.3	8.3	8.1	3.7	7.9	7.5	3.4
500	7.4	7.4	3.8	8.4	8.1	4.2	8.0	7.6	3.9
550	7.5	7.4	4.3	8.5	8.1	4.7	8.1	7.6	4.4
600	7.5	7.4	4.7	8.5	8.2	5.2	8.2	7.7	4.9
650	7.6	7.4	5.2	8.7	8.2	5.7	8.3	7.7	5.4
700	7.7	7.5	5.7	8.8	8.3	6.2	8.4	7.8	5.9
750	7.9	7.5	6.1	8.9	8.3	6.8	8.5	7.8	6.3
800	8.0	7.6	6.7	9.1	8.3	7.3	8.6	7.9	6.9
850	...	7.7	7.2	...	...	...	8.7	7.9	7.4
900	...	7.7	7.7	...	...	...	8.8	8.0	7.9
950	...	7.8	8.2	...	...	...	9.0	8.0	8.5
1000	...	7.8	8.7	...	...	...	9.1	8.1	9.0
1050	...	7.9	9.3	...	...	...	9.3	8.1	9.5
1100	...	8.0	9.9	...	...	...	9.5	8.2	10.1
1150	...	8.1	10.5	...	...	...	...	...	...
1200	...	8.2	11.1	...	...	...	...	...	...
1250	...	8.3	11.7	...	...	...	...	...	...
1300	...	8.4	12.3	...	...	...	...	...	...
1350	...	8.4	13.0	...	...	...	...	...	...
1400	...	8.5	13.6	...	...	...	...	...	...
1450	...	8.6	14.2	...	...	...	...	...	...
1500	...	8.7	14.9	...	...	...	...	...	...

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TABLE TE-4 (CONT'D)
THERMAL EXPANSION FOR NICKEL ALLOYS

Temperature, °F	Coefficients for N07750			Coefficients for N08330			Coefficients for N08800, N08810 and N08811		
	A	B	C	A	B	C	A	B	C
70	6.7	6.7	0	8.1	8.1	0	7.8	7.9	0
100	6.9	6.8	0.2	8.2	8.1	0.3	8.1	8.0	0.3
150	7.1	6.9	0.7	8.3	8.2	0.8	8.3	8.2	0.8
200	7.2	7.0	1.1	8.6	8.3	1.3	8.5	8.3	1.3
250	7.3	7.1	1.5	8.7	8.4	1.8	8.7	8.5	1.8
300	7.4	7.2	2.0	8.8	8.5	2.3	8.8	8.6	2.4
350	7.5	7.3	2.5	9.0	8.5	2.9	8.9	8.7	2.9
400	7.6	7.4	2.9	9.1	8.6	3.4	9.0	8.8	3.5
450	7.7	7.5	3.4	9.3	8.7	4.0	9.1	8.9	4.0
500	7.7	7.5	3.9	9.4	8.8	4.5	9.1	8.9	4.6
550	7.7	7.5	4.3	9.5	8.8	5.1	9.2	9.0	5.2
600	7.7	7.5	4.8	9.6	8.9	5.7	9.2	9.0	5.7
650	7.8	7.5	5.3	9.7	9.0	6.2	9.3	9.1	6.3
700	7.8	7.6	5.7	9.8	9.0	6.8	9.3	9.1	6.9
750	8.0	7.7	6.3	9.8	9.1	7.4	9.4	9.2	7.5
800	8.1	7.7	6.8	9.9	9.1	8.0	9.5	9.2	8.1
850	...	...	...	...	...	...	9.7	9.3	8.7
900	...	...	...	...	...	...	9.8	9.3	9.3
950	...	...	...	...	...	...	10.0	9.4	9.9
1000	...	...	...	...	...	...	10.2	9.4	10.5
1050	...	...	...	...	...	...	10.4	9.5	11.1
1100	...	...	...	...	...	...	10.6	9.5	11.7
1150	...	...	...	...	...	...	10.8	9.6	12.4
1200	...	...	...	...	...	...	11.0	9.6	13.0
1250	...	...	...	...	...	...	11.2	9.7	13.7
1300	...	...	...	...	...	...	11.4	9.7	14.3
1350	...	...	...	...	...	...	11.5	9.8	15.0
1400	...	...	...	...	...	...	11.7	9.8	15.7
1450	...	...	...	...	...	...	11.8	9.9	16.4
1500	...	...	...	...	...	...	11.9	10.0	17.2
1550	...	...	...	...	...	...	12.0	10.1	17.9
1600	...	...	...	...	...	...	12.1	10.2	18.7
1650	...	...	...	...	...	...	...	10.3	19.5

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TABLE TE-4 (CONT'D)
THERMAL EXPANSION FOR NICKEL ALLOYS

Temperature, °F	Coefficients for N08825			Coefficients for N10001			Coefficients for N10003		
	A	B	C	A	B	C	A	B	C
70	7.5	7.5	0	6.0	6.0	0	6.2	6.2	0
100	7.6	7.5	0.3	6.1	6.1	0.2	6.3	6.2	0.2
150	7.7	7.6	0.7	6.3	6.2	0.6	6.5	6.3	0.6
200	7.8	7.7	1.2	6.4	6.2	1.0	6.6	6.4	1.0
250	7.9	7.8	1.7	6.5	6.3	1.4	6.7	6.5	1.4
300	8.0	7.9	2.2	6.6	6.4	1.8	6.9	6.6	1.8
350	8.1	7.9	2.7	6.6	6.4	2.1	7.0	6.6	2.2
400	8.2	8.0	3.2	6.6	6.4	2.5	7.1	6.7	2.7
450	8.3	8.0	3.7	6.6	6.4	2.9	7.2	6.7	3.1
500	8.4	8.1	4.2	6.7	6.4	3.3	7.3	6.8	3.5
550	8.5	8.1	4.7	6.7	6.4	3.7	7.4	6.8	3.9
600	8.6	8.2	5.2	6.8	6.5	4.1	7.5	6.9	4.4
650	8.7	8.3	5.8	6.8	6.5	4.5	7.6	6.9	4.8
700	8.7	8.3	6.3	6.9	6.6	5.0	7.7	7.0	5.3
750	8.8	8.4	6.8	6.9	6.6	5.4	7.8	7.0	5.7
800	8.9	8.4	7.4	7.0	6.7	5.9	7.9	7.1	6.2
850	...	...	...	...	6.8	6.3	...	...	...
900	...	...	...	...	6.8	6.8	...	...	...
950	...	...	...	...	6.9	7.2	...	...	...
1000	...	...	...	...	6.9	7.7	...	...	...
1050	...	...	...	...	7.0	8.2	...	...	...
1100	...	...	...	...	7.1	8.7	...	...	...
1150	...	...	...	...	7.1	9.3	...	...	...
1200	...	...	...	...	7.2	9.8	...	...	...
1250	...	...	...	...	7.3	10.3	...	...	...
1300	...	...	...	...	7.4	10.9	...	...	...
1350	...	...	...	...	7.4	11.4	...	...	...
1400	...	...	...	...	7.5	12.0	...	...	...
1450	...	...	...	...	7.6	12.6	...	...	...
1500	...	...	...	...	7.7	13.1	...	...	...

