

XIV. DENSITY

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DENSITY OF ALUMINUM

RECOMMENDED VALUES

| T(°K) | ρ (g. cm ⁻³) | T(°K) | ρ (g. cm ⁻³) |
|------------|-------------------------------|----------------|-------------------------------|
| 0 | (s) 2.735 | 931(m. p.) | (1) 2.379 |
| 100 | 2.725 | 1000 | 2.360 |
| 200 | 2.713 | 1100 | 2.341 |
| 300 | 2.698 | 1200 | 2.322 |
| 400 | 2.681 | 1300 | 2.303 |
| 500 | 2.662 | 1400 | 2.284 |
| 600 | 2.640 | 1500 | 2.265 |
| 700 | 2.616 | 1600 | 2.246 |
| 800 | 2.590 | | |
| 900 | 2.552 | | |
| 931(m. p.) | 2.542 | 2329(n. b. p.) | (2.102) |

SOURCE OF DATA

1) Value at room temperature:

(a) Snoek, J. L. (1); (b) Smakula, A. and Sils, V. (2);
 (c) Miller, P. N., and Dumond, J. N. M. (3); (d) Foote, F.,
 and Jette, E. R. (4).

2) Solid range:

(e) from thermal expansion data (III)

3) Volume change on melting.

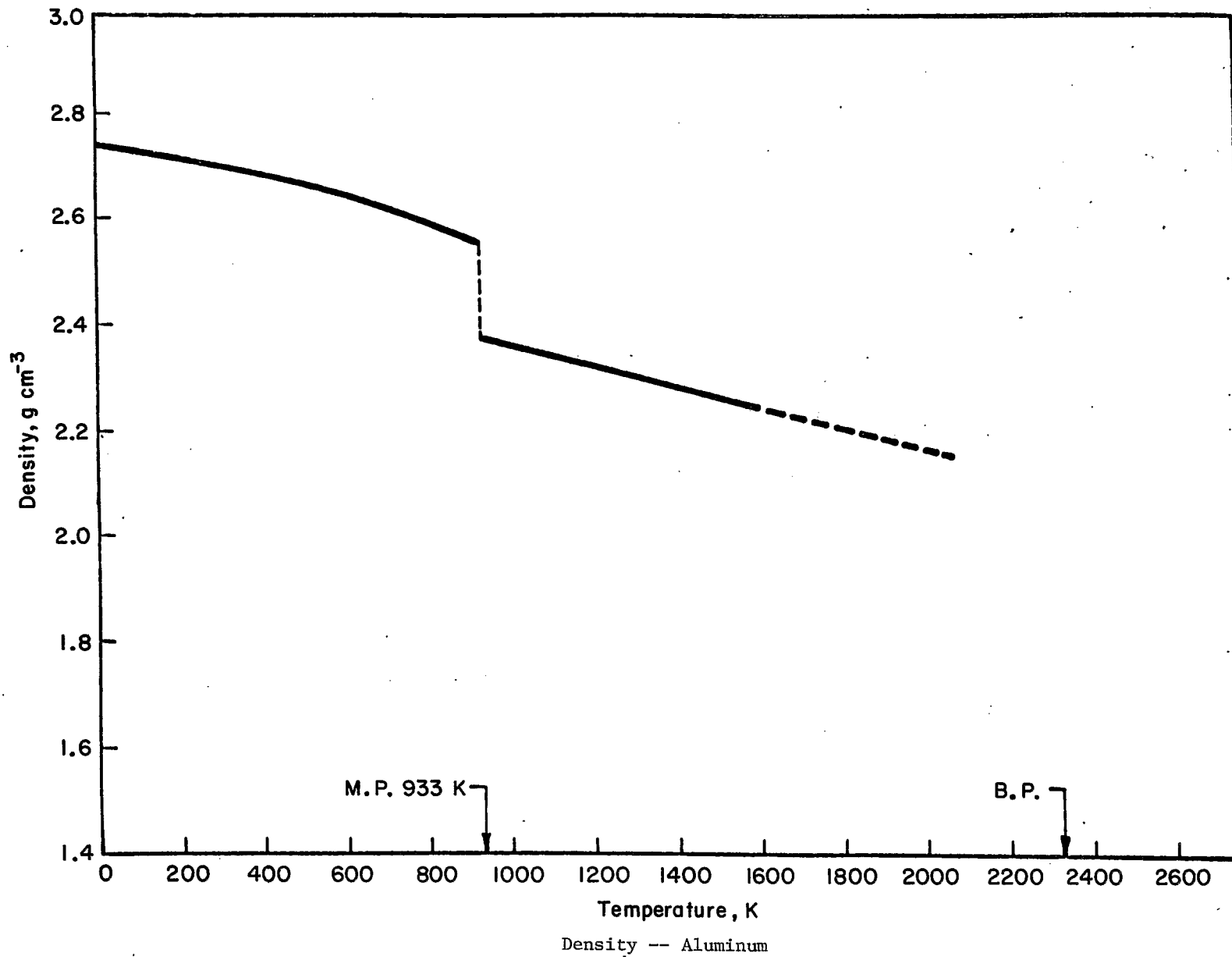
(f) Edwards, J. D., and Moorman, T. A. (5).

4) Liquid range:

(g) Kanda, K. A., and Keller, D. V. (6); (h) Gebhardt, E.,
 Becker, M., and Dorner, S. (7); (i) Solet, I. S., and St Clair,
 H. W., (8); (j) Naidich, Yu. V., and Eremenko, V. N. (9);
 (k) Bornemann, K., and Sauerwald, F. (10).

REMARKS: Accuracy solid range $\pm .5\%$ or better.
 liquid range $\pm .1\%$ or better.

