DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 101

PHYSICAL PROPERTIES OF MATERIALS:

I. Strengths and Related Properties of Metals and Certain Other Engineering Materials

EDITION No. 1

Preliminary and subject to criticism and revision

FEBRUARY 9, 1921

PRICE, 10 CENTS

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PHYSICAL PROPERTIES OF MATERIALS:

I. STRENGTHS AND RELATED PROPERTIES OF METALS AND CERTAIN OTHER ENGINEERING MATERIALS[1]

CONTENTS

[1] The preliminary edition was compiled by H. A. Anderson, assistant engineer physicist, in cooperation with the several divisions of the Bureau of Standards.

I. INTRODUCTION

The compilation of information contained in this Circular was begun in response to a request from the Smithsonian Institution for the assistance of the Bureau of Standards in the revision of the Smithsonian Physical Tables. As it was manifestly impossible in the available time to make a critical study of all the published data on the subjects treated herein, the authorities consulted are listed below. The numerical values shown represent a testing engineer's selection of the most probable of these values.

In an effort to improve the form of the definitions and the contents of the tables, the material in this Circular has been circulated in mimeographed form. In response to the Bureau's request for constructive criticisms, helpful comments have been received from members of engineering offices, technical societies and institutions, testing laboratories, and manufacturing concerns. It is evident from these comments that the writers believed that these data are greatly needed and that heretofore they have not been conveniently accessible in any one publication. Certain correspondents have suggested features of the material which could be improved. All feasible suggestions have been followed in revising the mimeographed text for the printers.

Special credit is due to all those who have assisted in putting the data in the present form, and especially to Prof. H. L. Whittemore, under whose supervision the compilation work was carried out.

II. SOURCES OF INCLUDED DATA

The sources of data used in the preparation of these tables are, in general:

1. Technical society proceedings, for example, American Society for Testing Materials, Society of Automotive Engineers, American Chemical Society, American and British institutes of metals, mining, mechanical, and civil engineers' societies, etc.

2. Technical journals, for example, Chemical and Metallurgical Engineering, Revue de Metallurgie, etc.

3. Government testing laboratories, including published data of Bureau of Standards, Watertown Arsenal, National Physical Laboratory (Great Britain).

4. Unpublished data, based on tests made at the Bureau of Standards.

5. Specification values as prescribed by International Aircraft Standards Board, Navy Department, American Society of Testing Materials, Society of Automotive Engineers, etc.

6. Manufacturers' test records as furnished to the Bureau in response to a questionnaire sent out two years ago, or to subsequent inquiries.

7. Engineering handbooks, etc., including tables of physical constants, and texts on engineering materials. (For a list of the latter, see p. 9.)

Since strengths and related properties of most engineering materials vary between wide limits, the values in the tables should be considered as representative of the material, rather than of a single specimen. The numerical values of the physical properties are either those listed in standard material specifications or averages of experimental or test results rounded off. These specification values are, of course, based on test data, but are usually nearer the lower than the upper limit of the range of values for acceptable material. Unless otherwise stated, the values shown are test data. It was deemed more important to give dependable average values than to cite individual results which might occasionally be extreme. In the majority of instances, tabular data are shown in parallel columns in English and metric units, to facilitate comparison with foreign data, the metric values being obtained ordinarily by conversion from the English.

III. TEST SPECIMENS AND CONDITIONS

In general, test specimens used in the determination of the tabulated data were in conformity with the recommendations of the American Society for Testing Materials. (See A. S. T. M. Standards Handbook, 1918, and triennially thereafter, especially Standard Methods for Testing, p. 759, ff.) As a rule, tensile specimens were of 12.8 mm, or 0.505 inch, diameter and 50.8 mm, or 2 inch, gage length. The sizes of compressive and transverse specimens are usually shown accompanying the tables.

All data shown in these tables were determined at ordinary room temperature, averaging 20° C (68° F). The properties of most metals vary considerably from the values shown, however, when the tests are conducted at higher or lower temperatures. (See Bureau Letter Circular VIII–5, June 15, 1918, for Mechanical Tests of Metals and Alloys at Higher and Lower Temperatures, Sources of Information and Data.)

IV. PHYSICAL PROPERTIES

1. DEFINITIONS

The following definitions represent the practice of the Bureau in reporting data on physical properties of engineering materials, and also govern the use of the terms in this Circular. In tensile and compressive tests, the stresses were computed on the basis of the original cross-sectional area of the specimen; in transverse tests, the stress in the extreme fiber was computed from the flexure formula. No attempt has been made to show data from torsion, impact, or fatigue tests of materials, as these are few and unreliable.

(*a*) Proportional Limit (Abbreviated P Limit).—Stress at which the deformation (or deflection) ceases to be proportional to the load as determined with extensometer for tension, compressometer for compression, and deflectometer for transverse tests. (Value read from plotted results.)

(*b*) Elastic Limit.—In tensile and compressive tests: The stress at which the initial permanent elongation (or shortening) of the gage length occurs, as shown by an instrument of high precision (determined from set readings with extensometer or compressometer). In transverse tests: The extreme fiber stress at which the initial appreciable permanent deflection occurs as determined with deflectometer. (Rarely determined, see General Note (*b*), p. 8.)

(*c*) Yield Point.—Stress at which marked increase in deformation (or deflection) of specimen occurs without increase in load as determined usually by drop of beam or with dividers for tension, compression, or transverse tests. (Reported for all tests of ductile materials.)