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TABLE TE-4 (CONT'D)
THERMAL EXPANSION FOR NICKEL ALLOYS

Temperature, °F	Coefficients for N10276			Coefficients for N10665		
	A	B	C	A	B	C
70	6.0	6.0	0	5.2	5.3	0
100	6.1	6.1	0.2	5.5	5.4	0.2
150	6.3	6.2	0.6	5.7	5.6	0.5
200	6.5	6.3	1.0	5.9	5.7	0.9
250	6.7	6.4	1.4	6.0	5.8	1.3
300	6.9	6.5	1.8	6.1	5.9	1.6
350	7.1	6.6	2.2	6.2	5.9	2.0
400	7.3	6.7	2.7	6.3	6.0	2.4
450	7.5	6.8	3.1	6.4	6.1	2.8
500	7.6	6.9	3.6	6.5	6.1	3.2
550	7.7	7.0	4.0	6.6	6.2	3.6
600	7.8	7.1	4.5	6.7	6.2	4.0
650	7.9	7.2	5.0	6.8	6.3	4.4
700	8.0	7.2	5.5	6.8	6.3	4.8
750	8.0	7.3	5.9	6.9	6.4	5.2
800	8.1	7.3	6.4	7.0	6.4	5.6
850	...	7.4	6.9	...	6.5	6.0
900	...	7.5	7.4	...	6.5	6.5
950	...	7.5	8.0	...	6.6	6.9
1000	...	7.6	8.5	...	6.6	7.3
1050	...	7.7	9.0	...	6.6	7.8
1100	...	7.7	9.5	...	6.6	8.2
1150	...	7.8	10.1	...	6.7	8.6
1200	...	7.8	10.6	...	6.7	9.1
1250	...	7.9	11.2	...	6.7	9.5
1300	...	7.9	11.7	...	6.7	9.9
1350	...	8.0	12.3	...	6.7	10.4
1400	...	8.0	12.8	...	6.8	10.8
1450	...	8.1	13.4	...	6.8	11.2
1500	...	8.1	13.9	...	6.8	11.7

GENERAL NOTES:

(a) 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./100 ft) in going from 70°F to indicated temperature.

(b) For SI units, multiply coefficients A and B by 1.8 to convert to mm/mm/°C and divide coefficient C by 2.16 to convert to mm/(m•°C).

(c) See Table SI-1 for the conversion of temperatures to degrees Celsius.

TABLE TE-5
THERMAL EXPANSION FOR TITANIUM ALLOYS

Temperature, °F	Coefficients for Titanium Alloy, Grades 1, 2, 3, 7, and 12			Coefficients for Titanium Alloy, Grade 9		
	A	B	C	A	B	C
70	4.6	4.6	0	4.8	4.7	0
100	4.7	4.7	0.2	4.8	4.7	0.2
150	4.7	4.7	0.5	4.9	4.8	0.5
200	4.8	4.7	0.7	5.0	4.8	0.8
250	4.8	4.7	1.0	5.0	4.9	1.1
300	4.8	4.8	1.3	5.1	4.9	1.4
350	4.9	4.8	1.6	5.2	5.0	1.7
400	4.9	4.8	1.9	5.3	5.0	2.0
450	5.0	4.8	2.2	5.4	5.1	2.3
500	5.0	4.9	2.5	5.4	5.1	2.6
550	5.0	4.9	2.8	5.5	5.1	3.0
600	5.1	4.9	3.1	5.6	5.2	3.3
650	5.1	4.9	3.4	...	...	...
700	5.2	5.0	3.8	...	...	...
750	5.2	5.0	4.1	...	...	...
800	5.2	5.1	4.4	...	...	...

GENERAL NOTES:

(a) 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./100 ft) in going from 70°F to indicated temperature.

(b) For SI units, multiply coefficients A and B by 1.8 to convert to mm/mm/°C and divide coefficient C by 2.16 to convert to mm/(m•°C).

(c) See Table SI-1 for the conversion of temperatures to degrees Celsius.

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TABLE TCD
NOMINAL COEFFICIENTS OF THERMAL CONDUCTIVITY (TC) AND THERMAL DIFFUSIVITY (TD)

	Carbon and Low Alloy Steels											
	Material Group A [Note (1)] Plain Carbon		Material Group B [Note (2)]		Material Group C [Note (3)]		Material Group D [Note (4)]		Material Group E [Note (5)]		Material Group F [Note (6)]	
Temp., °F	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD
70	35.1	0.695	27.5	0.529	23.5	0.458	20.9	0.408	15.9	0.308	12.8	0.256
100	34.7	0.674	27.6	0.512	23.6	0.450	21.0	0.397	16.2	0.310	13.1	0.258
150	34.1	0.645	27.6	0.496	23.6	0.438	21.2	0.391	16.7	0.313	13.6	0.260
200	33.6	0.613	27.6	0.486	23.6	0.425	21.3	0.385	17.1	0.315	14.0	0.261
250	32.9	0.585	27.4	0.467	23.5	0.413	21.4	0.378	17.5	0.314	14.4	0.263
300	32.3	0.561	27.2	0.453	23.4	0.401	21.5	0.371	17.8	0.313	14.7	0.262
350	31.6	0.534	27.0	0.440	23.3	0.389	21.5	0.364	18.0	0.310	15.0	0.261
400	30.9	0.512	26.7	0.428	23.1	0.378	21.5	0.357	18.2	0.305	15.2	0.259
450	30.3	0.495	26.3	0.413	22.9	0.367	21.5	0.349	18.4	0.300	15.4	0.256
500	29.5	0.472	25.9	0.398	22.7	0.356	21.4	0.341	18.5	0.295	15.6	0.253
550	28.8	0.453	25.5	0.387	22.5	0.346	21.3	0.332	18.5	0.289	15.8	0.249
600	28.0	0.433	25.0	0.374	22.2	0.336	21.1	0.323	18.5	0.283	15.9	0.245
650	27.3	0.414	24.5	0.360	21.9	0.326	20.9	0.314	18.5	0.274	16.0	0.240
700	26.6	0.394	24.0	0.346	21.6	0.315	20.7	0.305	18.5	0.266	16.0	0.235
750	25.9	0.374	23.5	0.332	21.3	0.303	20.5	0.295	18.4	0.258	16.1	0.229
800	25.2	0.355	23.0	0.318	21.0	0.292	20.2	0.285	18.3	0.250	16.1	0.222
850	24.5	0.335	22.6	0.305	20.7	0.280	20.0	0.274	18.2	0.242	16.2	0.214
900	23.8	0.317	22.1	0.291	20.3	0.269	19.7	0.264	18.1	0.233	16.1	0.207
950	23.1	0.301	21.5	0.277	20.0	0.258	19.4	0.252	18.0	0.224	16.1	0.199
1000	22.4	0.282	21.0	0.263	19.7	0.247	19.1	0.241	17.8	0.216	16.1	0.192
1050	21.6	0.265	20.5	0.249	19.4	0.236	18.8	0.229	17.6	0.207	16.0	0.182
1100	20.9	0.250	19.9	0.237	19.0	0.224	18.5	0.217	17.4	0.198	16.0	0.174
1150	20.2	0.234	19.3	0.219	18.7	0.213	18.3	0.205	17.2	0.187	15.9	0.165
1200	19.5	0.218	18.7	0.202	18.2	0.200	18.0	0.192	17.0	0.177	15.8	0.155
1250	18.7	0.197	18.0	0.184	17.7	0.185	17.7	0.179	16.8	0.166	15.7	0.143
1300	18.0	0.180	17.1	0.159	16.9	0.167	17.2	0.163	16.5	0.153	15.6	0.131
1350	17.2	0.134	16.2	0.122	15.6	0.139	16.4	0.136	16.2	0.138	15.5	0.117
1400	16.4	0.082	15.6	0.078	15.3	0.077	15.6	0.075	15.8	0.117	15.2	0.147
1450	15.9	0.147	15.2	0.155	15.2	0.129	15.4	0.127	15.6	0.144	15.0	0.165
1500	15.7	0.162	15.1	0.169	15.1	0.200	15.3	0.197	15.7	0.162	15.0	0.177

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TABLE TCD (CONT'D)
NOMINAL COEFFICIENTS OF THERMAL CONDUCTIVITY (TC) AND THERMAL DIFFUSIVITY (TD)