XIV-A-2



DENSITY OF BERYLLIUM ALLOY

RECOMMENDED VALUES

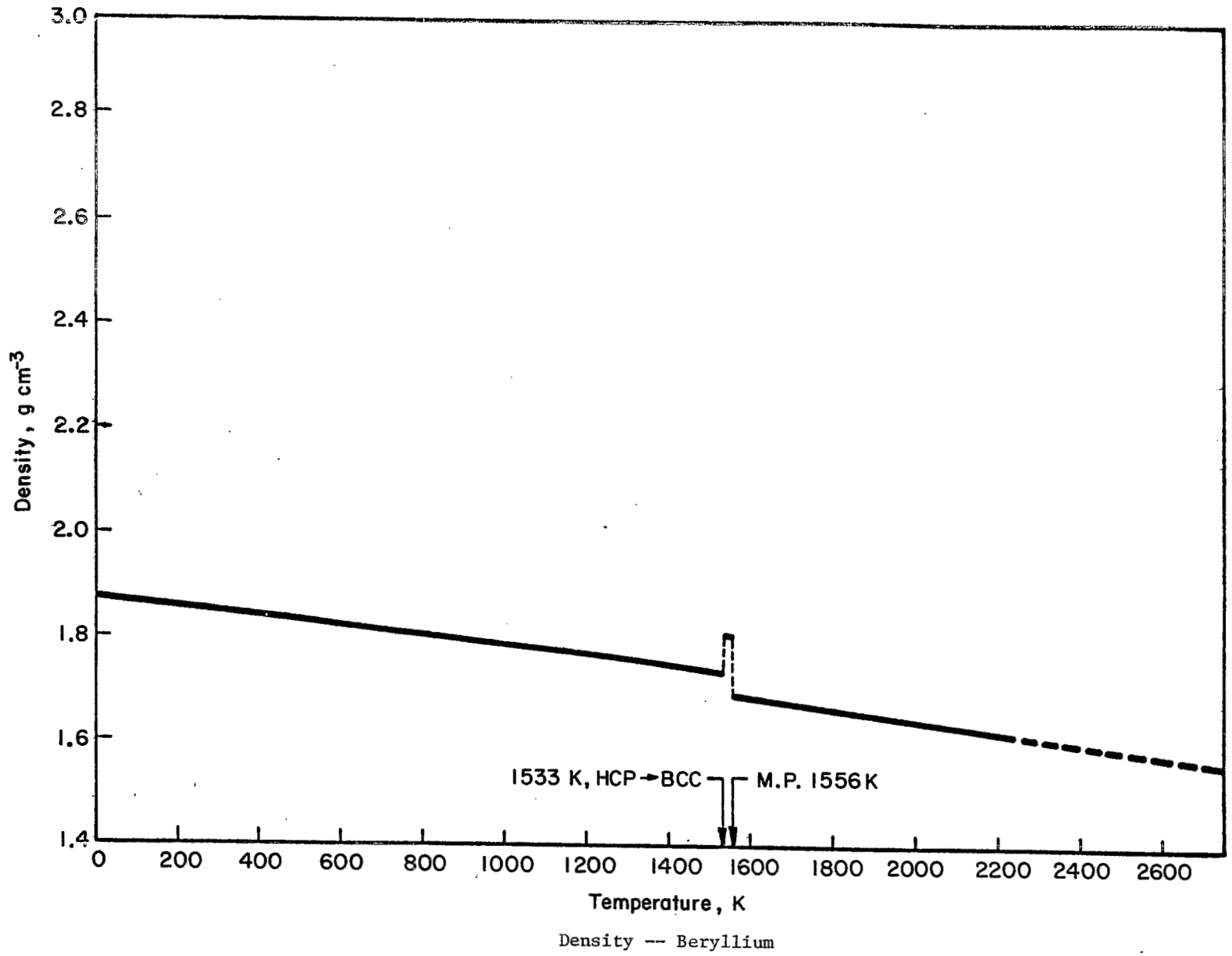
| T(°K) | ρ (g. cm ⁻³) | T(°K) | ρ (g. cm ⁻³) |
|-------|-------------------------------|---------------------------|-------------------------------|
| 0 | (s) 1.857 | 1200 | 1.763 |
| 100 | 1.853 | 1300 | 1.753 |
| 200 | 1.848 | 1400 | 1.742 |
| 300 | 1.842 | Melting range 1500-1550°K | |
| 400 | 1.835 | 1600 | (1) 1.694 |
| 500 | 1.828 | 1700 | 1.683 |
| 600 | 1.820 | 1800 | 1.672 |
| 700 | 1.812 | 1900 | 1.661 |
| 800 | 1.803 | 2000 | 1.650 |
| 900 | 1.794 | 2100 | 1.639 |
| 1000 | 1.784 | 2200 | 1.628 |
| 1100 | 1.774 | | |

SOURCE OF DATA

None

REMARKS: The curve was computed by means of mixing rules.
 The recommended curve is only slightly about 0.1% above
 the curve for pure beryllium.
 The accuracy can be estimated the same as for pure beryllium.

XIV-B-2



DENSITY OF CHROMIUM

RECOMMENDED VALUES

| T(°K) | ρ (g. cm ⁻³) | T(°K) | ρ (g. cm ⁻³) |
|-------|-------------------------------|-------------|-------------------------------|
| 299 | (s, HCP) 6.08 | 1300 | 6.98 |
| 299 | (s, BCC) 7.21 | 1400 | 6.94 |
| 300 | 7.21 | 1500 | 6.91 |
| 400 | 7.20 | 1600 | 6.87 |
| 500 | 7.18 | 1700 | 6.83 |
| 600 | 7.16 | 1800 | 6.78 |
| 800 | 7.11 | 1900 | 6.74 |
| 900 | 7.09 | 2000 | 6.69 |
| 1000 | 7.07 | 2100 | 6.63 |
| 1100 | 7.04 | 2123(m. p.) | (s) 6.61 |
| 1200 | 7.01 | | |
| | | 2223 | (1) 6.00 ± 0.13 |

SOURCE OF DATA

- 1) Value at room temperature:
 - (a) Metals handbook (I); (b) Handbook of Chemistry (IV)
- 2) Solid range:
 - (c) from thermal expansion data (III)
- 3) liquid range: (one value, see table)
 - (d) Eremenko, V. N. and Naidich, Yu. V. (48)

REMARKS: The data at room temperature are non-original and may be in error as much as ± 1%. Since no values are available for the phase transition near room temperature, the curve was not drawn below 300°K. Since no values were available for the change of volume on fusion, no recommended curve was drawn, in the liquid range. These values should be used with caution.

DENSITY OF COPPER

RECOMMENDED VALUES

| T(°K) | ρ (g. cm ⁻³) | T(°K) | ρ (g. cm ⁻³) |
|-------|-------------------------------|--------------|-------------------------------|
| 0 | (s) 9.08 | 1300 | 8.37 |
| 100 | 9.04 | 1356 (m. p.) | (s) 8.32 |
| 200 | 9.00 | 1356 (m. p.) | (l) 7.99 |
| 300 | 8.96 | 1400 | 7.96 |
| 400 | 8.91 | 1500 | 7.88 |
| 500 | 8.87 | 1600 | 7.80 |
| 600 | 8.82 | 1700 | 7.72 |
| 700 | 8.76 | 1800 | 7.64 |
| 800 | 8.71 | 1900 | 7.56 |
| 900 | 8.65 | 2000 | 7.48 |
| 1000 | 8.58 | 2100 | 7.46 |
| 1100 | 8.51 | 2200 | 7.32 |
| 1200 | 8.44 | 2300 | 7.24 |
| | | 2400 | 7.16 |

SOURCE OF DATA

1) Value at room temperature:

- (a) Smart, J.S., Smith, A.A., and Phillips, A.J. (13);
- (b) Metals Handbook (I);
- (c) Foote, F. and Jette, E.R. (4).

