IX. THERMAL EXPANSIVITY OF SOLIDS

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INTRODUCTION TO THERMAL EXPANSIVITY OF SOLIDS

Values of thermal expansion are given in the form of (a) total fractional expansion, $\frac{L_{293} - L_T}{L_{293}}$; and (b) by coefficient of expansion $\frac{1}{L} \frac{dL}{dT}$, change per unit length per ^{o}K. For example the total fractional expansion (or contraction) for copper for a temperature change from 293.15^{o}K (20^{o}C) to 50^{o}K is .00321 in./in., i.e., a bar will be .00321 inches shorter at 50^{o}K per inch of length than it was at 293.15 ^{o}K. However, the coefficient of expansion for copper at 50^{o}K is.0000038 in./in.-^{o}K, i.e. it will expand (or contract) .0000038 inches per inch per ^{o}K temperature change from 50^{o}K.

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THERMAL EXPANSION OF ALUMINUM

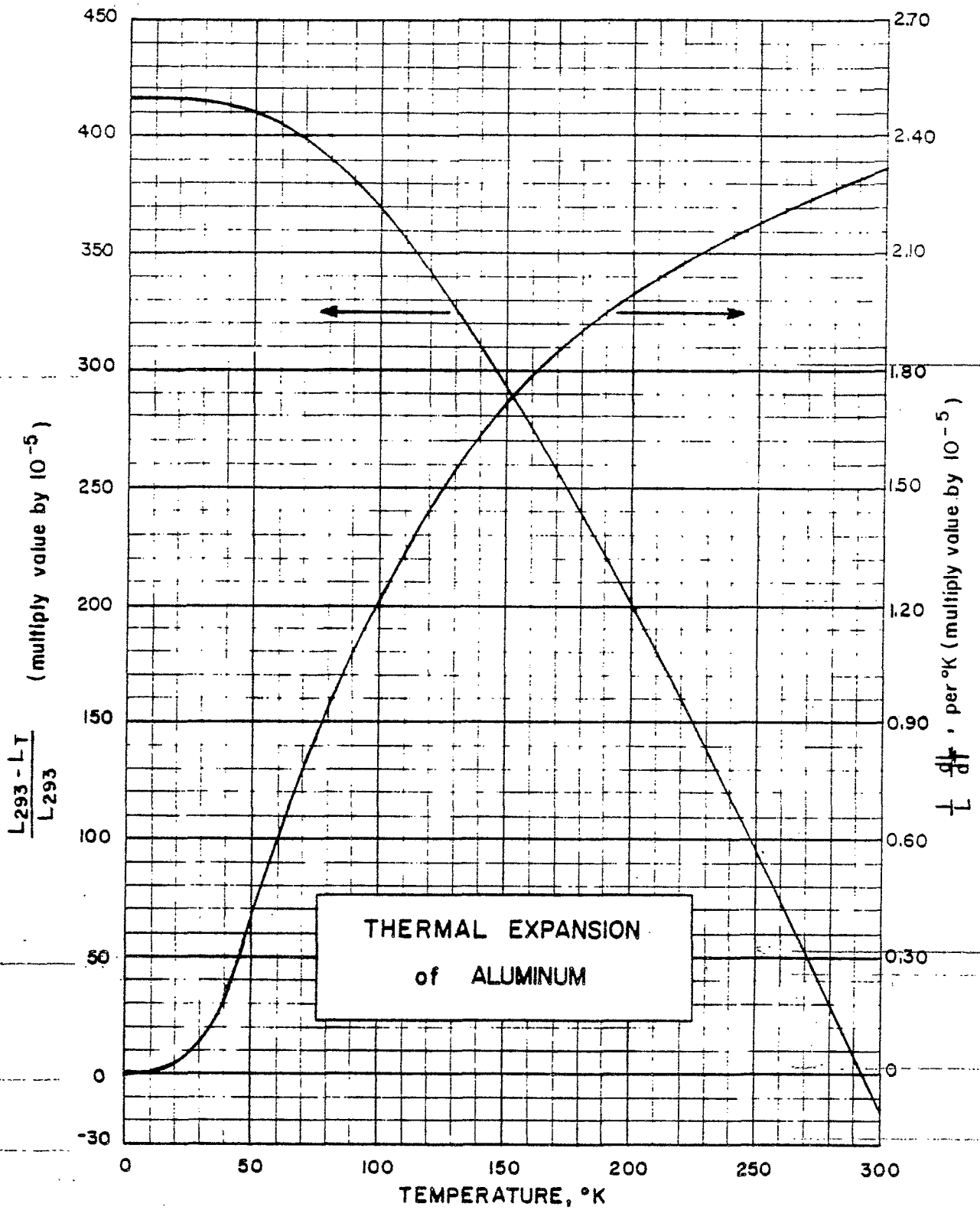
Source of Data: Altman, Rubin and Johnston 1954.

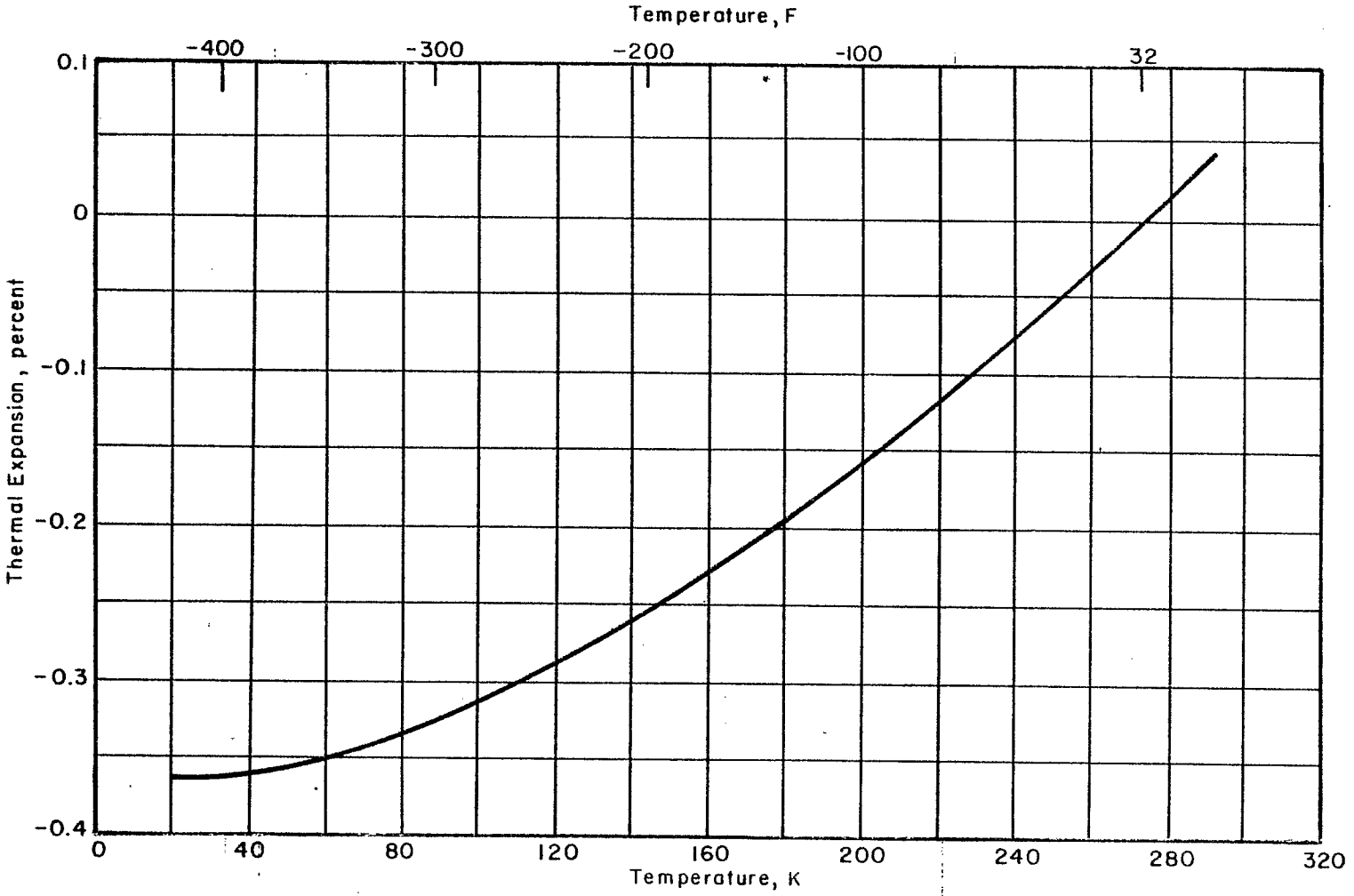
Other References: Ayres 1950, Bijl and Pullan 1955, Buffington and Latimer 1926, Ebert 1928, Gibbons 1958, Henning 1907, Hume-Rothery and Strawbridge 1947, Lindemann 1911, Nix and MacNair 1941.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	415×10^{-5}	0	120	343×10^{-5}	1.46×10^{-5}
10	415 "	$-.005 \times 10^{-5}$	140	312 "	1.65 "
20	415 "	.02 "	160	277 "	1.79 "
30	414 "	.09 "	180	240 "	1.90 "
40	413 "	.22 "	200	201 "	2.00 "
50	410 "	.38 "	220	160 "	2.08 "
60	405 "	.55 "	240	118 "	2.15 "
70	399 "	.74 "	260	75 "	2.21 "
80	391 "	.91 "	273	45 "	2.25 "
90	381 "	1.07 "	280	30 "	2.27 "
100	370 "	1.22 "	293	0 "	2.30 "
			300	-16 "	2.32 "

Taken from NBS 29


THERMAL EXPANSION
of ALUMINUM
$\frac{L_{293} - L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
450
400
350
300
250
200
150
100
50
0
-30
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0
0
50
100
150
200
250
300



THERMAL EXPANSION VERSUS TEMPERATURE FOR ALUMINUM ALLOY 1100-0

THERMAL EXPANSION OF BERYLLIUM

Sources of Data: Erfling 1939
Hidnert and Sweeney 1927

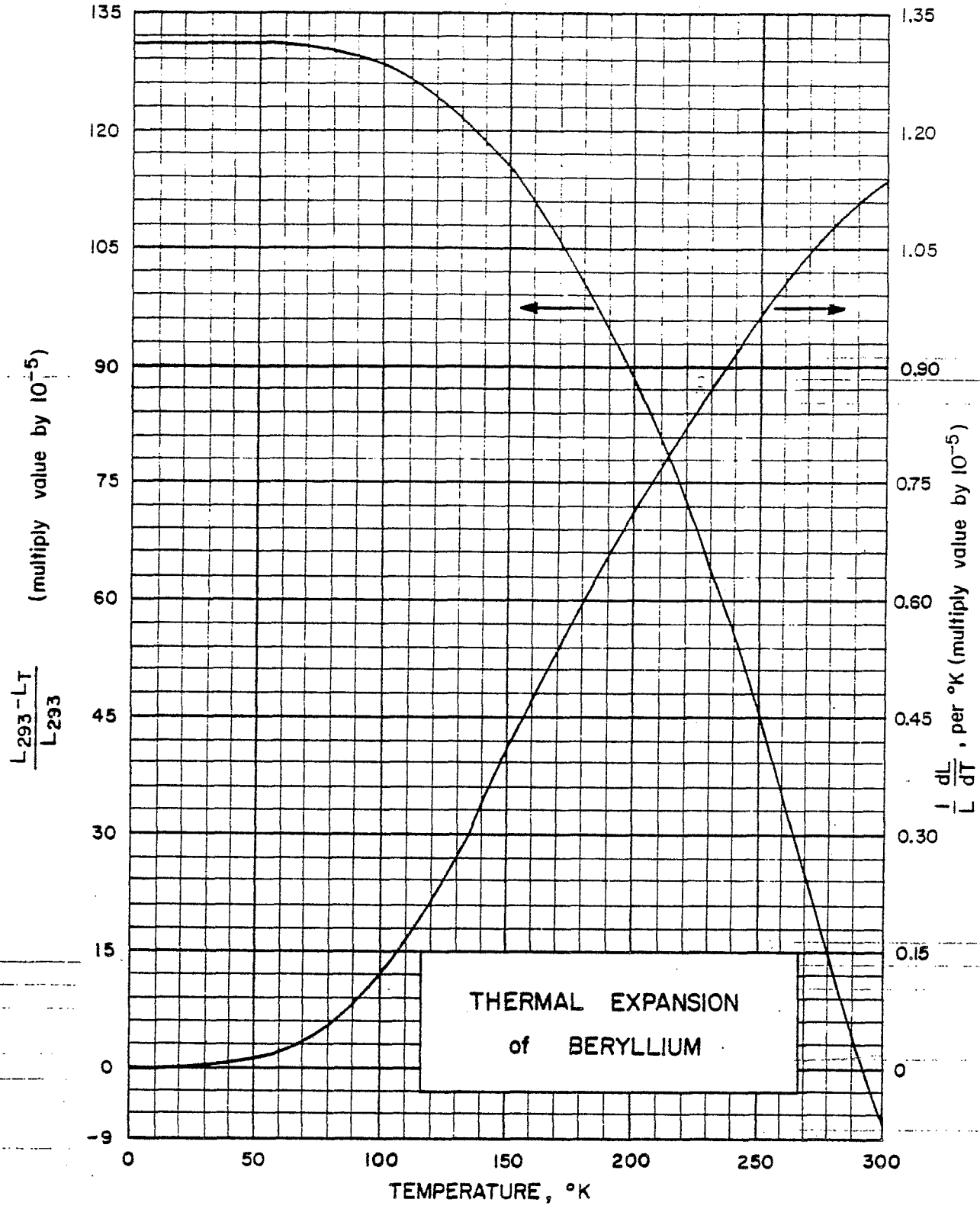
Other References: Head and Laquer 1952

Discussion: Anisotropic. The above values were calculated from the relation, Mean Value = 1/3 (∥)+2/3(⊥), where (∥) and (⊥) signify the the same property measured parallel and perpendicular, respectively, to the trigonal (Sb,Bi) or hexagonal (Be, Cd) axis.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	131×10^{-5}	0.	140	119×10^{-5}	$.34 \times 10^{-5}$
20	131 "	0.001×10^{-5}	160	111 "	.47 "
30	131 "	.003 "	180	100 "	.59 "
40	131 "	.007 "	200	87.3 "	.71 "
50	131 "	.013 "	220	72.0 "	.82 "
60	131 "	.02 "	240	54.6 "	.92 "
70	130 "	.04 "	260	35.2 "	1.01 "
80	130 "	.06 "	273	21.8 "	1.06 "
90	129 "	.09 "	280	14.3 "	1.08 "
100	128 "	.13 "	293	0.0 "	1.12 "
120	124 "	.22 "	300	-7.9 "	1.14 "

Taken from NBS 29


THERMAL EXPANSION
of BERYLLIUM
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
135
120
105
90
75
60
45
30
15
0
-9
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0
0
50
100
150
200
250
300

THERMAL EXPANSION OF BERYLLIUM COPPER

Sources of Data: Beenakker and Swenson 1955

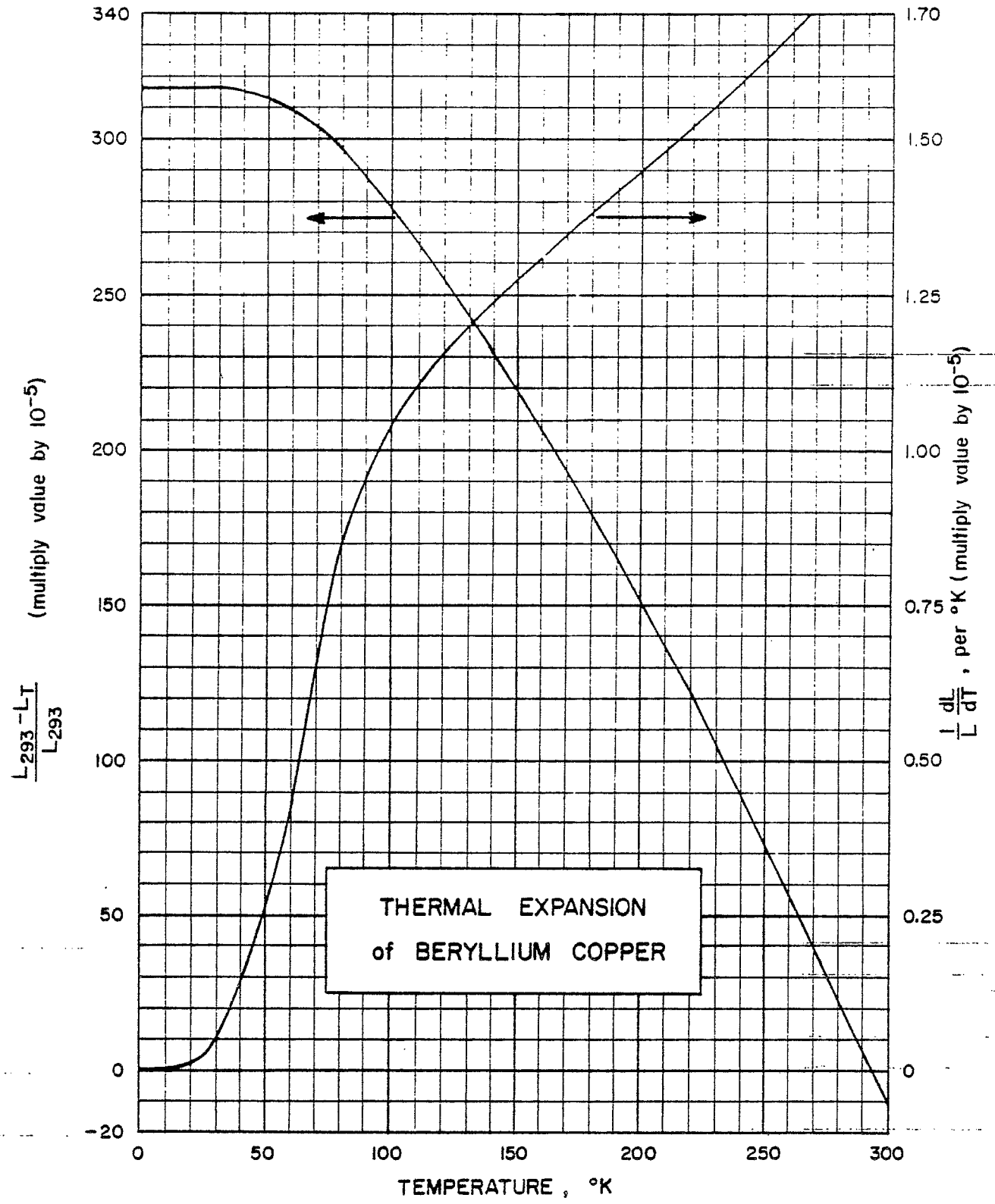
Other References:

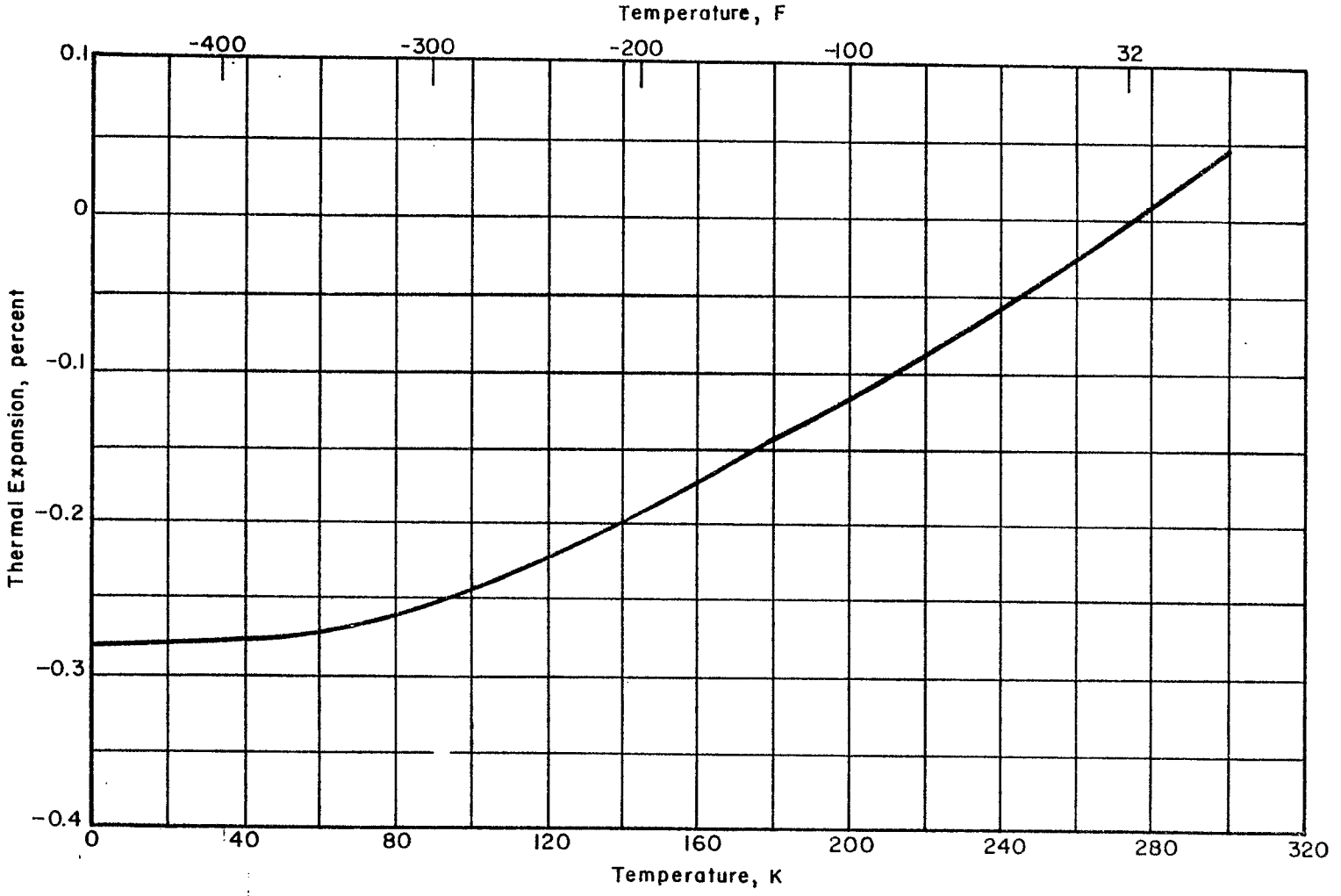
Discussion: 2 Be, 0.3 Co, bal. Cu (BERYLCO 25). Originally half-hard, then heat treated for 2 hours at 200° C. No observable difference was found in the thermal expansions for the two states of hardness.

Table of Selected Values

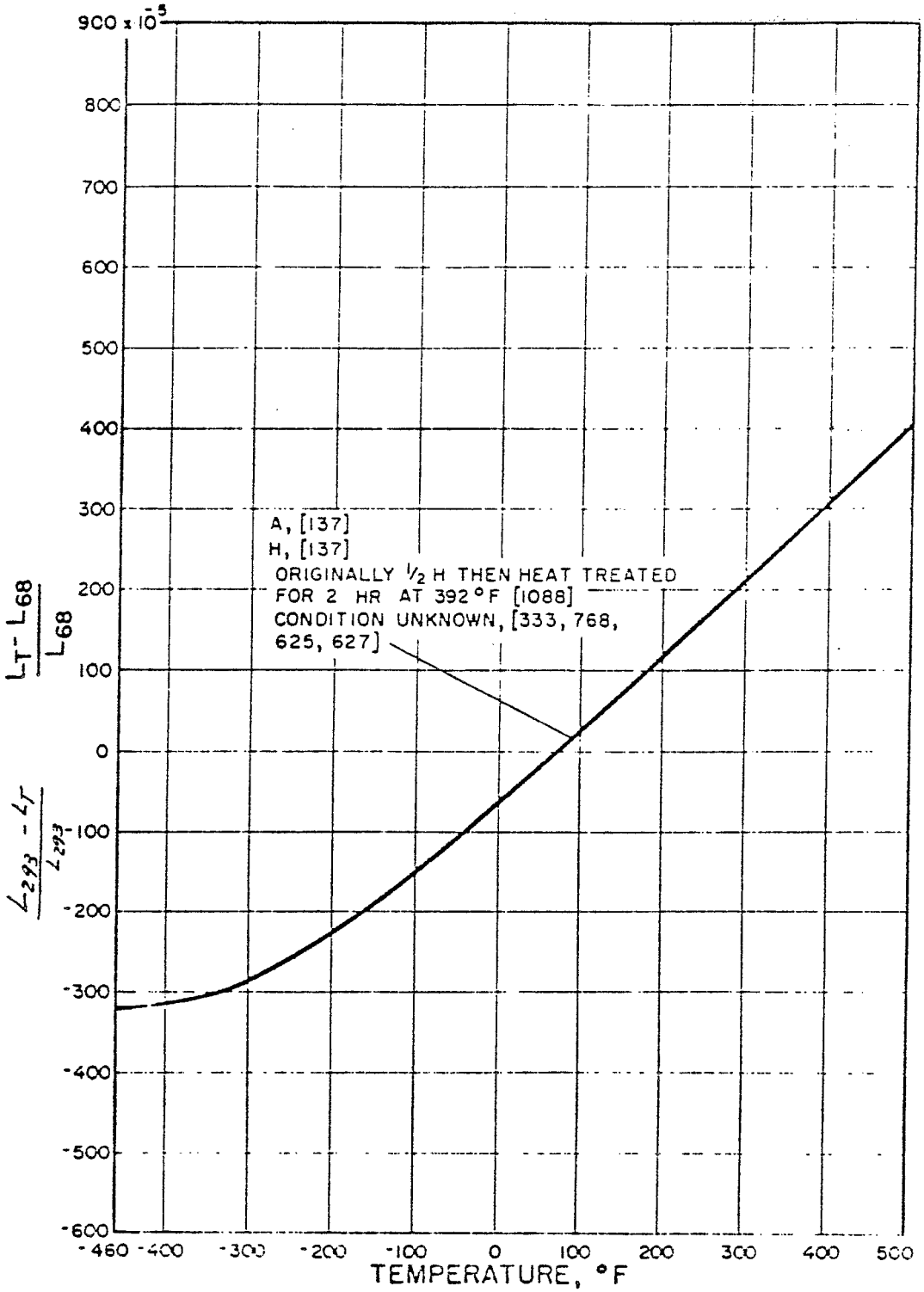
Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	316×10^{-5}	0.	140	231×10^{-5}	1.24×10^{-5}
10	316 "	0.004×10^{-5}	160	206 "	1.32 "
20	316 "	.009 "	180	179 "	1.38 "
30	316 "	.05 "	200	151 "	1.45 "
40	315 "	.14 "	220	121 "	1.52 "
50	313 "	.27 "	240	90 "	1.60 "
60	309 "	.43 "	260	57 "	1.67 "
70	304 "	.65 "	273	35 "	1.72 "
80	296 "	.84 "	280	23 "	1.74 "
90	287 "	.96 "	293	0 "	1.79 "
100	277 "	1.04 "	300	-13 "	1.81 "
120	255 "	1.16 "			

Taken from NBS 29


THERMAL EXPANSION
of BERYLLIUM COPPER
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
340
300
250
200
150
100
50
0
-20
1.70
1.50
1.25
1.00
0.75
0.50
0.25
0
0
50
100
150
200
250
300



THERMAL EXPANSION VERSUS TEMPERATURE FOR COPPER ALLOY 98 CU-2 BE



THERMAL EXPANSION OF BERYLCO* 25

*THE BERYLLIUM CORPORATION OF AMERICA

THERMAL EXPANSION OF BRASS (YELLOW)

Sources of Data: Altman, Rubin, and Johnston 1954

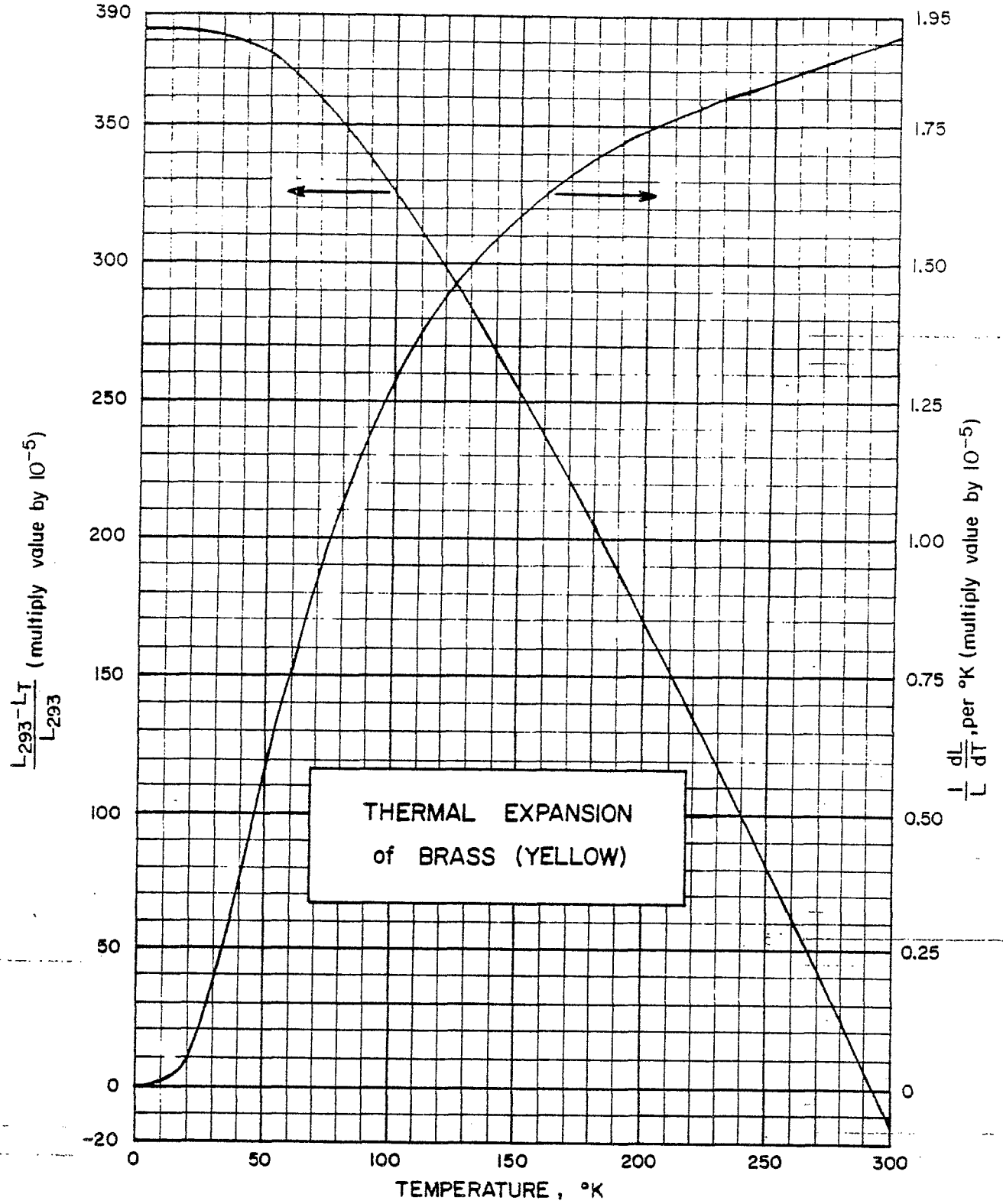
Other References: Beenakker and Swenson 1955
Fraser and Hollis-Hallet 1955
Henning 1907
Keyston, MacPherson, and Guptill 1959

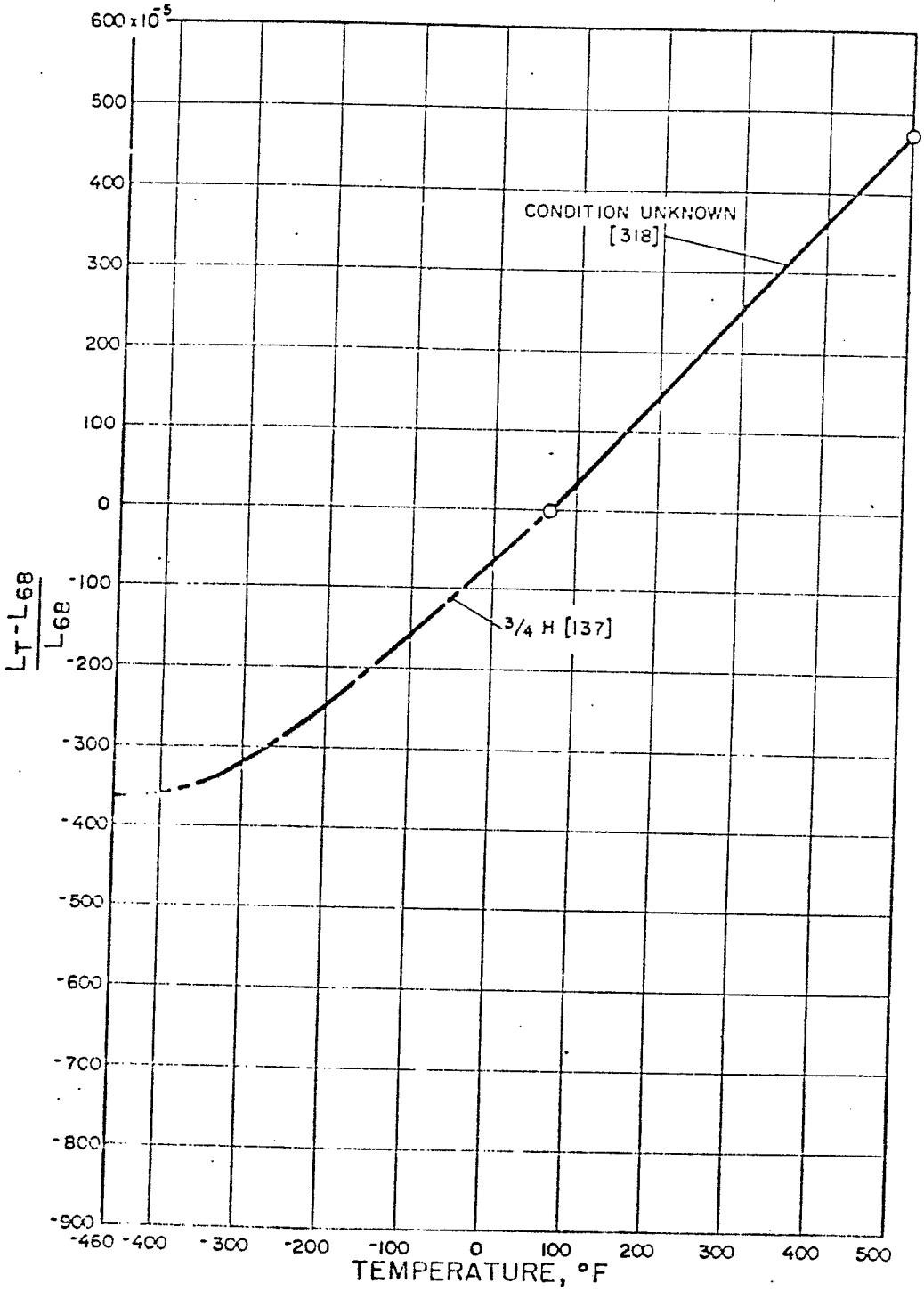
Discussion: 65 Cu, 35 Zn.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	384×10^{-5}	0	140	269×10^{-5}	1.54×10^{-5}
10	384 "	0.001×10^{-5}	160	237 "	1.63 "
20	383 "	.05 "	180	204 "	1.69 "
30	382 "	.18 "	200	169 "	1.74 "
40	380 "	.37 "	220	134 "	1.78 "
50	375 "	.58 "	240	98.4 "	1.81 "
60	368 "	.76 "	260	61.8 "	1.85 "
70	360 "	.92 "	273	37.3 "	1.87 "
80	350 "	1.06 "	280	24.6 "	1.88 "
90	339 "	1.18 "	293	0.0 "	1.90 "
100	326 "	1.29 "	300	-13.3 "	1.91 "
120	299 "	1.44 "			

Taken from NBS 29


THERMAL EXPANSION
of BRASS (YELLOW)
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
390
350
300
250
200
150
100
50
0
-20
1.95
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
0
50
100
150
200
250
300