	High Chrome Steels				High Alloy Steels							
	Material Group G [Note (7)]		Material Group H [Note (8)]		Material Group I [Note (9)]		Material Group J [Note (10)]		Material Group K [Note (11)]		Material Group L [Note (12)]	
Temp., °F	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD
70	14.2	0.274	11.6	0.222	9.9	0.188	8.6	0.151	8.2	0.139	6.4	0.115
100	14.2	0.271	11.6	0.220	10.1	0.189	8.7	0.152	8.3	0.140	6.6	0.116
150	14.3	0.266	11.7	0.217	10.4	0.189	9.0	0.154	8.6	0.142	6.9	0.118
200	14.3	0.261	11.7	0.214	10.6	0.189	9.3	0.156	8.8	0.145	7.1	0.121
250	14.4	0.256	11.8	0.211	10.9	0.190	9.6	0.158	9.1	0.147	7.4	0.124
300	14.4	0.251	11.8	0.208	11.2	0.190	9.8	0.160	9.3	0.150	7.7	0.126
350	14.4	0.246	11.9	0.206	11.4	0.191	10.1	0.162	9.5	0.152	8.0	0.129
400	14.5	0.241	11.9	0.203	11.7	0.191	10.4	0.165	9.8	0.155	8.2	0.132
450	14.5	0.236	12.0	0.201	12.0	0.191	10.6	0.167	10.0	0.157	8.5	0.135
500	14.5	0.231	12.0	0.198	12.2	0.190	10.9	0.170	10.2	0.160	8.8	0.138
550	14.6	0.226	12.1	0.195	12.5	0.190	11.1	0.172	10.5	0.162	9.1	0.141
600	14.6	0.221	12.2	0.192	12.7	0.190	11.3	0.174	10.7	0.165	9.3	0.143
650	14.6	0.216	12.2	0.189	13.0	0.188	11.6	0.177	10.9	0.167	9.6	0.146
700	14.6	0.211	12.3	0.186	13.2	0.186	11.8	0.179	11.2	0.170	9.9	0.149
750	14.6	0.206	12.3	0.183	13.4	0.183	12.0	0.181	11.4	0.172	10.1	0.152
800	14.7	0.201	12.4	0.179	13.5	0.180	12.2	0.184	11.6	0.175	10.4	0.155
850	14.7	0.196	12.5	0.174	13.6	0.176	12.5	0.186	11.9	0.177	10.6	0.158
900	14.7	0.191	12.6	0.170	13.7	0.172	12.7	0.189	12.1	0.179	10.9	0.161
950	14.7	0.185	12.6	0.165	13.8	0.167	12.9	0.191	12.3	0.182	11.2	0.164
1000	14.7	0.179	12.7	0.159	13.8	0.160	13.2	0.194	12.5	0.184	11.4	0.167
1050	14.7	0.173	12.8	0.152	13.9	0.153	13.4	0.196	12.8	0.187	11.7	0.170
1100	14.7	0.167	12.9	0.145	14.0	0.146	13.6	0.198	13.0	0.189	12.0	0.173
1150	14.8	0.159	13.0	0.150	14.1	0.134	13.8	0.201	13.2	0.191	12.2	0.175
1200	14.8	0.150	13.1	0.160	14.2	0.129	14.0	0.203	13.4	0.194	12.5	0.178
1250	14.8	0.138	13.2	0.169	14.4	0.140	14.3	0.205	13.6	0.196	12.7	0.181
1300	14.8	0.125	13.4	0.176	14.6	0.152	14.5	0.208	13.8	0.198	12.9	0.184
1350	14.8	0.106	13.5	0.183	14.8	0.171	14.7	0.210	14.1	0.200	13.2	0.186
1400	14.8	0.158	13.7	0.189	15.0	0.185	14.9	0.212	14.3	0.202	13.5	0.188
1450	14.8	0.172	13.8	0.194	15.2	0.194	15.1	0.214	14.5	0.205	13.7	0.190
1500	14.9	0.173	14.0	0.199	15.4	0.201	15.3	0.216	14.7	0.207	14.0	0.191

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TABLE TCD (CONT'D)
NOMINAL COEFFICIENTS OF THERMAL CONDUCTIVITY (TC) AND THERMAL DIFFUSIVITY (TD)

	High Nickel Alloys											
	Nickel N02200		Low C–Nickel N02201		Ni–Cu N04400		Ni–Cu N04405		Ni–Cr–Fe N06600		Ni–Cr–Fe N06690	
Temp., °F	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD
70	...	...	...	...	12.6	0.224	12.6	...	8.6	0.154	6.8	0.125
100	...	...	...	...	12.9	0.227	12.9	...	8.7	0.154	7.0	0.128
150	...	...	...	...	13.4	0.234	13.4	...	8.9	0.155	7.3	0.131
200	38.8	...	42.7	...	13.9	0.241	13.9	...	9.1	0.156	7.6	0.134
250	38.0	...	41.6	...	14.5	0.248	14.5	...	9.3	0.158	7.9	0.137
300	37.2	...	40.5	...	15.0	0.254	15.0	...	9.6	0.160	8.2	0.140
350	36.4	...	39.4	...	15.6	0.261	15.6	...	9.8	0.163	8.5	0.144
400	35.4	...	38.3	...	16.1	0.267	16.1	...	10.1	0.165	8.8	0.147
450	34.8	...	37.2	...	16.6	0.273	16.6	...	10.3	0.168	9.1	0.151
500	34.1	...	36.2	...	17.0	0.280	17.0	...	10.6	0.171	9.4	0.153
550	33.3	...	35.1	...	17.5	0.285	17.5	...	10.8	0.172	9.7	0.157
600	32.5	...	34.0	...	17.9	0.289	17.9	...	11.1	0.174	10.0	0.161
650	31.7	...	33.7	...	18.4	0.291	18.4	...	11.3	0.177	10.3	0.164
700	31.8	...	33.3	...	18.9	0.292	18.9	...	11.6	0.179	10.6	0.167
750	32.2	...	33.0	...	19.4	0.293	19.4	...	11.8	0.180	10.9	0.170
800	32.5	...	32.7	...	19.8	0.293	19.8	...	12.1	0.182	11.2	0.174
850	32.8	...	33.0	...	20.4	...	20.4	...	12.3	0.185	11.5	0.178
900	33.1	...	33.4	...	20.9	...	20.9	...	12.6	0.186	11.8	0.180
950	33.4	...	33.8	...	21.5	...	21.5	...	12.9	0.188	12.2	0.184
1000	33.8	...	34.2	...	22.0	...	22.0	...	13.2	0.190	12.5	0.187
1050	...	...	34.5	...	...	...	...	...	13.5	0.191	12.8	0.190
1100	...	...	34.9	...	...	...	...	...	13.8	0.192	13.1	0.192
1150	...	...	35.2	...	...	...	...	...	14.0	0.194	13.4	0.194
1200	...	...	35.7	...	...	...	...	...	14.3	0.195	13.7	0.197
1250	...	...	36.0	...	...	...	...	...	14.6	0.198	14.0	0.199
1300	...	...	36.4	...	...	...	...	...	14.9	0.199	14.3	0.201
1350	...	...	36.7	...	...	...	...	...	15.2	0.201	14.6	0.202
1400	...	...	37.1	...	...	...	...	...	15.5	0.204	14.9	0.204
1450	...	...	37.4	...	...	...	...	...	15.8	0.206	15.2	0.207
1500	...	...	37.8	...	...	...	...	...	16.0	0.208	15.5	0.208

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TABLE TCD (CONT'D)
NOMINAL COEFFICIENTS OF THERMAL CONDUCTIVITY (TC) AND THERMAL DIFFUSIVITY (TD)