2) Solid range:

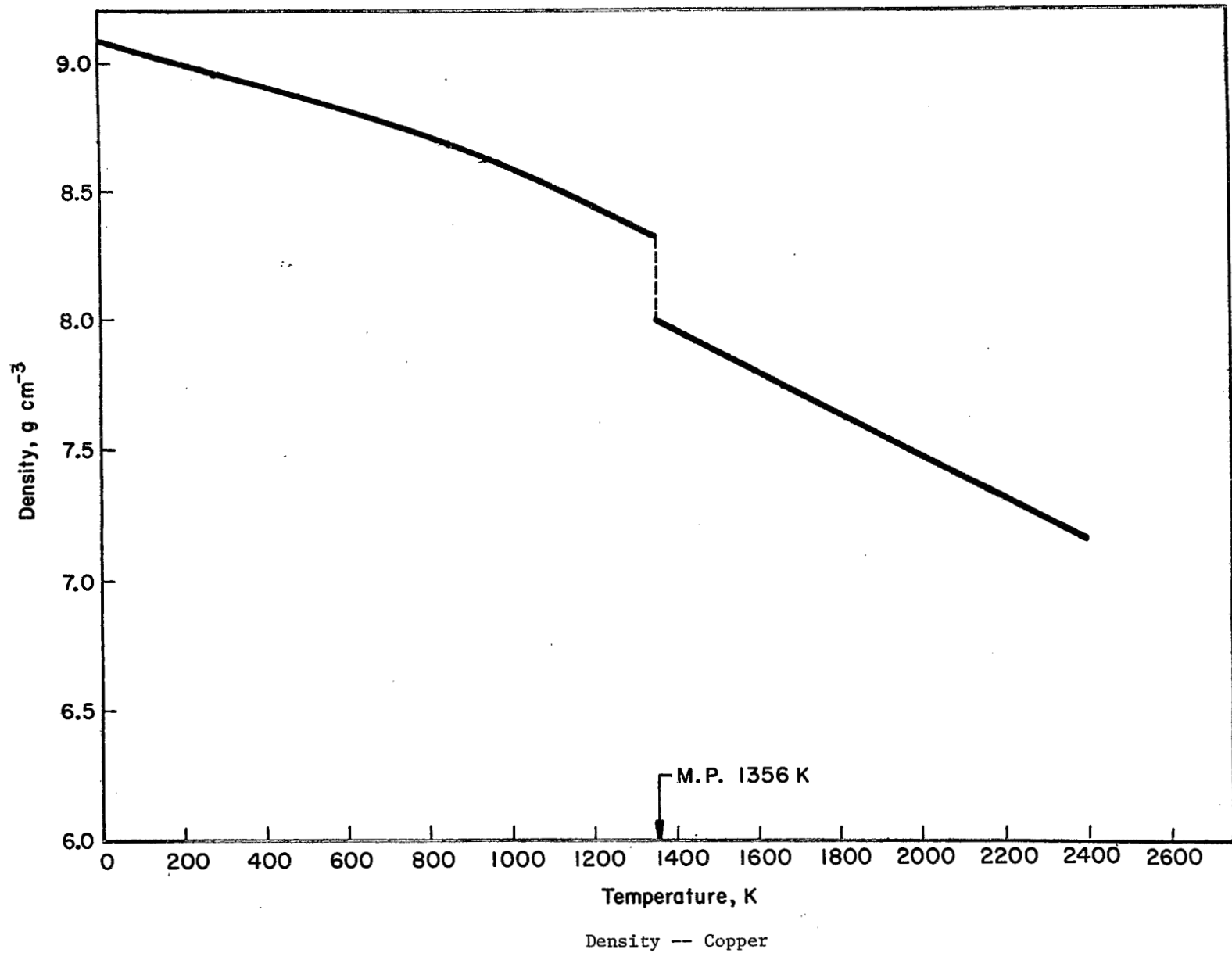
- (d) from thermal expansion data (III);
- (e) Bornemann, K. and Sauerwald (10).

3) Liquid range:

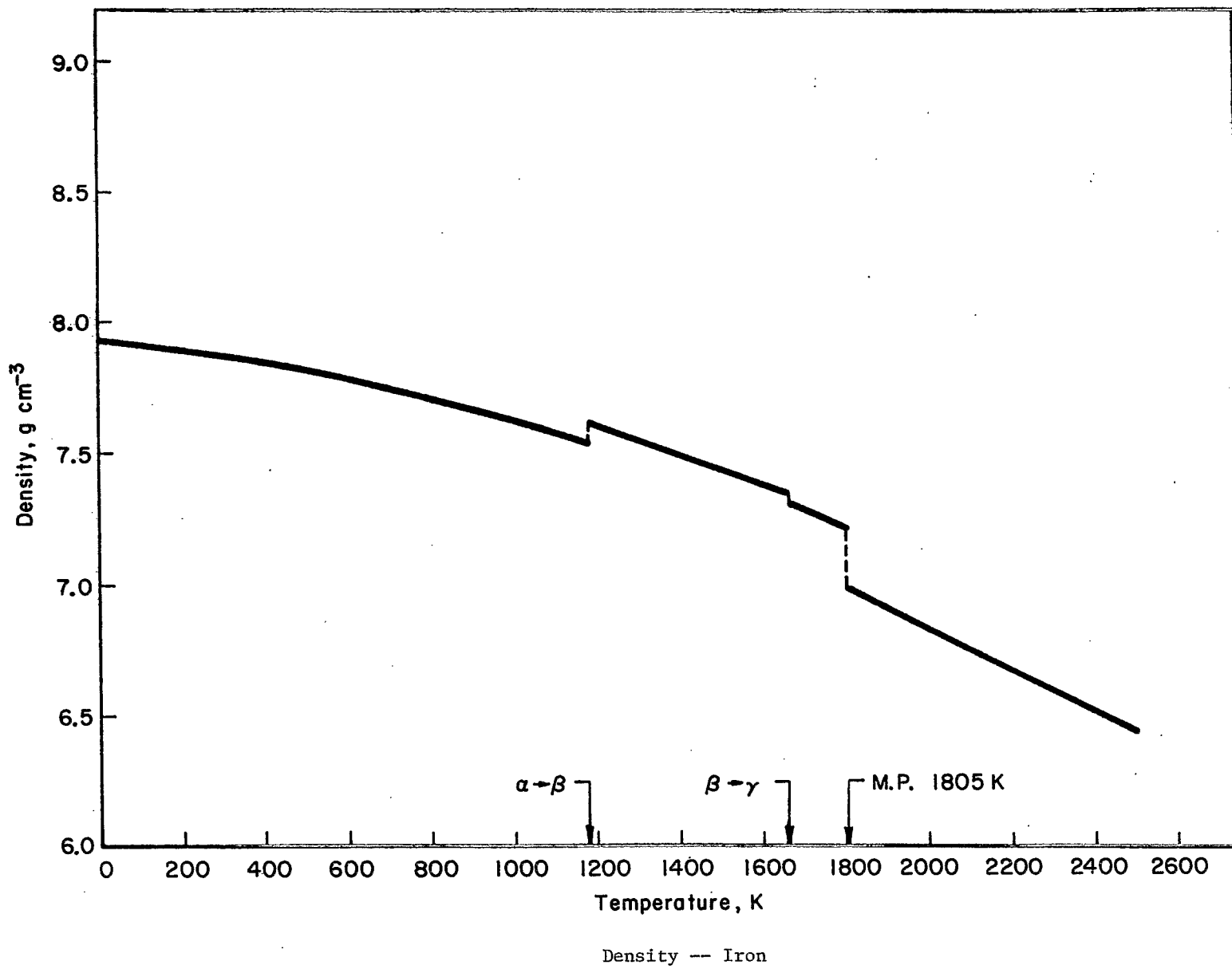
- (f) Lucas, L.D. (14); (g) Gebhardt, E., Becker, M. and Schafer, S. (15); (h) Cahill, J.A. and Kirshenbaum, A.D. (16);
- (i) Allen, B.C. and Kingery, W.D. (17); (j) Bornemann, K. and Sauerwald, F. (10)