THERMAL EXPANSION OF 70/30 BRASS

THERMAL EXPANSION OF CONSTANTAN

Sources of Data: Aoyama and Ito 1939
Krupkowski and deHaas 1928

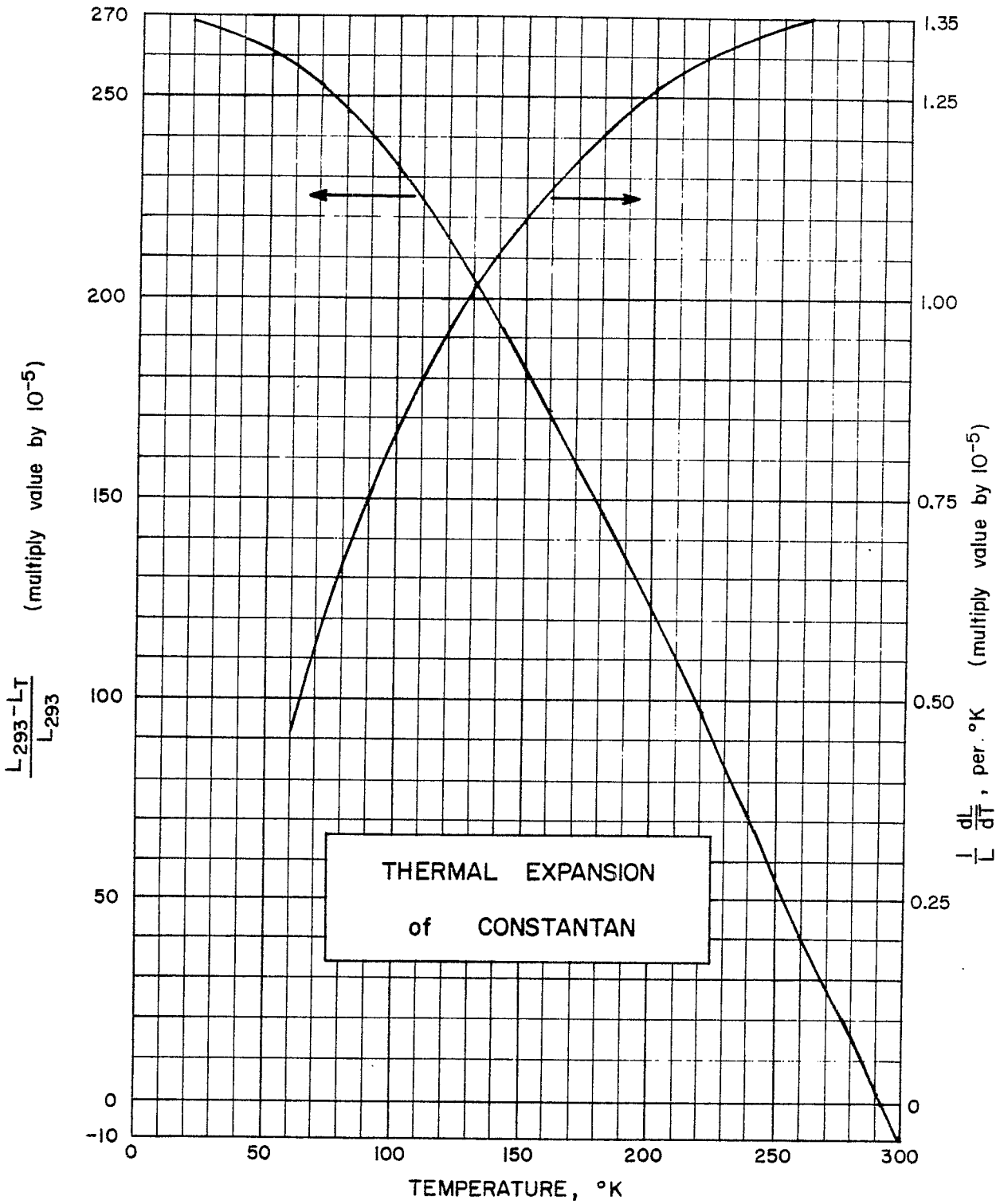
Other References: Henning 1907
Krupkowski 1929

Discussion: 50 Cu, 50 Ni. The name Constantan is applied to binary alloys in the range, 60 to 45 Cu, 40 to 55 Ni. The most common composition is 55 Cu, 45 Ni. The above expansion data should represent all Constantans within a few percent. Small expansion anomalies of magnetic origin occur in this system. The ferromagnetic Curie points range from about 0 °K for 40% Ni to roughly 150 °K for 55% Ni.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
20	269×10^{-5}	
60	258 "	0.46×10^{-5}
70	253 "	.56 "
80	247 "	.66 "
90	240 "	.75 "
100	232 "	.83 "
120	214 "	.96 "
140	194 "	1.06 "
160	172 "	1.14 "
180	148×10^{-5}	1.21×10^{-5}
200	124 "	1.26 "
220	98.1 "	1.30 "
240	71.8 "	1.33 "
260	45.0 "	1.35 "
273	27.3 "	1.36 "
280	17.8 "	1.37 "
293	0.0 "	1.37 "
300	-9.6 "	1.38 "

Taken from NBS 29


THERMAL EXPANSION
of CONSTANTAN
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per. °K (multiply value by 10^{-5})
TEMPERATURE, °K
270
250
200
150
100
50
0
-10
1.35
1.25
1.00
0.75
0.50
0.25
0
0
50
100
150
200
250
300

THERMAL EXPANSION OF COPPER

Source of Data:

Rubin, T., Altman, H.W. and Johnston, H.L., J.Am.Chem.Soc. 76, 5289-93 (1954)

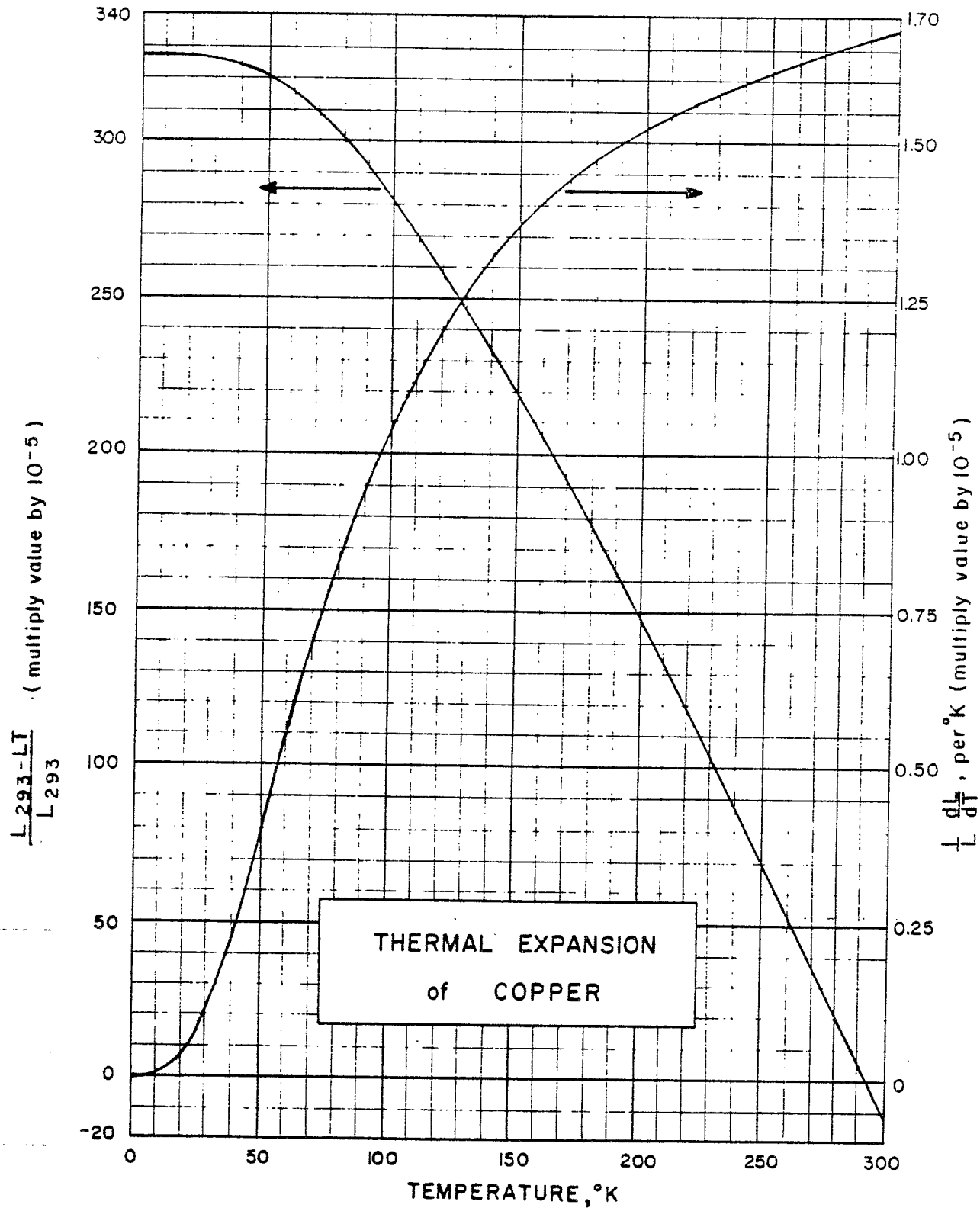
Other References:

Simmons,R.O. and Balluffi, R.W., Phys.Rev. 108, 278-80 (1957)
Beenakker, J.J.M. and Swenson, C.A., Rev.Sci.Instr. 26 1204 (1955)
Bijl,D. and Pullan H., Physica 21, 285 (1955)
Fraser, D.B. and Hollis-Hallet, A.C., Proc. 9th Intern. Congr. Refrig. 1, 1065 (1955)
Nix, F.C. and MacNair, D., Phys. Rev. 60, 597-605 (1941)
Aoyama, S. and Ito, T., Sci.Repts. Tohoku Univ. 27, 348-64 (1939)
Adenstedt, H., Ann. Physik 26, 69-96 (1936)
Simon, F. and Bergmann, R., Z. Physik Chem. 8, 255-80 (1930)
Krupkowski, A. and DeHaas, W.J., Communs. Phys. Lab. Univ. Leiden 194b (1928)
Keesom, W.H., Van Agt, F.P.G. and Jansen, A.T.J., Proc. Acad.Sci. Amsterdam 29, 786-91 (1926)
Buffington, R.M. and Latimer, W.M., J.Am.Chem.Soc. 48 2305-19 (1926)
Borelius, G. and Johansson, C.H., Ann. Physik 75, 23-36 (1924)
Lindemann, C.L., Phys. Z. 12, 1197-99 (1911)
Henning, F., Ann. Physik (4) 22, 631-39 (1907)
Dorsey, H.G., Phys. Rev. 25, 88-102 (1907)
Keyston, MacPherson and Gupstill (1959)

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	326×10^{-5}	0	120	260×10^{-5}	1.20×10^{-5}
10	326 "	0.004×10^{-5}	140	235 "	1.32 "
20	326 "	.03 "	160	208 "	1.41 "
30	325 "	.10 "	180	179 "	1.47 "
40	324 "	.23 "	200	149 "	1.52 "
50	321 "	.38 "	220	118 "	1.56 "
60	316 "	.55 "	240	87 "	1.59 "
70	310 "	.70 "	260	55 "	1.62 "
80	302 "	.84 "	273	33 "	1.64 "
90	293 "	.95 "	280	22 "	1.65 "
100	283 "	1.05 "	293	0 "	1.67 "
			300	-11 "	1.68 "

Taken from NBS 29


THERMAL EXPANSION
of COPPER
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
340
300
250
200
150
100
50
0
-20
0
50
100
150
200
250
300
1.70
1.50
1.25
1.00
0.75
0.50
0.25
0

THERMAL EXPANSION OF CROWN C-1 GLASS

Sources of Data: Molby 1949.

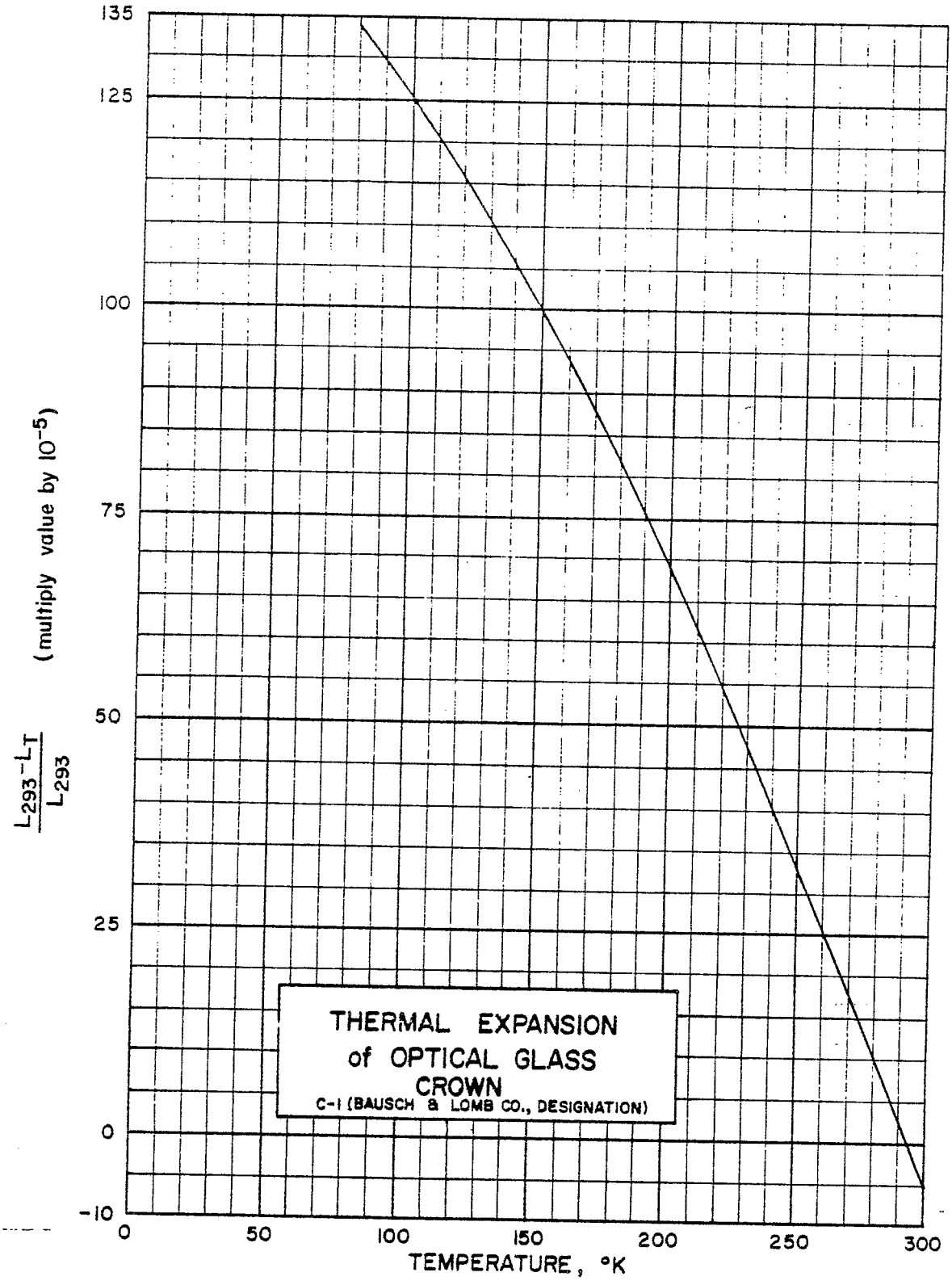
Other References: Dorsey 1907.

Discussion: Bausch and Lomb Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	134×10^{-5}	220	55×10^{-5}
90	130 "	240	41 "
100	126 "	260	26 "
120	116 "	273	16 "
140	105 "	280	10 "
160	95 "	293	0 "
180	82 "	300	-6 "
200	69 "		

Taken from NBS 29


135
125
100
75
50
25
0
-10
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of OPTICAL GLASS
CROWN
C-1 (BAUSCH & LOMB CO., DESIGNATION)

THERMAL EXPANSION OF OPTICAL GLASS BSC-1

Sources of Data: Molby 1949.

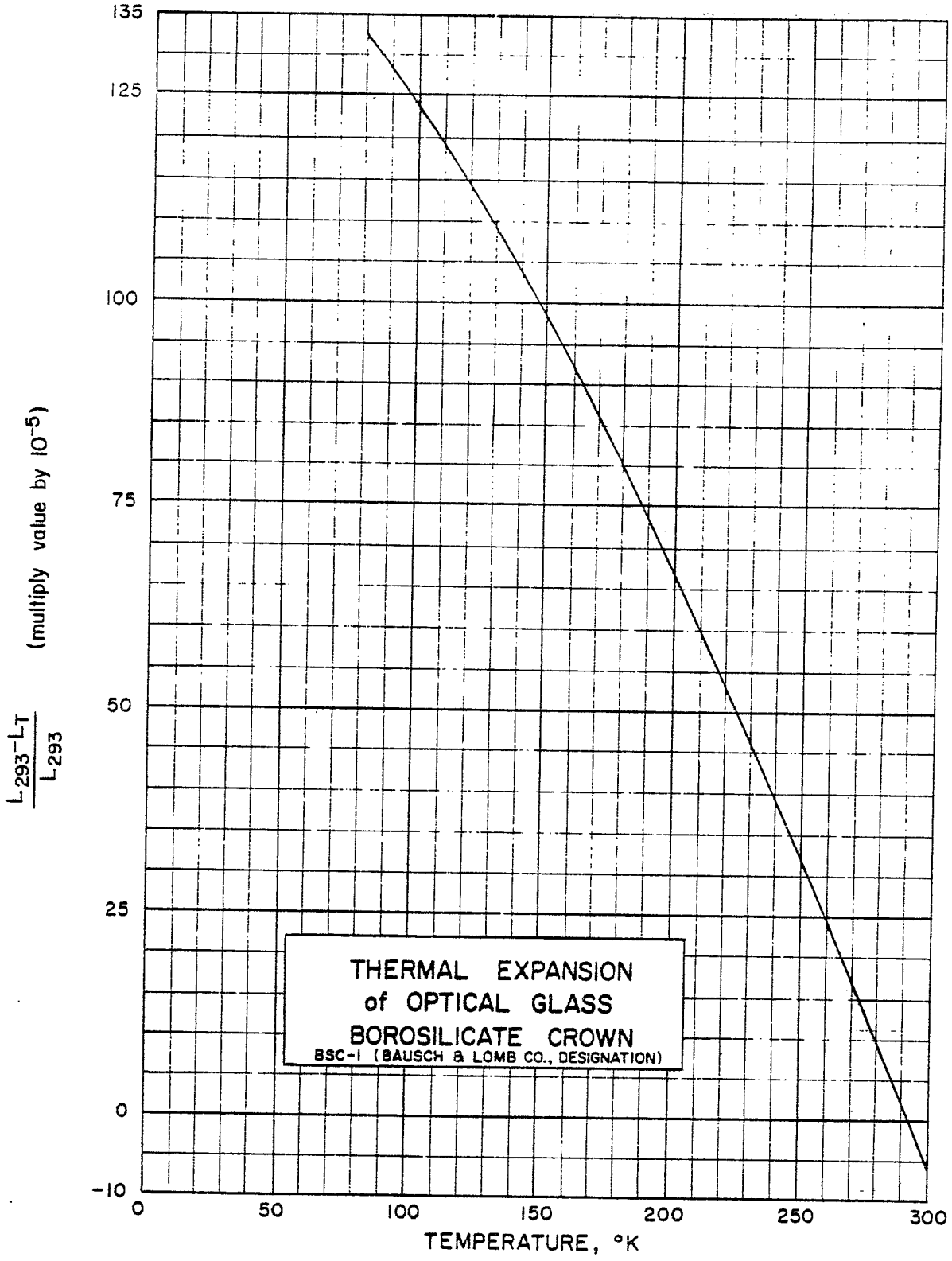
Other References: Dorsey 1907.

Discussion: Bausch and Lomb Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	133 x 10^{-5}	220	53 x 10^{-5}
90	128 "	240	39 "
100	124 "	260	25 "
120	114 "	273	15 "
140	104 "	280	10 "
160	92 "	293	0 "
180	80 "	300	-6 "
200	67 "		

Taken from NBS 29


THERMAL EXPANSION
of OPTICAL GLASS
BOROSILICATE CROWN
BSC-1 (BAUSCH & LOMB CO., DESIGNATION)
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
135
125
100
75
50
25
0
-10
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION OF OPTICAL GLASS BSC-2

Sources of Data: Molby 1949.

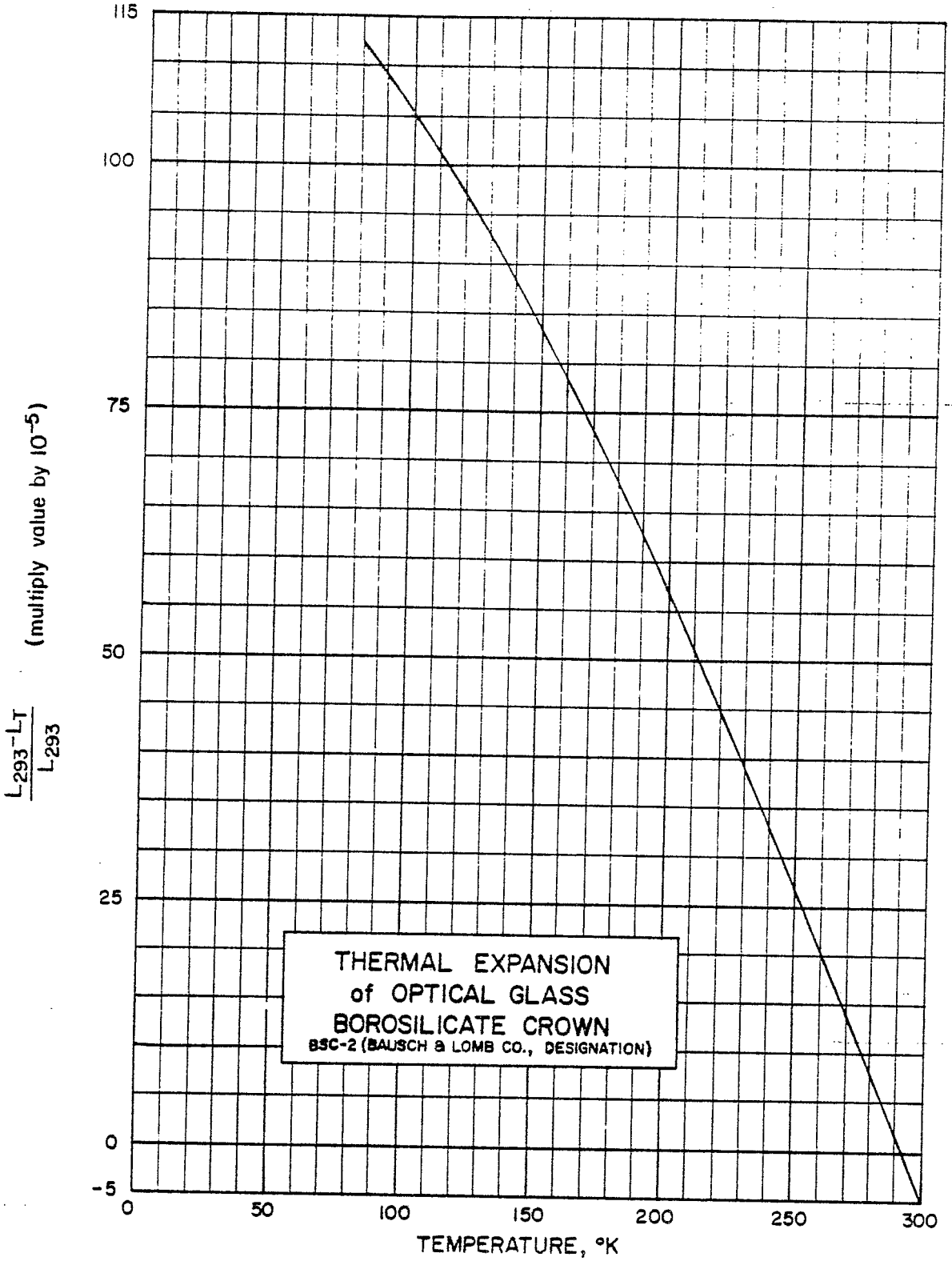
Other References: Dorsey 1907.

Discussion: Bausch and Lomb Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	112×10^{-5}	220	45×10^{-5}
90	109 "	240	33 "
100	105 "	260	21 "
120	97 "	273	13 "
140	88 "	280	8 "
160	77 "	293	0 "
180	66 "	300	-5 "
200	57 "		

Taken from NBS 29


THERMAL EXPANSION
of OPTICAL GLASS
BOROSILICATE CROWN
BSC-2 (BAUSCH & LOMB CO., DESIGNATION)
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
115
100
75
50
25
0
-5
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION OF OPTICAL GLASS LBC-2

Sources of Data: Molby 1949.

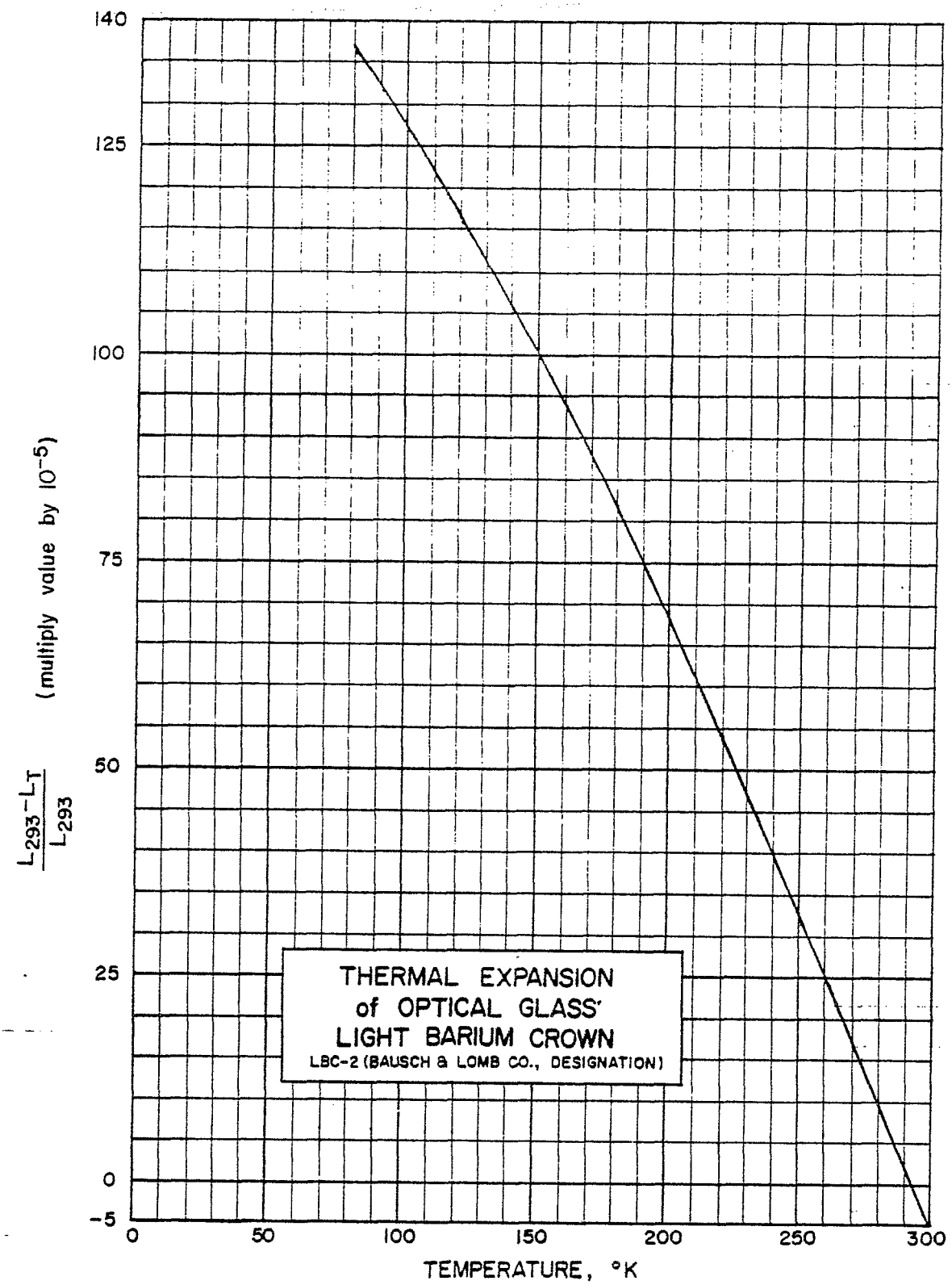
Other References: Dorsey 1907.

Discussion: Bausch and Lomb Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	137×10^{-5}	220	54×10^{-5}
90	132 "	240	40 "
100	128 "	260	25 "
120	117 "	273	15 "
140	106 "	280	10 "
160	95 "	293	0 "
180	82 "	300	-5 "
200	68 "		

Taken from NBS 29


140
125
100
75
50
25
0
-5
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of OPTICAL GLASS
LIGHT BARIUM CROWN
LBC-2 (BAUSCH & LOMB CO., DESIGNATION)

THERMAL EXPANSION OF OPTICAL GLASS DBC-1

Sources of Data: Molby 1949.

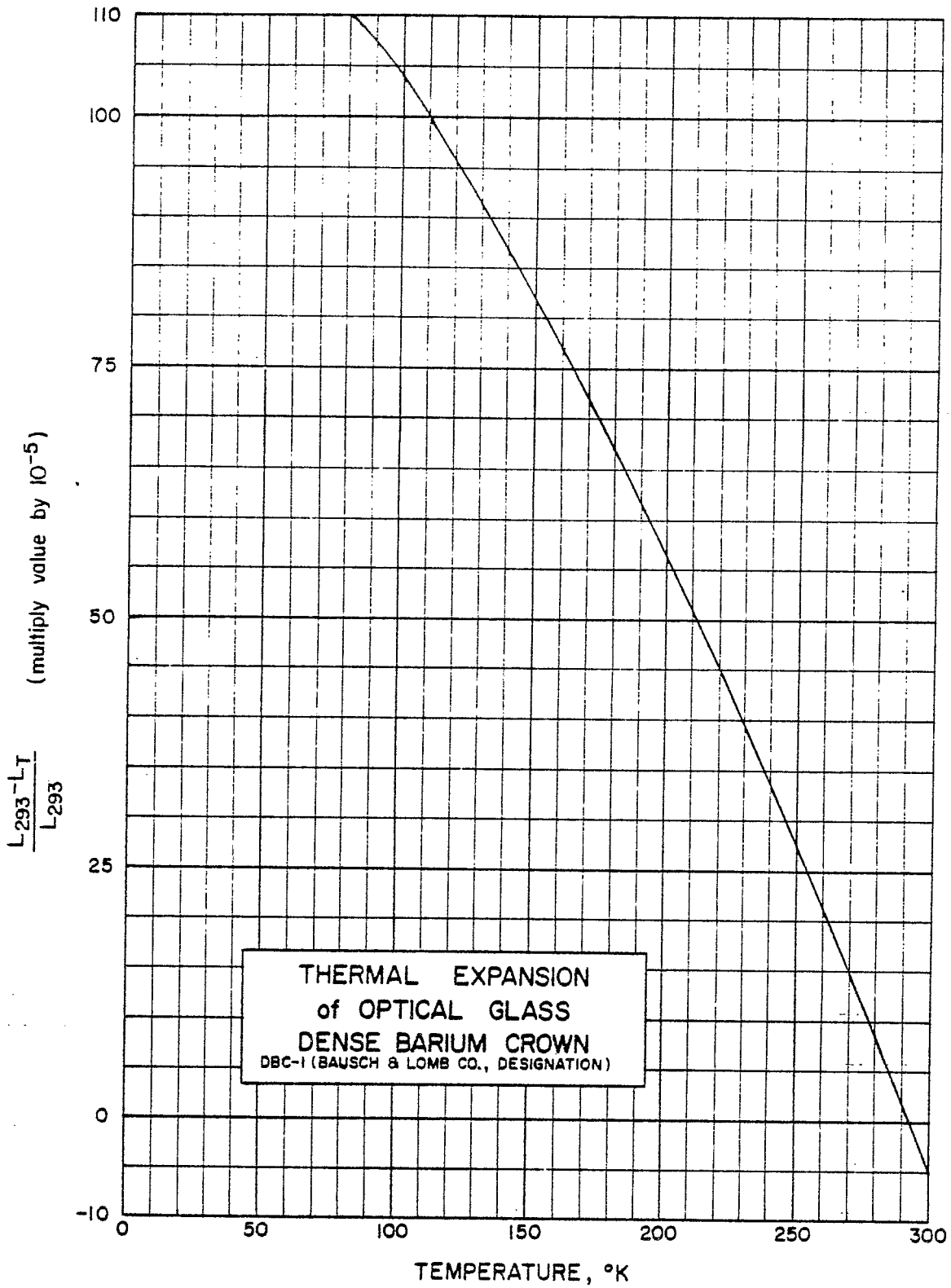
Other References: Dorsey 1907.

Discussion: Bausch and Lomb Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	110×10^{-5}	220	44×10^{-5}
90	107 "	240	33 "
100	104 "	260	21 "
120	95 "	273	13 "
140	87 "	280	8 "
160	77 "	293	0 "
180	67 "	300	-5 "
200	56 "		

Taken from NBS 29


110
100
75
50
25
0
-10
0
50
100
150
200
250
300
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
TEMPERATURE, °K
THERMAL EXPANSION
of OPTICAL GLASS
DENSE BARIUM CROWN
DBC-1 (BAUSCH & LOMB CO., DESIGNATION)

THERMAL EXPANSION OF OPTICAL GLASS DBC-3

Sources of Data: Molby 1949.

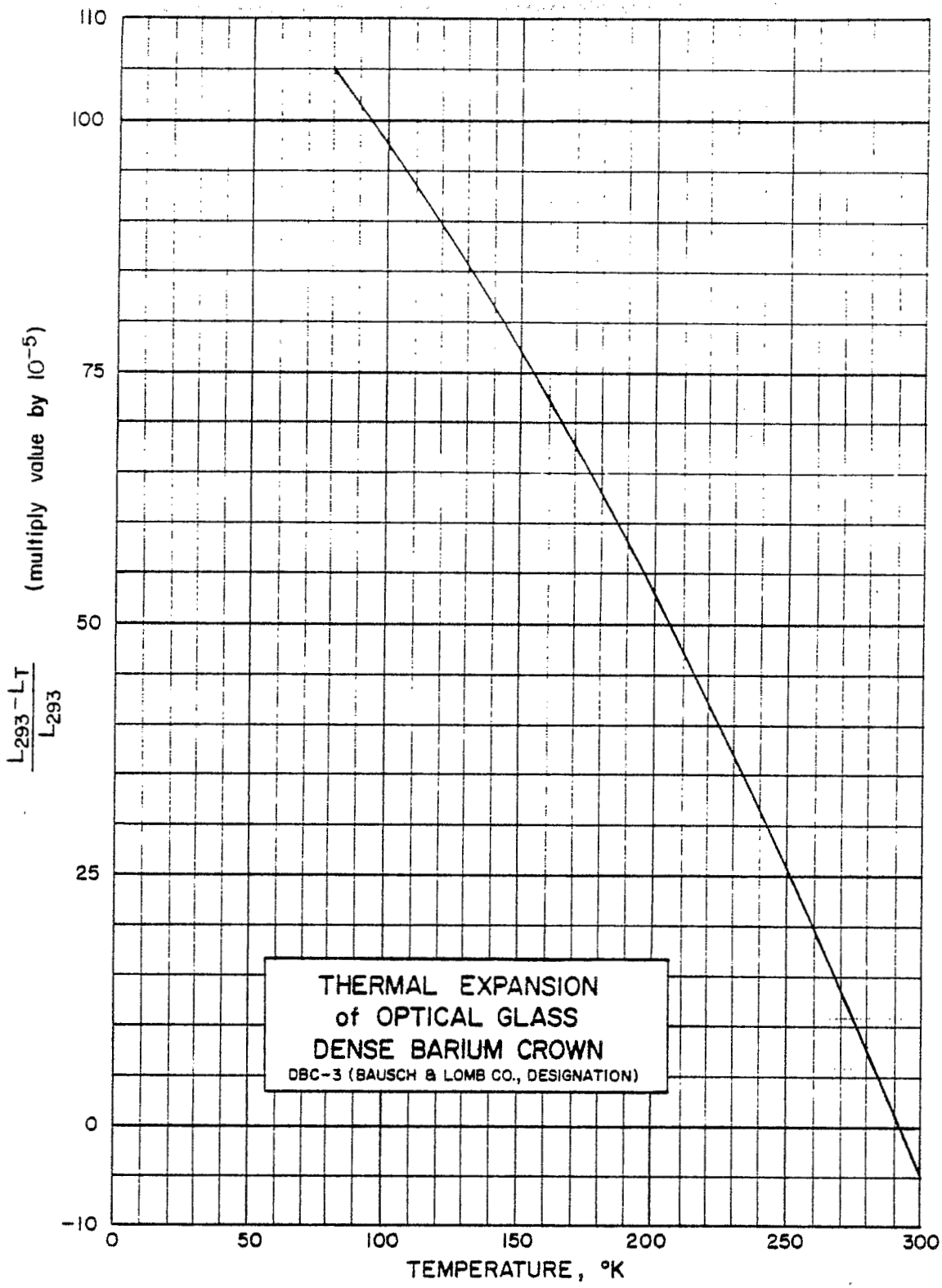
Other References: Dorsey 1907.