(*d*) Ultimate Strength in Tension or Compression.—Maximum stress developed in the material during test.

(*e*) Modulus of Rupture.—Maximum stress in the extreme fiber of a beam tested to rupture, as computed by the empirical application of the flexure formula to stresses above the transverse proportional limit, for simple rectangular beam with concentrated center load equals $1.5 \times \text{load} \times \text{span} \div (\text{area} \times \text{depth})$.

(*f*) Modulus of Elasticity (Young's Modulus).—Ratio of stress within the proportional limit to the corresponding strain, as determined with a precise extensometer. Note: All moduli shown are obtained from tensile tests of materials, unless otherwise stated. Accurate determinations of the modulus of elasticity are made with a gage length at least 8 inches in length.

(*g*) Brinell Hardness Numeral (Abbreviated B. h. n.).—Ratio of load on a sphere used to indent the material to be tested to the area of the spherical indentation produced. The standard sphere used is a 10 mm diameter hardened steel ball. The loads used are 3000 kg for steel and 500 kg for softer metals, and the time of application of load is 30 seconds. Values shown in the tables are based on spherical areas computed in the main from measurements of the diameters of the spherical indentations, by the following formula:

$$\text{B. h. n.} = P \div \pi t D = P \div \pi D\ (D/2 - \sqrt{D^2/4 - d^2/4}).$$

P = load in kg, t = depth of indentation,
D = diameter of ball, and d = diameter of indentation, all lengths being expressed in millimeters. Brinell hardness values have a direct relation to tensile strength, and hardness determinations may be used to define tensile strengths by employing the proper conversion factor for the material under consideration.[2]

(*h*) SHORE SCLEROSCOPE HARDNESS.—Height of rebound of a diamond-pointed hammer, falling on the object from a fixed height through a tube under the acceleration due to its own weight. The hardness is measured on an empirical scale on which the average hardness of martensitic high-carbon steel equals 100. On very soft metals a "magnifier" hammer is used in place of the commonly used "universal" hammer, and values may be converted to the corresponding "universal" value by multiplying the reading by 4/7. The scleroscope hardness, when accurately determined, is considered an index of the tensile elastic limit of the metal tested.[2]

(*i*) ERICHSEN VALUE.—Index of forming qualities of sheet metal. The test is conducted by supporting the sheet on a circular ring and deforming it at the center of the ring by a spherical pointed tool. The depth of impression (or cup), in millimeters, required to obtain fracture is the Erichsen value for the metal. Erichsen standard values for trade qualities of soft metal sheets, corresponding to various sheet thicknesses, are furnished by the manufacturer of the machine. (See Proc. A. S. T. M., **17**, (2), p. 200; 1917.)

2. GENERAL NOTES

(*a*) Definitions of mechanical properties of materials and methods of testing in use at the Bureau are in general conformity with the standard methods for testing of the American Society for Testing Materials. (A. S. T. M. Standards, pp. 759–773; 1918.)

(*b*) Tests are rarely made to determine the elastic limit, since such tests involve repeated application and release of load and require considerable time. For practical purposes, the elastic limit may be regarded as equal to the proportional limit.

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[2] Johnson, Materials of Construction, p. 128, Relations between resistance to indentation and strength; 1918.

V. TEXTS ON STRENGTH OF MATERIALS

For an interpretation of the physical significance of the elastic limit, proportional limit, yield point, and other properties, reference may be made to any good text on mechanics of materials, including the following:

Andrews, The strength of materials; 1916. Van Nostrand & Co., New York.

Boyd, Strength of materials; 1917. McGraw-Hill Book Co., New York.

Burr, The elasticity and resistance of the materials of engineering; 1915. John Wiley & Sons, New York.

Church, Mechanics of engineering; 1908. John Wiley & Sons, New York.

Ewing, Strength of materials; 1906. Putnam Co., London.

Goodman, Mechanics applied to engineering; 1899. Longmans, Green & Co., London.

Johnson, Materials of construction; 1918. John Wiley & Sons, New York.

Lanza, Applied mechanics; 1910. John Wiley & Sons, New York.

Merriman, Mechanics of materials; 1915. John Wiley & Sons, New York.

Moore, Materials of engineering; 1917. McGraw-Hill Book Co., New York.

Morley, Strength of materials; 1913. Longmans, Green & Co., London.

Murdock, Strength of materials; 1911. John Wiley & Sons, New York.

Slocum, Resistance of materials; 1914. Ginn & Co., Boston.

Unwin, The testing of materials of construction; 1910. Longmans, Green & Co., London.

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VI. FERROUS METALS AND ALLOYS

1. IRON AND IRON ALLOYS

TABLE 1.—Properties of Iron and Iron Alloys—Experimental Results Unless Otherwise Noted