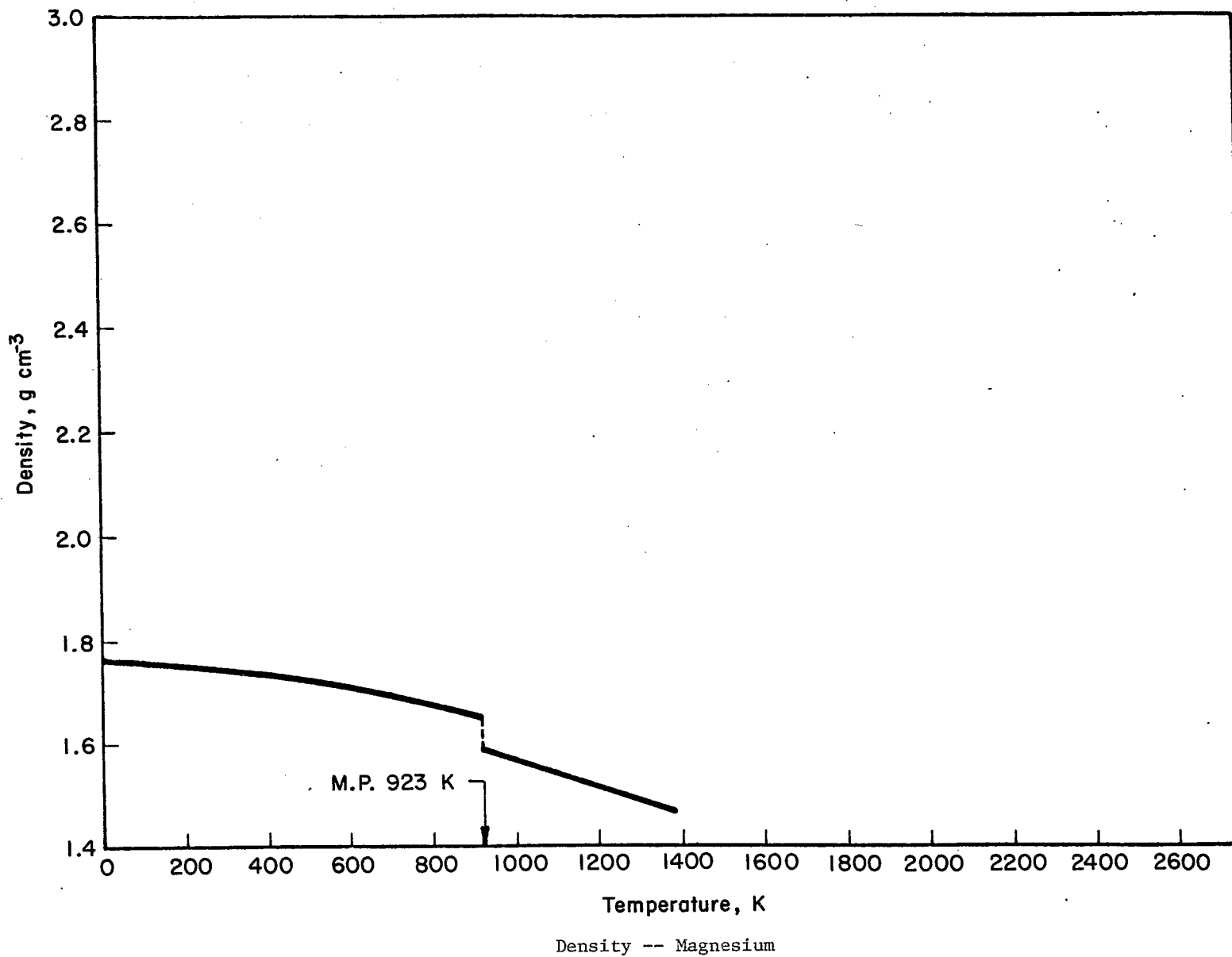
REMARKS: Accuracy solid and liquid range = ± .5% or better.

XIV-D-2



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DENSITY OF NIOBIUM

RECOMMENDED VALUES

| T(°K) | ρ (g.cm ⁻³) | T(°K) | ρ (g.cm ⁻³) |
|-------|------------------------------|-------|------------------------------|
| 0 | (s)8.61 | 1300 | 8.37 |
| 100 | 8.60 | 1400 | 8.34 |
| 200 | 8.59 | 1500 | 8.32 |
| 300 | 8.58 | 1600 | 8.29 |
| 400 | 8.56 | 1700 | 8.27 |
| 500 | 8.54 | 1800 | 8.24 |
| 600 | 8.52 | 1900 | 8.22 |
| 700 | 8.50 | 2000 | 8.19 |
| 800 | 8.48 | 2100 | 8.17 |
| 900 | 8.46 | 2200 | 8.14 |
| 1000 | 8.44 | 2300 | 8.11 |
| 1100 | 8.42 | 2400 | 8.09 |
| 1200 | 8.40 | 2500 | (s)8.05 |