Discussion: Bausch and Lomb Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	105×10^{-5}	220	42×10^{-5}
90	101 "	240	31 "
100	98 "	260	20 "
120	90 "	273	12 "
140	82 "	280	8 "
160	73 "	293	0 "
180	63 "	300	-4 "
200	53 "		

Taken from NBS 29


110
100
75
50
25
0
-10
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of OPTICAL GLASS
DENSE BARIUM CROWN
DBC-3 (BAUSCH & LOMB CO., DESIGNATION)

THERMAL EXPANSION OF OPTICAL GLASS DF2

Sources of Data: Molby 1949.

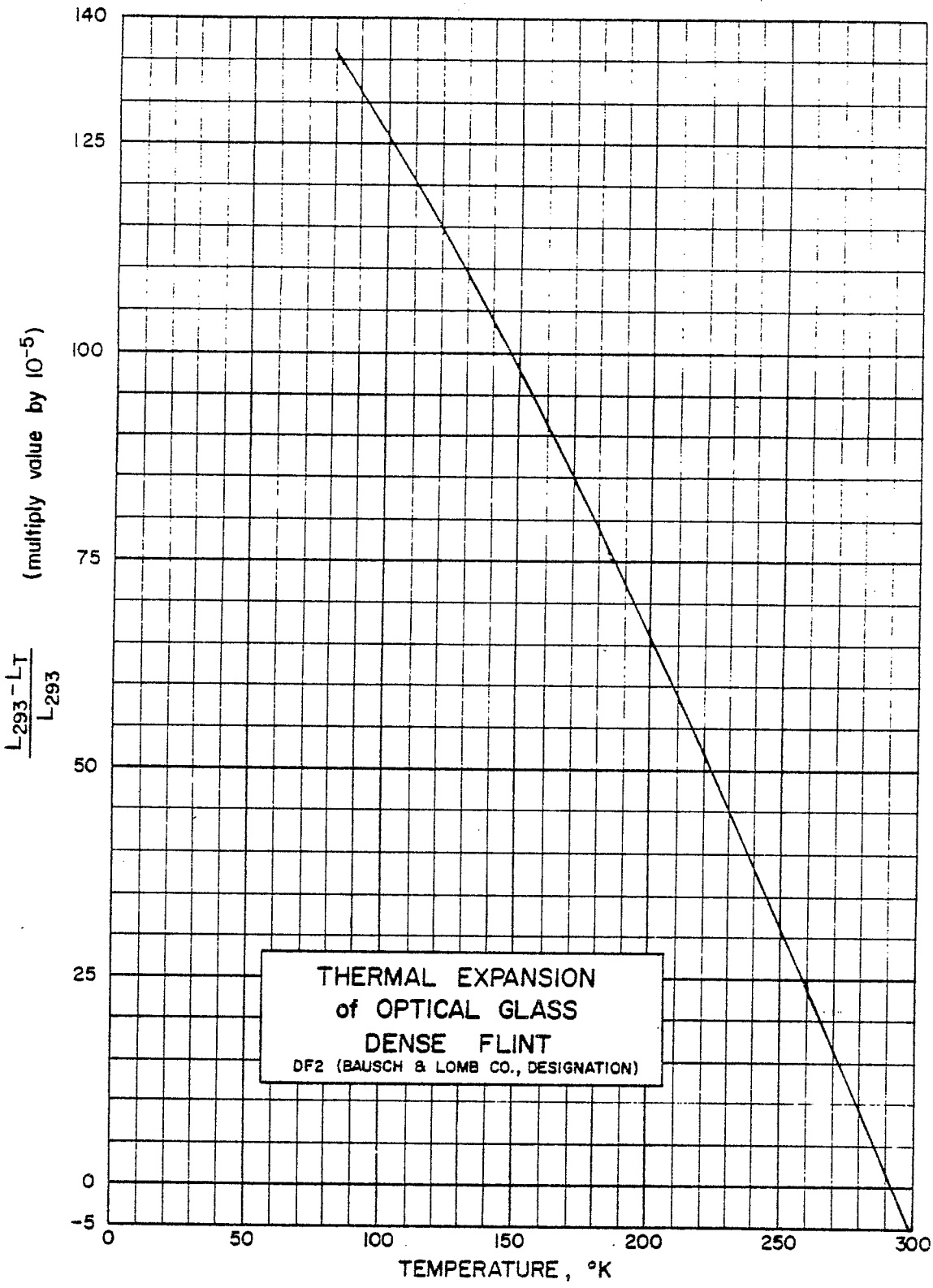
Other References: Dorsey 1907.

Discussion: Bausch and Lomb Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	136×10^{-5}	220	52×10^{-5}
90	131 "	240	38 "
100	126 "	260	24 "
120	115 "	273	15 "
140	104 "	280	9 "
160	92 "	293	0 "
180	79 "	300	-5 "
200	66 "		

Taken from NBS 29


140
125
100
75
50
25
0
-5
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of OPTICAL GLASS
DENSE FLINT
DF2 (BAUSCH & LOMB CO., DESIGNATION)

THERMAL EXPANSION OF OPTICAL GLASS EDF-3

Sources of Data: Molby 1949

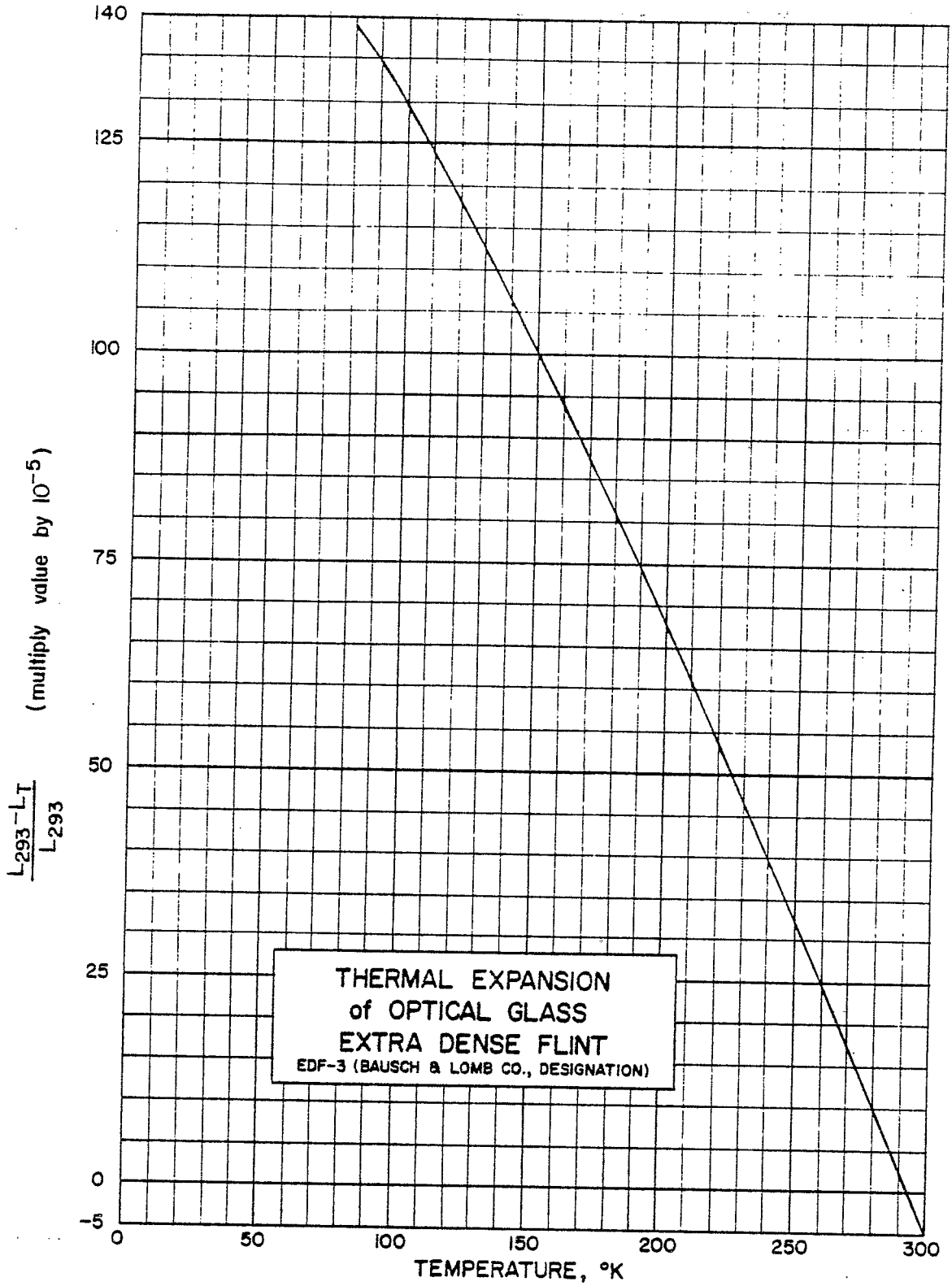
Other References: Dorsey 1907

Discussion: Bausch and Lomb Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	139×10^{-5}	220	53×10^{-5}
90	135 "	240	39 "
100	130 "	260	25 "
120	118 "	273	15 "
140	106 "	280	10 "
160	94 "	293	0 "
180	81 "	300	-5 "
200	67 "		

Taken from NBS 29


140
125
100
75
50
25
0
-5
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of OPTICAL GLASS
EXTRA DENSE FLINT
EDF-3 (BAUSCH & LOMB CO., DESIGNATION)

THERMAL EXPANSION OF OPTICAL GLASS BF-1

Sources of Data: Molby 1949.

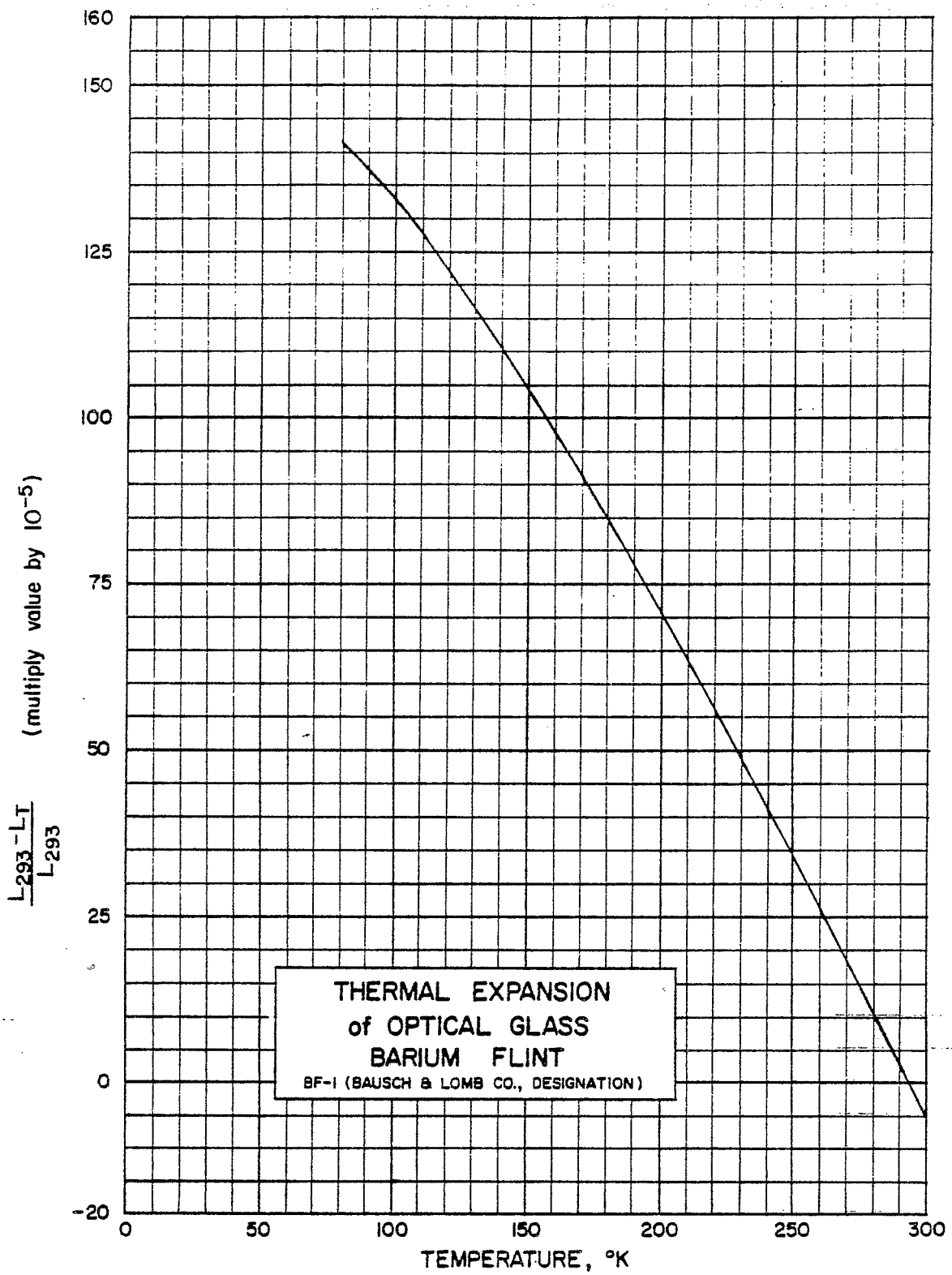
Other References: Dorsey 1907.

Discussion: Bausch and Lomb Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	142×10^{-5}	220	56×10^{-5}
90	137 "	240	41 "
100	133 "	260	26 "
120	122 "	273	16 "
140	111 "	280	10 "
160	98 "	293	0 "
180	85 "	300	-5 "
200	71 "		

Taken from NBS 29


160
150
125
100
75
50
25
0
-20
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of OPTICAL GLASS
BARIUM FLINT
BF-1 (BAUSCH & LOMB CO., DESIGNATION)

THERMAL EXPANSION OF OPTICAL GLASS CF-1

Sources of Data: Molby 1949.

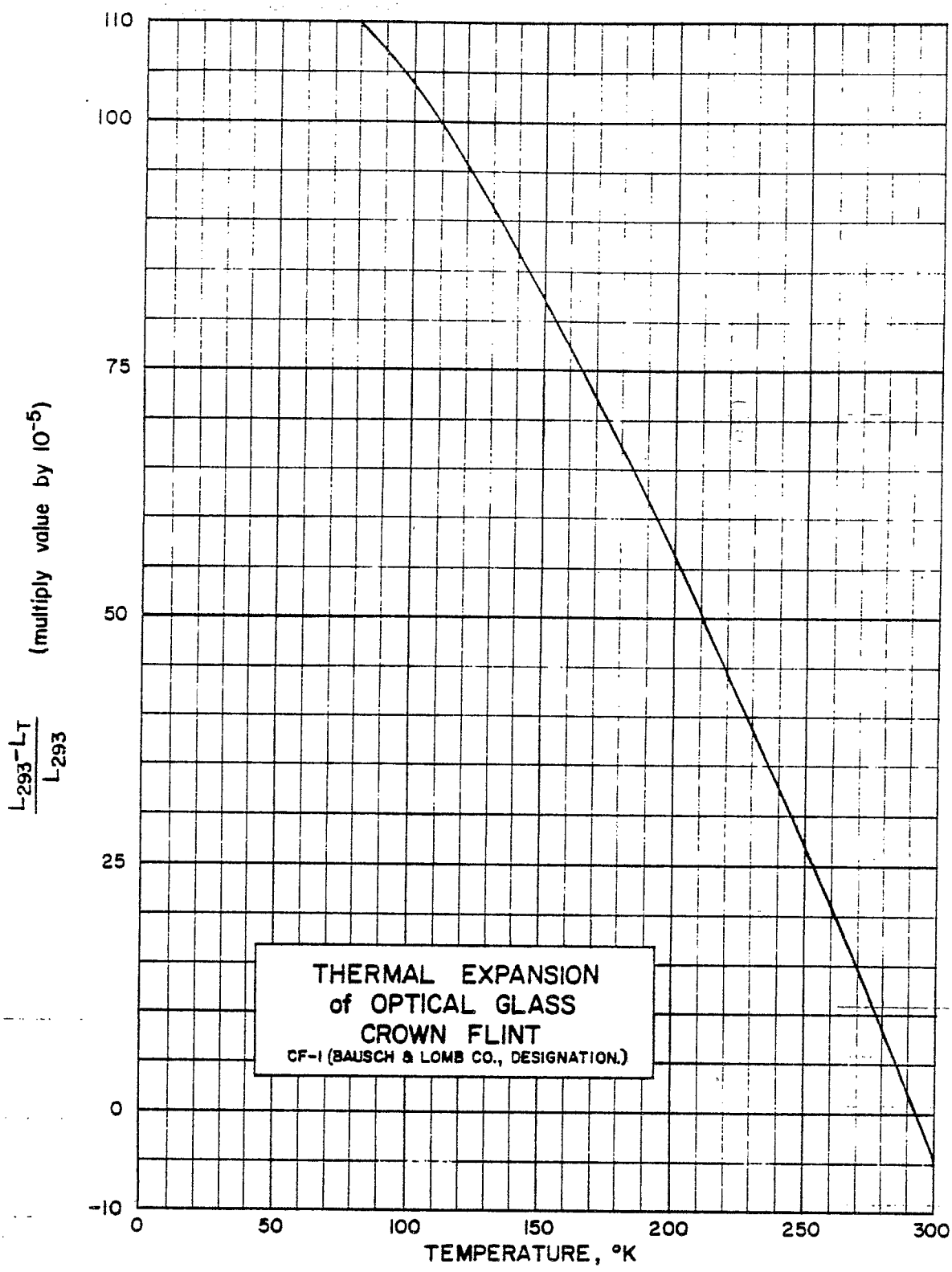
Other References: Dorsey 1907.

Discussion: Bausch and Lomb Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	110 x 10^{-5}	220	44 x 10^{-5}
90	107 "	240	33 "
100	104 "	260	21 "
120	95 "	273	13 "
140	87 "	280	8 "
160	77 "	293	0 "
180	67 "	300	-5 "
200	56 "		

Taken from NBS 29


110
100
75
50
25
0
-10
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of OPTICAL GLASS
CROWN FLINT
CF-1 (BAUSCH & LOMB CO., DESIGNATION.)

THERMAL EXPANSION OF OPTICAL GLASS NO.11

Sources of Data: Molby 1949

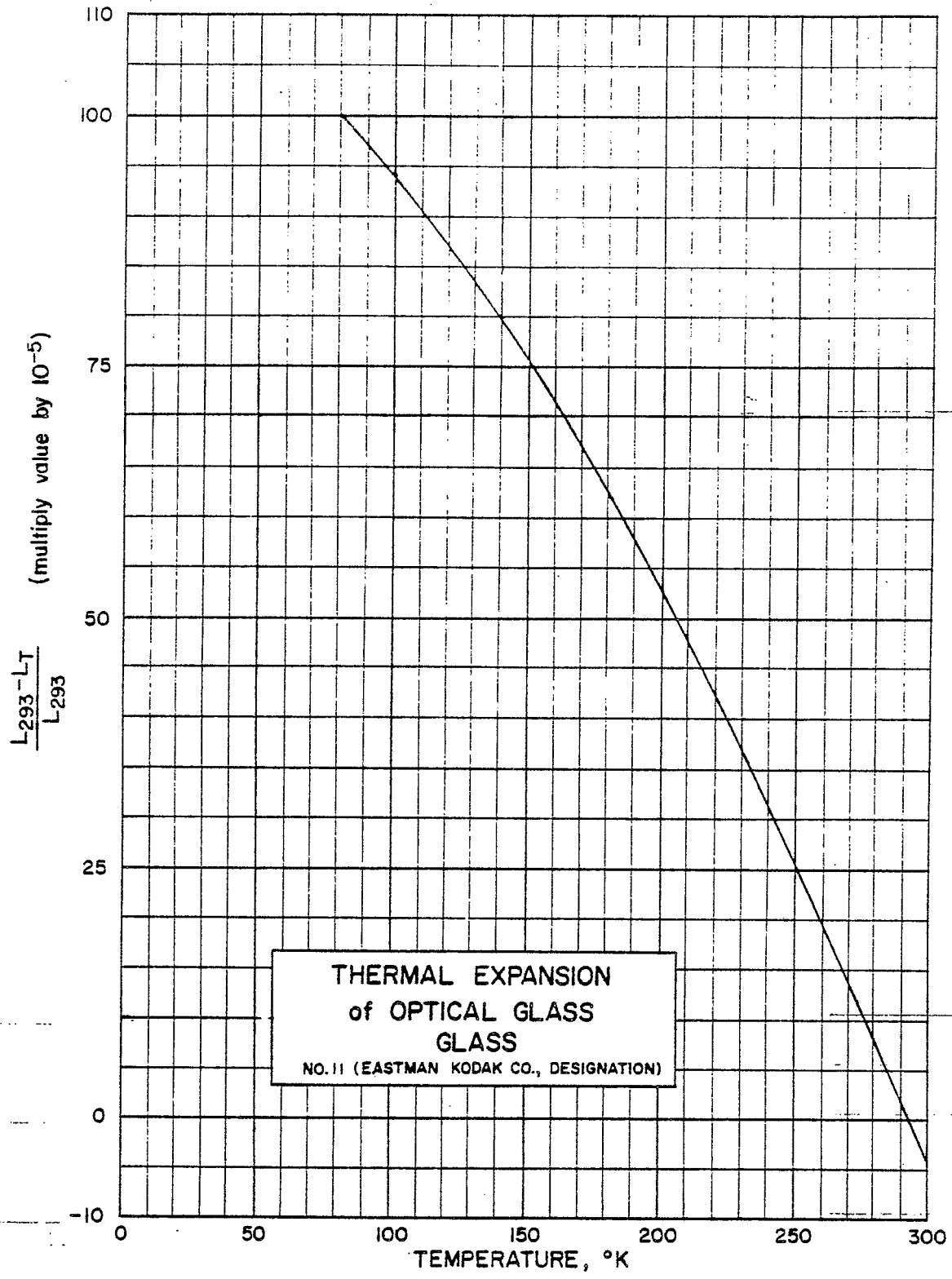
Other References: Dorsey 1907

Discussion: Eastman Kodak Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	100×10^{-5}	220	42×10^{-5}
90	97 "	240	31 "
100	94 "	260	20 "
120	88 "	273	12 "
140	80 "	280	8 "
160	72 "	293	0 "
180	63 "	300	-4 "
200	53 "		

Taken from NBS 29


110
100
75
50
25
0
-10
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of OPTICAL GLASS
GLASS
NO. 11 (EASTMAN KODAK CO., DESIGNATION)

THERMAL EXPANSION OF OPTICAL GLASS NO. 32

Sources of Data: Molby 1949.

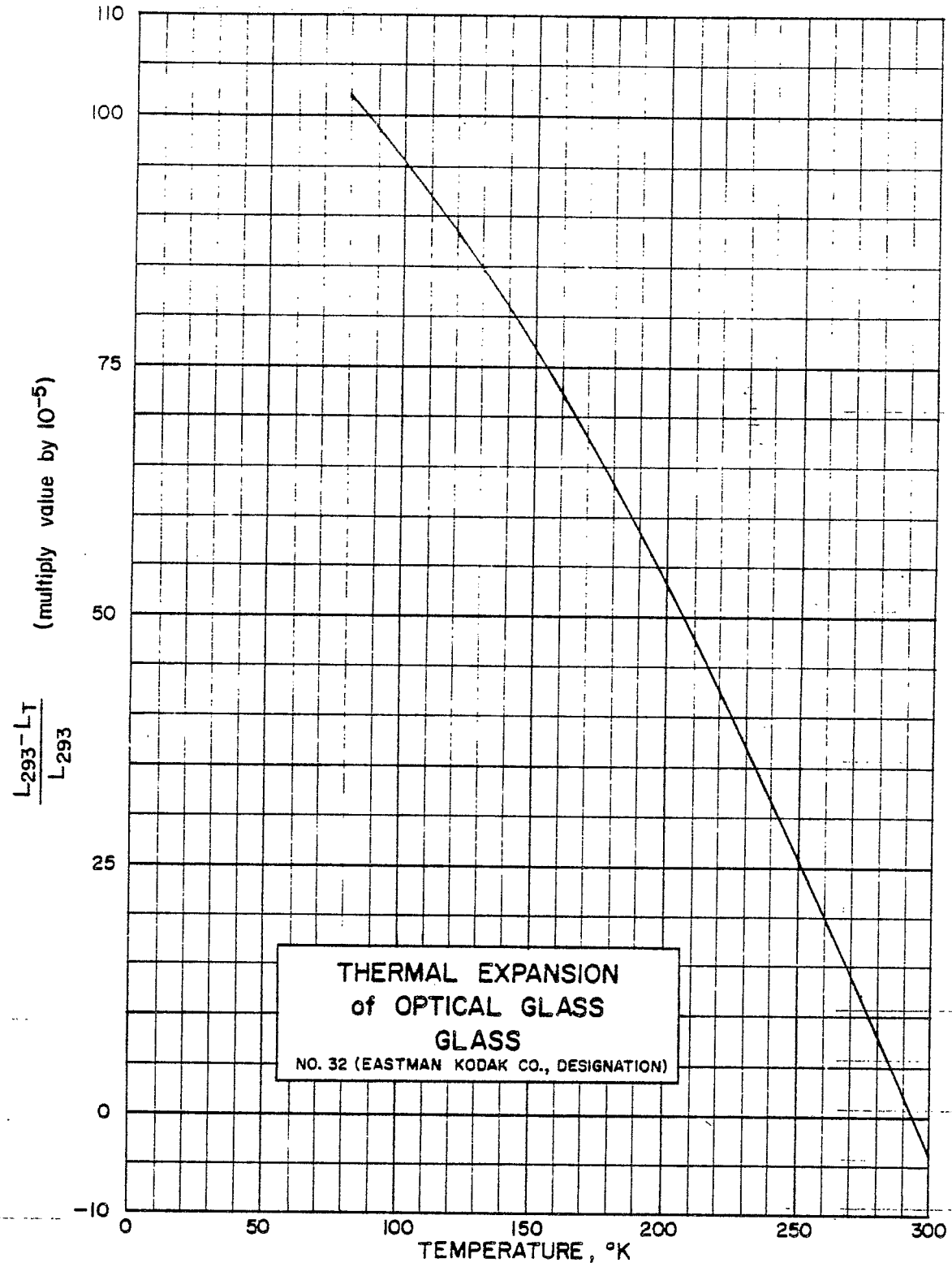
Other References: Dorsey 1907.

Discussion: Eastman Kodak Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	102×10^{-5}	220	42×10^{-5}
90	99 "	240	31 "
100	96 "	260	20 "
120	89 "	273	12 "
140	81 "	280	8 "
160	72 "	293	0 "
180	63 "	300	-4 "
200	53 "		

Taken from NBS 29


110
100
75
50
25
0
−10
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of OPTICAL GLASS
GLASS
NO. 32 (EASTMAN KODAK CO., DESIGNATION)

THERMAL EXPANSION OF OPTICAL GLASS NO.33

Sources of Data: Molby 1949.

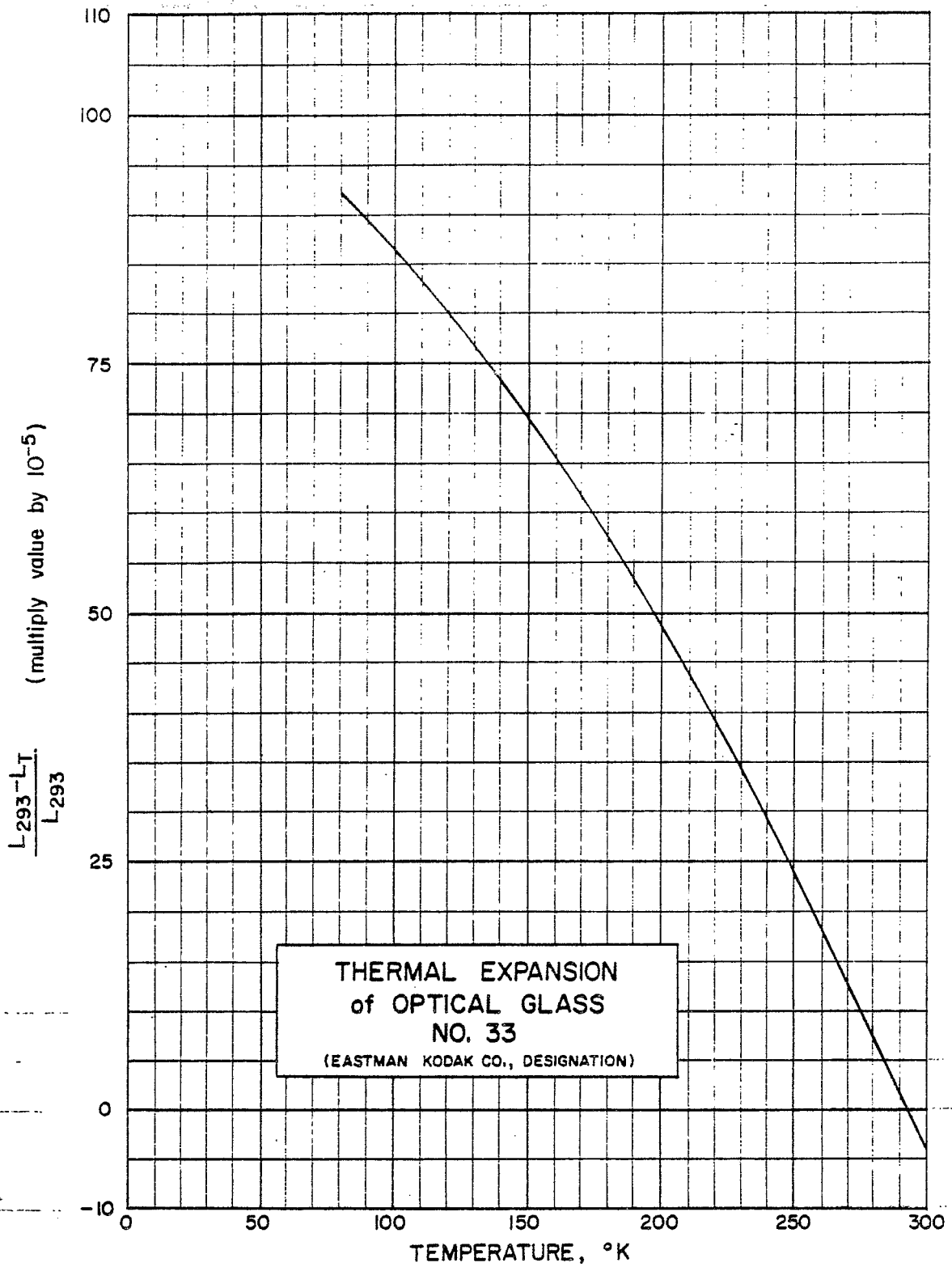
Other References: Dorsey 1907

Discussion: Eastman Kodak Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	92 x 10^{-5}	220	39 x 10^{-5}
90	90 "	240	29 "
100	87 "	260	18 "
120	83 "	273	11 "
140	74 "	280	7 "
160	66 "	293	0 "
180	58 "	300	-4 "
200	49 "		

Taken from NBS 29


THERMAL EXPANSION
of OPTICAL GLASS
NO. 33
(EASTMAN KODAK CO., DESIGNATION)
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
110
100
75
50
25
0
-10
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION OF OPTICAL GLASS NO.45

Sources of Data: Molby 1949.

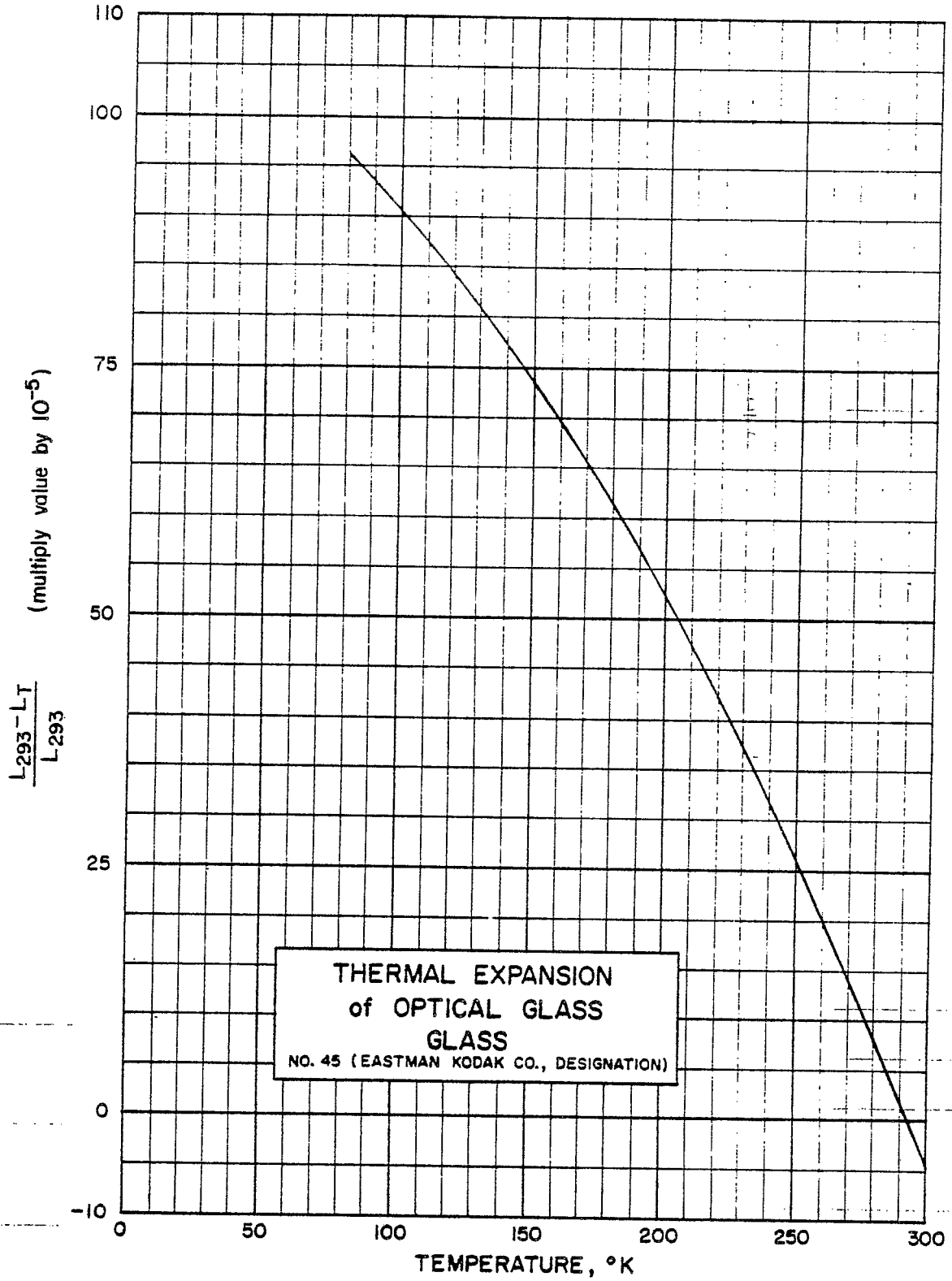
Other References: Dorsey 1907.