	High Nickel Alloys (Cont'd)									
	Ni–Cr–Mo–Cb N06625		Ni–Cr–Fe–Mo–Cb N07718		Ni–Fe–Cr N08800, N08810, and N08811		Ni–Fe–Cr–Mo–Cu N08825		Ni–Cr–Mo–Fe N06002	
Temp., °F	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD
70	5.7	0.110	6.4	0.120	6.7	0.122	...	...	5.2	0.087
100	5.8	0.112	6.6	0.122	6.8	0.125	...	...	5.5	0.092
150	6.0	0.117	6.8	0.125	7.1	0.129	...	...	5.9	0.099
200	6.2	0.121	7.1	0.129	7.4	0.133	7.1	0.127	6.3	0.105
250	6.5	0.121	7.4	0.132	7.7	0.137	7.3	0.126	6.6	0.110
300	6.8	0.122	7.7	0.135	8.0	0.140	7.6	0.125	7.0	0.117
350	7.0	0.125	7.9	0.138	8.3	0.144	7.9	0.129	7.3	0.121
400	7.2	0.127	8.2	0.142	8.6	0.147	8.1	0.134	7.6	0.126
450	7.5	0.130	8.5	0.145	8.8	0.150	8.4	0.133	7.9	0.132
500	7.7	0.132	8.8	0.148	9.1	0.153	8.6	0.132	8.2	0.137
550	7.9	0.134	9.0	0.152	9.3	0.156	8.9	0.131	8.5	0.141
600	8.2	0.136	9.3	0.155	9.6	0.159	9.1	0.130	8.8	0.146
650	8.4	0.138	9.6	0.159	9.8	0.161	9.3	0.133	9.1	0.149
700	8.6	0.140	9.8	0.163	10.1	0.164	9.6	0.136	9.4	0.152
750	8.9	0.142	10.1	0.167	10.3	0.167	9.8	0.135	9.8	0.157
800	9.1	0.144	10.4	0.171	10.6	0.169	10.0	0.133	10.1	0.159
850	9.4	0.146	10.7	0.176	10.8	0.171	10.2	0.132	10.4	0.163
900	9.6	0.148	11.0	0.182	11.1	0.174	10.4	0.131	10.7	0.165
950	9.8	0.150	11.2	0.190	11.3	0.176	10.7	0.130	11.0	0.167
1000	10.1	0.153	11.5	0.184	11.6	0.178	10.9	0.129	11.4	0.172
1050	10.3	0.154	11.8	0.181	11.9	0.181	11.1	...	11.7	0.174
1100	10.6	0.156	12.0	0.180	12.1	0.183	11.4	...	12.0	0.176
1150	10.8	0.157	12.3	0.180	12.4	0.185	11.6	...	12.3	0.180
1200	11.0	0.159	12.6	0.179	12.7	0.187	11.8	...	12.6	0.182
1250	11.3	0.161	12.8	0.172	13.0	0.189	12.1	...	12.9	0.181
1300	11.5	0.163	13.1	0.163	13.2	0.191	12.4	...	13.2	0.182
1350	11.8	0.165	13.3	0.161	13.6	0.192	12.7	...	13.6	0.183
1400	12.0	0.167	13.6	0.160	13.8	0.194	12.9	...	13.9	0.183
1450	12.3	0.169	13.8	0.161	14.2	0.196	13.3	...	14.2	0.183
1500	12.6	0.171	14.1	0.162	14.5	0.198	13.6	...	14.5	0.183

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TABLE TCD (CONT'D)
NOMINAL COEFFICIENTS OF THERMAL CONDUCTIVITY (TC) AND THERMAL DIFFUSIVITY (TD)

	High Nickel Alloys (Cont'd)									
	Ni–Mo N10001		Cr–Ni–Fe–Mo–Cu–Cb N08020		70Ni–16Cr–7Fe–Ti–Al N07750		Ni–Cr–Fe–Mo–Cu N06007		Ni–Mo–Cr–Fe N10003	
Temp., °F	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD
70	...	...	...	...	6.9	0.132	5.8	0.116	...	...
100	6.1	0.115	6.9	0.198	7.0	0.132	6.0	0.117	...	...
150	6.2	0.114	7.2	0.207	7.2	0.133	6.2	0.116	6.1	0.114
200	6.4	0.116	7.5	0.214	7.4	0.133	6.4	0.115	6.6	0.121
250	6.5	0.116	7.8	0.223	7.6	0.133	6.7	0.117	6.8	0.123
300	6.7	0.118	8.0	0.229	7.8	0.134	7.0	0.121	7.0	0.125
350	6.8	0.117	8.3	0.238	8.0	0.136	7.2	0.123	7.2	0.127
400	7.0	0.119	8.6	0.246	8.2	0.140	7.4	0.125	7.4	0.130
450	7.2	0.121	8.8	0.254	8.4	0.141	7.7	0.128	7.6	0.131
500	7.4	0.122	9.1	0.265	8.6	0.143	7.9	0.130	7.8	0.133
550	7.5	0.121	9.4	0.270	8.8	0.145	8.2	0.134	8.1	0.137
600	7.7	0.124	9.7	0.277	9.1	0.148	8.4	0.136	8.3	0.139
650	8.0	0.126	10.0	0.286	9.3	0.151	8.6	0.138	8.5	0.143
700	8.2	0.127	10.2	0.293	9.5	0.153	8.9	0.142	8.8	0.147
750	8.4	0.129	10.5	0.300	9.8	0.156	9.2	0.146	9.0	0.149
800	8.7	0.132	10.8	0.309	10.0	0.158	9.4	0.148	9.3	0.153
850	9.0	0.135	11.0	...	10.2	0.160	9.7	0.151	9.5	0.155
900	9.3	0.138	11.3	...	10.5	0.162	9.9	0.154	9.8	0.160
950	9.7	0.143	11.6	...	10.7	0.165	10.2	0.157	10.1	0.163
1000	10.0	0.145	11.9	...	10.9	0.169	10.5	0.160	10.4	0.167
1050	10.4	0.149	...	...	...	...	10.7	0.162	10.7	0.161
1100	10.7	0.153	...	...	...	...	11.0	0.165	11.1	0.154
1150	11.1	0.156	...	...	...	...	11.3	0.169	11.4	0.152
1200	...	...	...	...	...	...	11.5	0.171	11.7	0.158
1250	...	...	...	...	...	...	...	...	12.1	0.164
1300	...	...	...	...	...	...	...	...	12.5	0.170
1350	...	...	...	...	...	...	...	...	12.9	...
1400	...	...	...	...	...	...	...	...	13.3	...
1450	...	...	...	...	...	...	...	...	13.7	...
1500	...	...	...	...	...	...	...	...	14.2	...

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TABLE TCD (CONT'D)
NOMINAL COEFFICIENTS OF THERMAL CONDUCTIVITY (TC) AND THERMAL DIFFUSIVITY (TD)