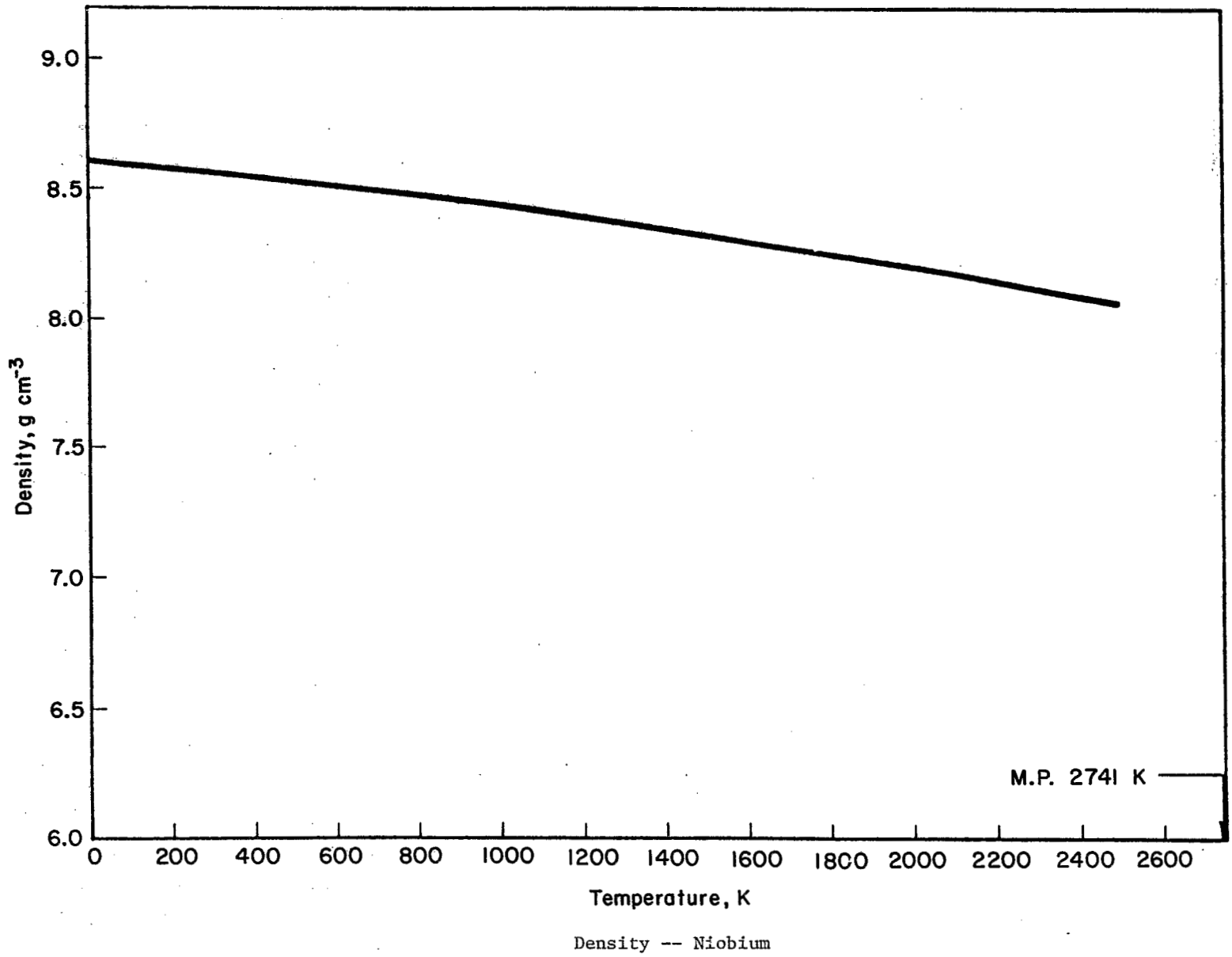
SOURCE OF DATA

- 1) Value at room temperature: (a) Schrijner, A.J. and Middlehoek, A. (37)
- 2) Solid range: (b) from thermal expansion coefficient of Tietz, T.E. and Wilson, J.W. (38)

REMARKS: Accuracy: \pm .5%

No value in liquid range (m.p. is 2740°K)

XIV-G-2



DENSITY OF NICKEL

RECOMMENDED VALUES

| T(°K) | ρ (g. cm ⁻³) | T(°K) | ρ (g. cm ⁻³) |
|-------|-------------------------------|--------------|-------------------------------|
| 0 | (s) 8.976 | 1300 | 8.477 |
| 100 | 8.953 | 1400 | 8.421 |
| 200 | 8.928 | 1500 | 8.362 |
| 300 | 8.901 | 1600 | 8.301 |
| 400 | 8.870 | 1700 | 8.237 |
| 500 | 8.836 | 1728 (m. p.) | (s) 8.220 |
| 600 | 8.800 | 1728 (m. p.) | (l) 7.898 |
| 700 | 8.761 | 1800 | 7.814 |
| 800 | 8.720 | 1900 | 7.696 |
| 900 | 8.677 | 2000 | 7.518 |
| 1000 | 8.631 | 2100 | 7.460 |
| 1100 | 8.582 | 2200 | 7.342 |
| 1200 | 8.531 | 2300 | 7.224 |

SOURCE OF DATA

- 1) Value at room temperature: (a) Metals Handbook (I);
(b) Handbook of Chemistry (IV); (c) Jordan, L. and Swanger, W.H. (34); (d) Foote, F. and Jette, E. R. (4);
- 2) Solid range: (e) from thermal expansion data (III);
- 3) liquid range: (f) Grosse, A.V. and Kirshenbaum, A.D. (35); (g) Kozakevitch, P. and Urbain, G. (21);
(h) Eremenko, V N. and Nizhenko, V.I. (36)

REMARKS: Accuracy: solid range: $\pm .5\%$
liquid range: $\pm 1.0\%$

10. DENSITY OF SILICON

RECOMMENDED VALUES

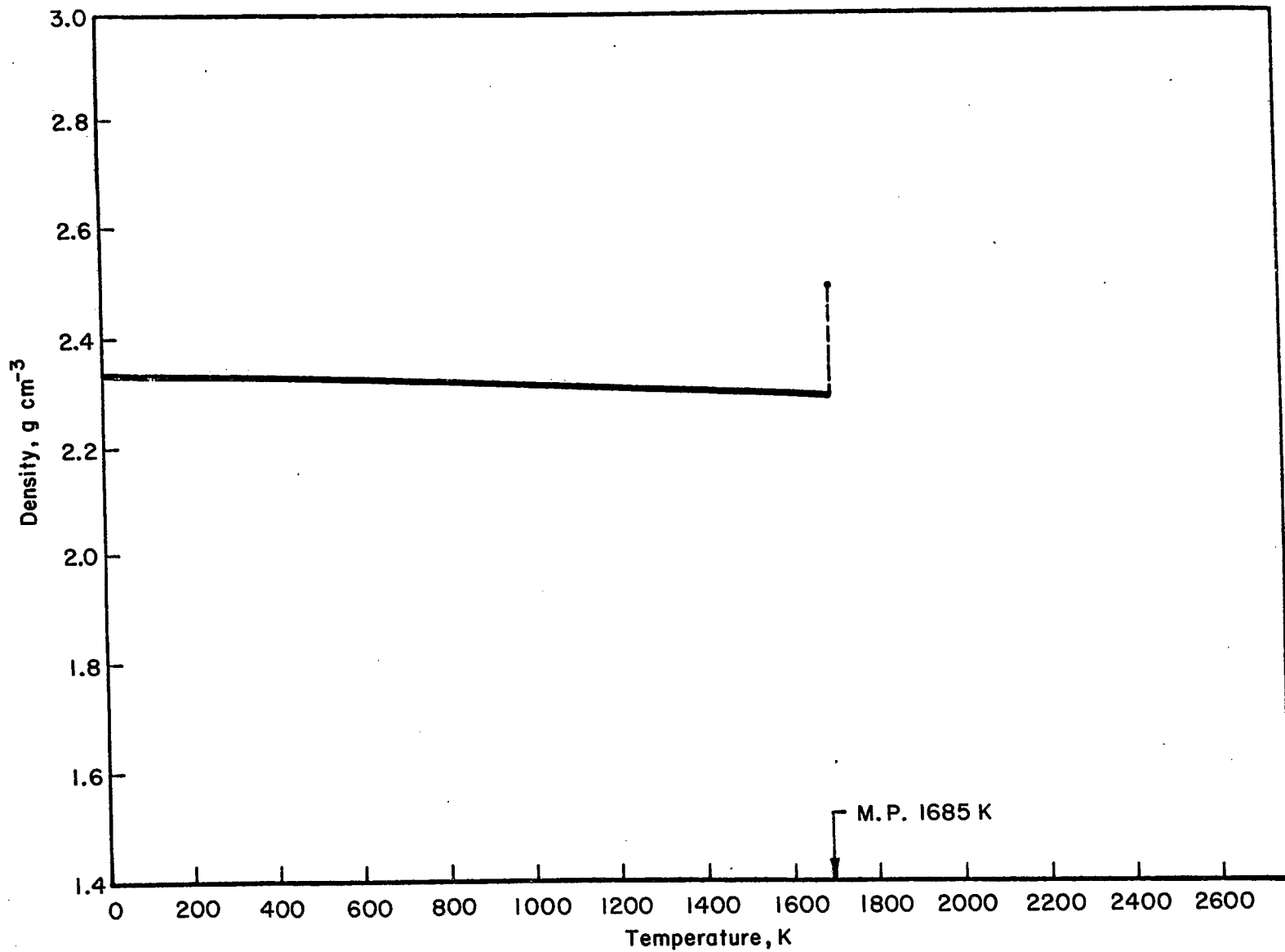
| T(°K) | ρ (g.cm ⁻³) | T(°K) | ρ (g.cm ⁻³) |
|-------|------------------------------|------------|------------------------------|
| 0 | (s)2.332 | 900 | 2.315 |
| 100 | 2.331 | 1000 | 2.312 |
| 200 | 2.330 | 1100 | 2.309 |
| 300 | 2.329 | 1200 | 2.306 |
| 400 | 2.327 | 1300 | 2.302 |
| 500 | 2.325 | 1400 | 2.298 |
| 600 | 2.323 | 1500 | 2.294 |
| 700 | 2.321 | 1600 | 2.290 |
| 800 | 2.318 | 1688(m.p.) | (s)2.286 |
| | | 1688(m.p.) | (l)2.49 |