Discussion: Eastman Kodak Co. designation. Composition was not given.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
80	96×10^{-5}	220	42×10^{-5}
90	94 "	240	31 "
100	91 "	260	20 "
120	85 "	273	12 "
140	78 "	280	8 "
160	70 "	293	0 "
180	62 "	300	-4 "
200	52 "		

Taken from NBS 29


110
100
75
50
25
0
-10
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of OPTICAL GLASS
GLASS
NO. 45 (EASTMAN KODAK CO., DESIGNATION)

THERMAL EXPANSION OF PYREX

Sources of Data: Head and Laquer 1952

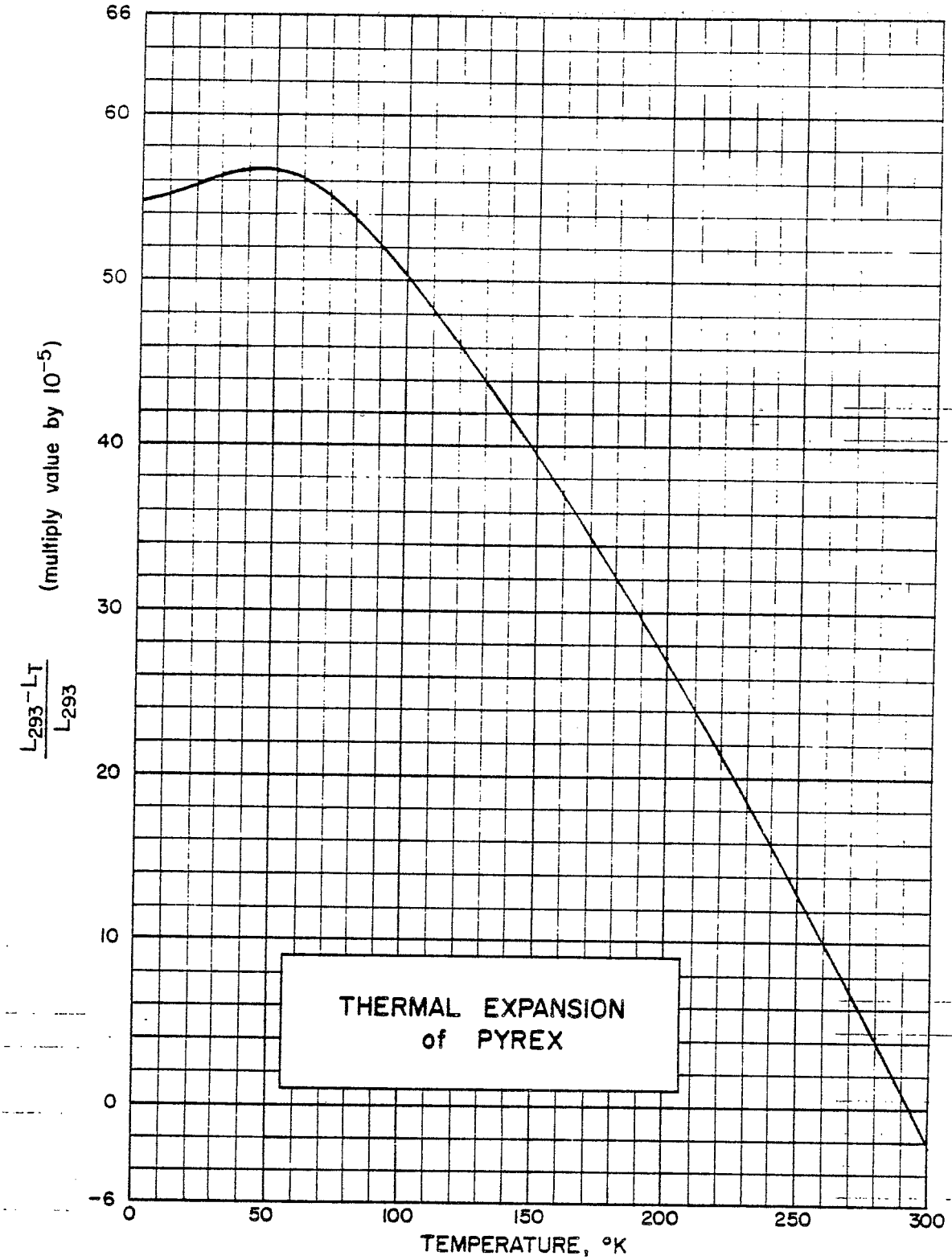
Other References: Buffington and Latimer 1926
Tool and Saunders 1948
Winter-Klein 1950

Discussion:

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
0	54.7×10^{-5}	180	32.2×10^{-5}
20	55.7 "	200	27.2 "
40	56.7 "	220	21.7 "
60	56.2 "	240	15.7 "
80	53.7 "	260	10.2 "
100	50.2 "	273	6.2 "
120	46.2 "	280	4.2 "
140	41.7 "	293	0.0 "
160	37.2 "	300	-2.3 "

Taken from NBS 29


66
60
50
40
30
20
10
0
-6
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of PYREX

THERMAL EXPANSION OF SILICA GLASS

Sources of Data: Keesom and Doborzynski 1934
Scheel and Heuse 1914

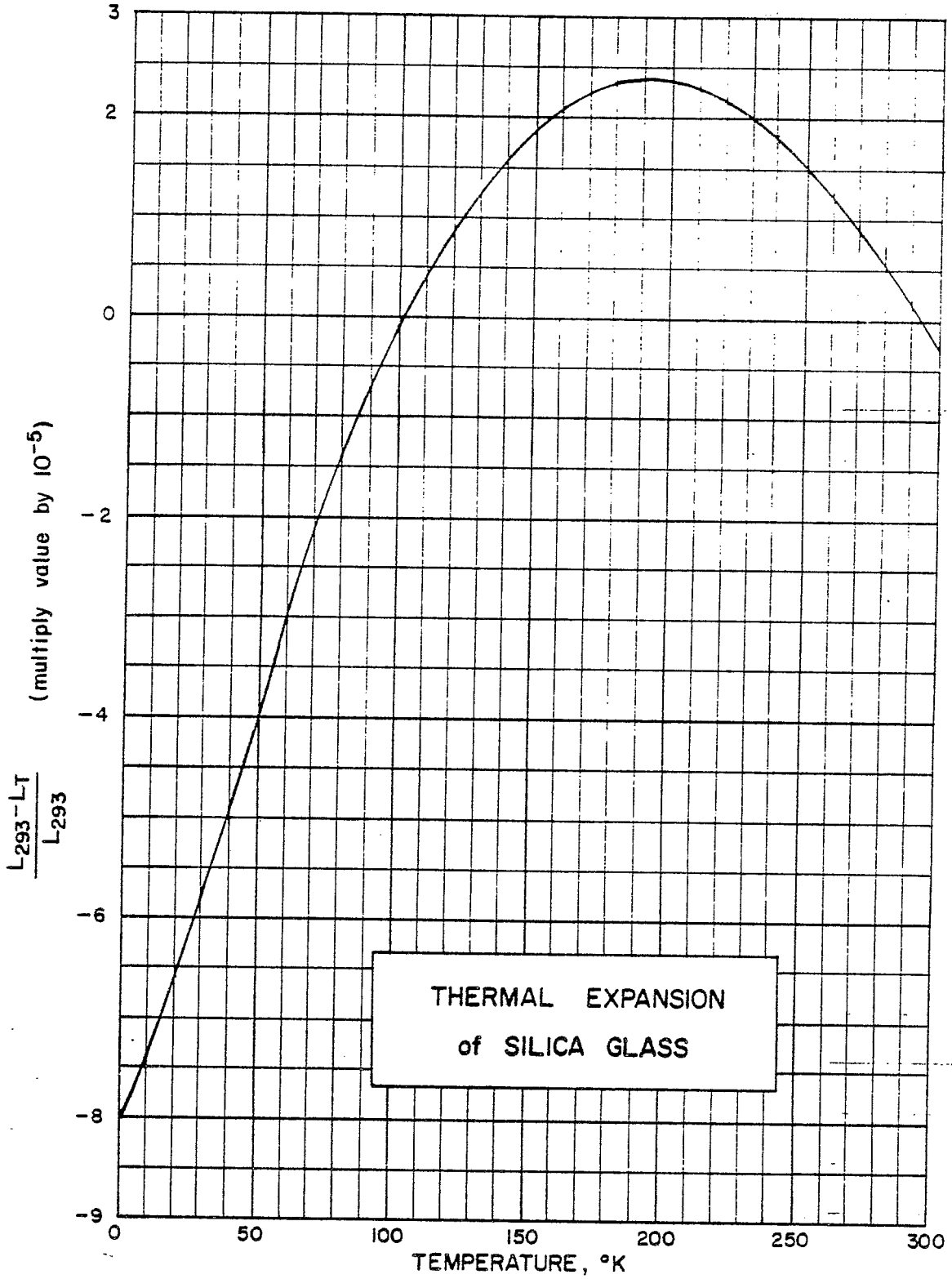
Discussion: The thermal expansion of silica glass (fused silica, vitreous silica) quartz glass), though small, is variable from sample to sample. The above values are thought to be fairly representative of average behavior. The temperature of minimum length can vary from 180 to 230°K. Variations from the above values as large as 2×10^{-5} below 180°K and 50% from 180 to 300°K are possible

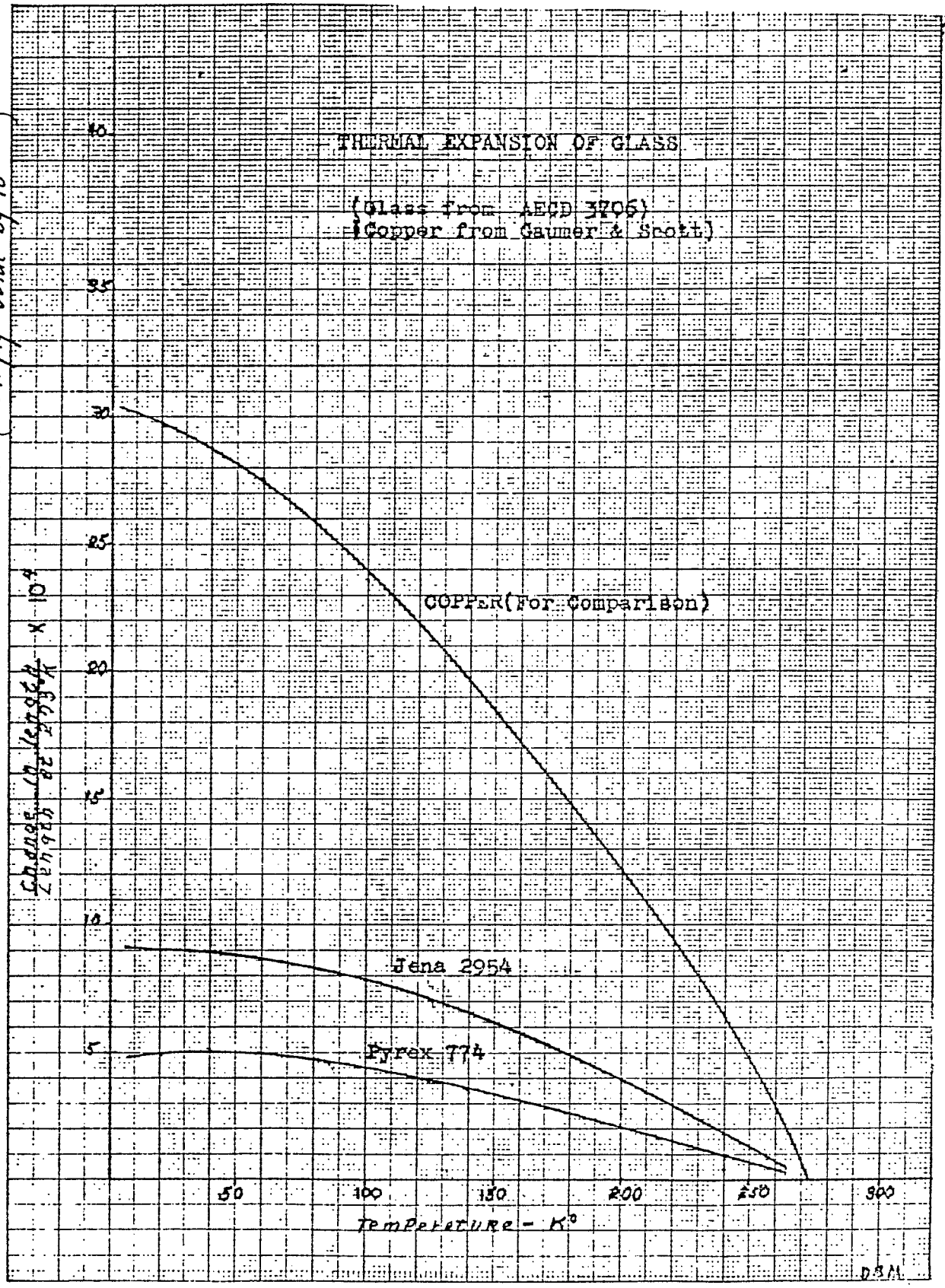
Other References: Beattie et al. 1941
Dorsey 1907.
Head and Laquer 1952, Henning 1907, Scheel 1907, Scott 1933, Sosman 1927, Souder and Hidnert 1926, Valentiner and Wallot 1915.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
0	-8×10^{-5}	180	2.32×10^{-5}
20	-6.60 "	200	2.36 "
40	-4.90 "	220	2.18 "
60	-3.02 "	240	1.81 "
80	-1.41 "	260	1.26 "
100	-0.12 "	273	0.81 "
120	+0.87 "	280	0.54 "
140	1.61 "	293	0.0
160	2.08 "	300	-0.29 "

Taken from NBS 29


THERMAL EXPANSION
of SILICA GLASS
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
TEMPERATURE, °K
3
2
0
-2
-4
-6
-8
-9
0
50
100
150
200
250
300


THERMAL EXPANSION OF GLASS
(Glass from AECD 3706)
(Copper from Gaumer & Scott)
COPPER(For Comparison)
Jena 2954
Pyrex 774
Temperature - K°
40
35
30
25
20
15
10
5
50
100
150
200
250
300

THERMAL EXPANSION OF INCONEL

Sources of Data: Altman, Rubin, and Johnston 1952

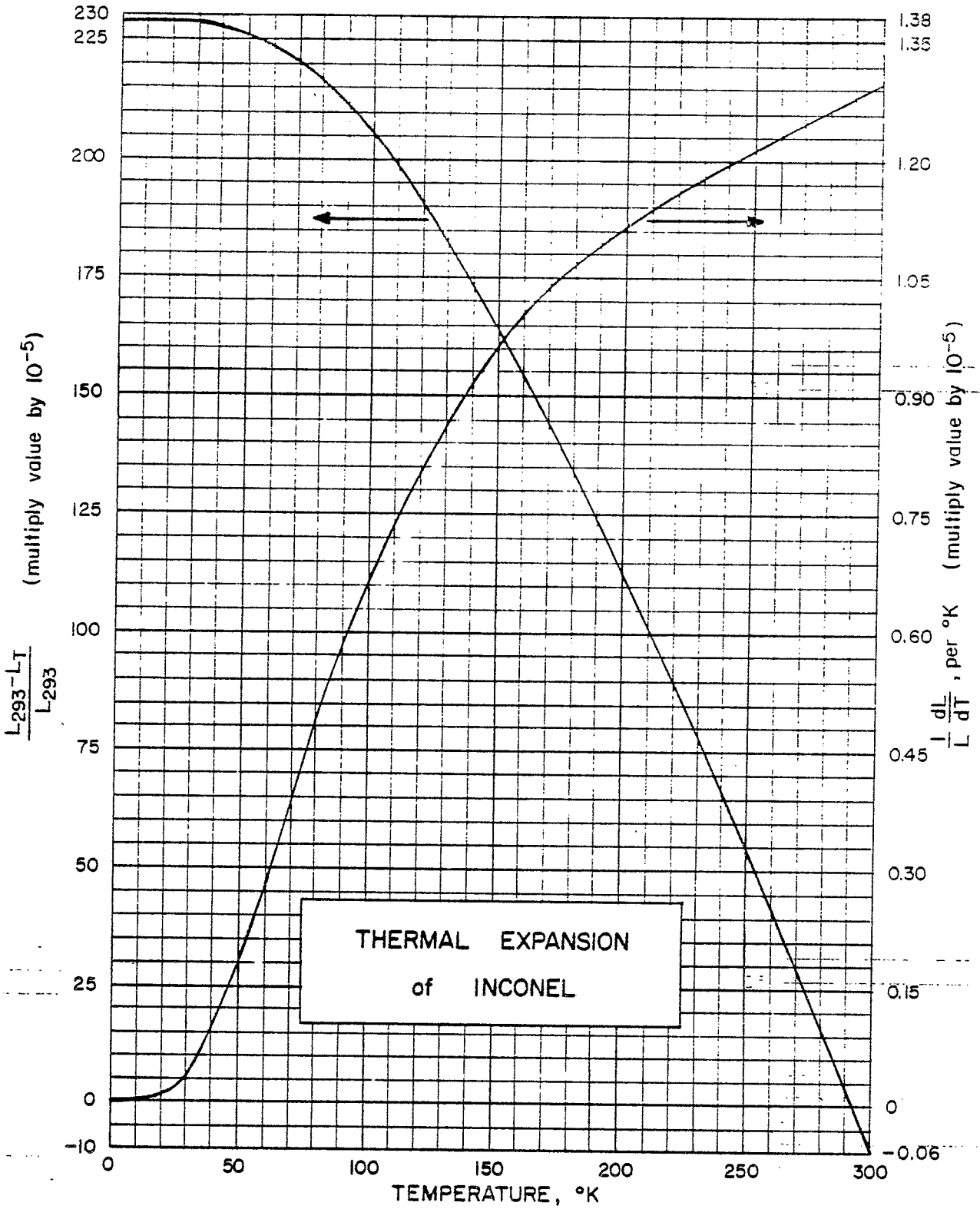
Other References: Lucks and Deem 1958

Discussion: 80 Ni, 14 Cr, 6 Fe.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	229×10^{-5}	0.
10	229 "	
20	229 "	0.003×10^{-5}
30	229 "	.03 "
40	228 "	.10 "
50	227 "	.19 "
60	224 "	.28 "
70	221 "	.38 "
80	217 "	.48 "
90	211 "	.57 "
100	205 "	.65 "
120	191 "	.79 "
140	174×10^{-5}	$.91 \times 10^{-5}$
160	154 "	1.00 "
180	134 "	1.07 "
200	112 "	1.12 "
220	89.1 "	1.16 "
240	65.6 "	1.20 "
260	41.4 "	1.23 "
273	25.2 "	1.25 "
280	16.6 "	1.26 "
293	0.0 "	1.29 "
300	-9.0 "	1.30 "

Taken from NBS 29


THERMAL EXPANSION
of INCONEL
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
230
225
200
175
150
125
100
75
50
25
0
-10
1.38
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0
-0.06
0
50
100
150
200
250
300

THERMAL EXPANSION OF INDIUM

Source of Data: Swenson 1955.

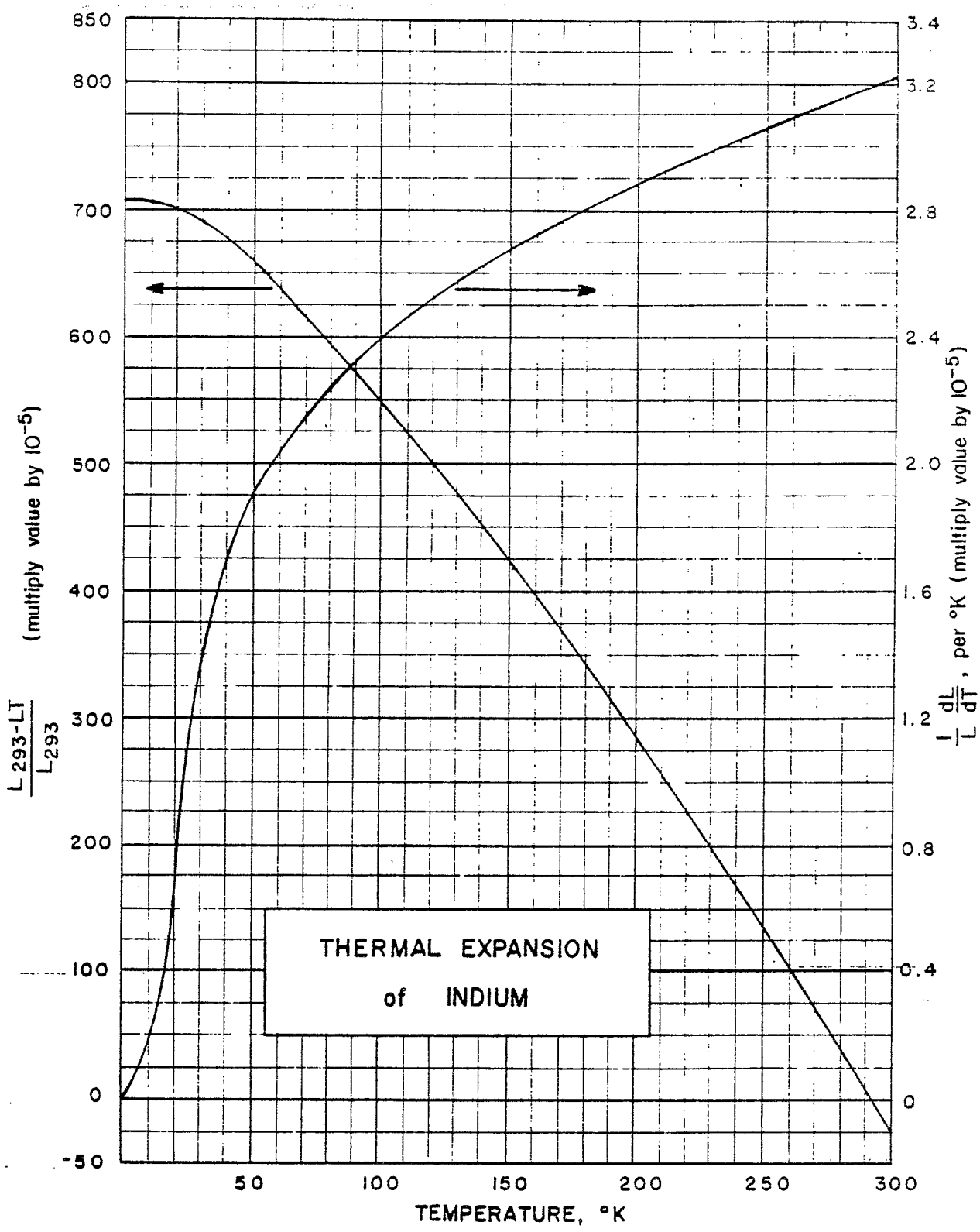
Other References: Hidnert and Blair 1943.

Discussion: In the two investigations above, the experimental methods and sample purities were very similar. Yet the two points by Hidnert and Blair, $(L_{273} - L_{195})/ L_{273}$ and $(L_{273} - L_{83})/ L_{273}$, are respectively 7% and 4% less than Swenson's corresponding points. Swenson's data have been adopted solely because they include more points over a wider temperature range.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	706×10^{-5}	0.	120	500×10^{-5}	2.52×10^{-5}
10	706 "	0.2×10^{-5}	140	448 "	2.63 "
20	701 "	0.7 "	160	394 "	2.72 "
30	691 "	1.3 "	180	339 "	2.79 "
40	676 "	1.7 "	200	282 "	2.86 "
50	658 "	1.91 "	220	224 "	2.93 "
60	638 "	2.04 "	240	165 "	3.01 "
70	617 "	2.15 "	260	104 "	3.08 "
80	595 "	2.24 "	273	63 "	3.13 "
90	572 "	2.32 "	280	42 "	3.15 "
100	549 "	2.39 "	293	0 "	3.20 "
			300	-22	3.22 "

Taken from WADD 60-56


THERMAL EXPANSION
of INDIUM
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
850
800
700
600
500
400
300
200
100
0
-50
3.4
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
50
100
150
200
250
300

THERMAL EXPANSION OF INVAR

Sources of Data: Beenakker and Swenson 1955

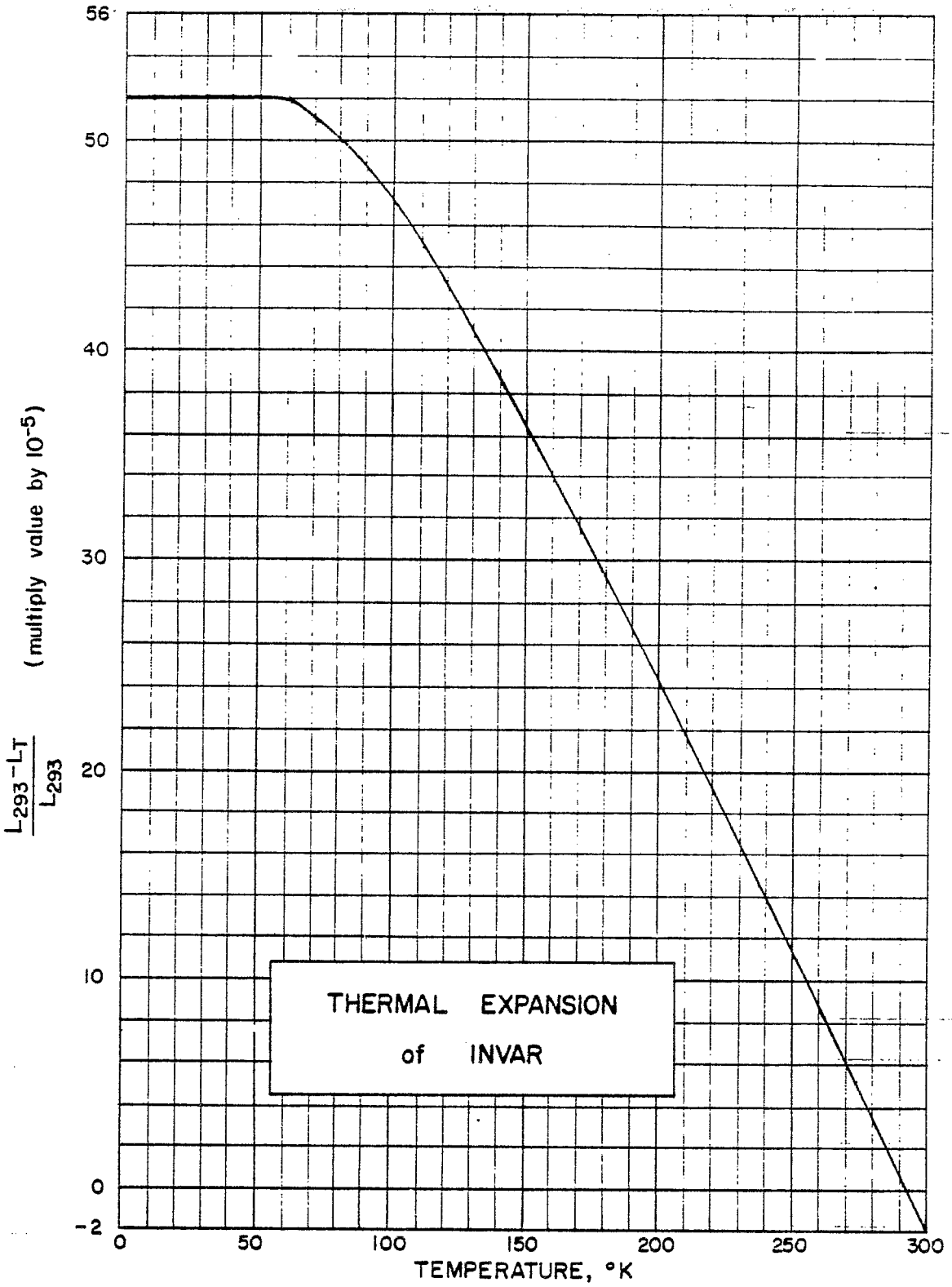
Other References:
Chevenard 1914
Gregg 1954
Masumoto 1934
Molby 1912
Scheel 1921

Discussion: The expansions of the Invar alloys are sensitive to composition and heat treatment. The above data are for an alloy believed to be 42 Ni, 0.8 Mn, bal. Fe, annealed (Lloyd B. Nesbitt, Private Communication). Although Beenakker and Swenson referred to this as "Invar", this composition approximates the alloy, Dumet, used for sealing to glass. In the iron-nickel alloy system, the minimum value of room temperature expansion coefficient occurs at about 36% Ni.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
0	52×10^{-5}	140	39×10^{-5}
10	52 "	160	34 "
20	52 "	180	29 "
30	52 "	200	23 "
40	52 "	220	18 "
50	52 "	240	14 "
60	52 "	260	8.6 "
70	51 "	273	5.2 "
80	50 "	280	3.4 "
90	49 "	293	0
100	47 "	300	-1.8 "
120	43 "		

Taken from NBS 29


THERMAL EXPANSION
of INVAR
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
56
50
40
30
20
10
0
-2
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION OF IRON

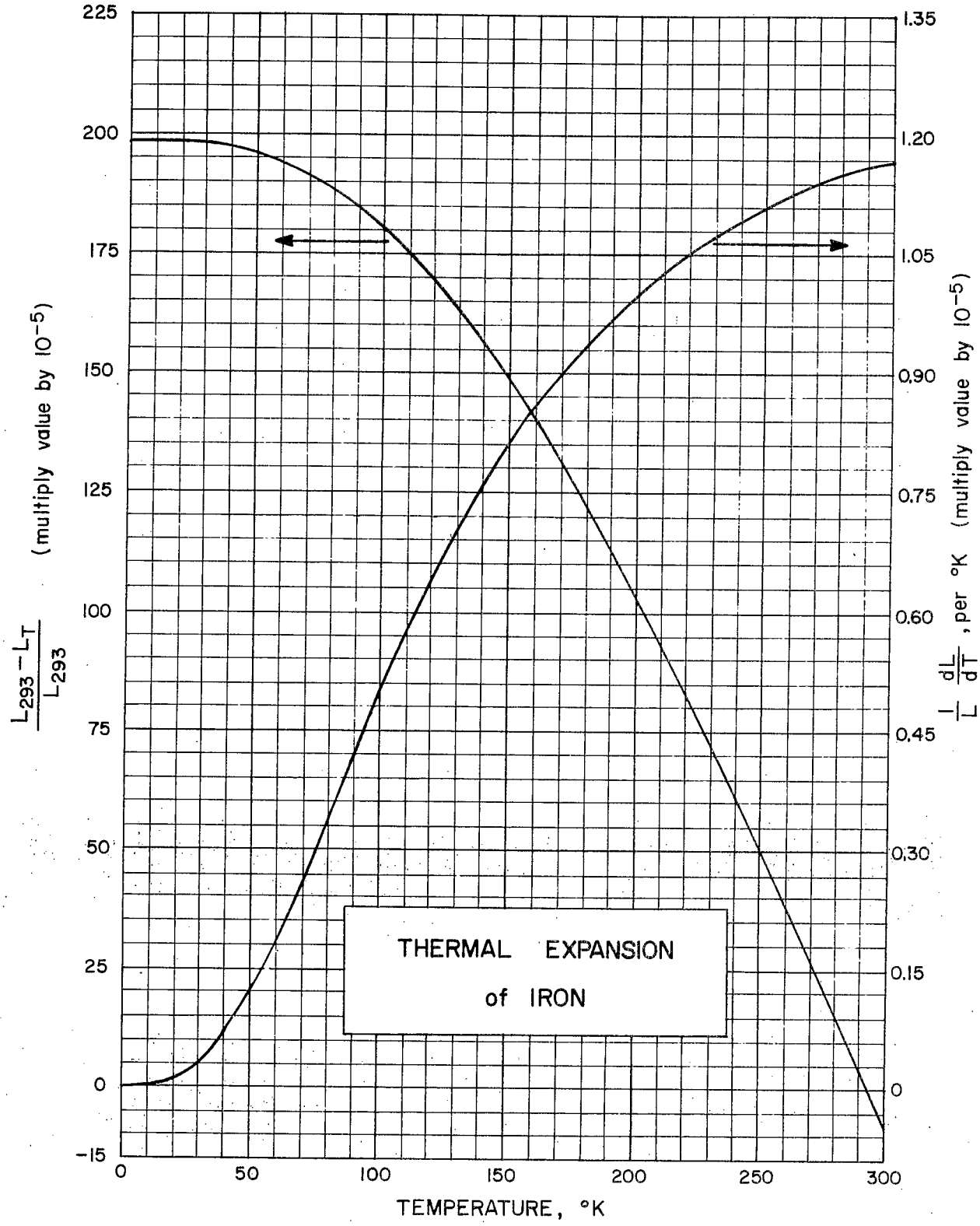
Sources of Data: Ebert 1928, Nix and MacNair 1941

Other References: Adenstedt 1936, Dorsey 1907, Simon and Bergmann 1930
Owen and Williams 1954.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	198×10^{-5}	0	140	156×10^{-5}	0.76×10^{-5}
20	198 "	0.01×10^{-5}	160	140 "	0.86 "
30	198 "	.03 "	180	122 "	0.94 "
40	197 "	.07 "	200	102 "	1.00 "
50	196 "	.13 "	220	82 "	1.05 "
60	195 "	.20 "	240	60 "	1.09 "
70	192 "	.28	260	38 "	1.13 "
80	189 "	.35 "	273	23 "	1.14 "
90	185 "	.42	280	15 "	1.15 "
100	181 "	.49 "	293	0 "	1.16 "
120	170 "	.63	300	-8 "	1.17 "

Taken from NBS 29


THERMAL EXPANSION
of IRON
$\frac{L_{293} - L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
225
200
175
150
125
100
75
50
25
0
-15
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0
0
50
100
150
200
250
300

THERMAL EXPANSION OF LEAD

Sources of Data: Dheer and Surange 1958, Ebert 1928, Nix and MacNair 1942, Olsen and Rohrer 1957.

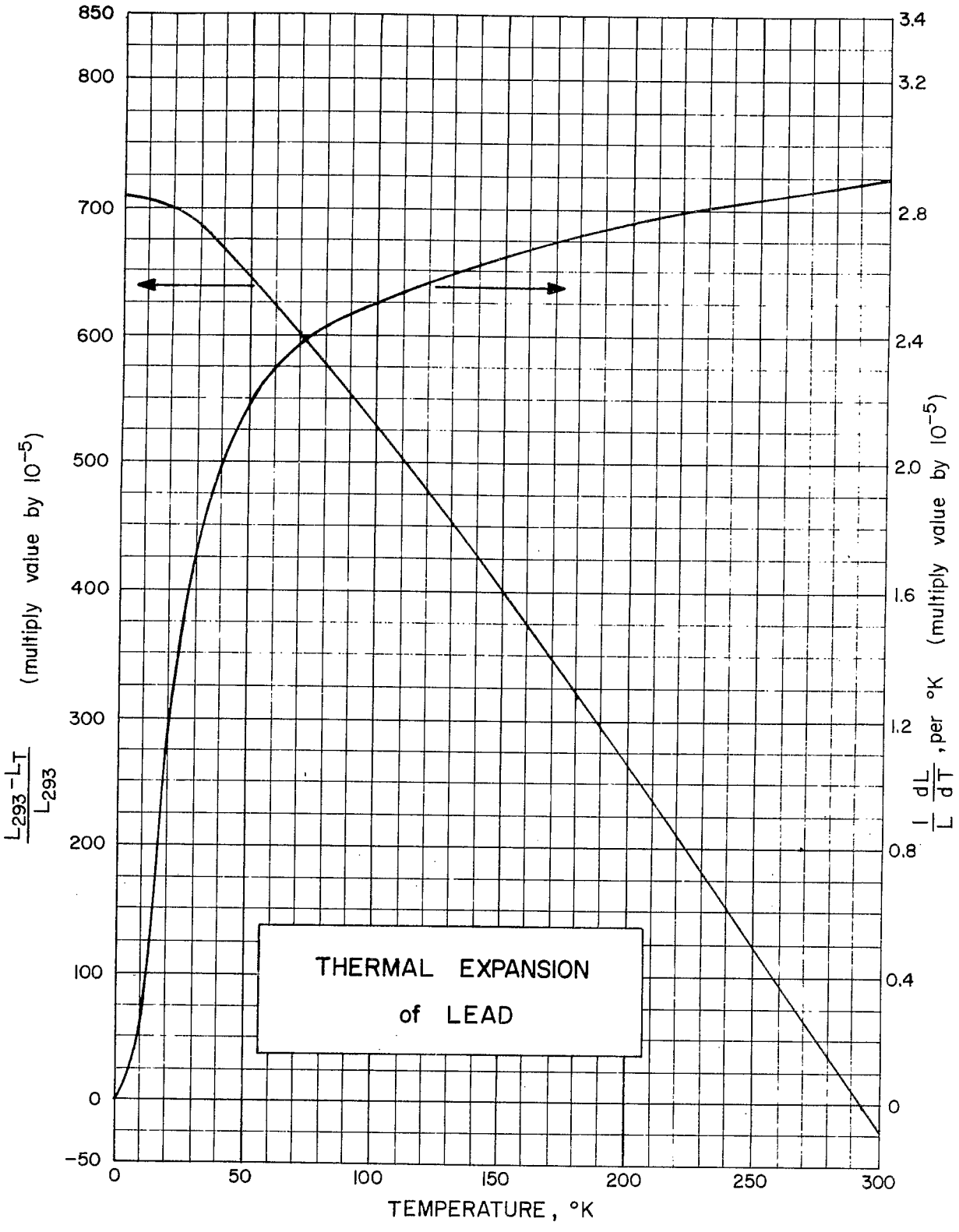
Other References: Dorsey 1908, Gruneisen 1910, Head and Laquer 1952, Lindemann 1911, McLennan, Allen and Wilhelm 1931.