	High Nickel Alloys (Cont'd)								Titanium Alloys			
	Ni–Mo–Cr N10276		Ni–Fe–Cr–Si N08330		Ni–Mo N10665		Ni–Mo–Cr–Low C N06455		Unalloyed Titanium (Grades 1, 2, 3, 7, 16, and 17)		Titanium Grade 9	
Temp., °F	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD
70	...	TBD	7.2	0.131	...	...	5.8	0.110	12.68	0.359	5.12	0.145
100	5.9	TBD	7.2	0.131	6.8	0.128	5.9	0.112	12.52	0.352	5.25	0.147
150	6.2	TBD	7.4	0.135	6.9	0.129	6.2	0.114	12.25	0.340	5.46	0.150
200	6.4	TBD	7.7	0.141	7.0	0.130	6.5	0.118	12.00	0.331	5.67	0.152
250	6.7	TBD	8.0	TBD	7.2	0.132	6.8	0.121	11.85	0.322	5.87	0.155
300	7.0	TBD	8.2	TBD	7.3	0.134	7.1	0.124	11.72	0.314	6.06	0.158
350	7.2	TBD	8.5	TBD	7.5	0.135	7.4	0.127	11.60	0.306	6.24	0.160
400	7.5	TBD	8.8	TBD	7.6	0.137	7.7	0.130	11.45	0.300	6.40	0.163
450	7.8	TBD	9.1	TBD	7.8	0.139	7.9	0.133	11.35	0.294	6.55	0.166
500	8.1	TBD	9.4	TBD	8.0	0.141	8.2	0.137	11.29	0.290	6.69	0.168
550	8.4	TBD	9.7	TBD	8.2	0.144	8.5	0.141	11.23	0.286	6.81	0.170
600	8.7	TBD	10.0	TBD	8.4	0.146	8.8	0.145	11.20	0.283	6.91	0.172
650	8.9	TBD	10.3	TBD	8.7	0.149	9.1	0.147	11.17	0.280	...	...
700	9.2	TBD	10.6	TBD	8.8	0.152	9.3	0.150	11.15	0.278	...	...
750	9.5	TBD	10.9	TBD	9.1	0.154	9.6	0.154	11.18	0.276	...	...
800	9.8	TBD	11.2	TBD	9.4	0.157	9.9	0.158	11.20	0.275	...	...
850	10.1	TBD	11.5	TBD	9.6	0.160	10.2	0.162	11.23	0.274	...	...
900	10.4	TBD	11.8	TBD	10.0	0.164	10.5	0.164	11.30	0.273	...	...
950	10.7	TBD	12.1	TBD	10.3	0.167	10.8	0.169	11.36	0.272	...	...
1000	11.0	TBD	12.4	TBD	10.7	0.171	11.1	0.172	11.43	0.271	...	...
1050	11.3	TBD	12.7	TBD	11.0	0.175	11.5	0.177	11.51	0.270	...	...
1100	11.5	TBD	13.0	TBD	11.4	0.179	11.8	0.181	11.58	0.270	...	...
1150	11.8	TBD	13.2	TBD	11.8	0.184	12.1	0.185	...	...	...	...
1200	12.1	TBD	13.5	TBD	12.2	0.188	12.5	0.189	...	...	...	...
1250	...	TBD	13.8	TBD	...	...	...	...	...	...	...	...
1300	...	...	...	...	...	...	...	...	...	...	...	...
1350	...	...	...	...	...	...	...	...	...	...	...	...
1400	...	...	...	...	...	...	...	...	...	...	...	...
1450	...	...	...	...	...	...	...	...	...	...	...	...
1500	...	...	...	...	...	...	...	...	...	...	...	...

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TABLE TCD (CONT'D)
NOMINAL COEFFICIENTS OF THERMAL CONDUCTIVITY (TC) AND THERMAL DIFFUSIVITY (TD)

	Aluminum Alloys											
	A24430		A03560		A91060		A91100		A92014		A92024	
Temp., °F	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD
70	94.0	2.64	92.0	2.61	135.2	3.72	133.1	3.67	89.9	2.47	85.8	2.36
100	94.9	2.64	92.9	2.61	133.7	3.65	131.8	3.61	90.9	2.48	86.9	2.37
150	96.1	2.63	94.2	2.60	131.7	3.54	130.0	3.50	92.3	2.48	88.5	2.38
200	97.2	2.63	95.4	2.60	130.1	3.46	128.5	3.42	93.6	2.48	90.0	2.39
250	98.1	2.63	96.4	2.59	128.7	3.38	127.3	3.35	94.7	2.48	91.3	2.39
300	99.0	2.62	97.4	2.59	127.5	3.31	126.2	3.28	95.7	2.48	92.4	2.40
350	99.7	2.61	98.2	2.59	126.5	3.25	125.3	3.23	96.6	2.47	93.4	2.40
400	100.4	2.60	98.9	2.58	125.6	3.19	124.5	3.17	97.4	2.47	94.4	2.39

	Aluminum Alloys (Cont'd)									
	A93003		A93004		A95052 & A95652		A95083		A95086	
Temp., °F	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD
70	102.3	2.81	94.0	2.60	79.6	2.22	67.2	1.88	73.4	2.05
100	102.8	2.80	94.9	2.60	80.8	2.23	68.7	1.91	74.8	2.08
150	103.5	2.78	96.1	2.59	82.7	2.25	70.8	1.94	76.8	2.10
200	104.2	2.76	97.2	2.59	84.4	2.27	72.8	1.97	78.7	2.12
250	104.7	2.75	98.1	2.59	85.9	2.28	74.6	1.99	80.3	2.14
300	105.2	2.73	99.0	2.58	87.2	2.29	76.2	2.01	81.9	2.16
350	105.7	2.71	99.7	2.57	88.4	2.30	77.8	2.03	83.2	2.17
400	106.1	2.69	100.4	2.56	89.6	2.30	79.2	2.05	84.5	2.18

	Aluminum Alloys (Cont'd)									
	A95154 & A95254		A95454		A95456		A96061		A96063	
Temp., °F	TC	TD	TC	TD	TC	TD	TC	TD	TC	TD
70	73.4	2.05	77.5	2.15	67.2	1.89	96.1	2.66	120.8	3.34
100	74.8	2.08	78.8	2.17	68.7	1.91	96.9	2.66	120.3	3.30
150	76.8	2.10	80.8	2.19	70.8	1.94	98.0	2.65	119.7	3.23
200	78.7	2.12	82.5	2.21	72.8	1.97	99.0	2.65	119.1	3.18
250	80.3	2.14	84.1	2.23	74.6	2.00	99.8	2.64	118.3	3.13
300	81.9	2.16	85.5	2.24	76.3	2.02	100.6	2.63	118.3	3.09
350	83.2	2.17	86.7	2.25	77.8	2.04	101.3	2.62	117.9	3.04
400	84.5	2.18	87.9	2.25	79.2	2.05	101.9	2.62	117.6	3.00

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TABLE TCD (CONT'D)

GENERAL NOTES:

(a) TC is the thermal conductivity, Btu/hr-ft-°F, and TD is the thermal diffusivity, ft^2/hr:

$$TD = \frac{TC\ (Btu/hr\text{-}ft\text{-}°F)}{density\ (lb/ft^3) \times specific\ heat\ (Btu/lb\text{-}°F)}$$

(b) Values of thermal expansion and thermal diffusivity should be used with the understanding that there is an associated ±10% uncertainty. This uncertainty results from compositional variations and variables associated with original data acquisition and analysis.

(c) For SI units, multiply TC by 1.7295 to convert to W/(m•K) and TD by 2.58064×10^{-5} to convert to m^2/s.

(d) See Table SI-1 for the conversion of temperatures to degrees Celsius.

NOTES:

(1) Material Group A includes plain carbon steels in which there are no specified amounts of manganese or silicon.

(2) Material Group B includes carbon steels in which there are specified amounts of manganese and/or silicon, with or without additional small amounts of columbium, titanium, or vanadium (microalloyed steels). Also includes:

¾Cr–½Ni–Cu	¾Ni–½Cu–Mo
1Cr–½Mo–Si	2½Ni

(3) Material Group C includes the following carbon–moly steels:

C–¼Mo	C–½Mo

The following low chrome steels:

½Cr–⅕Mo–V	1Cr–½Mo
½Cr–¼Mo–Si	1¼Cr–½Mo
½Cr–½Mo	1¼Cr–½Mo–Si
½Cr–½Ni–⅕Mo	1¾Cr–½Mo–Cu
¾Cr–¾Ni–Cu–Al	1¾Cr–½Mo–Ti
1Cr–1Mn–¼Mo	2Cr–½Mo
1Cr–⅕Mo	

The following manganese steels:

Mn–½Mo	Mn–½Mo–¾Ni
Mn–½Mo–¼Ni	Mn–½Ni–V
Mn–½Mo–½Ni	Mn–V

The following nickel steels:

½Ni–½Cr–¼Mo–V	¾Ni–1Mo–¾Cr
½Ni–½Mo–V	1Ni–½Cr–½Mo
¾Ni–½Cr–½Mo–V	1¼Ni–1Cr–½Mo
¾Ni–½Mo–⅓Cr–V	3½Ni–1¾Cr–½Mo–V
¾Ni–½Mo–Cr–V	4Ni–1½Cr–½Mo-V

(4) Material Group D includes the following low chrome steels:

2¼Cr–1Mo	3Cr–1Mo

The following manganese steel:

Mn–¼Mo

The following nickel steels:

1¾Ni–¾Cr–¼Mo	2¾Ni–1½Cr–½Mo–V
2Ni–¾Cr–¼Mo	5Ni–¼Mo
2Ni–¾Cr–⅓Mo	8Ni
2Ni–1½Cr–¼Mo–V	9Ni
2Ni–1Cu	

(5) Material Group E includes:

5Cr–½Mo	5Cr–½Mo–Ti
5Cr–½Mo–Si	

TD at 1420°F = 0.105 and at 1425°F = 0.122 ft^2/hr.