Metal	Grade and condition	Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
		Yield point	Ultimate	Yield point	Ultimate			Brinell at 3000 kg	Scleroscope
Iron	Electrolytic (remelt)[a]*:	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
	As forged	34.0	38.5	48 500	55 000	33.0	83.0	[b] 95	18
	Annealed at 900° C.	12.5	26.8	18 000	38 000	52.0	87.0	[b] 75	....
	Gray cast[c]:								
	19 mm (diameter) bars	Indeterminate	17.5–26.8	Indeterminate	25 000–38 000	Negligible	Negligible	100–150	24–40
	Malleable cast [d] (range):								
	American manufacture ("black heart")	14.0–31.5	24.5–40.0	20 000–45 000	35 000–57 000	15.0–4.5	15.0–4.5	....	....
	European manufacture (decarbonized)	19.0–28.0	29.5–45.5	27 000–40 000	42 000–65 000	6.0–2.0	6.0–2.0	....	....
	American practice, 1918 [e]	18.6–20.0	33.7–35.1	26 500–28 500	48 000–50 000	10.0–15.0	15.0–20.0	100–145	12–16
	American specification value [f]	....	Minimum, 31.6	....	Minimum, 45 000	Minimum, 7.5	....	....	....
	Wrought (commercial range)	19.7–22.5	34.0–37.3	28 000–32 000	48 000–53 000	40.0–30.0	45.0–35.0	....	25–30
Iron alloys	Silicon:								
	Si, 0.01, C max., 0.01 (laboratory product[g]), as forged	29.5	31.8	41 800	45 200	35.0	78.0	....	....
	melted in vacuo and annealed at 970° C.	11.2	24.5	16 000	34 900	53.0	81.5	....	....
	Si, 1.71, as forged	48.0	53.5	68 100	76 300	29.0	87.2	....	....
	annealed at 970° C.	25.1	38.0	35 800	54 200	50.0	90.6	....	....
	Si, 4.40, as forged	66.0	74.0	94 000	105 000	6.0	7.5	....	....
	annealed at 970° C.	51.3	64.5	72 900	91 600	24.0	25.1	....	....
	Aluminum:								
	Al, 0.00, C max., 0.01 (laboratory product[h]), as forged	35.5	38.5	50 700	54 700	26.0	84.3	....	....
	annealed at 1000° C.	12.5	24.5	17 600	34 900	60.0	93.5	....	....
	Al, 3.08,[h] as forged	48.0	54.5	68 200	77 500	21.0	76.4	....	....
	annealed at 1000° C.	22.4	37.5	31 800	53 400	51.0	85.3	....	....
	Al, 6.24,[h] as forged	54.6	60.5	77 700	86 000	28.0	74.7	....	....
	annealed at 1000° C.	37.6	49.1	53 400	69 800	27.0	55.5	....	....

COMPOSITION, APPROXIMATE:
Electrolytic, C, 0.0125 per cent; other impurities less than 0.05 per cent.
Cast, gray, graphitic, C, 3.0; Si, 1.3–2.0; Mn, 0.6–0.9; S max., 0.1; P max., 1.2.
A. S. T. M. specification, A 48–18, S max., 0.10, except S max. 0.12 for heavy castings.
Malleable—
American "black heart," C, 2.8–3.5; Si, 0.6–0.8; Mn, max., 0.4; S max., 0.07; P max., 0.2.
European "steely fracture," C 2.8–3.5; Si, 0.6–0.8; Mn, 0.15; S max., 0.35; P max., 0.2.

COMPRESSIVE STRENGTHS (Specimens tested, cylinders 25.4 mm, or 1 inch, diameter, 76.2 mm, or 3 inches, long):
Electrolytic iron, 56.3 kg/mm^2, or 80 000 lbs./in.^{2}
Gray and malleable cast iron, 56.3–84.4 kg/mm^2 or 80 000–120 000 lbs./in.^{2}
Wrought iron, approximately equal to tensile yield point (slightly above P limit).

DENSITY:
Electrolytic iron, about .... 7.8 g/cm^3, or 487 lbs./ft.^{3}
Cast iron, about .... 7.2 g/cm^3, or 449 lbs./ft.^{3}
Malleable iron, about .... 7.6 g/cm^3, or 474 lbs./ft.^{3}
Wrought iron, about .... 7.85 g/cm^3, or 490 lbs./ft.^{3}

DUCTILITY: Normal Erichsen values for good trade quality sheets, 0.4 mm, or 0.0156 inch, thickness, soft annealed.

Kind	Depth of impression	
	mm	Inch
Sheet metal, hoop iron, polished	9.5	0.374
Charcoal iron, tinned sheet	7.5	.295
Second quality tinned sheet	6.7	.264

* Footnotes on following page.

TABLE 1—Continued

MODULUS OF ELASTICITY IN TENSION AND COMPRESSION:	
Electrolytic iron	17 600 kg/mm², or 25 000 000 lbs./in.²
Cast iron	10 500 kg/mm², or 15 000 000 lbs./in.²
Malleable iron	17 600 kg/mm², or 25 000 000 lbs./in.²
Wrought iron	17 600 kg/mm², or 25 000 000 lbs./in.²
MODULUS OF ELASTICITY IN SHEAR:	
Electrolytic iron	7030 kg/mm², or 10 000 000 lbs./in.²
Cast iron	8450 kg/mm², or 12 000 000 lbs./in.²
Wrought iron	7030 kg/mm², or 10 000 000 lbs./in.²
SCLEROSCOPE HARDNESS values shown are as determined with the Shore universal hammer.	
STRENGTH IN SHEAR:	
Electrolytic (remelt)—	
P limit	8.4 kg/mm², or 12 000 lbs./in.²
Ultimate strength	21.1 kg/mm², or 30 000 lbs./in.²
Commercial wrought—	
P limit	21.1 kg/mm², or 30 000 lbs./in.²
Ultimate strength	35.2 kg/mm², or 50 000 lbs./in.²
TRANSVERSE STRENGTH, FROM FLEXURE FORMULA:	
Gray cast iron—	
Modulus of rupture	33.0 kg/mm², or 47 000 lbs./in.²
"Arbitration bar" [i]	31.8 mm, or 1 1/4 inches, diameter, on 304.8 mm or 12-inch span.