Discussion: Superconducting lead has a slightly greater volume and a slightly smaller expansion coefficient than normal lead according to data by Olsen and Rohrer covering the region from 1^{o} to the transititon temperature, $7.2^{o}K$. For example, the difference in expansion coefficients at $5^{o}K$ is about 10%.

Table of Selected Values

Temp. ^{o}K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per ^{o}K	Temp. ^{o}K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per ^{o}K
0	708×10^{-5}	0	120	477×10^{-5}	2.56×10^{-5}
5	708 "	0.03×10^{-5}	140	425 "	2.63 "
10	707 "	0.32 "	160	372 "	2.68 "
20	700 "	1.1 "	180	318 "	2.72 "
30	686 "	1.7 "	200	263 "	2.75 "
40	667 "	2.0 "	220	208 "	2.78 "
50	646 "	2.2 "	240	152 "	2.82 "
60	624 "	2.3 "	260	96 "	2.85 "
70	601 "	2.4 "	273	58 "	2.88 "
80	577 "	2.4 "	280	38 "	2.89 "
90	552 "	2.5 "	293	0	2.9 "
100	528 "	2.5 "	300	-20	2.9 "

Taken from NBS 29


THERMAL EXPANSION
of LEAD
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
850
800
700
600
500
400
300
200
100
0
-50
3.4
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
0
50
100
150
200
250
300

THERMAL EXPANSION OF MAGNESIUM

Sources of Data: Ebert 1928
Goens and Schmid 1936
Head and Laquer 1952

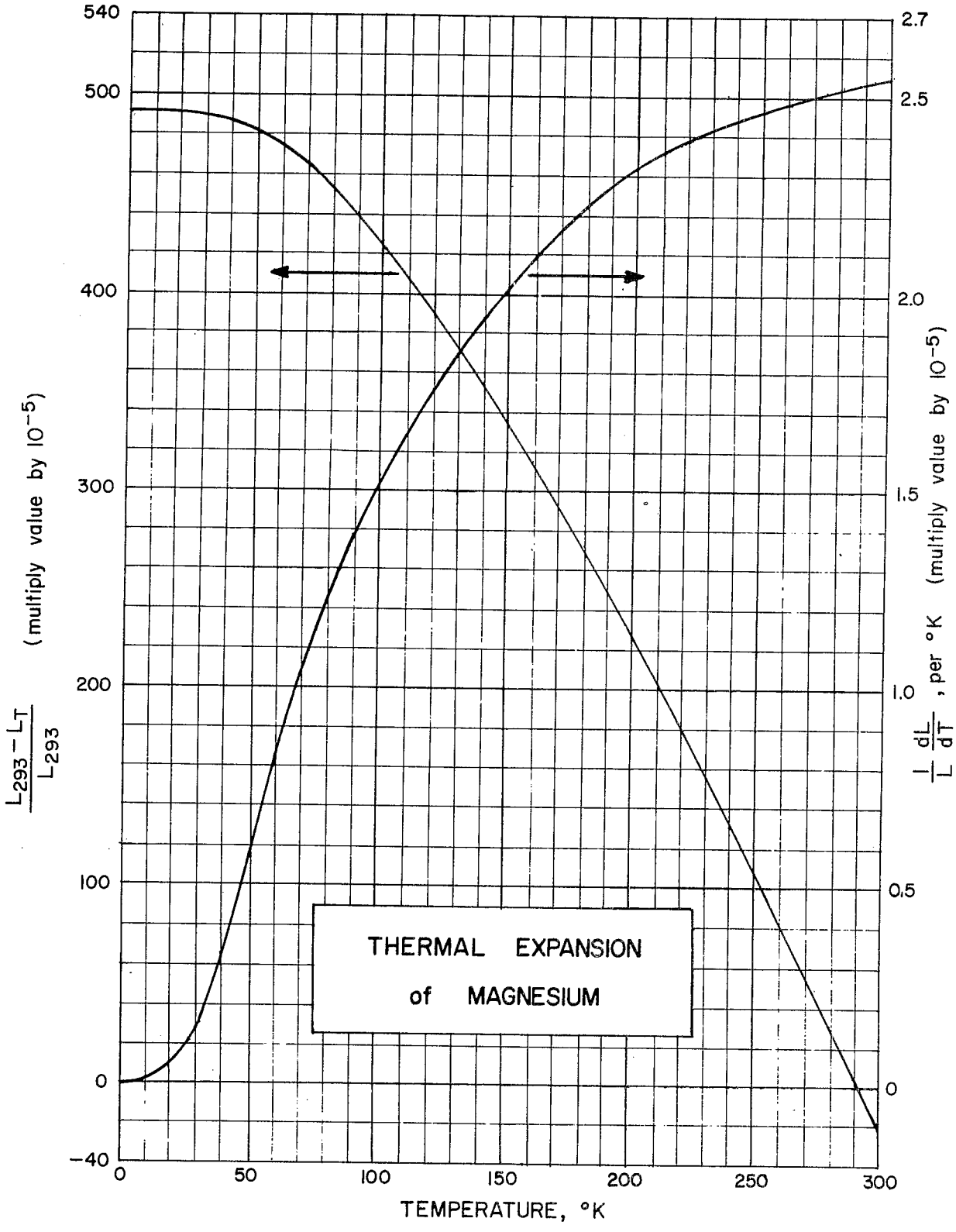
Other References: Gruneisen 1910
Hidnert and Sweeney 1928

Discussion: Anisotropic. The above values were calculated from the relation, Mean Value = 1/3 ($\parallel$) + 2/3 ($\perp$), where ($\parallel$) and ($\perp$) signify the same property measured parallel and perpendicular, respectively, to the hexagonal axis.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	490×10^{-5}	0.	140	356×10^{-5}	1.94×10^{-5}
10	490 "	0.005×10^{-5}	160	316 "	2.10 "
20	490 "	.04 "	180	273 "	2.22 "
30	489 "	.14 "	200	227 "	2.32 "
40	486 "	.33 "	220	180 "	2.39 "
50	482 "	.57 "	240	132 "	2.44 "
60	475 "	.81 "	260	82.9 "	2.48 "
70	466 "	1.03 "	273	50.4 "	2.51 "
80	454 "	1.22 "	280	32.9 "	2.52 "
90	441 "	1.39 "	293	0.0 "	2.54 "
100	427 "	1.54 "	300	-17.8 "	2.55 "
120	393 "	1.76 "			

Taken from NBS 29


THERMAL EXPANSION
of MAGNESIUM
$\frac{L_{293} - L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
540
500
400
300
200
100
0
-40
2.7
2.5
2.0
1.5
1.0
0.5
0
0
50
100
150
200
250
300

THERMAL EXPANSION OF MONEL

Sources of Data: Altman, Rubin, and Johnston 1952

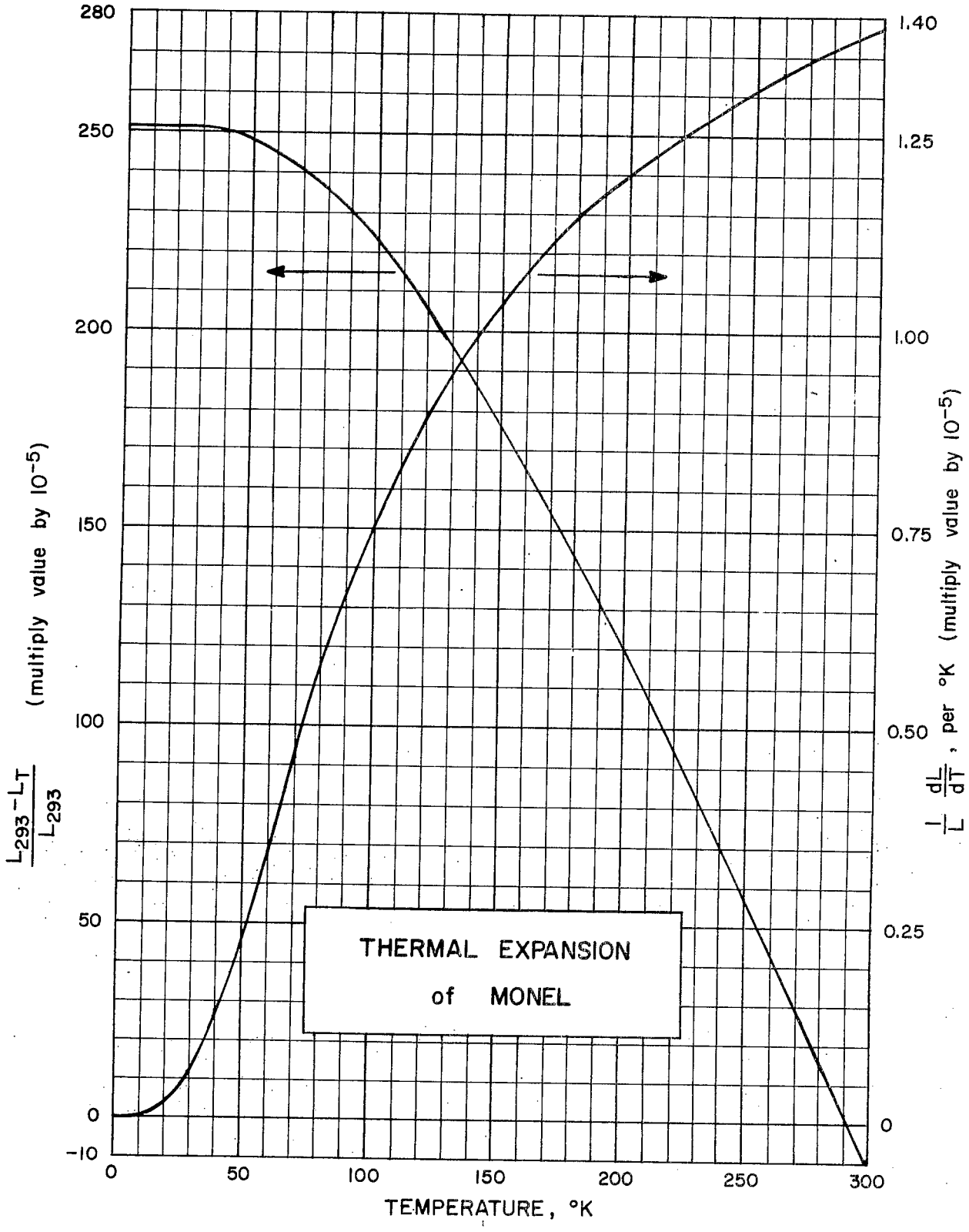
Other References: Ackerman 1936
Aoyama and Ito 1939
Fraser and Hollis-Hallet 1955
Krupkowski and de Haas 1928

Discussion: 67 Ni, 30 Cu, 1.5 Fe, "cold-rolled".

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	251×10^{-5}	0.	140	187×10^{-5}	0.99×10^{-5}
10	251 "	0.003×10^{-5}	160	167 "	1.08 "
20	251 "	.02 "	180	144 "	1.15 "
30	251 "	.06 "	200	121 "	1.20 "
40	250 "	.14 "	220	96.4 "	1.25 "
50	248 "	.23 "	240	70.9 "	1.29 "
60	245 "	.34 "	260	44.7 "	1.33 "
70	244 "	.46 "	273	27.1 "	1.35 "
80	236 "	.57 "	280	15.1 "	1.36 "
90	230 "	.67 "	293	0.0 "	1.38 "
100	223 "	.75 "	300	- 9.7 "	1.39 "
120	206 "	.89 "			

Taken from NBS 29


THERMAL EXPANSION
of MONEL
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
280
250
200
150
100
50
0
-10
1.40
1.25
1.00
0.75
0.50
0.25
0
0
50
100
150
200
250
300

THERMAL EXPANSION OF NICKEL

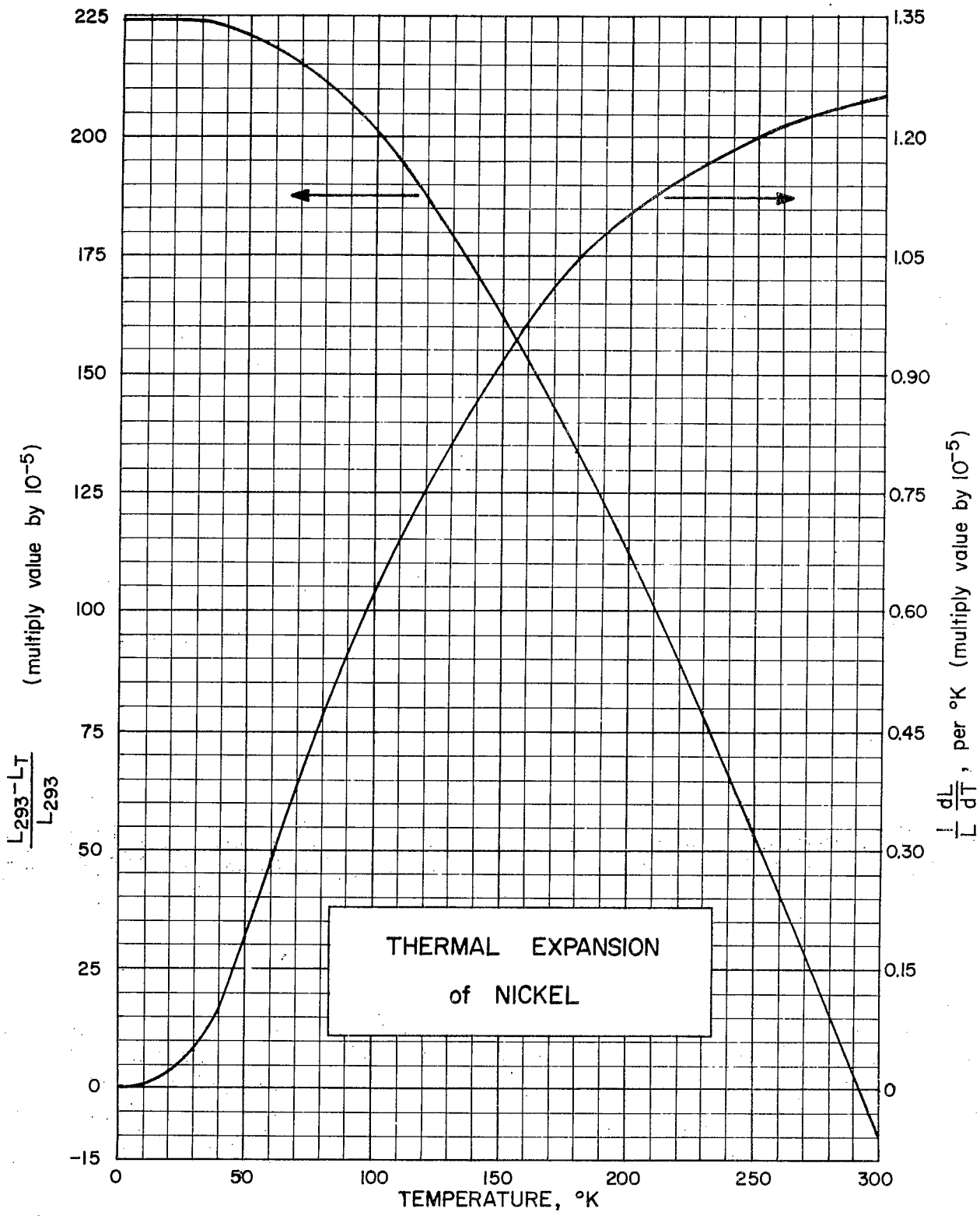
Sources of Data: Krupkowski and DeHaas 1928, Nix and MacNair 1941.

Other References: Adenstedt 1936, Altman, Rubin and Johnston 1954, Aoyama and Ito 1939, Disch 1921, Henning 1907, Simon and Bergmann 1930.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	224×10^{-5}	0.	140	171×10^{-5}	0.88×10^{-5}
20	224 "	0.02×10^{-5}	160	152 "	0.98 "
30	224 "	.05 "	180	132 "	1.05 "
40	223 "	.10 "	200	111 "	1.10 "
50	221 "	.19 "	220	88 "	1.15 "
60	219 "	.28 "	240	65 "	1.19 "
70	216 "	.38 "	260	41 "	1.22 "
80	211 "	.47 "	273	25 "	1.23 "
90	206 "	.55 "	280	16 "	1.24 "
100	201 "	.61 "	293	0 "	1.26 "
120	187 "	.75 "	300	-9 "	1.26 "

Taken from NBS 29


THERMAL EXPANSION
of NICKEL
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
225
200
175
150
125
100
75
50
25
0
-15
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0
0
50
100
150
200
250
300

THERMAL EXPANSION OF NIOBIUM

Sources of Data: Erfling 1942.

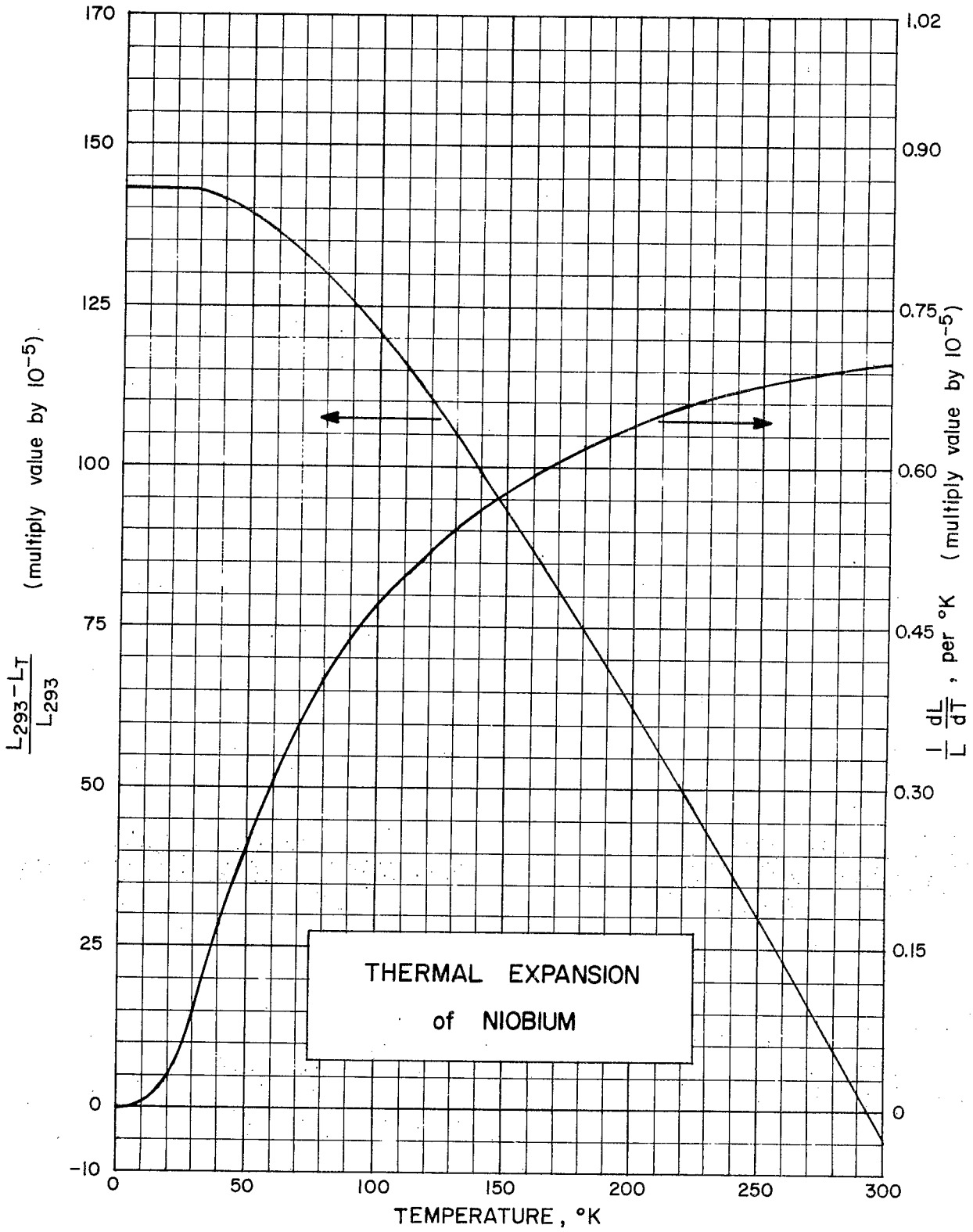
Other References: Hidnert and Krider 1933.

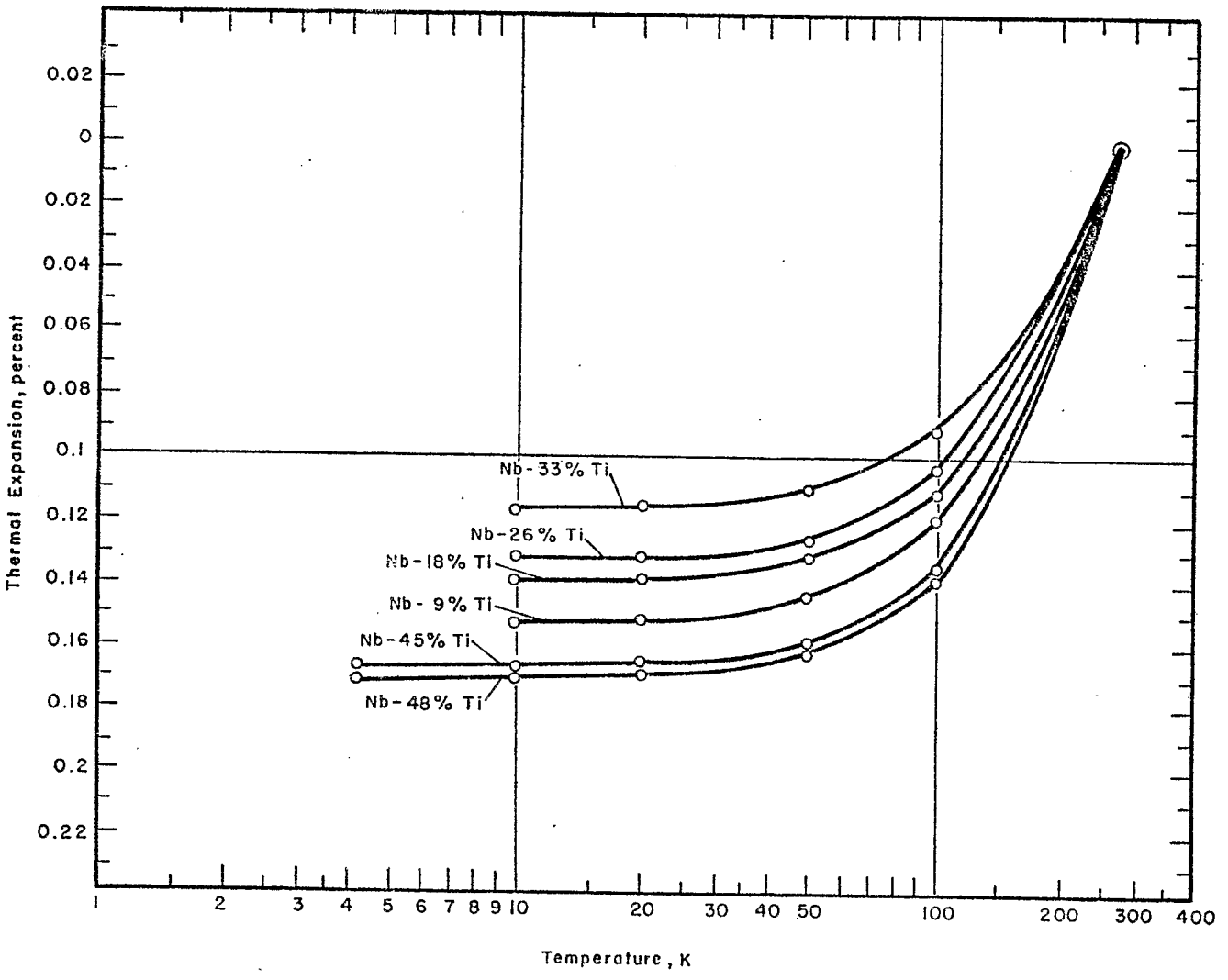
Discussion: Also termed columbium.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	143×10^{-5}	0.	140	99.4×10^{-5}	$.56 \times 10^{-5}$
10			160	87.7 "	.59 "
20	143 "	$.03 \times 10^{-5}$	180	75.5 "	.62 "
30	143 "	.09 "	200	63.0 "	.64
40	141 "	.17 "	220	50.0 "	.66
50	139 "	.24 "		"	
60	137 "	.31 "	240	36.7 "	.67 "
70	133 "	.36 "	260	23.1 "	.68 "
80	129 "	.40 "	273	14.1 "	.69 "
90	125 "	.44 "	280	9.2 "	.69 "
100	121 "	.47 "	293	0.0	.70 "
120	111 "	.52	300	-5.0	.70 "

Taken from NBS 29


THERMAL EXPANSION
of NIOBIUM
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
170
150
125
100
75
50
25
0
-10
1.02
0.90
0.75
0.60
0.45
0.30
0.15
0
0
50
100
150
200
250
300



THERMAL EXPANSION VERSUS TEMPERATURE FOR NB-TI-ALLOYS

THERMAL EXPANSION OF ARALDITE NO.501

Sources of Data: Laquer and Head 1952.

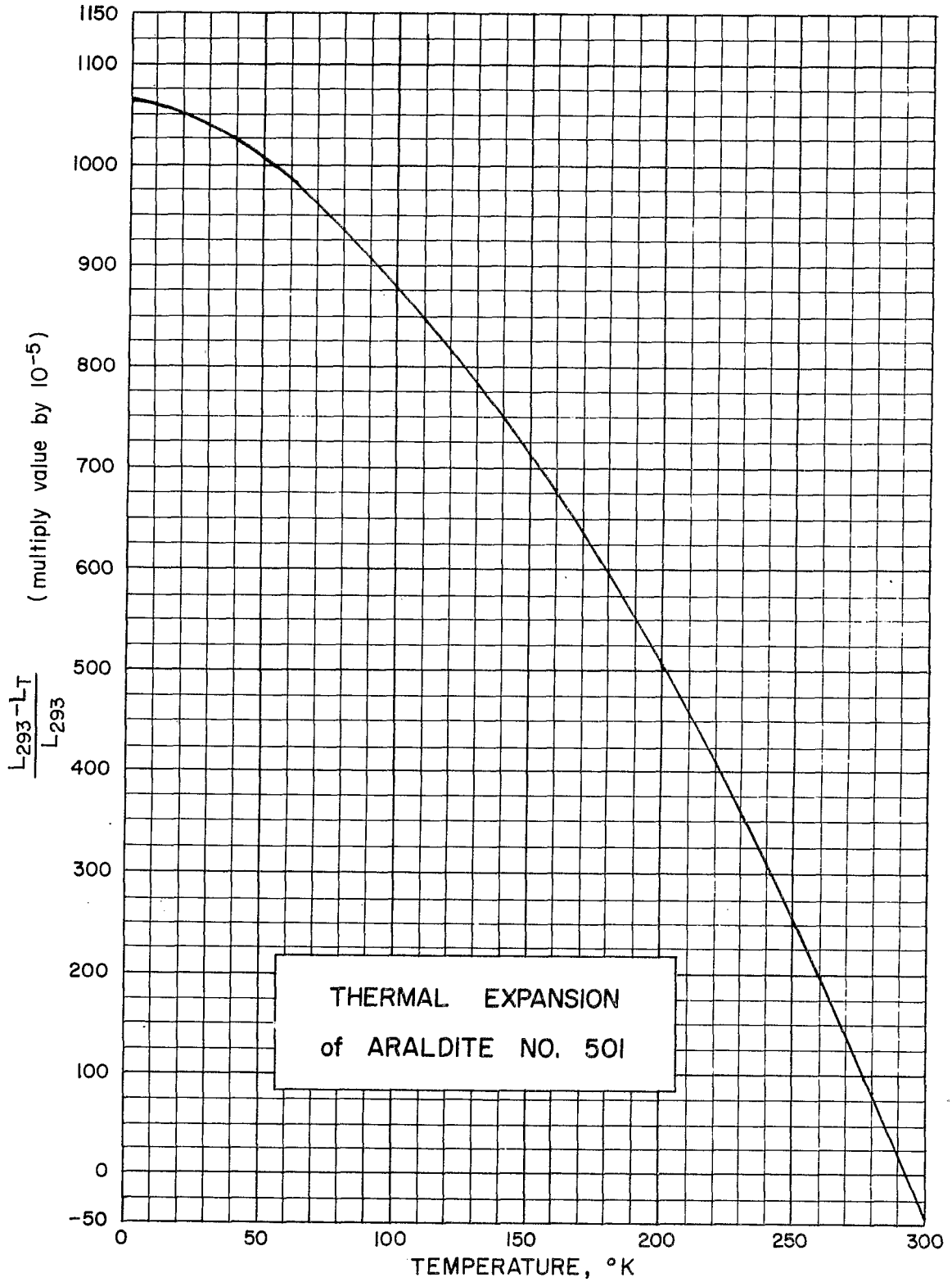
Other References:

Discussion: Epoxy casting resin made by Ciba Co. 40 g of the material was catalyzed with 2 ml triethanolamine. Cured 8 hr. at 120° C and then 24 hr. at 180° C.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
0	1061 x 10^{-5}	200	505 x 10^{-5}
20	1051 "	220	410 "
40	1022 "	240	308 "
60	983 "	260	199 "
80	935 "	273	122 "
100	880 "	280	81 "
120	819 "	293	0 "
140	751 "	300	-46 "
160	676 "		
180	594 "		

Taken from NBS 29


THERMAL EXPANSION
of ARALDITE NO. 501
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
TEMPERATURE, °K
1150
1100
1000
900
800
700
600
500
400
300
200
100
0
-50
0
50
100
150
200
250
300

THERMAL EXPANSION OF FLUOROTHENE or KEL-F

Sources of Data: Laquer and Head 1952.

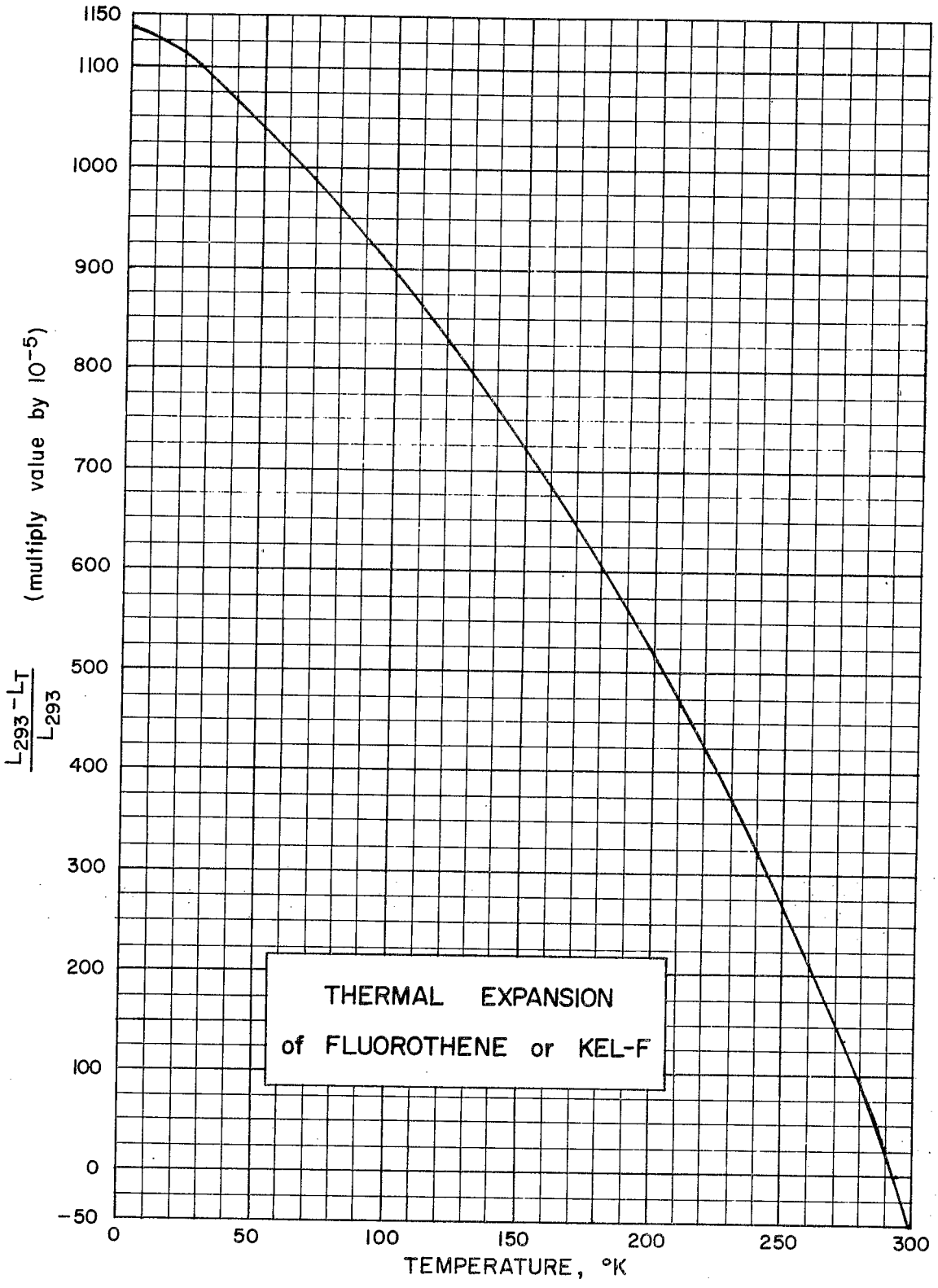
Other References:

Discussion: Polychlorotrifluoroethylene. The samples were, respectively, from a 5 in. diameter rod of Fluorothene made by Union Carbon and Carbide and from a 1/16 in. thick sheet of Kel-F made by M.W. Kellog and Co.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
0	1135 x 10^{-5}	180	604 x 10^{-5}
20	1114 "	200	517 "
40	1070 "	220	424 "
60	1019 "	240	324 "
80	962 "	260	214 "
100	900 "	273	134 "
120	834 "	280	90 "
140	763 "	293	0 "
160	686 "	300	-52 "

Taken from NBS 29


THERMAL EXPANSION
of FLUOROTHENE or KEL-F
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
1150
1100
1000
900
800
700
600
500
400
300
200
100
0
-50
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION OF LUCITE

Sources of Data: Laquer and Head 1952.