(6) Material Group F includes:

9Cr–1Mo

TD at 1375°F = 0.109 ft^2/hr.

(7) Material Group G includes:

12Cr	13Cr–4Ni
12Cr–1Al	15Cr
13Cr	17Cr

(8) Material Group H includes:

27Cr

(9) Material Group I includes:

17Cr–4Ni–4Cu	15Cr–5Ni–3Mo (only to 800°F)

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TABLE TCD (CONT'D)

NOTES (CONT'D):

(10) Material Group J includes:

15Cr–6Ni–Cu–Mo (only to 800°F)	18Cr–8Ni–S (or Se)
17Cr–7Ni–1Al (only to 800°F)	18Cr–11Ni
18Cr–8Ni	23Cr–4Ni–Mo–Cu

These thermal conductivity and diffusivity values are also appropriate for H, L, N, and LN grades of austenitic stainless steels.

(11) Material Group K includes:

13Cr–8Ni–2Mo (only to 800°F)	19Cr–9Ni–Mo–W
29Cr–7Ni–2Mo–N	21Cr–11Ni–N
25Ni–15Cr–2Ti	22Cr–5Ni–3Mo–N
29Ni–20Cr–3Cu–2Mo	23Cr–12Ni
16Cr–12Ni–2Mo	25Cr–7Ni–4Mo–N
18Cr–5Ni–3Mo	25Cr–20Ni
18Cr–10Ni–Cb	25Cr–20Ni–2Mo
18Cr–10Ni–Ti	44Fe–25Ni–21Cr–Mo
18Cr–13Ni–3Mo	

These thermal conductivity and diffusivity values are also appropriate for H, L, N, and LN grades of austenitic stainless steels.

(12) Material Group L includes:

18Cr–18Ni–2Si	25Cr–12Ni
22Cr–13Ni–5Mn	25Cr–35Ni–N–Ce
24Cr–22Ni–7.5Mo	31Ni–31Fe–29Cr–Mo

These thermal conductivity and diffusivity values are also appropriate for H, L, N, and LN grades of austenitic stainless steels.

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TABLE TM-1
MODULI OF ELASTICITY E OF FERROUS MATERIALS FOR GIVEN TEMPERATURES

Materials	Modulus of Elasticity E = Value Given × 10^6 psi, for Temperature, °F, of															
	–325	–200	–100	70	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
Carbon steels with C ≤ 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	20.4	18.0	...	...	...	...
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	20.2	17.9	15.4	...	...	...
Material Group A [Note (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	20.1	17.8	15.3	...	...	...
Material Group B [Note (2)]	29.6	29.1	28.5	27.8	27.1	26.7	26.1	25.7	25.2	24.6	23.9	23.2	22.4	21.5	20.4	19.2	17.7	...
Material Group C [Note (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	23.9	23.0	21.8	20.5	18.9	...
Material Group D [Note (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	24.6	23.7	22.5	21.1	19.4	...
Material Group E [Note (5)]	33.0	32.4	31.8	31.0	30.2	29.8	29.1	28.7	28.1	27.4	26.8	26.2	25.4	24.5	23.3	22.0	20.5	...
Material Group F [Note (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	21.5	19.1	16.6	...	...	...
Material Group G [Note (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	22.8	22.1	21.2	20.2	19.2	18.1
S13800 [Note (8)]	31.5	30.9	30.3	29.4	28.7	28.1	27.5	26.9	26.3	25.7	25.0	24.4	...	...	...	...	...	...
S15500 [Note (9)]	30.5	29.9	29.4	28.5	27.8	27.2	26.6	26.1	25.5	24.9	24.2	23.7	...	...	...	...	...	...
S45000 [Note (10)]	31.6	31.0	30.4	29.5	28.8	28.2	27.6	27.0	26.4	25.8	25.1	24.5	...	...	...	...	...	...
S17400 [Note (11)]	30.5	29.9	29.4	28.5	27.8	27.2	26.6	26.1	25.5	24.9	24.2	23.7	...	...	...	...	...	...
S17700 [Note (12)]	31.6	31.0	30.4	29.5	28.8	28.2	27.6	27.0	26.4	25.8	25.1	24.5	...	...	...	...	...	...
S66286 [Note (13)]	31.2	30.7	30.1	29.2	28.5	27.9	27.3	26.7	26.1	25.6	24.8	24.2	...	...	...	...	...	...

Notes appear on following page.

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TABLE TM-1 (CONT'D)

GENERAL NOTES:
(a) For the SI unit, multiply the modulus of elasticity E by 6.895×10^6 kPa.
(b) See Table SI-1 for the conversion of temperatures to degrees Celsius.

NOTES:
(1) Material Group A consists of the following carbon–molybdenum and manganese steels:

C–¼Mo	Mn–½Mo–¼Ni
C–½Mo	Mn–½Mo–½Ni
Mn–¼Mo	Mn–½Ni–V
Mn–½Mo	Mn–V

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

¾Cr–½Ni–Cu	1¼Ni–1Cr–½Mo
¾Cr–¾Ni–Cu–Al	1¾Ni–¾Cr–¼Mo
½Ni–½Cr–¼Mo–V	2Ni–1½Cr–¼Mo–V
½Ni–½Mo–V	2Ni–1Cu
¾Ni–½Cr–½Mo–V	2½Ni
¾Ni–½Cu–Mo	2¾Ni–1½Cr–½Mo–V
¾Ni–½Mo–⅓Cr–V	3½Ni
¾Ni–½Mo–Cr–V	3½Ni–1¾Cr–½Mo–V
¾Ni–1Mo–¾Cr	4Ni–1½Cr–½Mo–V
1Ni–½Cr–½Mo	

(3) Material Group C consists of the following ½–2Cr steels:

½Cr–⅕Mo–V	1Cr–½Mo–V
½Cr–¼Mo–Si	1¼Cr–½Mo
½Cr–½Mo	1¼Cr–½Mo–Si
1Cr–⅕Mo	1¾Cr–½Mo–Ti
1Cr–½Mo	2Cr–½Mo

(4) Material Group D consists of the following 2¼–3Cr steels:

2¼Cr–1Mo	3Cr–1Mo

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

5Cr–½Mo	7Cr–½Mo
5Cr–½Mo–Si	9Cr–Mo, including variations thereof
5Cr–½Mo–Ti	

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

12Cr–Al	15Cr
13Cr	17Cr

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

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

(8) Also known as 13Cr–8Ni–2Mo, XM-13, or PH13-8Mo.
(9) Also known as 15Cr–5Ni–3Mo, XM-12, or 15-5PH.
(10) Also known as 15Cr–6Ni–Cu–Mo, Custom 450, or XM-25. Modulus values are for material aged at 900°F.
(11) Also known as 17Cr–4Ni–4Cu, Grade 630, or 17-4PH.
(12) Also known as 17Cr–7Ni–1Al, Grade 631, or 17-7PH.
(13) Also known as 25Ni–15Cr–2Ti, Grade 660, or A-286 stainless steel.