[a] Properties of Swedish iron (impurities less than 1 per cent) approximately equal those of electrolytic iron.
[b] B. h. n. at 500 kg.
[c] U. S. Navy 4912a specifications, minimum tensile strength, 14.1 kg/mm², or 20 000 lbs./in.²
[d] Malleable values from Hatfield, cast iron.
[e] After H. A. Schwartz, Proc. A. S. T. M., (2), pp. 247–265; 1919.
[f] A. S. T. M. specifications, A 75–18 T.
[g] After T. D. Yensen, Univ. of Ill., Eng. Exp. Station Bulletin No. 83; 1915.
[h] After T. D. Yensen, Univ. of Ill., Eng. Exp. Station Bulletin No. 95; 1917.
[i] Minimum central load at rupture, 1130 to 1500 kg (2500–3300 pounds). Minimum central deflection at rupture, 2.5 mm or 0.1 inch (A. S. T. M. specification A 48–18).

2. STEELS

(*a*) Classification

S. A. E. (Society of Automotive Engineers) classification scheme is used as the basis for the numbering of the steels shown in the tables. The first figure indicates the class to which the steel belongs, thus, 1 indicates a carbon steel, 2 nickel steel, etc. In the case of alloy steels, the second figure generally indicates the approximate percentage of the predominant alloying element. The last two figures indicate the average carbon content in hundredths of 1 per cent.

Values given for P limit are average minimum, except those for hardness, which are average. The P limit and ductility of cast steel average slightly lower, and the ultimate strength averages 10 to 15 per cent higher than the values shown for the same composition steel in the annealed condition. The properties of rolled steel (raw) are approximately equal to those of annealed steel. Here they indicate the normalized condition of the metal rather than the soft-annealed state.

Tabular values were obtained by averaging test results for specimens ranging in size from one-half to 1½ inches in diameter. The properties of heat-treated steels should therefore be taken as representing the average strengths which can be obtained by treating bars of such sizes. The final drawing or quenching temperature used to obtain the properties shown is indicated in degrees centigrade with the heat-treatment letter wherever the information is available. In general, the specimens were drawn near the lower limit of the indicated temperature range.

Heat Treatment D, After Forging or Machining—

1. Heat to 1500 to 1600° F (816–871° C).
2. Quench.
3. Reheat to 1450 to 1500° F (788–816° C).
4. Quench.
5. Reheat to 600 to 1200° F (316–649° C) and cool slowly.

Heat Treatment E, After Forging or Machining—

1. Heat to 1500 to 1550° F (816–843° C).
2. Cool slowly.
3. Reheat to 1450 to 1500° F (788–816° C).
4. Quench.
5. Reheat to 600 to 1200° F (316–649° C) and cool slowly.

Heat Treatment H, After Forging or Machining—

1. Heat to 1500 to 1600° F (816–871° C).
2. Quench.
3. Reheat to 600 to 1200° F (316–649° C) and cool slowly.

Heat Treatment M, After Forging or Machining—

1. Heat to 1450 to 1500° F (788–816° C).
2. Quench.
3. Reheat to 500 to 1250° F (260–677° C) and cool slowly.

Heat Treatment P, After Forging or Machining—

1. Heat to 1450 to 1500° F (788–816° C).
2. Quench.
3. Reheat to 1375 to 1450° F (746–788° C).
4. Quench.
5. Reheat to 500 to 1250° F (260–677° C) and cool slowly.

Heat Treatment Q, After Forging—

1. Heat to 1475 to 1525° F (802–829° C). (Hold at this temperature one-half hour to insure thorough heating.)
2. Cool slowly.
3. Machine.
4. Reheat to 1375 to 1425° F (746–774° C).
5. Quench.
6. Reheat to 250 to 550° F (121–288° C) and cool slowly.

Heat Treatment R, After Forging—

1. Heat to 1500 to 1550° F (816–843° C).
2. Quench in oil.
3. Reheat to 1200 to 1300° F (649–704° C). (Hold at this temperature three hours.)
4. Cool slowly.
5. Machine.
6. Reheat to 1350 to 1450° F (732–788° C).
7. Quench in oil.
8. Reheat to 250 to 500° F (121–260° C) and cool slowly.

Heat Treatment T, After Forging or Machining—

1. Heat to 1650 to 1750° F (899–954° C).
2. Quench.
3. Reheat to 500 to 1300° F (260–704° C) and cool slowly.

Heat Treatment U, After Forging—

1. Heat to 1525 to 1600° F (829–871° C). (Hold for about one-half hour.)
2. Cool slowly.
3. Machine.

4. Reheat to 1650 to 1700° F (899–926° C).
5. Quench.
6. Reheat to 350 to 550° F (177–288° C) and cool slowly.

Heat Treatment V, After Forging or Machining—

1. Heat to 1650 to 1750° F (899–954° C).
2. Quench.
3. Reheat to 400 to 1200° F (204–649° C) and cool slowly.

NOTE.—Oil quenching is recommended wherever the instructions specify "quench," inasmuch as the data in the table are taken from tests of automobile parts, which must resist considerable vibration and which are usually small in section. The quenching medium must always be carefully considered.