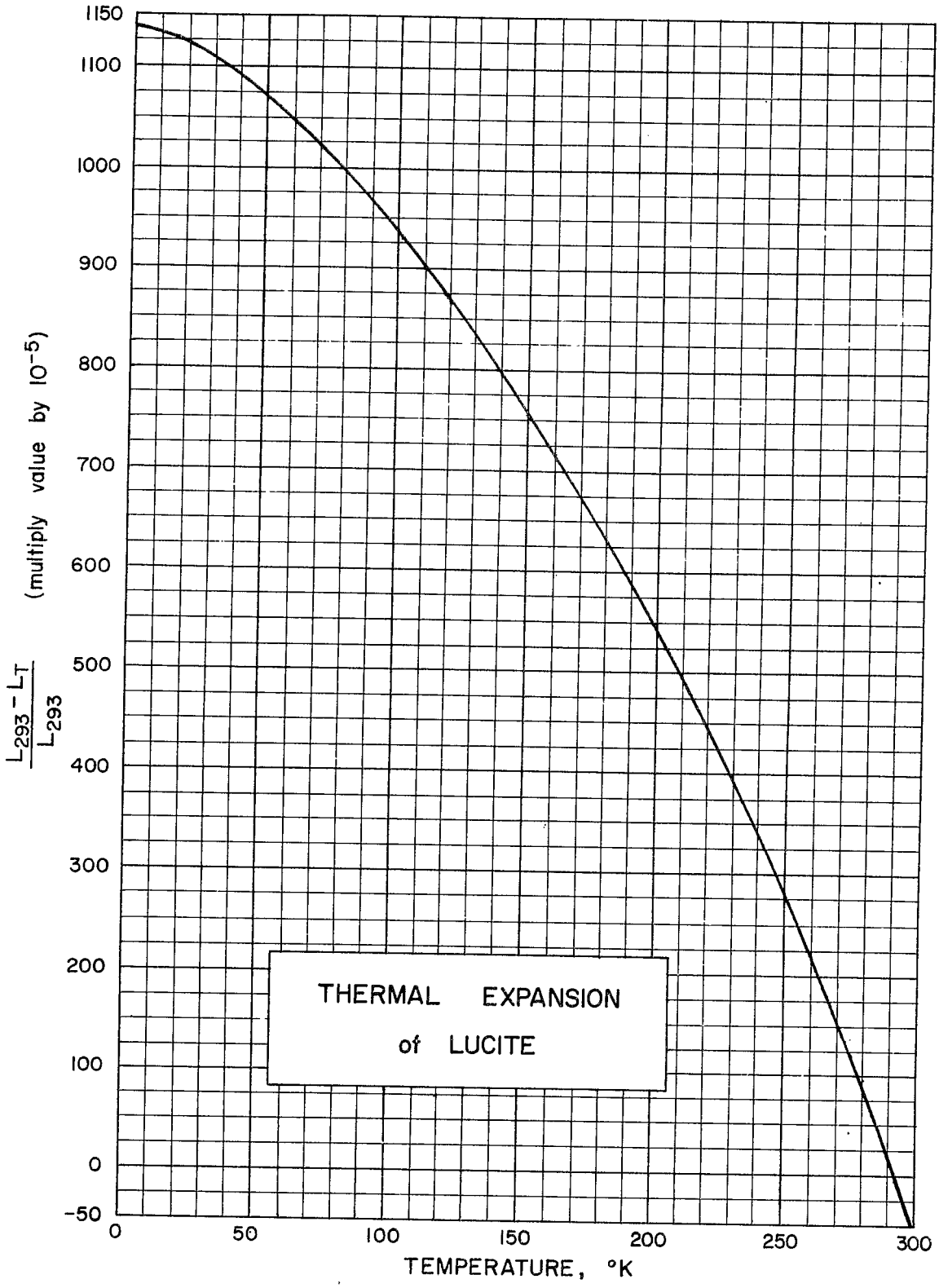
Other References:

Discussion: Polymethylmethacrylate. "Probably DuPont Lucite". Average of two samples from rod stock.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
0	1134 x 10^{-5}	180	632 x 10^{-5}
20	1123 "	200	540 "
40	1092 "	220	441 "
60	1048 "	240	335 "
80	995 "	260	220 "
100	936 "	273	136 "
120	869 "	280	91 "
140	796 "	293	0 "
160	717 "	300	-53 "

Taken from NBS 29


THERMAL EXPANSION
of LUCITE
$\frac{L_{293} - L_T}{L_{293}}$ (multiply value by 10^{-5})
TEMPERATURE, °K
1150
1100
1000
900
800
700
600
500
400
300
200
100
0
-50
0
50
100
150
200
250
300

THERMAL EXPANSION OF NYLON

Sources of Data: Laquer and Head 1952.

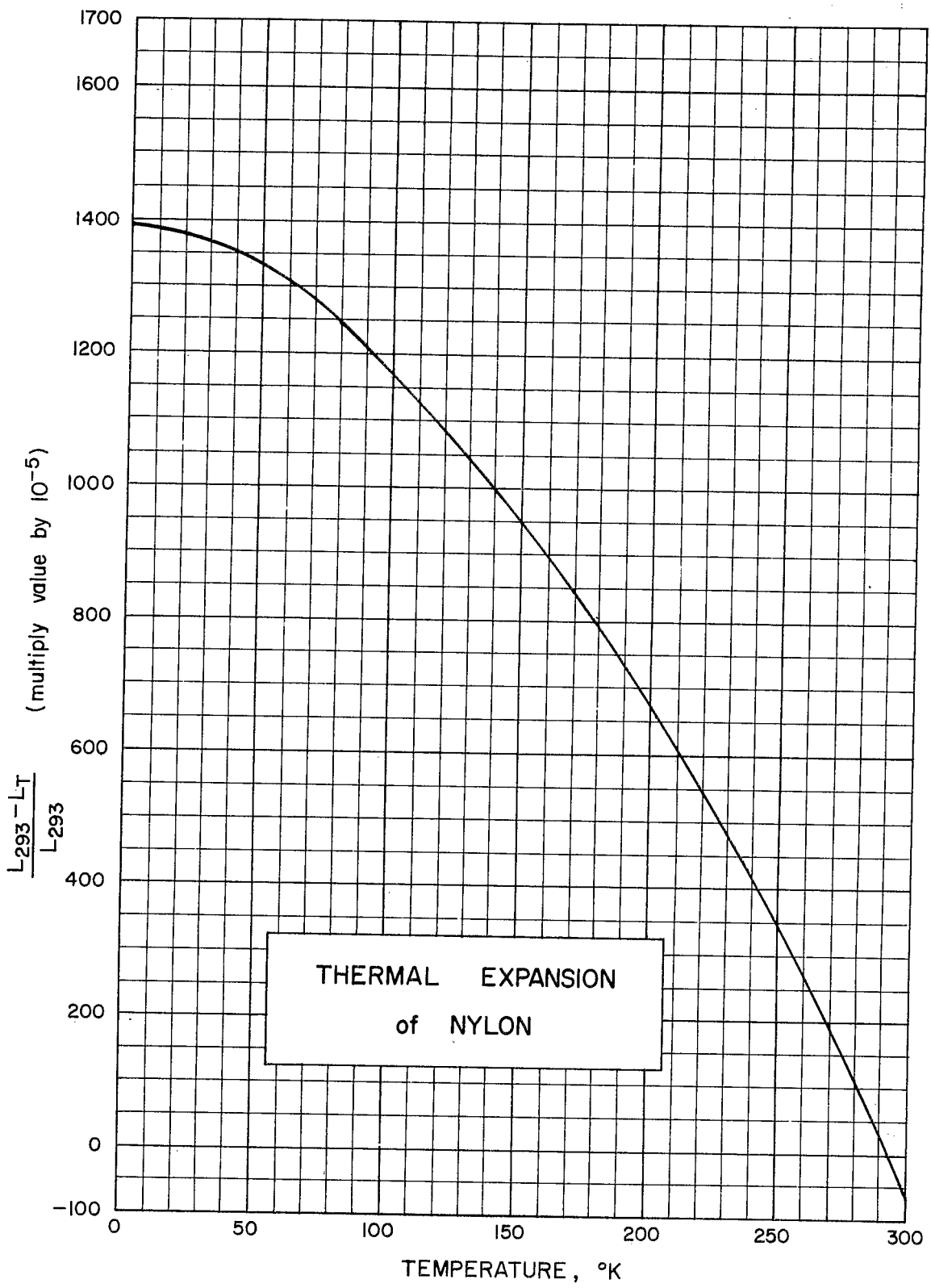
Other References:

Discussion: From 3/4 inch diameter rod. "Probably E.I. DuPont de Nemours and Co. grade FM-1".

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
0	1389 x 10^{-5}	180	789 x 10^{-5}
20	1379 "	200	673 "
40	1352 "	220	548 "
60	1308 "	240	412 "
80	1247 "	260	265 "
100	1172 "	273	161 "
120	1088 "	280	107 "
140	996 "	300	0 "
160	896 "		-61 "

Taken from NBS 29


THERMAL EXPANSION
of NYLON
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
TEMPERATURE, °K
1700
1600
1400
1200
1000
800
600
400
200
0
−100
0
50
100
150
200
250
300

THERMAL EXPANSION OF PLEXIGLAS

Sources of Data: Data from Laquer and Head 1952. (In addition to the substances listed in the table, data have been given for 16 specially compounded rubbers by Dunsmoor et al. 1958 and Trepus et al. 1959. These data consist mainly of values of $\frac{(L_{293}-L_{78})}{L_{293}}$.

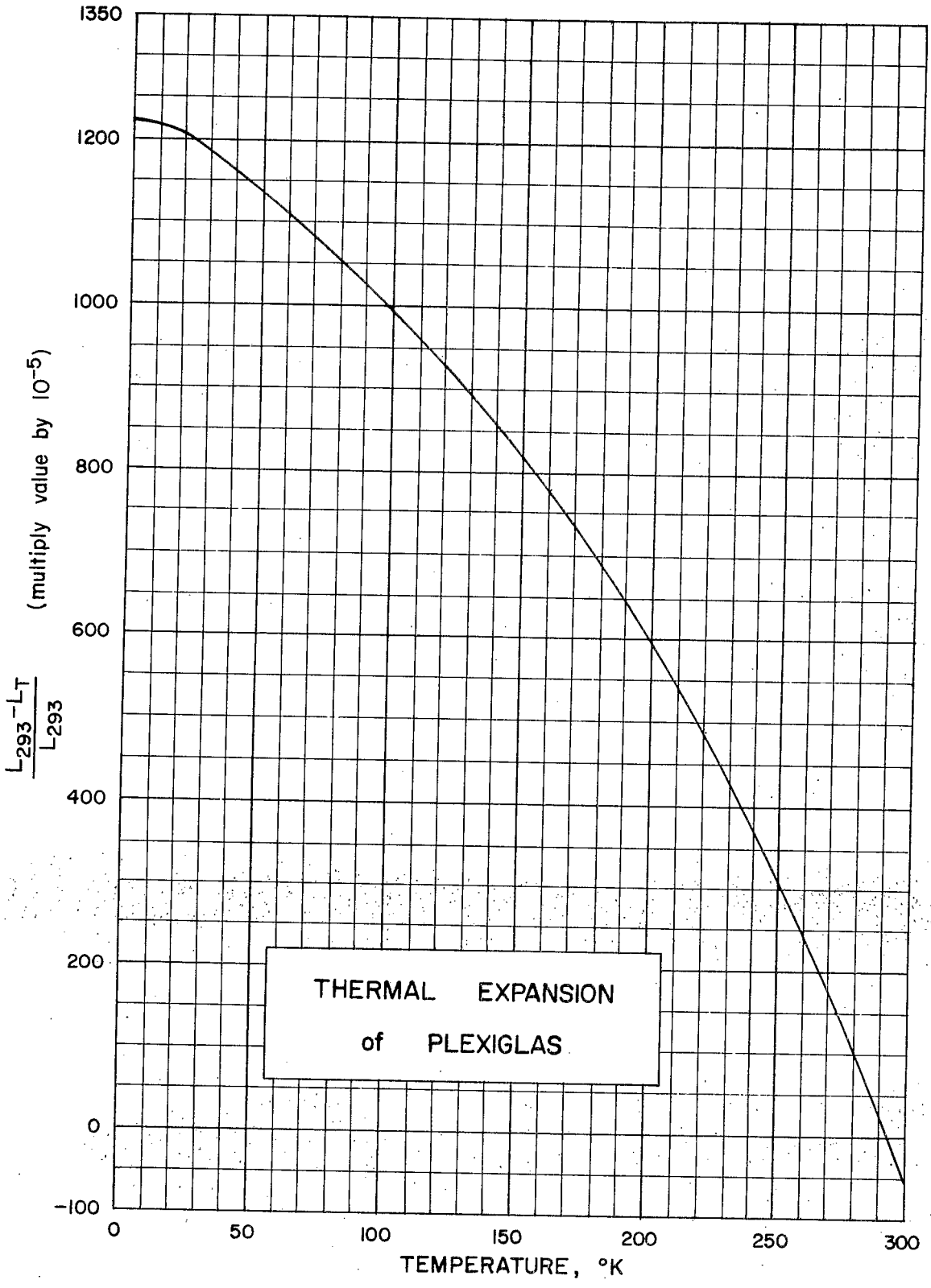
Other References: Wood, Bekkedahl and Peters 1939.

Discussion: Polymethylmethacrylate made by Rohm and Haas Co. Data from Giauque, Geballe, Lyon and Fritz 1952.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
0	1220 x 10^{-5}	200	590 x 10^{-5}
20	1210 "	220	490 "
40	1160 "	240	370 "
60	1110 "	260	240 "
80	1050 "	273	150 "
100	990 "	280	99 "
120	930 "	293	0 "
140	860 "	298	
160	780 "	300	-55 "
180	690 "		

Taken from NBS 29


1350
1200
1000
800
600
400
200
0
-100
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of PLEXIGLAS

THERMAL EXPANSION OF POLYSTYRENE

Sources of Data: Laquer and Head 1952. (In addition to the substances listed in the table, data have been given for 16 specially compounded rubbers by Dunsmoor et al. 1958 and Trepus et al. 1959. These data consist mainly of values of $(L_{293}-L_{78})/L_{293}$.

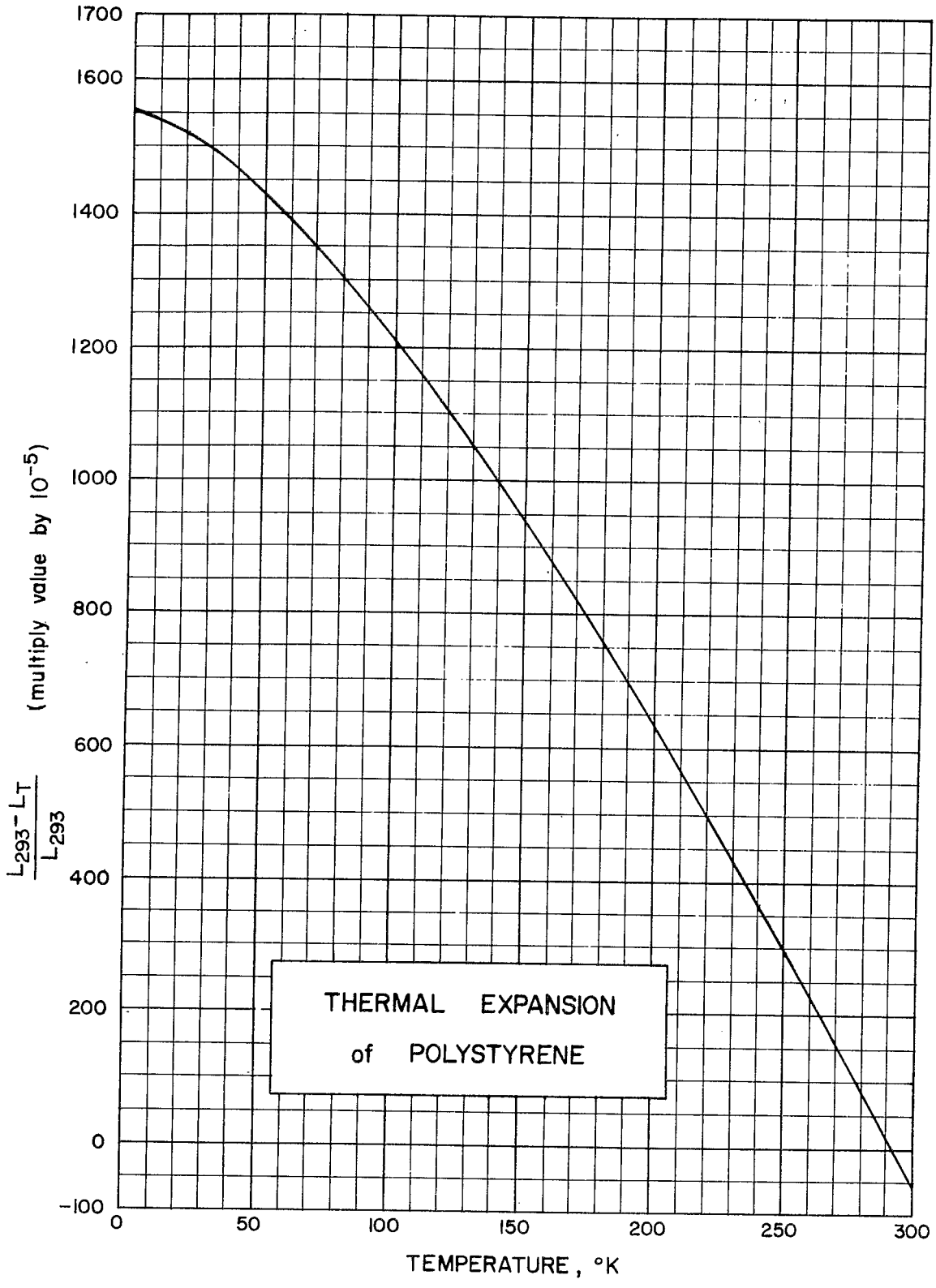
Other References: Wood, Bekkedahl and Peters 1939.

Discussion: Average of two samples from rod stock, both "probably American Phenolic Corp. grade 912A.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
0	1550 x 10^{-5}	200	626 x 10^{-5}
20	1552 "	220	499 "
40	1466 "	240	368 "
60	1394 "	260	232 "
80	1308 "	273	141 "
100	1211 "	280	93 "
120	1105 "	293	0 "
140	992 "	298	
160	874 "	300	-51 "
180	752 "		

Taken from NBS 29


1700
1600
1400
1200
1000
800
600
400
200
0
-100
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
0
50
100
150
200
250
300
TEMPERATURE, °K
THERMAL EXPANSION
of POLYSTYRENE

THERMAL EXPANSION OF POLYTHENE

Sources of Data: Laquer and Head 1952. (In addition to the substances listed in the table, data have been given for 16 specially compounded rubbers by Dunsmoor et al. 1958 and Trepus et al. 1959. These data consist mainly of values of $(L_{293}-L_{78})/L_{293}$.

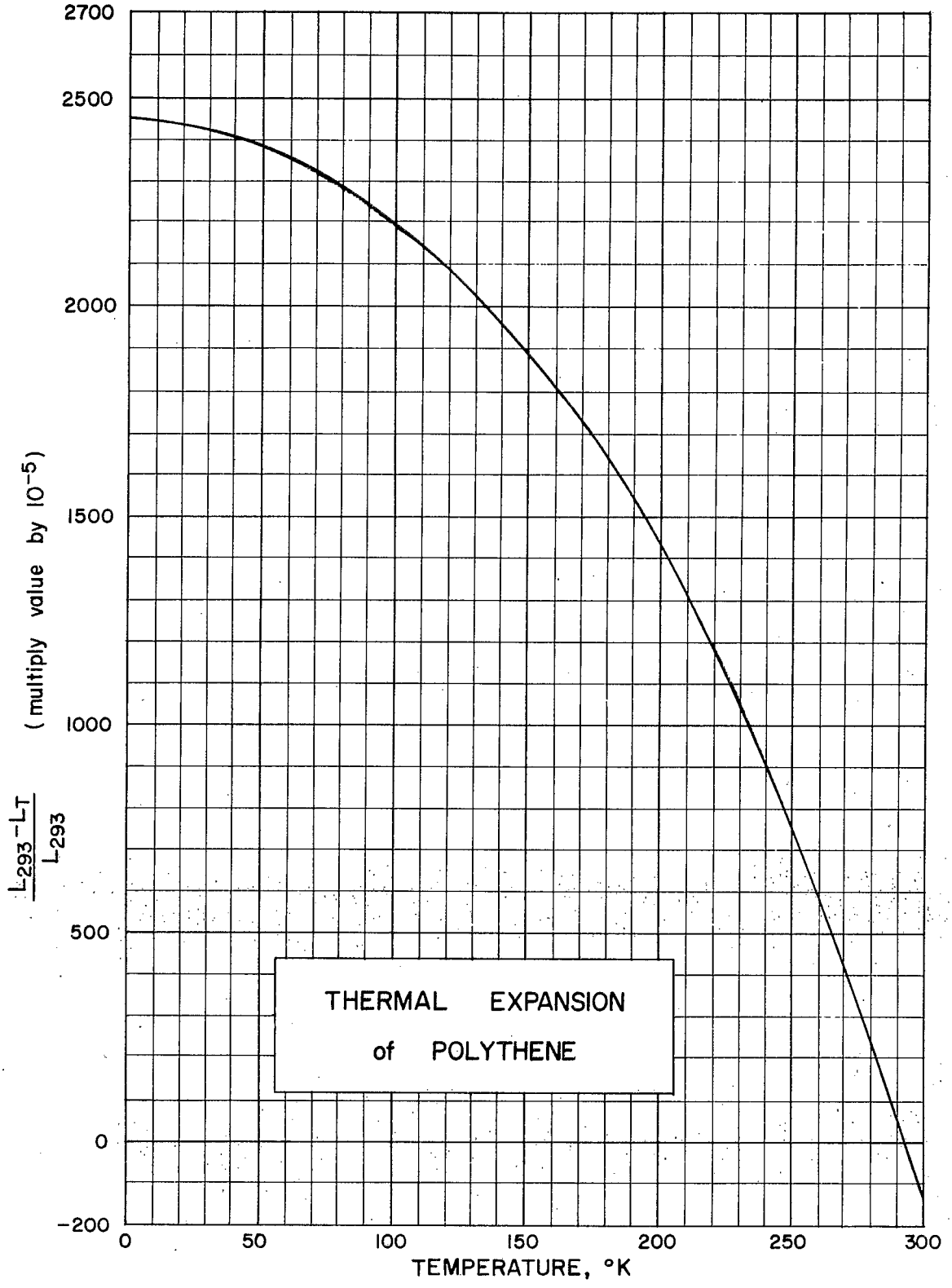
Other References: Wood, Bekkedahl and Peters 1939.

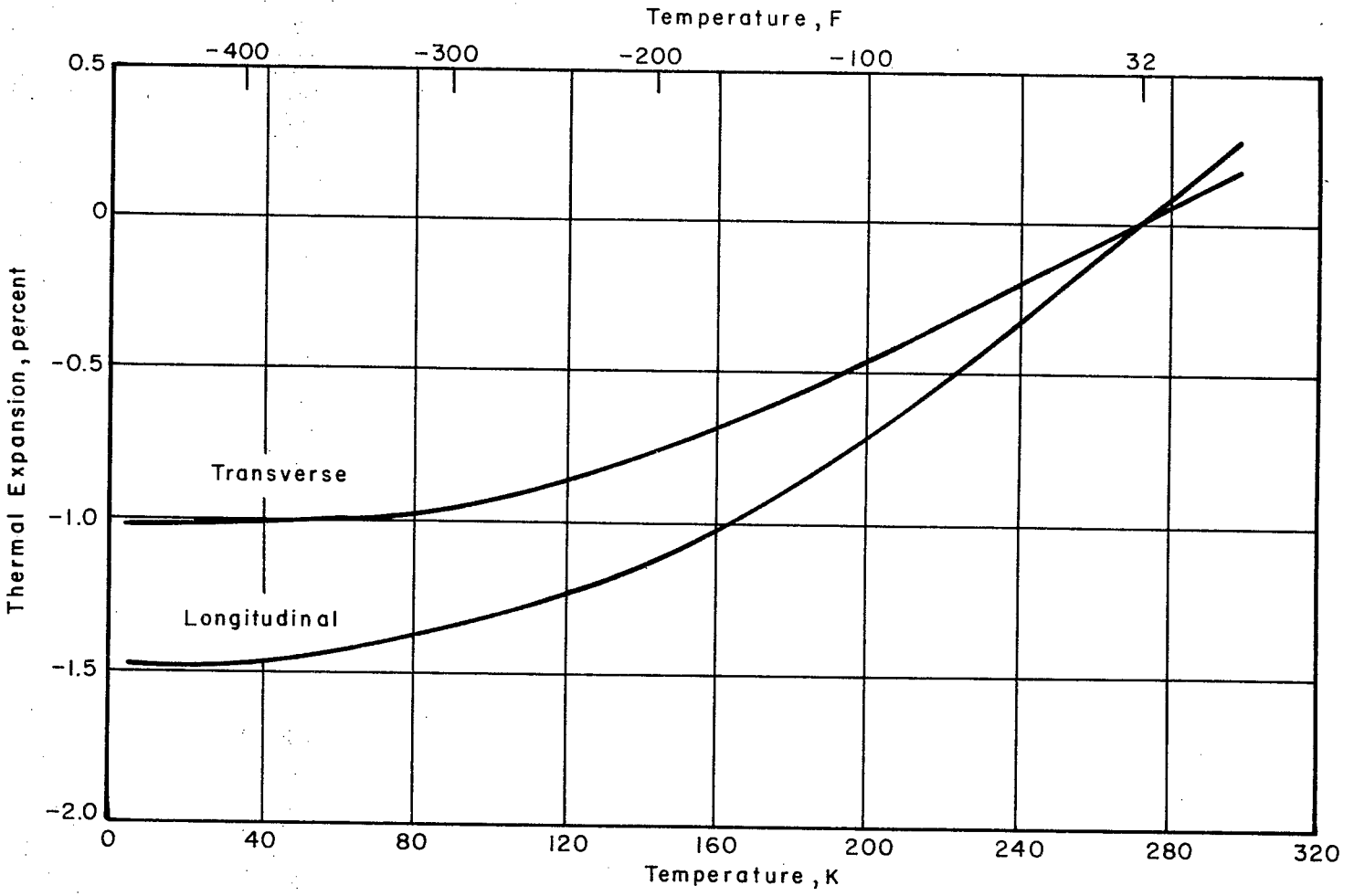
Discussion: Polyethylene made by E.I. Du Pont de Nemours and Co.. Molded under 2000 psi pressure at 150°C for 10 min. Directional variations were negligible. See also Hunter and Oakes 1945. Five filled polythenes were measured by Head and Laquer 1952.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
0	2449 x 10^{-5}	200	1439 x 10^{-5}
20	2439 "	220	1199 "
40	2404 "	240	919 "
60	2349 "	260	594 "
80	2279 "	273	359 "
100	2194 "	280	239 "
120	2089 "	293	0 "
140	1964 "	298	
160	1814 "	300	-131 "
180	1639 "		

Taken from NBS 29


2700
2500
2000
1500
1000
500
0
-200
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of POLYTHENE



THERMAL EXPANSION VERSUS TEMPERATURE FOR POLYETHYLENE

THERMAL EXPANSION OF TEFLON

Sources of Data: Laquer and Head 1952

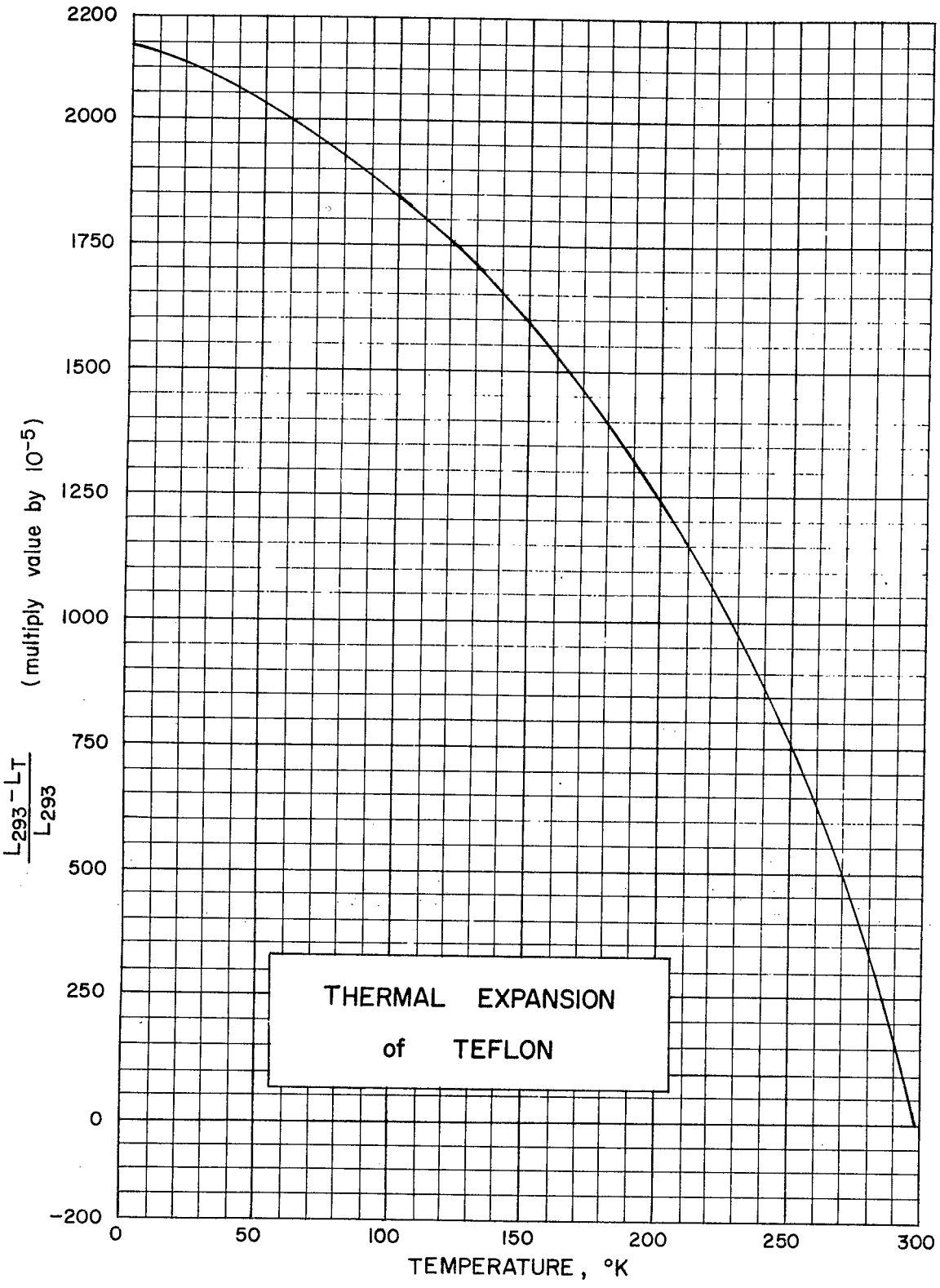
Other References: Dunsmoor et al. 1958
Trepus et al. 1959
Wood, Bekkedahl and Peters 1939.

Discussion: Polytetrafluoroethylene. Extruded and annealed sample measured by Kirby 1956. He found that strained samples could have expansions larger or smaller than those of annealed Teflon, the differences being as large as 20%. Laquer and Head (1952) measured two samples of DuPont Teflon rod taken normal and parallel to the extrusion direction. The expansions parallel were roughly 15% larger than those normal, and the average is 10 to 15% larger than the the above data by Kirby. The data of Laquer and Head were used only to guide the extrapolation of Kirby's values below 80°K. Teflon has a first order transition at 20°C. Therefore we use 25° C as a reference temperature and tabulate 10^5 $(L_{298}-L_T)$ L_{298} above.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$
0	2140 x 10^{-5}	160	1540 x 10^{-5}
20	2110 "	180	1400 "
40	2060 "	200	1240 "
60	2000 "	220	1050 "
80	1930 "	240	855 "
100	1850 "	260	645 "
120	1760 "	273	500 "
140	1660 "	298	0 "

Taken from NBS 29


2200
2000
1750
1500
1250
1000
750
500
250
0
-200
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
THERMAL EXPANSION
of TEFLON

THERMAL EXPANSION OF PLATINUM

Sources of Data: Nix and MacNair 1942.

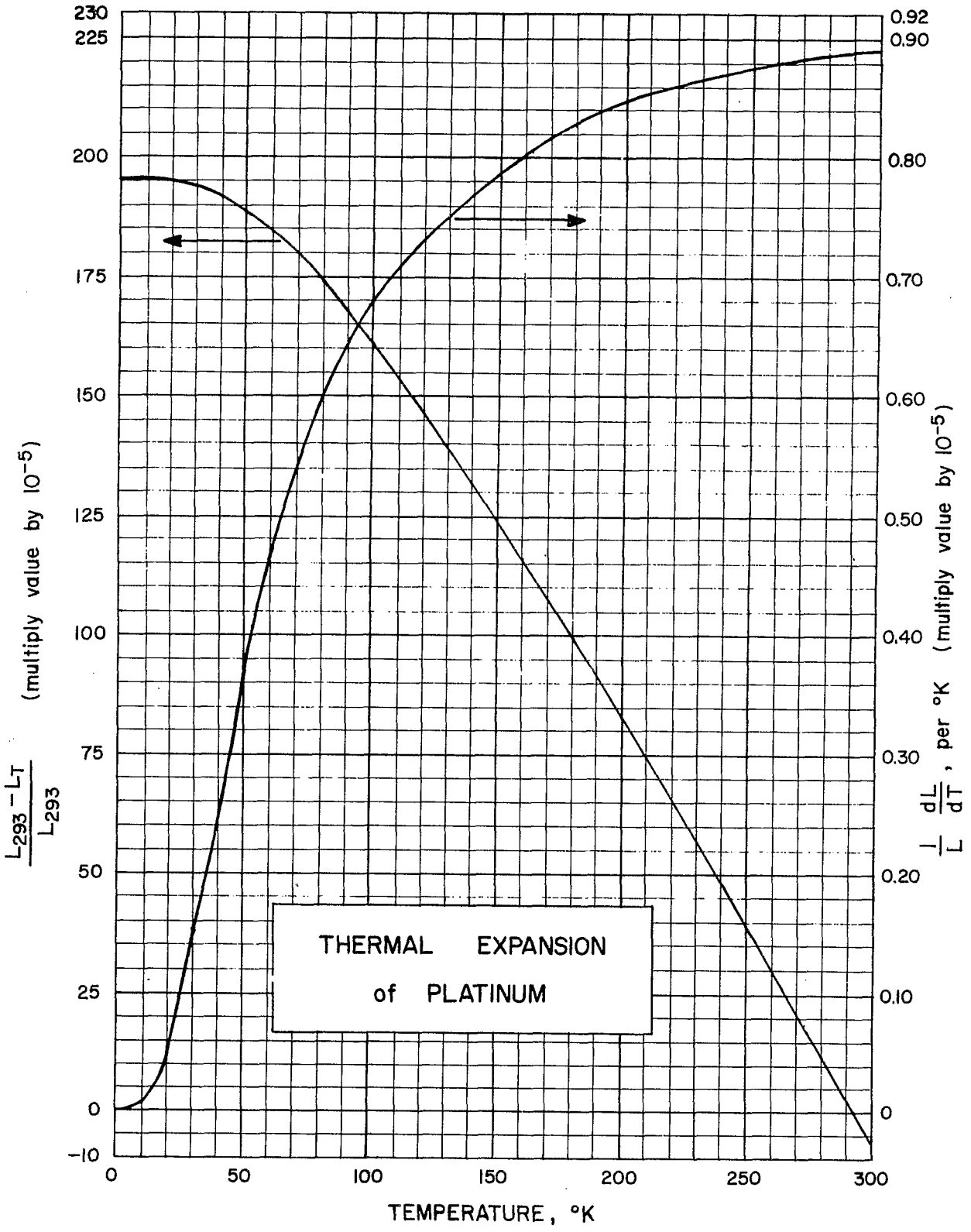
Other References: Dorsey 1907.
Henning 1907.
Onnes and Clay 1096.
Scheel 1907.
Scheel and Heuse 1907.
Valentiner and Wallot 1915.