SOURCE OF DATA

- 1) Value at room temperature: (a) Prener, J.S. and William, F.E. (39); (b) Smakula, A. and Sils, V. (2); (c) Horn, F.H. (40); (d) Smakula, A., Kalnass, J., and Sils, V. (41)
- 2) Solid range: (e) from thermal expansion coefficient (III)
- 3) Change of volume on fusion: (f) Logan, R.A. and Bond, W.L. (42)

REMARKS: Accuracy = $\pm 0.5\%$ or better.

XIV-1-2



Density -- Silicon

DENSITY OF TIN

RECOMMENDED VALUES

| T(°K) | ρ (g. cm ⁻³) | T(°K) | ρ (g. cm ⁻³) |
|-------------|-------------------------------|-----------------|-------------------------------|
| 0 | (s, α) 7.418 | 1200 | 6.563 |
| 100 | 7.375 | 1300 | 6.503 |
| 200 | 7.331 | 1400 | 6.443 |
| 286.36* | 7.290 | 1500 | 6.383 |
| 300 | 7.283 | 1600 | 6.323 |
| 400 | 7.234 | 1700 | 6.263 |
| 500 | 7.185 | 1800 | 6.203 |
| 505 (m. p.) | (s) 7.182 | 1900 | 6.143 |
| 505 (m. p.) | (l) 6.980 | 2000 | 6.083 |
| 600 | 6.923 | 2100 | 6.023 |
| 700 | 6.863 | 2200 | 5.963 |
| 800 | 6.803 | 2300 | 5.903 |
| 900 | 6.743 | 2400 | 5.843 |
| 1000 | 6.683 | 2753 (n. b. p.) | (5.822) |
| 1100 | 6.623 | | |

* below 286 K, white tin (α - tin) transforms to gray tin (β - tin) but the transformation is slow. The density of β - tin at 286.36 is 5.765 g cm⁻³

SOURCE OF DATA

1) Value near room temperature:

β -tin (tetragonal) and α -tin (cubic)

(a) Metals Handbook (I); (b) Handbook of Chemistry (IV);

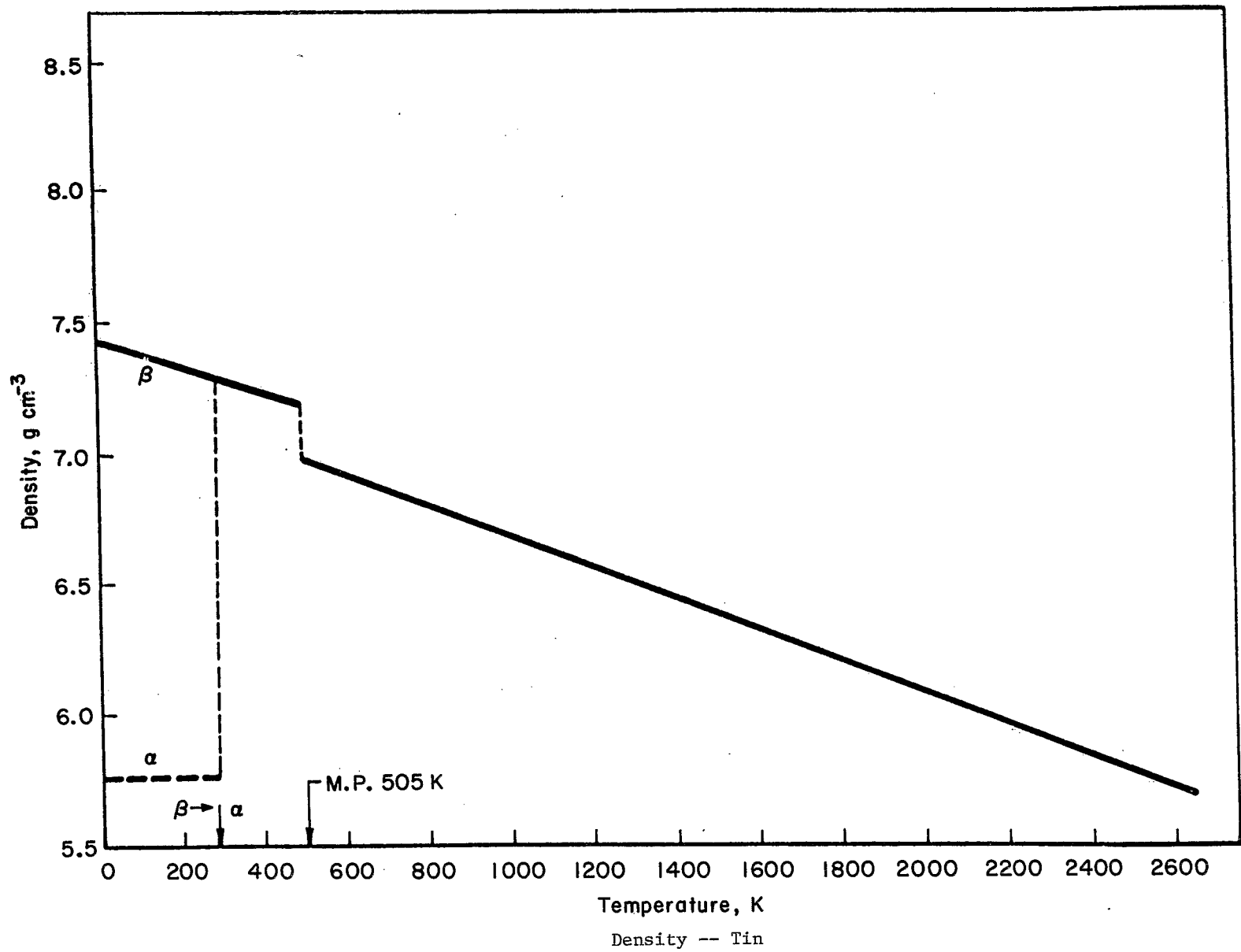
(c) Hedges, E. S. and Homer, C. F. (43)