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TABLE TM-2
MODULI OF ELASTICITY *E* OF ALUMINUM AND ALUMINUM ALLOYS
FOR GIVEN TEMPERATURES

	Modulus of Elasticity E = Value Given × 10^6 psi, for Temperature, °F, of							
Material	–325	–200	–100	70	200	300	400	500
A03560	11.4	11.1	10.8	10.3	9.8	9.5	9.0	8.1
A95083	11.4	11.1	10.8	10.3	9.8	9.5	9.0	8.1
A95086	11.4	11.1	10.8	10.3	9.8	9.5	9.0	8.1
A95456	11.4	11.1	10.8	10.3	9.8	9.5	9.0	8.1
A24430	11.1	10.8	10.5	10.0	9.6	9.2	8.7	8.1
A91060	11.1	10.8	10.5	10.0	9.6	9.2	8.7	8.1
A91100	11.1	10.8	10.5	10.0	9.6	9.2	8.7	8.1
A93003	11.1	10.8	10.5	10.0	9.6	9.2	8.7	8.1
A93004	11.1	10.8	10.5	10.0	9.6	9.2	8.7	8.1
A96061	11.1	10.8	10.5	10.0	9.6	9.2	8.7	8.1
A96063	11.1	10.8	10.5	10.0	9.6	9.2	8.7	8.1
A92014	11.7	11.4	11.1	10.6	10.1	9.8	9.2	8.6
A92024	11.7	11.4	11.1	10.6	10.1	9.8	9.2	8.6
A95052	11.3	11.0	10.7	10.2	9.7	9.4	8.9	8.3
A95154	11.3	11.0	10.7	10.2	9.7	9.4	8.9	8.3
A95254	11.3	11.0	10.7	10.2	9.7	9.4	8.9	8.3
A95454	11.3	11.0	10.7	10.2	9.7	9.4	8.9	8.3
A95652	11.3	11.0	10.7	10.2	9.7	9.4	8.9	8.3

GENERAL NOTES:
(a) For the SI unit, multiply the modulus of elasticity E by 6.895×10^6 kPa.
(b) See Table SI-1 for the conversion of temperatures to degrees Celsius.

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TABLE TM-3
MODULI OF ELASTICITY *E* OF COPPER AND COPPER ALLOYS FOR GIVEN TEMPERATURES

	Modulus of Elasticity E = Value Given × 10^6 psi, for Temperature, °F, of									
Material	–325	–200	–100	70	200	300	400	500	600	700
C93700	11.6	11.4	11.3	11.0	10.7	10.6	10.3	10.1	9.8	9.4
C83600	14.8	14.6	14.4	14.0	13.7	13.4	13.2	12.9	12.5	12.0
C92200	14.8	14.6	14.4	14.0	13.7	13.4	13.2	12.9	12.5	12.0
C28000	15.9	15.6	15.4	15.0	14.6	14.4	14.1	13.8	13.4	12.8
C36500	15.9	15.6	15.4	15.0	14.6	14.4	14.1	13.8	13.4	12.8
C46400	15.9	15.6	15.4	15.0	14.6	14.4	14.1	13.8	13.4	12.8
C65500	15.9	15.6	15.4	15.0	14.6	14.4	14.1	13.8	13.4	12.8
C66100	15.9	15.6	15.4	15.0	14.6	14.4	14.1	13.8	13.4	12.8
C95200	15.9	15.6	15.4	15.0	14.6	14.4	14.1	13.8	13.4	12.8
C95400	15.9	15.6	15.4	15.0	14.6	14.4	14.1	13.8	13.4	12.8
C44300	16.9	16.6	16.5	16.0	15.6	15.4	15.0	14.7	14.2	13.7
C44400	16.9	16.6	16.5	16.0	15.6	15.4	15.0	14.7	14.2	13.7
C44500	16.9	16.6	16.5	16.0	15.6	15.4	15.0	14.7	14.2	13.7
C64200	16.9	16.6	16.5	16.0	15.6	15.4	15.0	14.7	14.2	13.7
C68700	16.9	16.6	16.5	16.0	15.6	15.4	15.0	14.7	14.2	13.7
C10200	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C10400	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C10500	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C10700	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C11000	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C12000	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C12200	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C12300	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C12500	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C14200	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C23000	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C61000	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C61400	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C65100	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C70400	18.0	17.7	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5
C19400	18.5	18.2	18.0	17.5	17.1	16.8	16.5	16.1	15.6	15.0
C60800	18.5	18.2	18.0	17.5	17.1	16.8	16.5	16.1	15.6	15.0
C63000	18.5	18.2	18.0	17.5	17.1	16.8	16.5	16.1	15.6	15.0
C70600	19.0	18.7	18.5	18.0	17.6	17.3	16.9	16.6	16.0	15.4
C97600	20.1	19.8	19.6	19.0	18.5	18.2	17.9	17.5	16.9	16.2
C71000	21.2	20.8	20.6	20.0	19.5	19.2	18.8	18.4	17.8	17.1
C71500	23.3	22.9	22.7	22.0	21.5	21.1	20.7	20.2	19.6	18.8

GENERAL NOTES:
(a) For the SI unit, multiply the modulus of elasticity E by 6.895×10^6 kPa.
(b) See Table SI-1 for the conversion of temperatures to degrees Celsius.

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TABLE TM-4
MODULI OF ELASTICITY E OF HIGH NICKEL ALLOYS FOR GIVEN TEMPERATURES

	Modulus of Elasticity E = Value Given × 10^6 psi, for Temperature, °F, of														
Material	–325	–200	–100	70	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
N02200	32.1	31.5	30.9	30.0	29.3	28.8	28.5	28.1	27.8	27.3	26.7	26.1	25.5	25.1	24.5	23.9	23.1	22.4
N02201	32.1	31.5	30.9	30.0	29.3	28.8	28.5	28.1	27.8	27.3	26.7	26.1	25.5	25.1	24.5	23.9	23.1	22.4
N04400	27.8	27.3	26.8	26.0	25.4	25.0	24.7	24.3	24.1	23.7	23.1	22.6	22.1	21.7	21.2	20.7	20.0	19.4
N04405	27.8	27.3	26.8	26.0	25.4	25.0	24.7	24.3	24.1	23.7	23.1	22.6	22.1	21.7	21.2	20.7	20.0	19.4
N06002	30.5	29.9	29.4	28.5	27.8	27.4	27.1	26.6	26.4	25.9	25.4	24.8	24.2	23.7	23.2	22.6	21.9	21.2
N06007	29.7	29.2	28.6	27.8	27.1	26.7	26.4	26.0	25.7	25.3	24.7	24.2	23.6	23.2	22.7	22.1	21.4	20.7
N06455	31.9	31.3	30.7	29.8	29.1	28.6	28.3	27.9	27.6	27.1	26.5	25.9	25.3	24.9	24.3	23.7	22.9	22.2
N06600	33.2	32.6	31.9	31.0	30.2	29.8	29.5	29.0	28.7	28.2	27.6	27.0	26.4	25.9	25.3	24.6	23.9	23.1
N06625	32.1	31.5	30.9	30.0	29.3	28.8	28.5	28.1	27.8	27.3	26.7	26.1	25.5	25.1	24.5	23.9	23.1	22.4
N06690	32.5	31.9	31.2	30.3	29.5	29.1	28.8	28.3	28.1	27.6	27.0	26.4	25.8	25.3	24.7	24.1	23.3	22.6
N07718	31.0	30.5	29.9	29.0	28.3	27.8	27.6	27.1	26.8	26.4	25.8	25.2	24.7	24.2	...	...	...	...
N07750	33.2	32.6	31.9	31.0	30.2	29.8	29.5	29.0	28.7	28.2	27.6	27.0	26.4	25.9	25.3	...	...	...
N08020	30.0	29.4	28.8	28.0	27.3	26.9	26.6	26.2	25.9	25.5	24.9	24.4	23.8	23.4	22.8	22.3	21.6	20.9
N08330	30.0	29.4	28.8	28.0	27.3	26.9	26.6	26.2	25.9	25.5	24.9	24.4	23.8	23.4	22.8	22.3	21.6	20.9
N08800	30.5	29.9	29.4	28.5	27.8	27.4	27.1	26.6	26.4	25.9	25.4	24.8	24.2	23.8	23.2	22.7	21.9	21.2
N08810	30.5	29.9	29.4	28.5	27.8	27.4	27.1	26.6	26.4	25.9	25.4	24.8	24.2	23.8	23.2	22.7	21.9	21.2
N08825	30.0	29.4	28.8	28.0	27.3	26.9	26.6	26.2	25.9	25.5	24.9	24.4	23.8	23.4	22.8	22.3	21.6	20.9
N10001	33.3	32.7	32.0	31.1	30.3	29.9	29.5	29.1	28.8	28.3	27.7	27.1	26.4	26.0	25.3	24.7	23.9	23.2
N10003	33.9	33.3	32.7	31.7	30.9	30.4	30.1	29.6	29.3	28.8	28.2	27.6	26.9	26.5	25.8	25.2	24.4	23.6
N10276	31.9	31.3	30.7	29.8	29.1	28.6	28.3	27.9	27.6	27.1	26.5	25.9	25.3	24.9	24.3	23.7	22.9	22.2
N10665	33.6	33.0	32.3	31.4	30.6	30.1	29.8	29.3	29.0	28.6	27.9	27.3	26.7	26.2	25.6	25.0	24.2	23.4

GENERAL NOTES:
(a) For the SI unit, multiply the modulus of elasticity E by 6.895×10^6 kPa.
(b) See Table SI-1 for the conversion of temperatures to degrees Celsius.