Discussion:

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	195×10^{-5}	0.	140	132×10^{-5}	0.77×10^{-5}
10	195 "	0.008×10^{-5}	160	116 "	.80 "
20	195 "	.05 "	180	99.4 "	.83 "
30	194 "	.15 "	200	82.4 "	.85 "
40	192 "	.26 "	220	65.0 "	.86 "
50	189 "	.38 "	240	47.5 "	.87 "
60	185 "	.47 "	260	29.6 "	.88 "
70	180 "	.54 "	273	18.0 "	.88 "
80	174 "	.60 "	280	11.6 "	.89 "
90	168 "	.65 "	293	0.0 "	.89 "
100	161 "	.68 "	300	-6.4 "	.89 "
120	147 "	.73 "			

Taken from NBS 29


THERMAL EXPANSION
of PLATINUM
$\frac{L_{293} - L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
230
225
200
175
150
125
100
75
50
25
0
−10
0.92
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0
0
50
100
150
200
250
300

THERMAL EXPANSION OF QUARTZ (CRYSTALLINE ||)

Sources of Data: Buffington and Latimer 1926

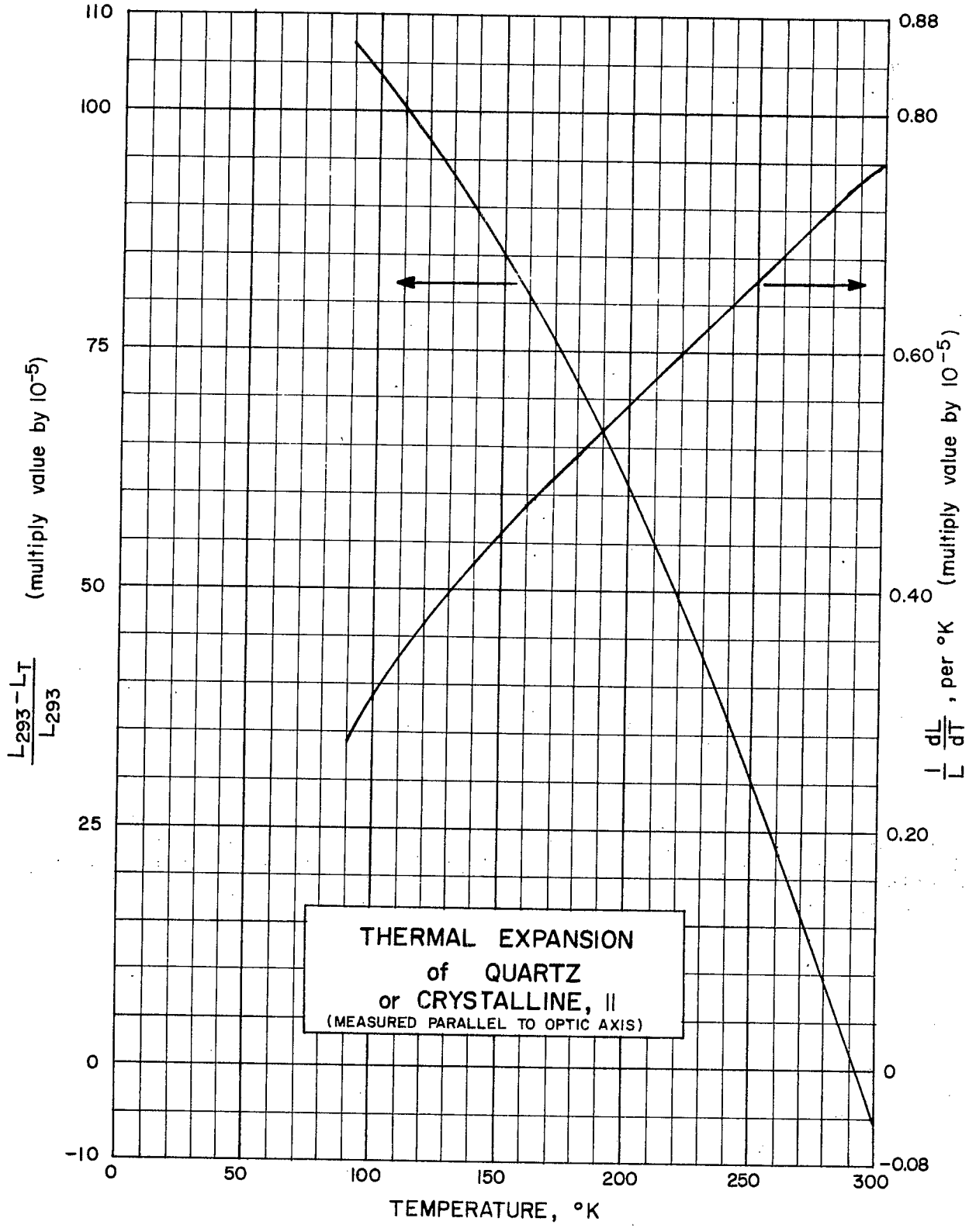
Other References: Dorsey 1908
Lindemann 1912
Nix and MacNair 1941
Scheel 1907
Sosman 1927

Discussion: Measured parallel to the optic axis. Nix and MacNair measured expansions perpendicular to the optic axis but presented only a coarse graph of the results, from which the following values of $10^6 (dL/LdT)$ were taken: 7 at 100°K, 10 at 150°, 12 at 200°, 13 at 250°, 14 at 300°K.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
90	107×10^{-5}	0.27×10^{-5}	240	36.7×10^{-5}	0.64×10^{-5}
100	104 "	.31 "	260	23.6 "	.68 "
120	97.7 "	.37 "	273	14.6 "	.71 "
140	89.8 "	.42 "	280	9.6 "	.72 "
160	80.9 "	.47 "	293	0.0 "	.75 "
180	71.2 "	.51 "	300	- 5.3 "	.76 "
200	60.5 "	.55 "			
220	49.1 "	.59 "			

Taken from NBS 29


THERMAL EXPANSION
of QUARTZ
or CRYSTALLINE, ||
(MEASURED PARALLEL TO OPTIC AXIS)
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
110
100
75
50
25
0
-10
0.88
0.80
0.60
0.40
0.20
0
-0.08
0
50
100
150
200
250
300

THERMAL EXPANSION OF SILVER

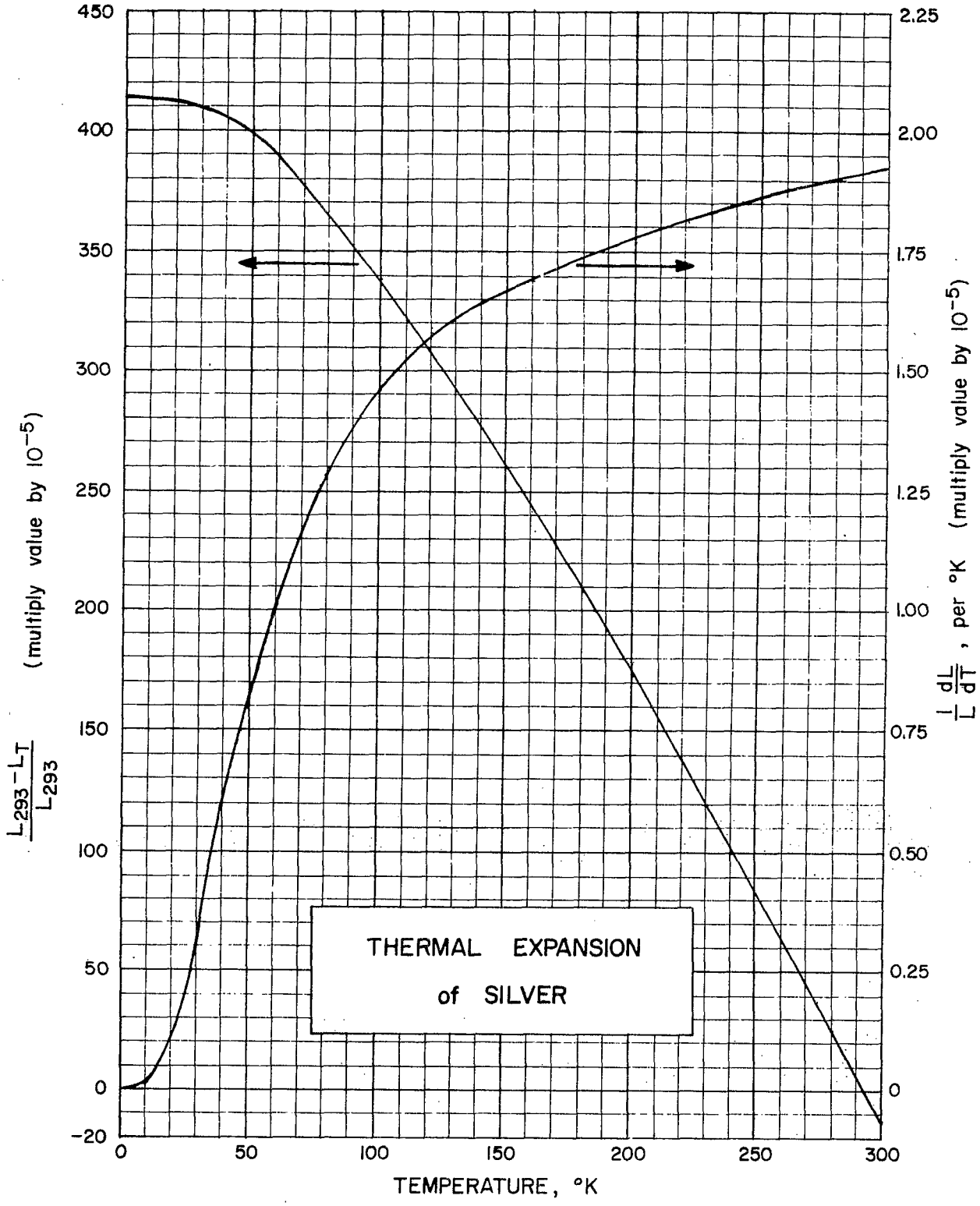
Sources of Data: Ebert 1928, Nix and MacNair 1942.

Other References: Ayres 1905, Buffington and Latimer 1926, Dorsey 1907, Henning 1907, Keesom and Jansen 1927, Lindemann 1911. Keesom and Kohler 1933. Owen and Williams 1954. Shearer 1950.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	413×10^{-5}	0	120	308×10^{-5}	1.59×10^{-5}
10	413 "	0.01×10^{-5}	140	276 "	1.65 "
20	412 "	.1 "	160	242 "	1.69 "
30	410 "	.3 "	180	208 "	1.73 "
40	405 "	.6 "	200	173 "	1.77 "
50	398 "	.8 "	220	137 "	1.81 "
60	389 "	1.0 "	240	100 "	1.85 "
70	378 "	1.2 "	260	63 "	1.88 "
80	366 "	1.3 "	273	38 "	1.90 "
90	353 "	1.36 "	280	25 "	1.91 "
100	339 "	1.46 "	293	0 "	1.92 "
			300	- 13 "	1.93 "

Taken from NBS 29


THERMAL EXPANSION
of SILVER
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
450
400
350
300
250
200
150
100
50
0
-20
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
0
50
100
150
200
250
300

THERMAL EXPANSION OF SOFT SOLDER

Sources of Data: Dorsey 1907

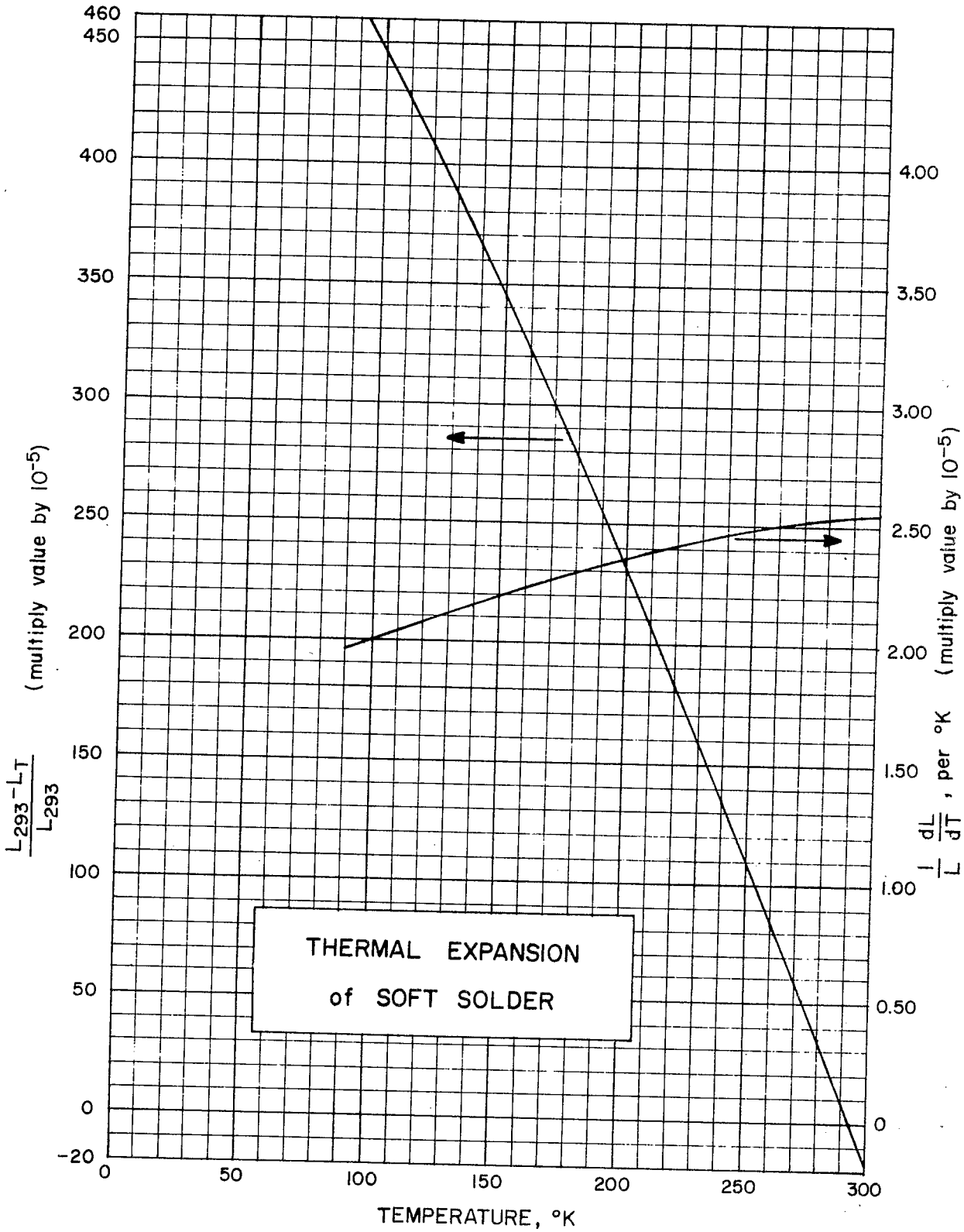
Other References:

Discussion: 50 Pb, 50 Sn.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
90	467×10^{-5}	1.96×10^{-5}	220	182×10^{-5}	2.41×10^{-5}
100	447 "	2.00 "	240	133 "	2.46 "
120	407 "	2.07 "	260	83 "	2.50 "
140	365 "	2.14 "	273	51 "	2.52 "
160	321 "	2.22 "	280	33 "	2.53 "
180	276 "	2.29 "	293	0 "	2.54 "
200	229 "	2.35 "	300	-18 "	2.55 "

Taken from NBS 29


460
450
400
350
300
250
200
150
100
50
0
-20
0
50
100
150
200
250
300
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
THERMAL EXPANSION
of SOFT SOLDER

THERMAL EXPANSION OF STEEL AISI 304

Sources of Data: Altman, Rubin, and Johnston 1954
Beenakker and Swenson 1955

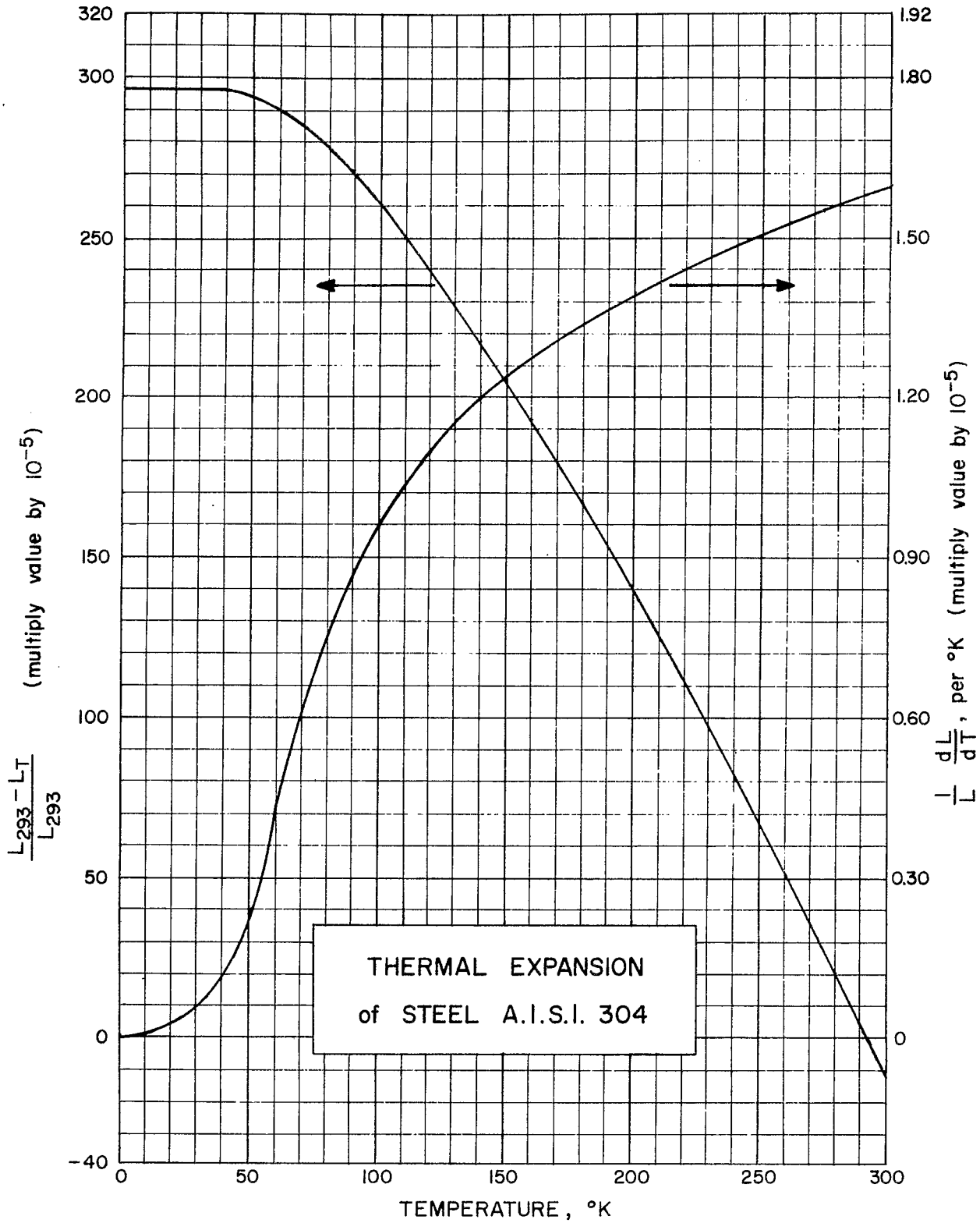
Other References: Fontana 1948
Fontana, Bishop, and Spretnak 1953
Furman 1950

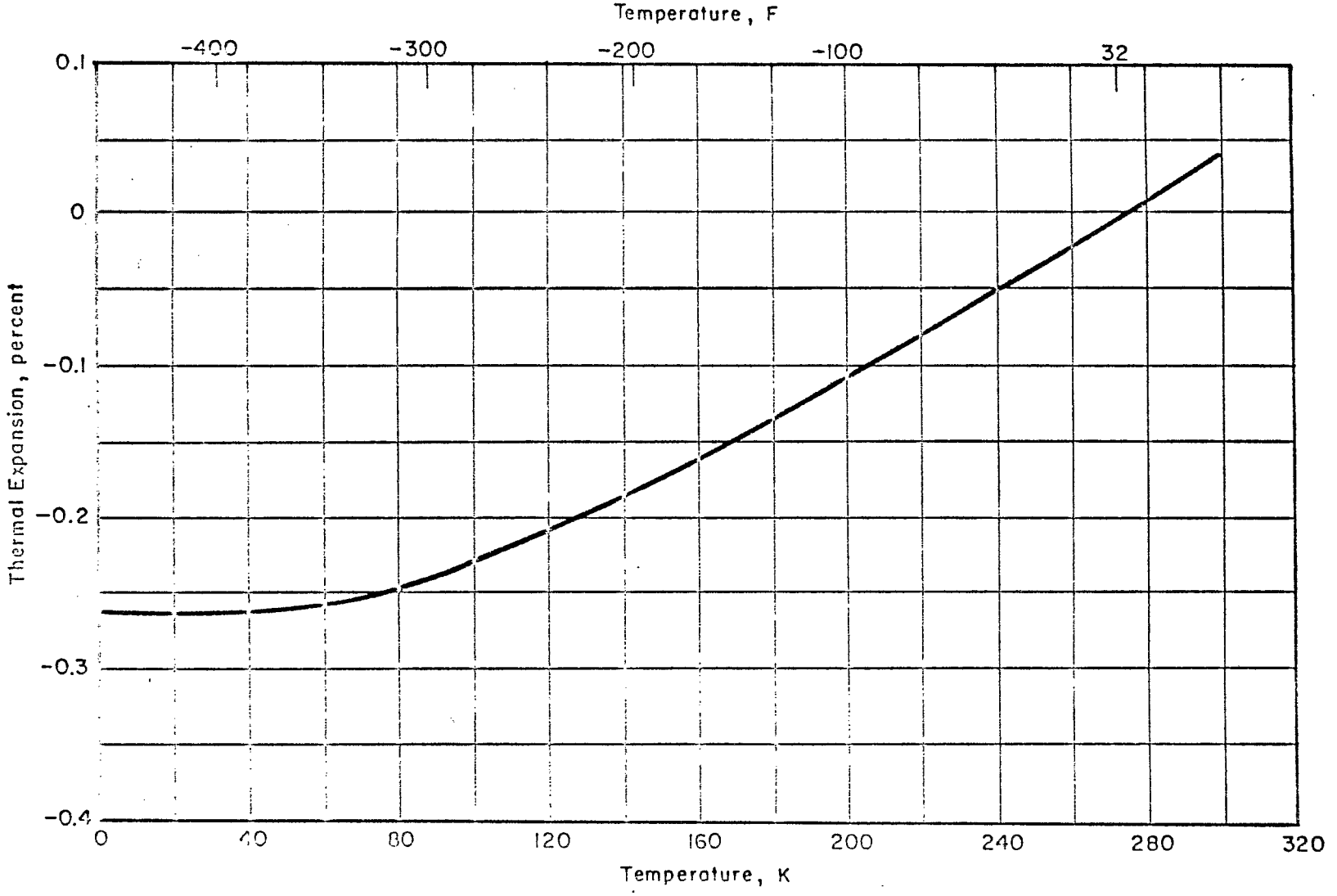
Discussion: Composition limits for this alloy are: 0.08 max. C, 2 max. Mn, 1 max. Si, 18-20 Cr, 8-11 Ni. Altman et al., found small irreversible effects and, below 35°K, small negative values of expansion coefficient. While we have given their results inferior weight in this region, the effects were undoubtedly real and attributable to martensitic transformation on cooling (Reed and Mikesell, 1958). In this alloy the extent of transformation that is produced by cooling is sensitive to composition and has been found to vary from zero to about 50%. (R.P.Reed, private communication). Complete transformation would be accompanied by a mean increase in linear dimension of roughly 1% (Ward, Jepson, and Rait, 1952; and Fiedler, Averbach, and Cohen, 1955.)

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	296×10^{-5}	0.	140	218×10^{-5}	1.20×10^{-5}
10	296 "	0.001×10^{-5}	160	193 "	1.28 "
20	296 "	.002 "	180	167 "	1.34 "
30	296 "	.062 "	200	139 "	1.40 "
40	296 "	.11 "	220	111 "	1.45 "
50	294 "	.23 "	240	81.7 "	1.49 "
60	291 "	.43 "	260	51.4 "	1.53 "
70	285 "	.61 "	273	31.4 "	1.55 "
80	279 "	.75 "	280	20.5 "	1.56 "
90	271 "	.87 "	293	0.0 "	1.59 "
100	261 "	.96 "	300	-11.1 "	1.60 "
120	241 "	1.09 "			

Taken from NBS 29


320
300
250
200
150
100
50
0
-40
1.92
1.80
1.50
1.20
0.90
0.60
0.30
0
0
50
100
150
200
250
300
TEMPERATURE, °K
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
THERMAL EXPANSION
of STEEL A.I.S.I. 304



THERMAL EXPANSION VERSUS TEMPERATURE FOR TYPE 304 STAINLESS STEEL

THERMAL EXPANSION OF STEEL AISI 310

Sources of Data: Furman 1950

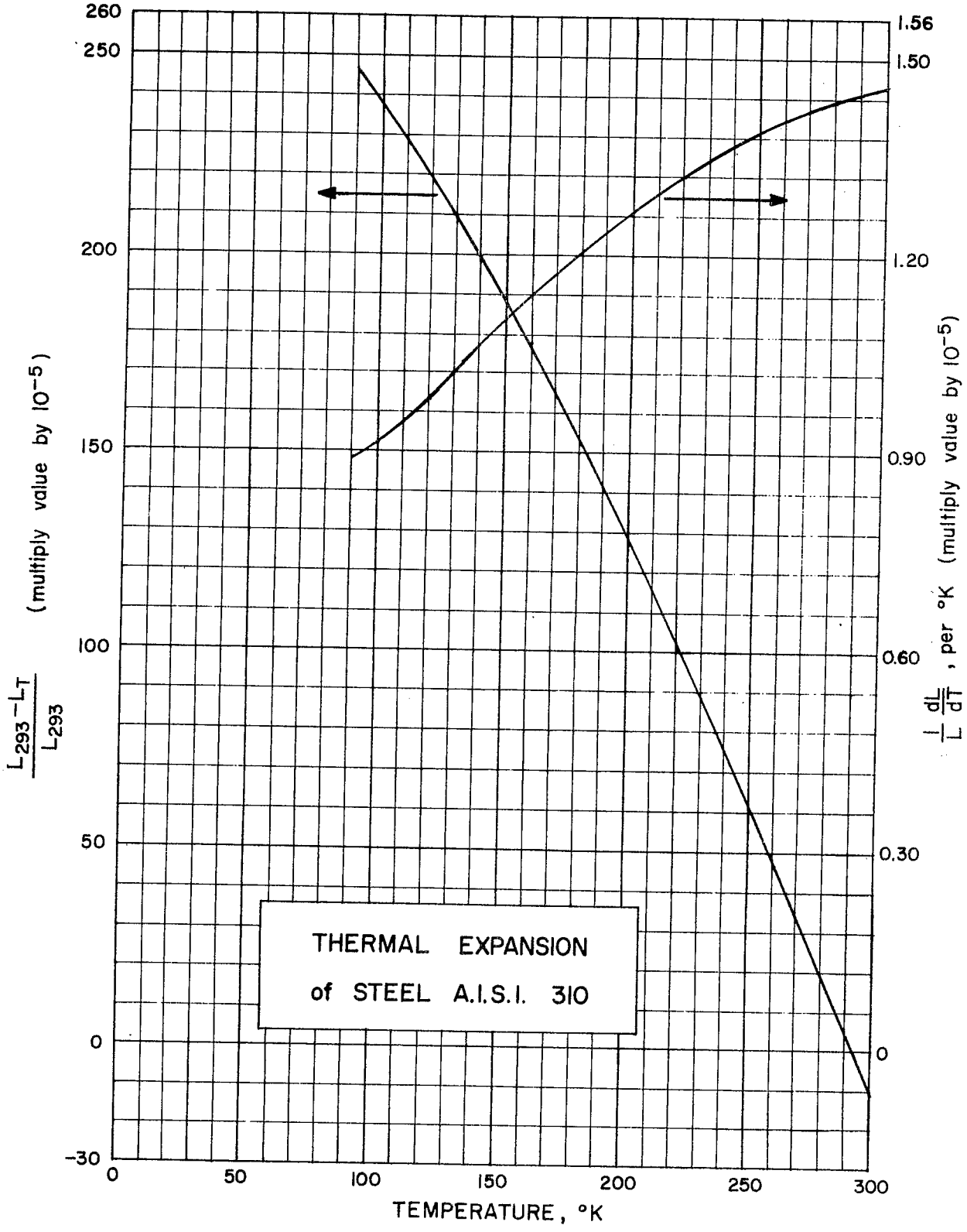
Other References:

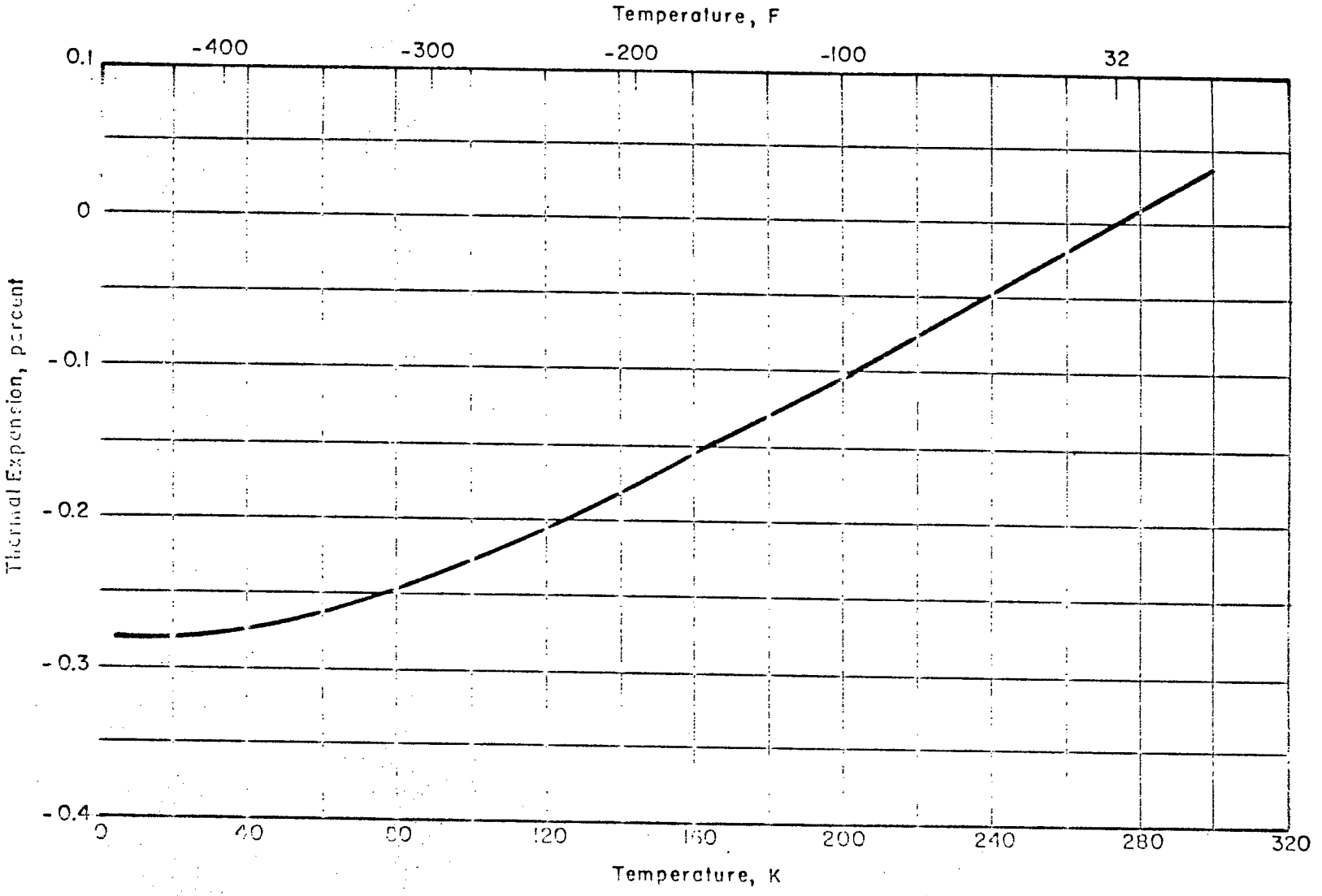
Discussion: 0.11 C, 1.51 Mn, 0.42 Si, 0.01 S, 0.02 P, 27.2 Cr, 21.6 Ni, bal. Fe. Annealed 30 min. at 1950° F and water quenched.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
90	246×10^{-5}	0.89×10^{-5}	220	101×10^{-5}	1.32×10^{-5}
100	237 "	.91 "	240	74.5 "	1.36 "
120	218 "	.98 "	260	46.9 "	1.40 "
140	198 "	1.07 "	273	28.6 "	1.42 "
160	176 "	1.14 "	280	18.7 "	1.43 "
180	152 "	1.21 "	293	0.0 "	1.45 "
200	127 "	1.27 "	300	-10.2 "	1.46 "

Taken from NBS 29


THERMAL EXPANSION
of STEEL A.I.S.I. 310
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
260
250
200
150
100
50
0
-30
1.56
1.50
1.20
0.90
0.60
0.30
0
0
50
100
150
200
250
300



THERMAL EXPANSION VERSUS TEMPERATURE FOR TYPE 310 STAINLESS STEEL

THERMAL EXPANSION OF STEEL AISI 316

Sources of Data: Beenakker and Swenson 1955.

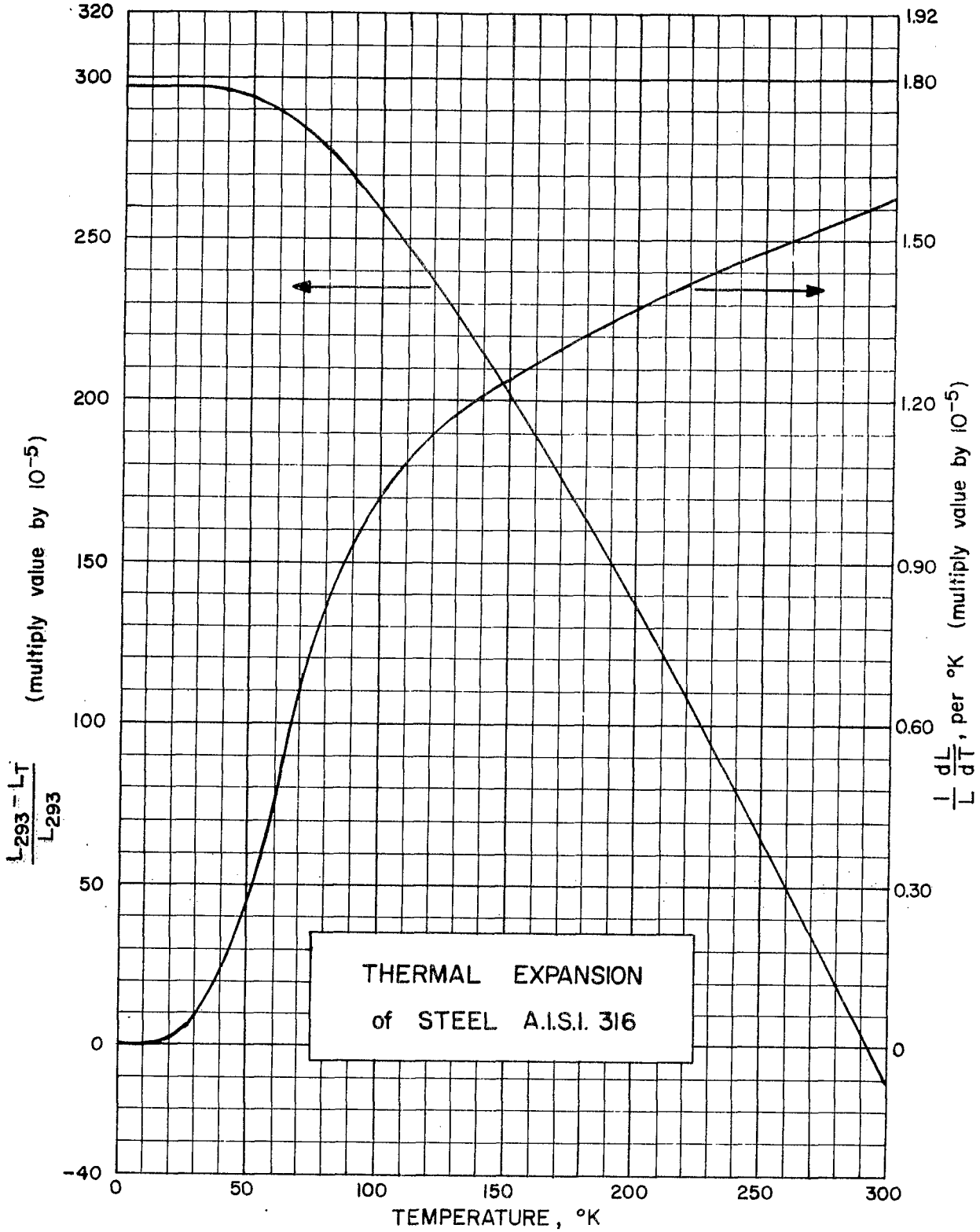
Other References: Furman 1950
Lucks and Deem 1958

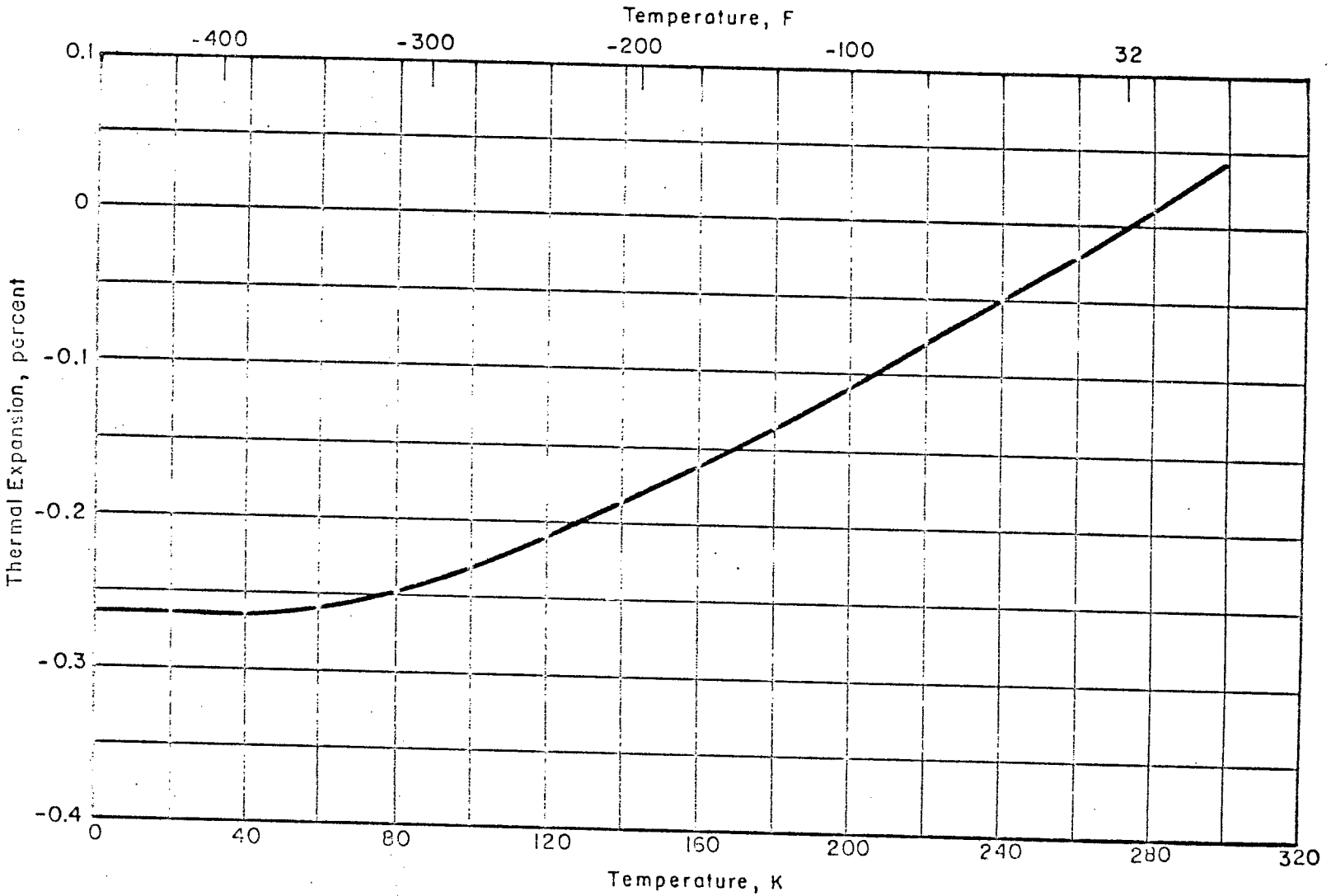
Discussion: Composition and heat treatment of sample not stated. Composition limits for this alloy are: 0.10 (max.) C, 2 (max.) Mn, 1 (max.) Si, 16-18 Cr, 10-14 Ni, 2-3 Mo, bal. Fe.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	297×10^{-5}	0.	140	214×10^{-5}	1.21×10^{-5}
10	297 "	0.004×10^{-5}	160	189 "	1.27 "
20	297 "	.009 "	180	163 "	1.32 "
30	297 "	.05 "	200	136 "	1.36 "
40	296 "	.14 "	220	109 "	1.41 "
50	294 "	.27 "	240	80.1 "	1.45 "
60	290 "	.43 "	260	50.6 "	1.50 "
70	285 "	.65 "	273	30.9 "	1.53 "
80	277 "	.82 "	280	20.2 "	1.54 "
90	269 "	.94 "	293	0.0 "	1.57 "
100	259 "	1.02 "	300	-11.0 "	1.58 "
120	237 "	1.13 "			

Taken from NBS 29


THERMAL EXPANSION
of STEEL A.I.S.I. 316
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
320
300
250
200
150
100
50
0
-40
1.92
1.80
1.50
1.20
0.90
0.60
0.30
0
0
50
100
150
200
250
300



THERMAL EXPANSION VERSUS TEMPERATURE FOR TYPE 316 STAINLESS STEEL

THERMAL EXPANSION OF STEEL AISI 347

Sources of Data: Furman 1950.