(b) Carbon Steels

TABLE 2.—Properties of Carbon Steels [a]—Experimental Results

Class of steel (S. A. E. specification No.)	Nominal contents	S. A. E. heat treatment and reheating temperature	Tensile strength: P limit	Tensile strength: Ultimate	Tensile strength: P limit	Tensile strength: Ultimate	Elongation in (50.8 mm 2 inches)	Reduction of area	Hardness: Brinell at 3000 kg	Hardness: Scleroscope
	Per cent		kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
Carbon steel 1010	C, 0.05–0.15; Mn, .30–.60; P, .045 max; S, .05 max	Annealed	19.7–25.3	....	[b]28 000–36 000	....	40–30	65–55	....	....
		Cold rolled	28.1–42.2	....	[b]40 000–60 000	....	....	55–45	....	....
Carbon steel 1020	C, .15–.25; Mn, .30–.60; P, .045 max; S, .05 max	Cold rolled	28.1–52.7	....	[b]40 000–75 000	....	....	35–30	....	....
		Drawn at— °C °F								
		H 205 400	35.2	56.2	50 000	80 000	20.0	60.0	180	34
		H 260 500	34.4	55.5	49 000	79 000	20.5	60.5	175	34
		H 315 600	33.7	54.8	48 000	78 000	21.0	61.0	170	34
		H 371 700	32.6	54.1	46 500	77 000	22.5	62.0	160	33
		H 427 800	31.2	53.4	44 500	76 000	24.5	63.5	150	33
		H 482 900	29.8	52.7	42 500	75 000	26.5	65.0	140	32
		H 538 1000	28.4	52.0	40 500	74 000	28.5	66.5	130	32
		H 593 1100	27.0	51.3	38 500	73 000	30.0	68.0	120	31
		H 649 1200	26.0	50.6	37 000	72 000	31.5	69.0	110	31
		H 704 1300	25.3	49.9	36 000	71 000	32.0	69.5	105	30
		H 760 1400	24.6	49.2	35 000	70 000	32.5	70.0	100	30
Carbon steel 1025	C, .20–.30; Mn, .50–.80; P, .045 max; S, .05 max	H 205 400	42.2	63.2	60 000	90 000	17.0	55.0	215	37
		H 260 500	41.5	62.5	59 000	89 000	17.5	55.5	210	37
		H 315 600	40.1	61.8	57 000	88 000	18.5	56.0	200	36
		H 371 700	38.7	60.8	55 000	86 500	20.0	57.5	185	36
		H 427 800	36.9	59.4	52 500	84 500	21.5	59.0	175	35
		H 482 900	35.2	58.0	50 000	82 500	23.5	61.0	160	34
		H 538 1000	33.4	56.5	47 500	80 500	25.5	63.0	145	33
		H 593 1100	31.6	55.2	45 000	78 500	27.0	64.5	135	32
		H 649 1200	30.2	54.1	43 000	77 000	28.5	66.0	125	31
		H 704 1300	28.8	53.4	41 000	76 000	29.5	67.0	115	30
		H 760 1400	28.1	52.7	40 000	75 000	30.0	67.5	110	30

		H 205 400	52.7	73.8	75 000	105 000	15.0	42.5	260	42
		H 260 500	52.0	73.1	74 000	104 000	15.5	43.5	255	41
		H 315 600	50.6	72.1	72 000	102 500	16.5	45.0	245	42
	C, .30- .40	H 371 700	48.5	70.3	69 000	100 000	18.0	47.0	235	40
Carbon steel 1035	Mn, .50- .80	H 427 800	46.4	68.1	66 000	97 000	19.5	49.5	220	39
	P, .045 max	H 482 900	44.3	66.0	63 000	94 000	21.5	52.5	200	37
	S, .05 max	H 538 1000	41.9	63.9	59 500	91 000	23.5	55.5	180	35
		H 593 1100	39.4	61.8	56 000	88 000	25.0	58.0	165	34
		H 649 1200	37.3	60.1	53 000	85 500	26.5	60.0	150	33
		H 704 1300	35.9	58.6	51 000	83 500	27.5	61.5	140	32
		H 760 1400	35.2	57.6	50 000	82 000	28.0	62.5	135	32
		H 205 400	63.2	87.9	90 000	125 000	12.5	35.0	300	45
		H 260 500	61.8	86.8	88 000	123 500	13.0	36.0	290	45
		H 315 600	60.0	85.1	85 500	121 000	13.5	37.0	280	44
	C, .40- .50	H 371 700	57.9	82.9	82 500	118 000	14.5	39.0	265	43
Carbon steel 1045	Mn, .50- .80	H 427 800	55.5	80.1	79 000	114 000	16.0	42.0	250	41
	P, .045 max	H 482 900	52.7	77.3	75 000	110 000	17.5	45.0	230	40
	S, .05 max	H 538 1000	49.9	74.5	71 000	106 000	19.0	48.0	210	38
		H 593 1100	47.1	71.7	67 000	102 000	20.5	50.5	195	37
		H 649 1200	44.6	69.6	63 500	99 000	21.5	53.0	180	36
		H 704 1300	43.2	67.7	61 500	96 500	22.0	54.0	165	35
		H 760 1400	42.2	66.7	60 000	95 000	22.5	55.0	160	35
	C, as required for physical properties	Hard	25.3	56.2	c 36 000	c 80 000	c 15	c 20		
Cast steel 1235	P, 0.05 max	Medium	22.1	49.2	c 31 500	c 70 000	c 18	c 25		
	S, .05 max	Soft	19.0	42.2	c 27 000	c 60 000	c 22	c 30		

[a] The tables on steels are from the 11th report of the iron and steel division, standards committee, Society of Automotive Engineers (Inc.), revised August, 1919.
[b] These figures represent yield point.
[c] Minimum requirements.