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TABLE TM-5
MODULI OF ELASTICITY *E* OF TITANIUM AND ZIRCONIUM FOR GIVEN TEMPERATURES

Material Grade/UNS No.	Modulus of Elasticity E = Value Given × 10^6 psi, for Temperature, °F, of							
	70	200	300	400	500	600	700	800
Titanium Alloys								
1 (R50250)	15.5	15.0	14.6	14.0	13.3	12.6	11.9	11.2
2 (R50400)	15.5	15.0	14.6	14.0	13.3	12.6	11.9	11.2
3 (R50550)	15.5	15.0	14.6	14.0	13.3	12.6	11.9	11.2
7 (R52400)	15.5	15.0	14.6	14.0	13.3	12.6	11.9	11.2
9 (R56320)	15.9	15.3	14.6	13.9	13.2	12.4	...	...
12 (R53400)	15.5	15.0	14.6	14.0	13.3	12.6	11.9	11.2
16 (R52402)	15.5	15.0	14.6	14.0	13.3	12.6	11.9	11.2
17 (R52252)	15.5	15.0	14.6	14.0	13.3	12.6	11.9	11.2
Zirconium Alloys								
702 (R60702)	14.4	...	...	...	...	...	...	...
705 (R60705)	14.2	...	...	...	...	...	...	...

GENERAL NOTES:
(a) For the SI unit, multiply the modulus of elasticity E by 6.895×10^6 kPa.
(b) See Table SI-1 for the conversion of temperatures to degrees Celsius.

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TABLE NF-1
TYPICAL MECHANICAL PROPERTIES OF MATERIALS

Material	Poisson's Ratio	Modulus of Rigidity, psi
Aluminum	0.33	3,800,000
Copper, Deoxidized	0.33	6,400,000
Red Brass	0.33	6,400,000
Admiralty	0.33	6,000,000
Aluminum Brass	0.33	6,000,000
Naval Brass	0.33	5,600,000
Muntz Metal	0.33	5,600,000
30% Cupro Nickel	0.33	8,200,000
20% Cupro Nickel	0.33	7,500,000
10% Cupro Nickel	0.33	6,800,000
Copper–Silicon (A, C, D)	0.33	5,600,000
Copper–Silicon (B)	0.33	6,400,000
Aluminum Bronze (D)	0.33	6,500,000
Aluminum Bronze (E)	0.33	6,400,000
Nickel	0.31	11,000,000
Nickel–Copper	0.32	9,500,000
Ni–Cr–Fe	0.29	11,000,000
Unalloyed Titanium	0.32	6,000,000
Titanium Grades 16 and 17	0.32	6,000,000
Nickel–Iron–Chromium	0.339	10,600,000
Zirconium	0.35	5,250,000
Cr–Ni–Fe–Mo–Cu–Cb	0.31	11,000,000

GENERAL NOTES:
(a) See Tables TM-2 through TM-4 for modulus of elasticity values as a function of temperature.
(b) For the SI unit, multiply by 6.895 to convert to kPa.

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TABLE NF-2
TYPICAL PHYSICAL PROPERTIES OF NONFERROUS MATERIALS

Material	Corresponding UNS No.	Density, lb/cu in. [Note (1)]	Approx. Melting Range, °F [Note (2)]	Specific Heat, Btu/lb/°F at 212°F (100°C) [Note (3)]
356.0 (SG70A)	A03560	0.097	1035–1135	0.23
B443.0 (S5A)	A24430	0.097	1065–1170	0.23
Al alloy 1060	A91060	0.098	1195–1215	0.23
Al alloy 1100	A91100	0.098	1190–1215	0.23
Al alloy 2014	A92014	0.101	945–1180	0.23
Al alloy 2024	A92024	0.101	935–1180	0.23
Al alloy 3003	A93003	0.099	1190–1210	0.23
Al alloy 3004	A93004	0.098	1165–1211	0.23
Al alloy 5052	A95052	0.097	1125–1200	0.23
Al alloy 5083	A95083	0.096	1095–1180	0.23
Al alloy 5086	A95086	0.096	1085–1185	0.23
Al alloy 5154	A95154	0.096	1100–1190	0.23
Al alloy 5254	A95254	0.096	1100–1190	0.23
Al alloy 5454	A95454	0.097	1115–1195	0.23
Al alloy 5456	A95456	0.096	1055–1180	0.23
Al alloy 5652	A95652	0.097	1125–1200	0.23
Al alloy 6061	A96061	0.098	1080–1205	0.23
Al alloy 6063	A96063	0.097	1140–1210	0.23
Copper, deoxidized	C10200, C12000, C12200, C14200	0.323	1980	0.09
Red brass	C23000	0.316	1810–1880	0.09
Muntz metal	C36500	0.303	1650–1660	0.09
Admiralty	C44300, C44400, C44500	0.308	1650–1720	0.09
Naval brass	C46400, C46500	0.304	1630–1650	0.09
Aluminum bronze	C60800	0.301	1710–1780	0.09
Aluminum bronze (D)	C61400	0.281	1850–1900	0.09
Aluminum bronze (E)	C63000	0.274	1900–1930	0.09
Copper–silicon (B)	C65100	0.316	1890–1940	0.09
Copper–silicon (A and D)	C65500, C66100	0.308	1780–1880	0.09
10% Cupro nickel	C70600	0.323	2020–2100	0.09
20% Cupro nickel	C71000	0.323	2100–2200	0.09
30% Cupro nickel	C71500	0.323	2140–2260	0.09
Nickel and low carbon nickel	N02200, N02201	0.321	2615–2635	0.13
Nickel–copper	N04400	0.319	2370–2460	0.13
Ni–Cr–Fe	N06600	0.300	2540–2600	0.11
Ni–Cr–Fe	N06690	0.293	...	...
Cr–Ni–Fe–Mo–Cu–Cb	N08020	0.291	2550–2600	0.12
Ni–Fe–Cr–Mo	N08028	0.289	...	...
Ni–Fe–Cr	N08800, N08810, N08811	0.290	2475–2525	0.12
Ni–Cr–Mo–Cu	N08825	0.293	...	...
Titanium, unalloyed	R50250, R50400, R50550, R50700, R52400	0.163	3100	0.13
Zirconium	R60702, R60704, R60705	0.234	3350	0.068

Notes appear on following page.

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TABLE NF-2 (CONT'D)

GENERAL NOTES:
(a) See Tables TE-2 through TE-5 for thermal expansion as a function of temperature.
(b) See Table TCD for thermal conductivity as a function of temperature.

NOTES:
(1) For SI units, multiply by 2.768×10^4 to convert to kg/m^3.
(2) See Table SI-1 for the conversion of temperatures to degrees Celsius.
(3) For SI units, multiply by 4.1868×10^3 to convert to J/(kg•K).

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