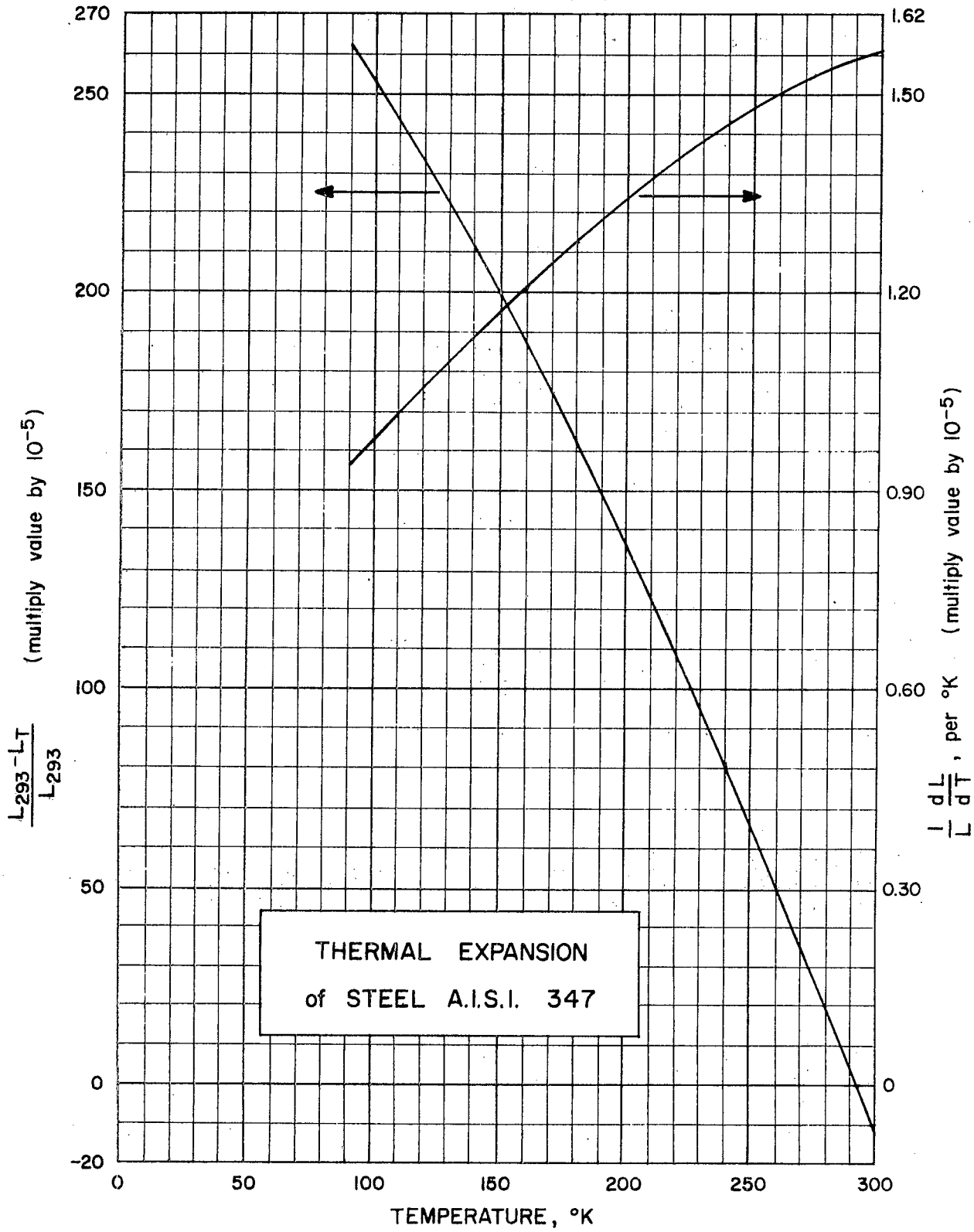
Other References: Lucks and Deem 1958.

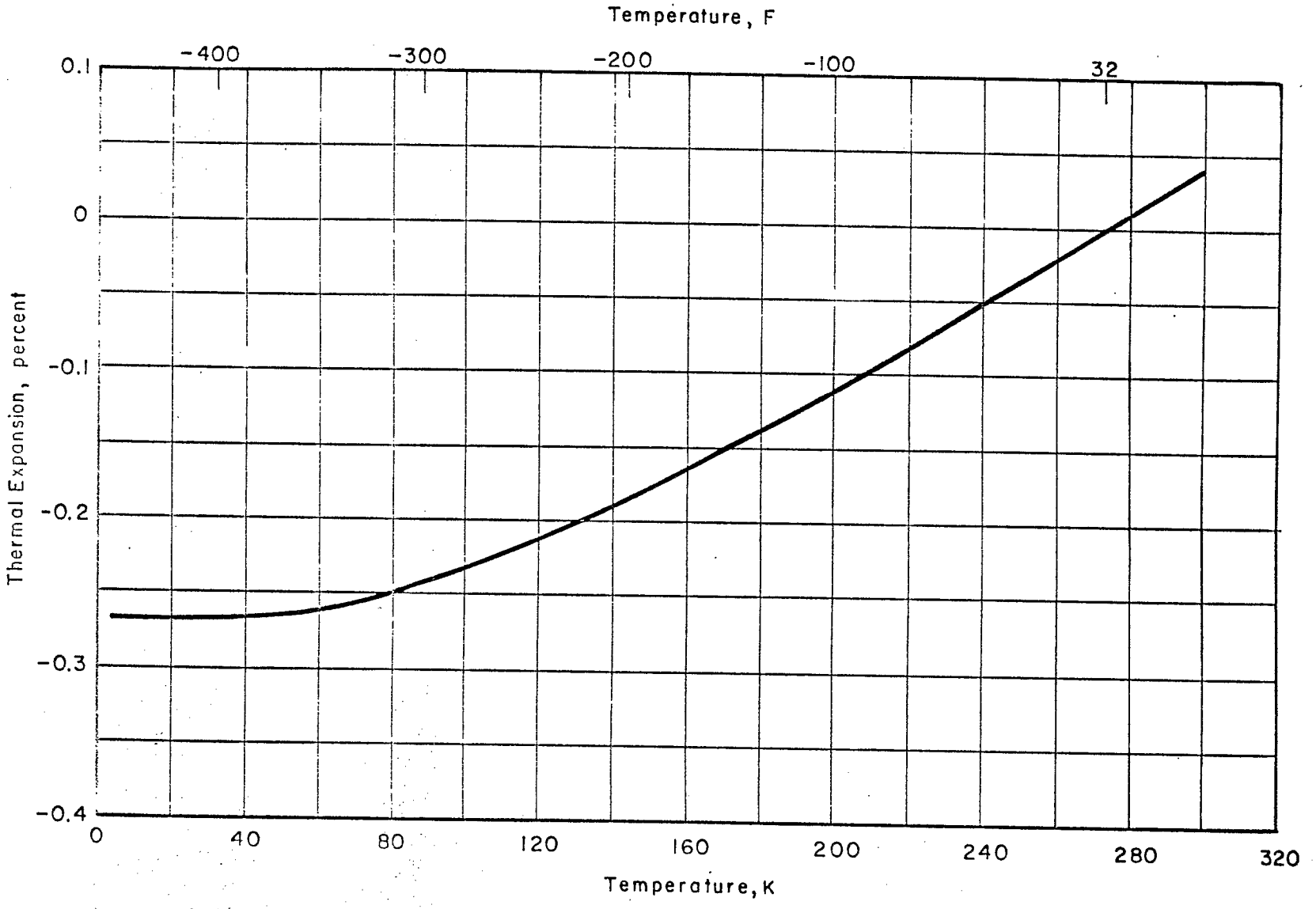
Discussion: 0.07 C, 1.74 Mn, 0.56 Si, 0.006 S, 0.019 P, 18.65 Cr, 11.3 Ni, 0.77 Nb, bal. Fe. Annealed 30 min. at 1950° F and water quenched.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
90	262×10^{-5}	0.94×10^{-5}	220	109×10^{-5}	1.40×10^{-5}
100	253 "	.98 "	240	80.2 "	1.46 "
120	233 "	1.05 "	260	50.6 "	1.50 "
140	211 "	1.13 "	273	30.9 "	1.53 "
160	187 "	1.21 "	280	20.2 "	1.54 "
180	163 "	1.28 "	293	0.0 "	1.56 "
200	136 "	1.34 "	300	-11.0 "	1.57 "

Taken from NBS 29


THERMAL EXPANSION
of STEEL A.I.S.I. 347
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
270
250
200
150
100
50
0
-20
1.62
1.50
1.20
0.90
0.60
0.30
0
0
50
100
150
200
250
300



THERMAL EXPANSION VERSUS TEMPERATURE FOR TYPE 321 STAINLESS STEEL

THERMAL EXPANSION OF STEEL, S.A.E.1020

Sources of Data: Altman, Rubin and Johnston 1952

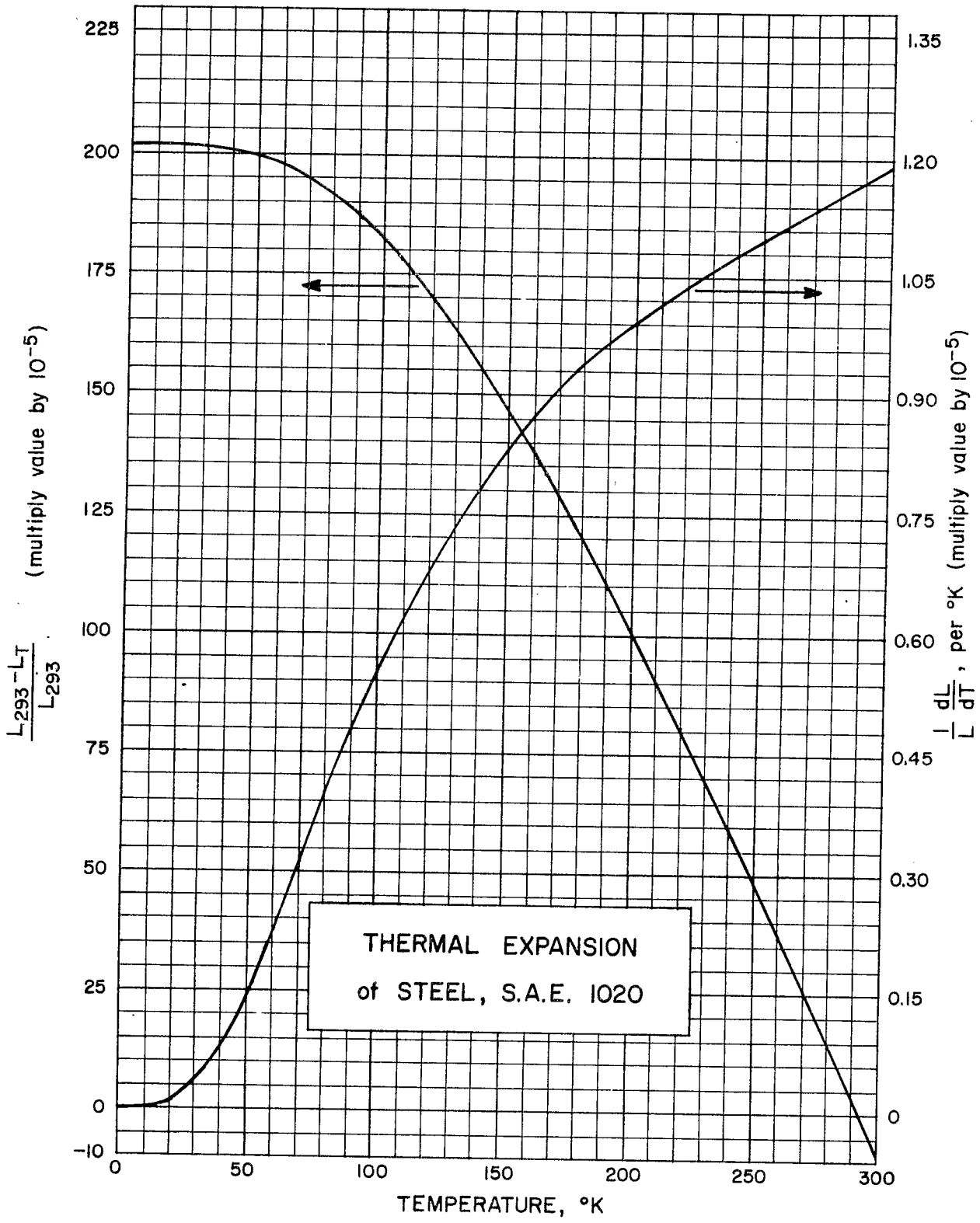
Other References: Beenakker and Swenson 1955
Dorsey 1910
Gregg 1954

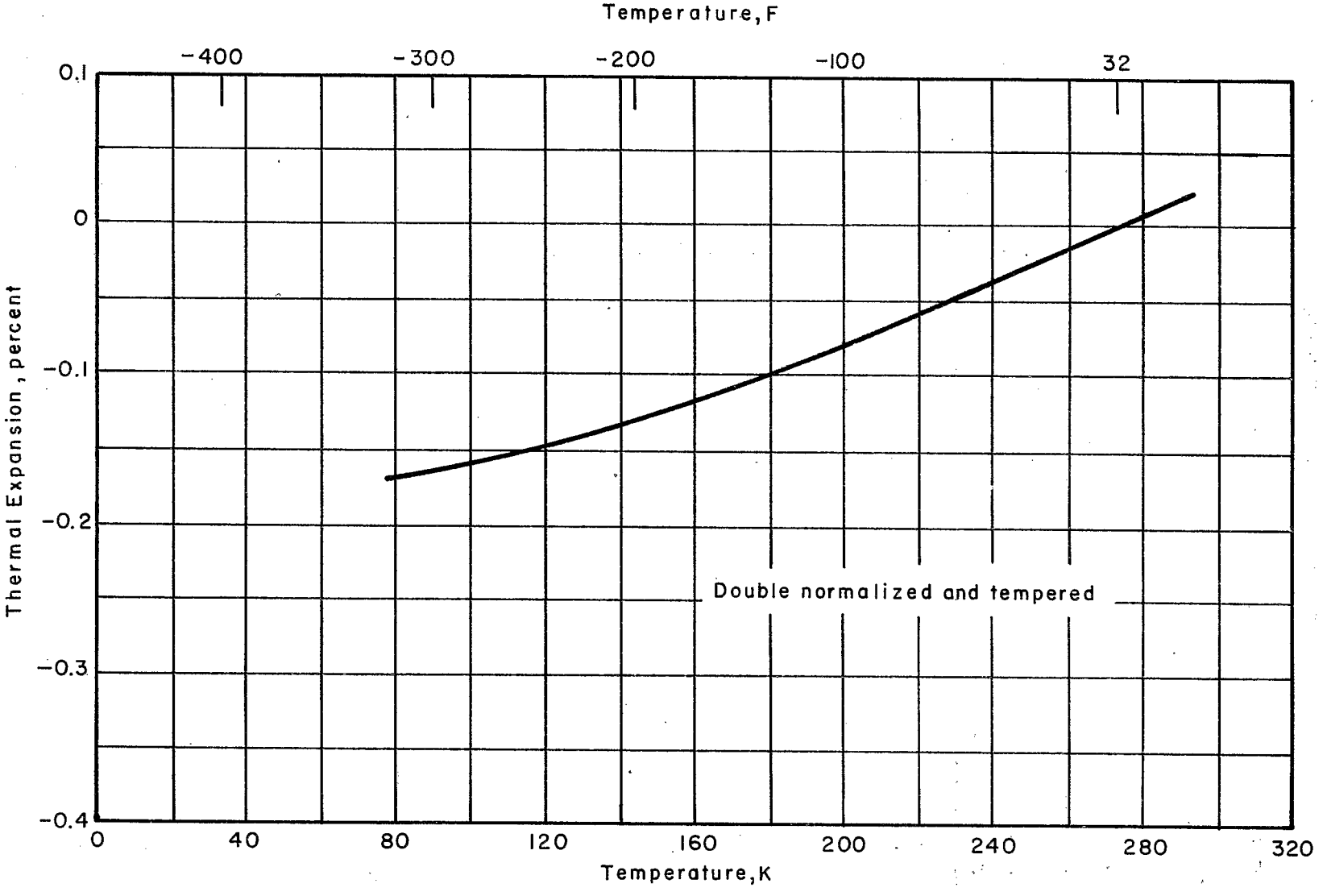
Discussion: 0.18 C, 0.33 Mn, 0.01 Si, bal. Fe. According to Beenakker and Swenson, cast iron had the same thermal expansion as 1020 steel within their experimental uncertainty of $\pm 3 \times 10^{-5}$ in $\Delta L/L$.

Table of Selected Values

Temp. ^{o}K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per ^{o}K	Temp. ^{o}K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per ^{o}K
0	202×10^{-5}	0.	140	155×10^{-5}	0.78×10^{-5}
10			160	138 "	.87 "
20	202×10^{-5}	0.001×10^{-5}	180	120 "	.94 "
30	201 "	.03 "	200	101 "	.99 "
40	201 "	.08 "	220	80.7 "	1.04 "
50	200 "	.14 "	240	59.6 "	1.08 "
60	198 "	.23 "	260	37.7 "	1.11 "
70	195 "	.31 "	273	22.9 "	1.14 "
80	192 "	.40 "	280	15.1 "	1.15 "
90	187 "	.48 "	293	0.0 "	1.17 "
100	182 "	.55 "	300	-8.3 "	1.19 "
120	170 "	.68 "			

Taken from NBS 29


THERMAL EXPANSION
of STEEL, S.A.E. 1020
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
225
200
175
150
125
100
75
50
25
0
-10
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0
0
50
100
150
200
250
300



THERMAL EXPANSION VERSUS TEMPERATURE FOR 9 NI STEEL

THERMAL EXPANSION OF TANTALUM

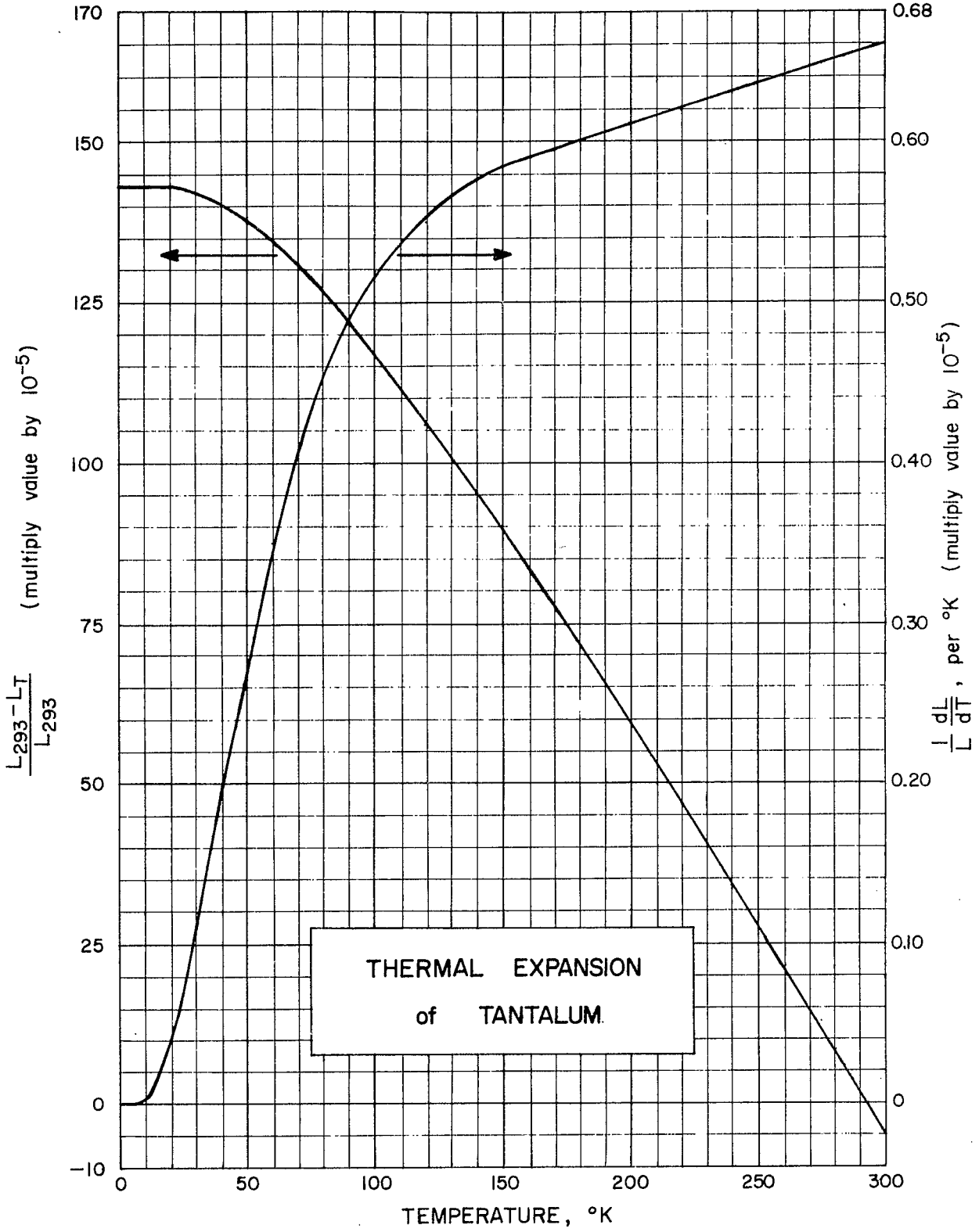
Sources of Data: Nix and MacNair 1942

Other References: Disch 1921
Hidnert 1929

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	143×10^{-5}	0.	140	95.1×10^{-5}	0.58×10^{-5}
10	143 "	0.005×10^{-5}	160	83.5 "	.59 "
20	143 "	.04 "	180	71.5 "	.60 "
30	142 "	.11 "	200	59.3 "	.61 "
40	141 "	.20 "	220	47.0 "	.62 "
50	138 "	.28 "	240	34.4 "	.63 "
60	135 "	.35 "	260	21.6 "	.65 "
70	131 "	.41 "	273	13.1 "	.65 "
80	127 "	.45 "	280	8.5 "	.66 "
90	122 "	.49 "	293	0.0 "	.66 "
100	117 "	.52 "	300	-4.6 "	.66 "
120	106	.55 "			

Taken from NBS 29


THERMAL EXPANSION
of TANTALUM
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
170
150
125
100
75
50
25
0
−10
0.68
0.60
0.50
0.40
0.30
0.20
0.10
0
0
50
100
150
200
250
300

THERMAL EXPANSION OF TIN (WHITE)

Sources of Data: Erfling 1939

Other References: Cohen and Olie 1910
Dorsey 1907
Gruneisen 1910

Discussion: Anisotropic. The above values were calculated from the relation, Mean Value = 1/3 ($\parallel$) + 2/3 ($\perp$), where ($\parallel$) and ($\perp$) signify the same property measured parallel and perpendicular, respectively, to the tetragonal axis.

Thewlis and Davey (1954) measured the lattice parameter of grey tin, a brittle form with diamond-type lattice that is stable below 18°C. Their data cover the range, -130 to +20°C, and are, represented by a constant expansion coefficient, $dL/LdT = 4.7 \times 10^{-6} deg^{-1}C$. See also Cohen and Olie (1910). The ordinary ductile variety (white tin) if pure may transform to grey tin at low ambient temperatures but is stabilized by impurities.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	447×10^{-5}	0.	140	290×10^{-5}	1.71×10^{-5}
10	447 "	$.07 \times 10^{-5}$	160	255 "	1.77 "
20	445 "	.3 "	180	219 "	1.82 "
30	441 "	.6 "	200	183 "	1.87 "
40	433 "	.9 "	220	145 "	1.91 "
50	423 "	1.1 "	240	106 "	1.95 "
60	412 "	1.2 "	260	66.7 "	1.99 "
70	399 "	1.3 "	273	40.7 "	2.01 "
80	385 "	1.42 "	280	26.5 "	2.03 "
90	371 "	1.50 "	293	0.0 "	2.05 "
100	356 "	1.56 "	300	-14.4 "	2.06 "
120	324 "	1.64 "			

Taken from NBS 29

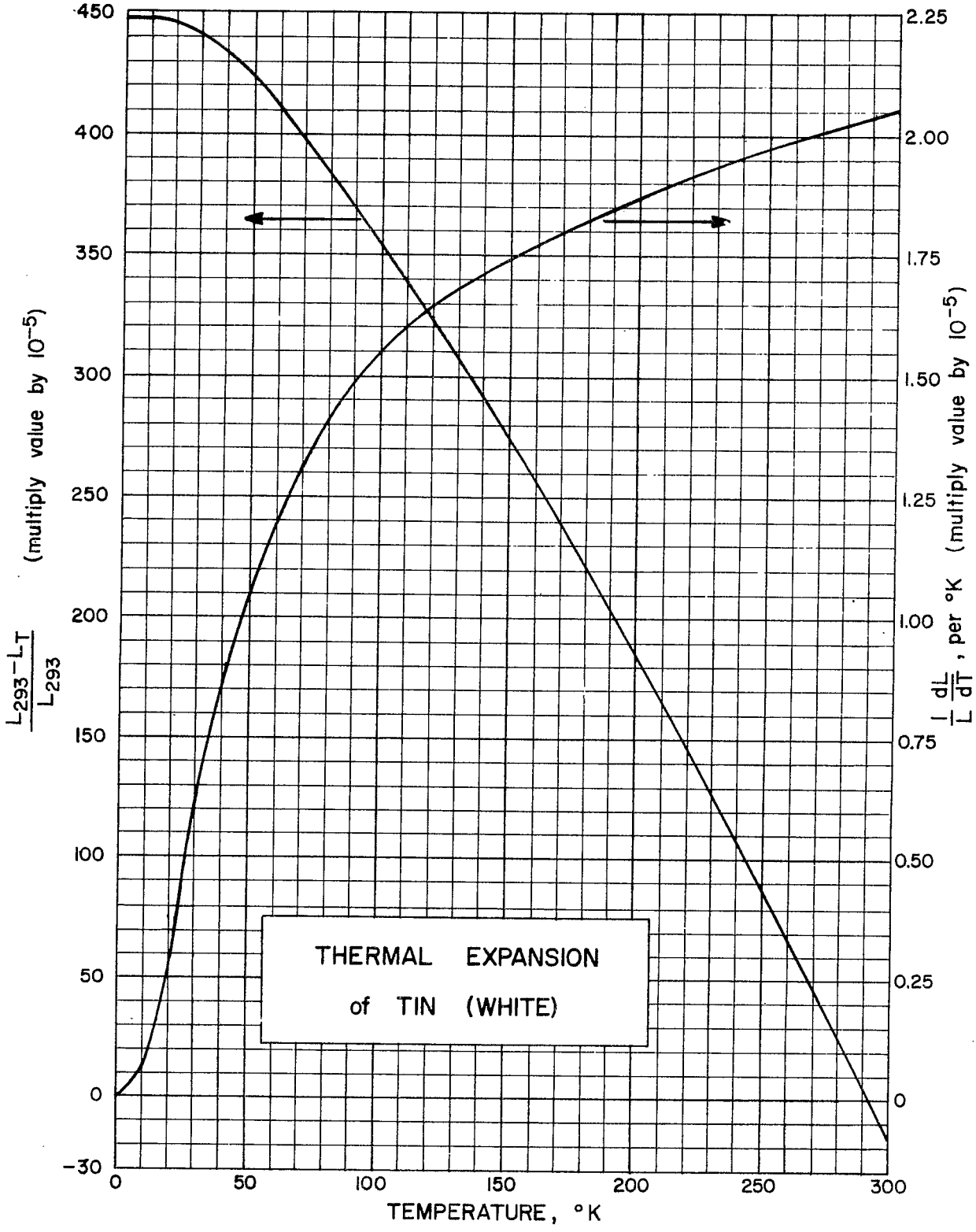
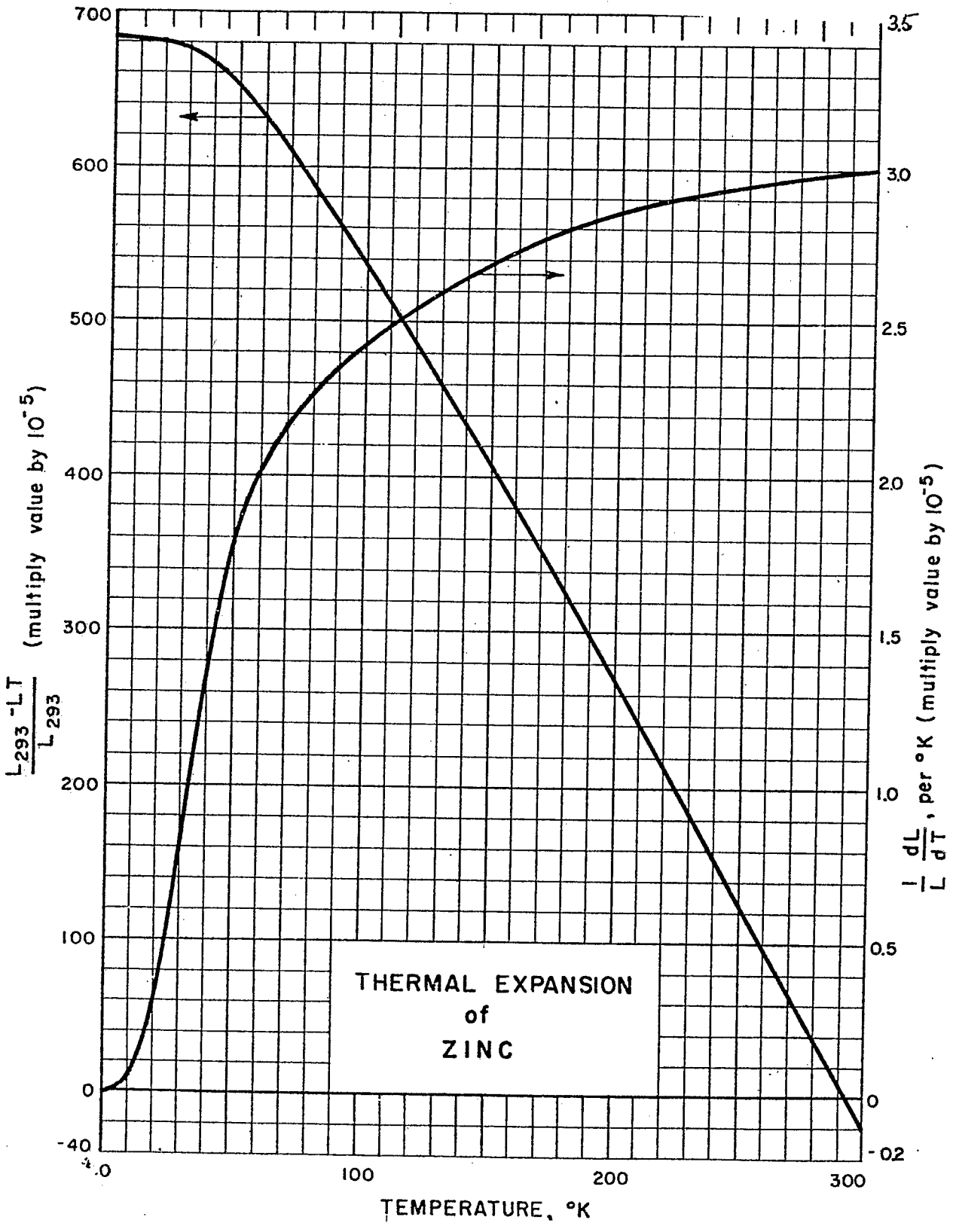

THERMAL EXPANSION
of TIN (WHITE)
$\frac{L_{293}-L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
450
400
350
300
250
200
150
100
50
0
-30
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
0
50
100
150
200
250
300

Table II

AVERAGE EXPANSION of ZINC*

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$, per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$, per °K
0	683×10^{-5}	0	120	492×10^{-5}	2.53×10^{-5}
10	683 "	$.03 \times 10^{-5}$	140	440 "	2.63 "
20	682 "	.3 "	160	386 "	2.73 "
30	677 "	.8 "	180	331 "	2.81 "
40	667 "	1.3 "	200	274 "	2.87 "
50	652 "	1.7 "	220	216 "	2.91 "
60	633 "	2.1 "	240	157 "	2.94 "
70	611 "	2.2 "	260	98 "	2.96 "
80	588 "	2.3 "	273	60 "	2.97 "
90	565 "	2.36 "	280	39 "	2.98 "
100	541 "	2.42 "	293	0	2.99 "
			300	-21 "	3.00 "

* Calculated on the basis: $\left(\frac{1}{L} \times \frac{dL}{dT}\right)_{av} = \left(\frac{1}{3L} \times \frac{dL}{dT}\right)_{\parallel} + \left(\frac{2}{3L} \times \frac{dL}{dT}\right)_{\perp}$


THERMAL EXPANSION
of
ZINC
$\frac{L_{293} - L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
TEMPERATURE, °K
700
600
500
400
300
200
100
0
-40
4.0
100
200
300
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.2