TABLE 3.—Properties of Carbon Steels (Castings and Structural)—Specification Values [a]

Material	Grade	A. S. T. M. yield point ÷ ultimate	Ultimate tensile strength		Elongation in 50.8 mm (2 inches)	Reduction of area
			kg/mm²	Lbs./in.²	Per cent	Per cent
Steel, castings	Hard	0.45	56.2	80 000	15	20
	Medium	.45	49.2	70 000	18	25
	Soft	.45	42.2	60 000	22	30
Steel,[b] structural, building[c]	....	.5	38.7–45.7	55 000–65 000	22	....

[a] Specification values for castings, A, 27–16, class B, annealed [c]: P max., 0.05; S max, 0.05. Specification values for structural, A. S. T. M. A 9–16, P max., (Bessemer), 0.10, or (Open-hearth), 0.06.

[b] These values are for rolled mild-carbon steel.

[c] Average carbon. castings, 0.30–0.40; structural, 0.15–0.30.

(c) Alloy Steels

TABLE 4.—Properties of Alloy Steels [a]*—Commercial Experimental Results

Class of steel (With S. A. E. specification No.)	Nominal contents	S. A. E. heat treatment and reheating temperature	Tensile strength: P limit	Tensile strength: Ultimate	Tensile strength: P limit	Tensile strength: Ultimate	Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness: Brinell at 3000 kg	Hardness: Scleroscope
	Per cent		kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
Nickel steel 2315	C, 0.10–0.20; Mn, .50– .80; P, .04 max; S, .045 max; Ni, 3.25–3.75	Annealed	24.6– 31.6	....	b 35 000– 45 000	....	35–25	65–45	....	....
		H	28.1– 56.2	....	b 40 000– 80 000	....	35–15	65–40	....	....
Nickel steel 2320	C, .15– .25; Mn, .50– .80; P, .04 max; S, .045 max; Ni, 3.25–3.75	Annealed	28.1– 35.2	....	b 40 000– 50 000	....	30–20	65–40	....	....
		Drawn at °C °F								
		H 205 400	98.4	119.5	140 000	170 000	11.0	45.0	375	55
		H 260 500	96.0	118.1	136 500	168 000	12.0	46.0	368	54
		H 315 600	91.4	113.9	130 000	162 000	13.5	48.5	355	52
		H 371 700	86.5	109.0	123 000	155 000	15.5	51.5	340	50
		H 427 800	78.7	101.9	112 000	145 000	18.5	55.5	310	46
		H 482 900	69.6	91.4	99 000	130 000	21.5	60.5	280	42
		H 538 1000	59.0	78.7	84 000	112 000	25.0	65.5	240	38
		H 593 1100	47.8	67.4	68 000	96 000	27.0	69.5	200	34
		H 649 1200	37.0	57.6	54 000	82 000	29.0	72.5	165	31
		H 704 1300	31.6	52.7	45 000	75 000	29.5	74.5	140	29
		H 760 1400	28.1	49.2	40 000	70 000	30.0	75.0	125	28
Nickel steel 2330	C, .25– .35; Mn, .50– .80; P, .04 max; S, .045 max; Ni, 3.25–3.75	Annealed	28.1– 35.2	....	b 40 000– 50 000	....	30–20	60–40	....	....
		H or M 205 400	133.5	154.7	190 000	220 000	10.0	35.0	436	60
		H or M 260 500	127.9	147.6	182 000	210 000	10.7	37.0	420	59
		H or M 315 600	119.5	139.2	170 000	198 000	11.5	40.0	400	57
		H or M 371 700	108.3	126.5	154 000	180 000	12.7	44.0	375	54
		H or M 427 800	94.9	112.5	135 000	160 000	14.5	49.0	340	50
		H or M 482 900	80.8	98.4	115 000	140 000	16.0	54.0	300	46
		H or M 538 1000	66.7	84.4	95 000	120 000	18.0	59.0	250	41
		H or M 593 1100	54.1	73.1	77 000	104 000	20.5	62.7	210	37
		H or M 649 1200	45.0	64.6	64 000	92 000	22.5	66.0	180	34
		H or M 704 1300	38.7	59.7	55 000	85 000	24.5	68.5	162	32
		H or M 760 1400	35.2	56.2	50 000	80 000	25.0	70.0	150	30