2) Solid range: see (a) (b) (c)

3) Volume change on fusion: see (a) and discussion by (d) Kirshenbaum, A. D. and Cahill, J. A. (44) and (e) Matuyama, Y. (45)

4) Liquid range : see (d) (e); and (f) Bornemann, K. and Siebe, P. (46); (g) Hogness, T. R. (47); (h) Bornemann, K. and Sauerwald, F. (10); (i) Allen, B. C. and Kingery, W. D. (17); (j) Kanda, F. A. and Keller, D. V. (6); (k) Ubelacker, E. and Lucas, L. D. (49); (l) Gebhardt, E. Becker, M. and Schafer, S. (15); (m) Kutateladze, S. S., Borishanskii, V. M. and Novikov, I. J. (50); (n) Atterton, D. V. and Hoar, T. P. (51); (o) Pascal, P., and Jouniaux, A. (52); (p) Herezynska, E. (53); (q) Gamertsfelder, C. (54); (r) Majima, M. (55); (s) Pluss, M. (56); (t) Sosman, R. B., Day, A. L. and Hostetter, J. C. (57)

REMARKS: Accuracy: Both liquid and solid range: = .5% or better



DENSITY OF ALUMINUM ALLOY 6061-T6

RECOMMENDED VALUES

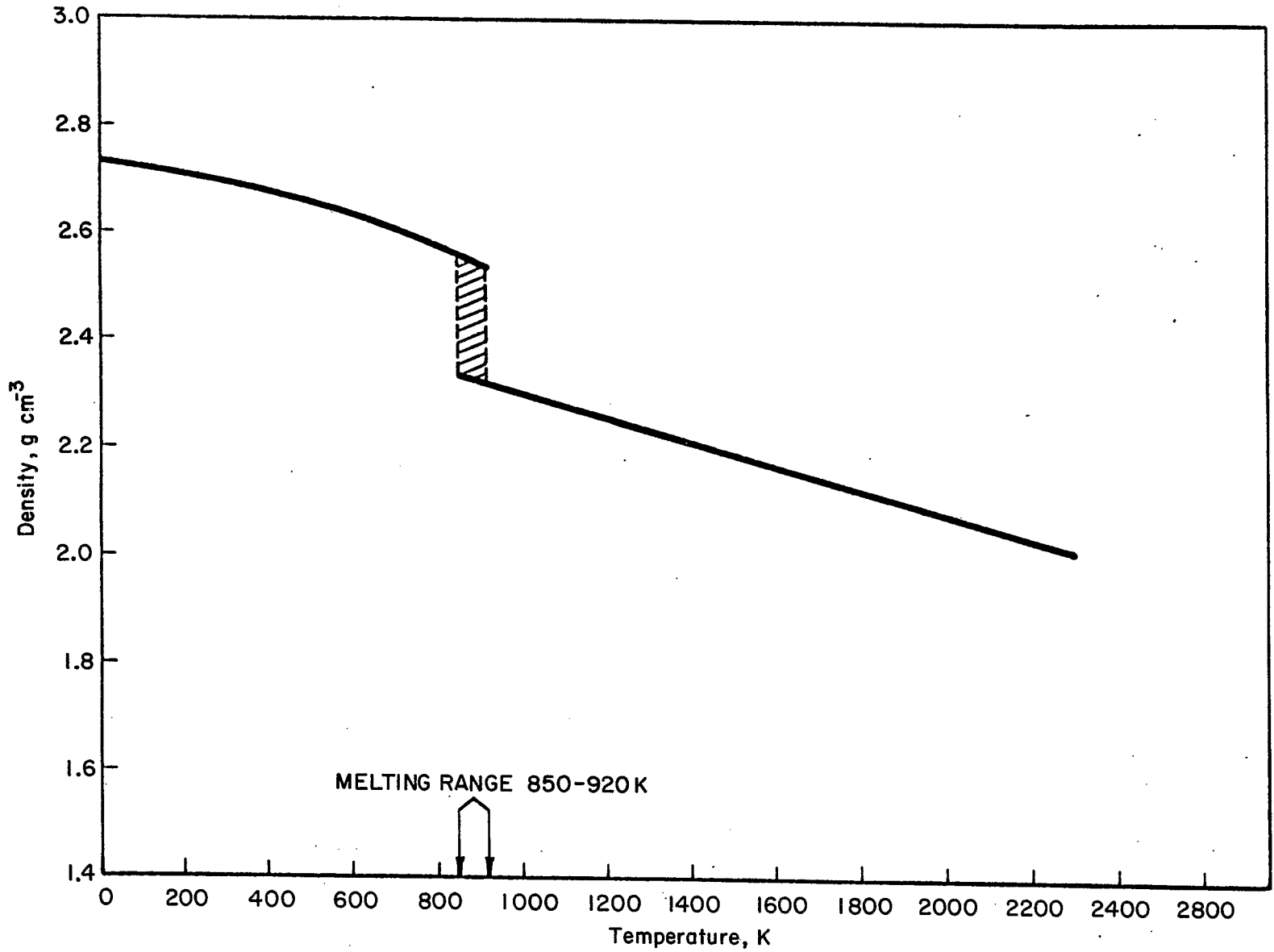
| T(°K) | ρ (g. cm ⁻³) | T(°K) | ρ (g. cm ⁻³) |
|----------------------------|-------------------------------|-------|-------------------------------|
| 0 | (s) 2.73 | 1200 | 2.26 |
| 100 | 2.72 | 1300 | 2.23 |
| 200 | 2.71 | 1400 | 2.21 |
| 300 | 2.70 | 1500 | 2.19 |
| 400 | 2.68 | 1600 | 2.17 |
| 500 | 2.66 | 1700 | 2.15 |
| 600 | 2.63 | 1800 | 2.12 |
| 700 | 2.60 | 1900 | 2.10 |
| 800 | 2.57 | 2000 | 2.08 |
| Melting range: 850°K-920°K | | 2100 | 2.06 |
| 1000 | (l) 2.30 | 2200 | 2.04 |
| 1100 | 2.28 | 2300 | 2.01 |

SOURCE OF DATA

- 1) Solid range: Material properties Handbook (62)
- 2) Melting range: from Metals handbook (1)
- 3) liquid range: computed from mixing rule.