* Footnotes on p. 24

TABLE 4—Continued

Class of steel (With S. A. E. specification No.)	Nominal contents	S. A. E. heat treatment and reheating temperature	Tensile strength: P limit	Tensile strength: Ultimate	Tensile strength: P limit	Tensile strength: Ultimate	Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness: Brinell at 3000 kg	Hardness: Scleroscope
	Per cent	Drawn at °C °F	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
Nickel steel 2335	C, 0.30-0.40; Mn, .50- .80; P, .04 max; S, .045 max; Ni, 3.25-3.75	Annealed	....	....	*b 45 000- 55 000	....	25-15	55-35	....	....
		H or K	....	....	b 65 000-160 000	....	25-10	55-25	....	....
Nickel steel 2340	C, .35- .45; Mn, .50- .80; P, .04 max; S, .045 max; Ni, 3.25-3.75	Annealed	38.7- 45.7	....	b 55 000- 65 000	....	25-15	50-30	....	....
		M 205 400	151.1	168.7	215 000	240 000	10.0	32.5	450	70
		M 260 500	143.4	161.7	204 000	230 000	11.0	34.5	427	65
		M 315 600	133.5	151.1	190 000	215 000	12.0	37.5	400	61
		M 371 700	120.2	137.7	171 000	196 000	13.0	42.0	370	56
		M 427 800	105.5	123.0	150 000	175 000	14.0	47.0	335	51
		M 482 900	91.4	109.0	130 000	155 000	16.0	51.0	295	46
		M 538 1000	77.3	94.9	110 000	135 000	18.0	55.0	260	42
		M 593 1100	64.6	82.2	92 000	117 000	20.0	58.0	235	38
		M 649 1200	54.8	73.8	78 000	105 000	21.5	60.0	215	36
		M 704 1300	48.5	67.4	69 000	96 000	22.0	61.0	205	35
		M 760 1400	42.2	63.2	60 000	90 000	22.5	62.5	200	35
Nickel-chromium steel 3120	C, .15- .25; Mn, .50- .80; P, .04 max; S, .045 max; Ni, 1.00-1.50; Cr, .45- .75	Annealed	21.1- 28.1	....	b 30 000- 40 000	....	35-25	55-40	....	....
		H or M 205 400	84.4	112.5	120 000	160 000	15.0	52.5	275	....
		H or M 260 500	81.5	109.0	116 000	155 000	15.5	54.0	265	....
		H or M 315 600	77.3	104.0	110 000	148 000	16.0	57.0	250	....
		H or M 371 700	71.7	96.3	102 000	137 000	16.5	61.0	240	....
		H or M 427 800	66.8	87.9	95 000	125 000	18.0	65.5	225	....
		H or M 482 900	59.0	78.0	84 000	111 000	21.0	69.0	205	....
		H or M 538 1000	52.0	70.3	74 000	100 000	24.5	71.0	185	....
		H or M 593 1100	46.4	63.9	66 000	91 000	28.5	71.5	175	....
		H or M 649 1200	42.2	59.0	60 000	84 000	31.5	72.0	160	....
		H or M 704 1300	38.0	56.2	54 000	80 000	33.5	72.5	150	....
		H or M 760 1400	35.2	52.7	50 000	75 000	35.0	72.5	150	....
Nickel-chromium steels 3125, 3135, and 3140.	C as indicated by two last figures of specification numbers; other components as with the steel 3120.	Annealed	28.1- 38.7	....	b 40 000- 55 000	....	30-20	50-35	....	....
		H, D, or E	35.2- 87.9	....	b 50 000-125 000	....	25-10	55-25	....	....
		Annealed	31.6- 42.2	....	b 45 000- 60 000	....	25-15	45-30	....	....
		H, D, or E	38.7-105.5	....	b 55 000-150 000	....	20- 5	50-25	....	....

Nickel-chromium steel 3130	C, 0.25–0.35 Mn, .50– .80 P, .04 max S, .045 max Ni, 1.00–1.50 Cr, .45– .75	H 205 400	109.0	133.6	155 000	190 000	10.0	37.5	....	50
		H 260 500	105.5	132.2	150 000	188 000	11.0	41.0	....	49
		H 315 600	98.4	126.5	140 000	180 000	12.5	46.0	....	48
		H 371 700	90.0	117.4	128 000	167 000	13.5	52.5	....	46
		H 427 800	80.8	105.5	115 000	150 000	15.5	59.0	....	43
		H 482 900	71.7	94.2	102 000	134 000	17.5	63.0	....	40
		H 538 1000	63.3	84.4	90 000	120 000	20.0	65.0	....	38
		H 593 1100	56.9	73.1	81 000	104 000	23.5	66.5	....	35
		H 649 1200	53.4	64.7	76 000	92 000	26.5	68.0	....	32
		H 704 1300	50.6	60.4	72 000	86 000	28.5	69.0	....	31
		H 760 1400	49.2	56.2	70 000	80 000	30.0	70.0	....	30
Nickel-chromium steel 3140	C, .35– .45 Mn, .50– .80 P, .04 max S, .045 max Ni, 1.00–1.50 Cr, .45– .75	H or M 205 400	140.6	161.7	200 000	230 000	7.5	27.0	425	65
		H or M 260 500	137.0	158.9	195 000	226 000	8.0	28.0	410	64
		H or M 315 600	130.0	154.7	185 000	220 000	9.0	30.0	390	62
		H or M 371 700	118.1	143.4	168 000	204 000	10.5	34.0	360	59
		H or M 427 800	104.0	127.9	148 000	182 000	12.5	39.0	330	56
		H or M 482 900	88.6	110.4	126 000	157 000	14.0	46.5	300	52
		H or M 538 1000	73.8	91.4	105 000	130 000	16.0	52.5	275	47
		H or M 593 1100	66.0	78.7	94 000	112 000	17.0	56.5	245	42
		H or M 649 1200	59.0	70.3	84 000	100 000	18.0	60.0	225	38
		H or M 704 1300	56.2	65.3	80 000	93 000	19.0	61.0	215	36
		H or M 760 1400	52.7	63.2	75 000	90 000	20.0	62.0	210	35
Nickel-chromium steel 3220	C, .15– .25 Mn, .30– .60 P, .04 max S, .04 max Ni, 1.50–2.00 Cr, .90–1.25	Annealed	24.6– 31.6	....	b 35 000– 45 000	....	25–20	60–45	....	....
		H or D	31.6– 84.4	....	b 45 000–120 000	....	20– 5	65–30	....	....
Nickel-chromium steel 3230	C, .25– .35 Mn, .30– .60 P, .04 max S, .04 max Ni, 1.50–2.00 Cr, .90–1.25	Annealed	28.1– 35.2	....	b 40 000– 50 000	....	25–15	55–40	....	....
		H or D	42.2–123.0	....	b 60 000–175 000	....	20– 5	60–30	....	....
Nickel-chromium steel 3240	C, .35– .45 Mn, .30– .60 P, .04 max S, .04 max Ni, 1.50–2.00 Cr, .90–1.25	Annealed	31.6– 42.2	....	b 45 000– 60 000	....	25–15	50–40	....	....
		H or D	45.7–140.6	....	b 65 000–200 000	....	15– 2	50–20	....	....
Nickel-chromium steel 3250	C, .45– .55 Mn, .30– .60 P, .04 max S, .04 max Ni, 1.50–2.00 Cr, .90–1.25	Annealed	35.2– 42.2	....	b 50 000– 60 000	....	25–15	50–40	....	....
		M or Q	105.5–175.8	....	b 150 000–250 000	....	15– 2	25–15	....	....