REMARKS: The values obtained from mixing rule calculations were 1.25% higher at all temperature in the solid range.
No accuracy can be stated. These data are only tentative values.

XIV-1-1.2



Density -- Aluminum Alloy 6061-T6

DENSITY OF ALUMINUM ALLOY 2219-T852

RECOMMENDED VALUES

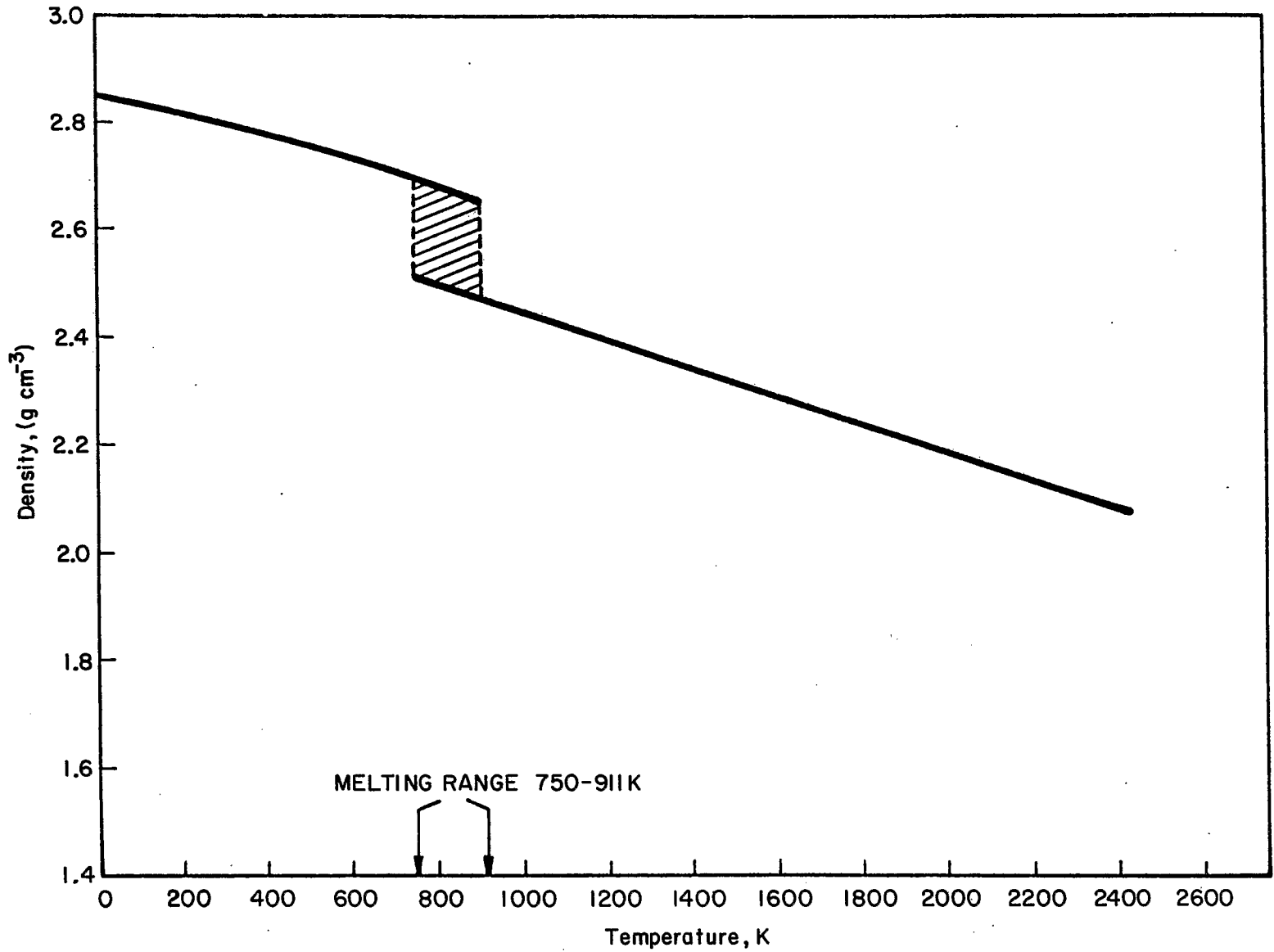
| T(°K) | ρ (g. cm ⁻³) | T(°K) | ρ (g. cm ⁻³) |
|-------------------------|-------------------------------|-------|-------------------------------|
| 0 | (s) 2.87 | 1400 | 2.36 |
| 100 | 2.85 | 1500 | 2.34 |
| 200 | 2.84 | 1600 | 2.31 |
| 300 | 2.82 | 1700 | 2.28 |
| 400 | 2.80 | 1800 | 2.26 |
| 500 | 2.78 | 1900 | 2.24 |
| 600 | 2.76 | 2000 | 2.21 |
| 700 | 2.73 | 2100 | 2.28 |
| Melting range 783-911°K | | 2200 | 2.16 |
| 1000 | (l) 2.46 | 2300 | 2.14 |
| 1100 | 2.44 | | |
| 1200 | 2.41 | | |
| 1300 | 2.38 | | |

SOURCE OF DATA

- 1) Value at room temperature: (a) Levy, A.V. (61)
- 2) Solid range: (b) from thermal expansion coefficient (III)
- 3) liquid range: (c) computed from mixing rule.

REMARKS: The value computed from mixing rule was found from 1.25 to 3% higher at room temperature, depending on composition. No accuracy can be stated. These data are only tentative values.

XIV-I-2.2



Density -- Aluminum Alloy 7075-T6

DENSITY OF STAINLESS STEEL 304A

RECOMMENDED VALUES

| T(°K) | ρ (g. cm ⁻³) | T(°K) | ρ (g. cm ⁻³) |
|-------|-------------------------------|-------|-------------------------------|
| 0 | (s) 7.998 | 900 | 7.655 |
| 100 | 7.967 | 1000 | 7.606 |
| 200 | 7.934 | 1100 | 7.555 |
| 300 | 7.899 | 1200 | 7.502 |
| 400 | 7.860 | 1300 | 7.446 |
| 500 | 7.821 | 1400 | 7.387 |
| 600 | 7.780 | 1500 | 7.325 |
| 700 | 7.737 | 1600 | 7.260 |
| 800 | 7.692 | | |

SOURCE OF DATA

- (a) Thornburg, D. L., Thall, E., Brous, J. (65)
- (b) Stein, D. B., (63)
- (c) Goldsmith, A. et al (III)

REMARKS: Densities between 7.86 (a) and 8.02 (b) have been reported at room temperature. The coefficient of thermal expansion is nearly the same as the coefficient of SS347 (c). More weight is given to information from (a) and this gives for SS 304 the same density as SS 347.