* Footnotes on page 24.

TABLE 4—Continued

Class of steel (With S. A. E. specification No.)	Nominal contents	S. A. E. heat treatment and reheating temperature	Tensile strength: P limit	Tensile strength: Ultimate	Tensile strength: P limit	Tensile strength: Ultimate	Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness: Brinell at 3000 kg	Hardness: Scleroscope
	Per cent		kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
Nickel-chromium steel 3415	C, 0.10– 0.20 Mn, .45– .75 P, .04 max S, .04 max Ni, 2.75–3.25 Cr, .60– .95	Annealed	24.6– 31.6		*[b] 35 000– 45 000		25–20	60–45		
		M	28.1– 70.3		[b] 40 000–100 000		20– 5	65–30		
Nickel-chromium steel 3435	C, .30– .40 Mn, .45– .75 P, .04 max S, .04 max Ni, 2.75–3.25 Cr, .60– .95	Annealed	31.6– 38.7		[b] 45 000– 55 000		25–15	55–40		
		P or R	42.2–123.0		[b] 60 000–175 000		20– 5	60–30		
Chromium-vanadium steel 6120	C, .15– .25 Mn, .50– .80 P, .04 max S, .04 max Cr, .80–1.10 Va, .15 min	Annealed	28.1– 35.2		[b] 40 000– 50 000		30–20	65–50		
		T	38.7– 70.3		[b] 55 000–100 000		25–10	65–45		
Chromium-vanadium steel 6125	C, .20– .30 Mn, .50– .80 P, .04 max S, .04 max Cr, .80–1.10 Va, .15 min	Annealed	28.1– 35.2		[b] 40 000– 50 000		32–20	65–50		
		T	38.7– 70.3		[b] 55 000–100 000		25–10	65–45		
Chromium-vanadium steel 6130	C, .25– .35 Mn, .50– .80 P, .04 max S, .04 max Cr, .80–1.10 Va, .15 min	Annealed	31.6– 38.7		[b] 45 000– 55 000		25–20	60–50		
		T	42.2–105.5		[b] 60 000–150 000		15– 5	55–25		

Chromium-vanadium steel 6135	C, 0.30–0.40 Mn, .50– .80 P, .04 max S, .04 max Cr, .80–1.10 Va, .15 min	Annealed T	31.6– 38.7 42.2–105.5	....	b 45 000– 55 000 b 60 000–150 000	....	25–20 15– 5	60–50 55–25	....	....
Chromium-vanadium steel 6140	C, .35– .45 Mn, .50– .80 P, .04 max S, .04 max Cr, .80–1.10 Va, .15 min	Annealed T	35.2– 42.2 45.7–123.0	....	b 50 000– 60 000 b 65 000–175 000	....	25–15 15– 2	55–45 50–15	....	....
Chromium-vanadium steel 6145	C, .40– .50 Mn, .50– .80 P, .04 max S, .04 max Cr, .80–1.10 Va, .15 min	Annealed U	38.7– 45.7 105.5–140.6	....	b 55 000– 65 000 b 150 000–200 000	....	25–15 10– 2	55–40 25–10	....	....
Chromium-vanadium steel 6150	C, .45– .55 Mn, .50– .80 P, .04 max S, .04 max Cr, .80–1.10 Va, .15 min	Annealed U	42.2– 49.2 105.5–158.2	....	b 60 000– 70 000 b 150 000–225 000	....	20–15 10– 2	50–35 35–15	....	....
Silico-manganese steel 9250	C, .45– .55 Mn, .60– .80 P, .045 max S, .045 max Si, 1.80–2.10	Annealed V	38.7– 45.7 42.2–126.5	....	b 55 000– 65 000 b 60 000–180 000	....	25–20 20– 5	45–30 40–10	....	....
Silico-manganese steel 9260	C, .55– .65 Mn, .50– .70 P, .045 max S, .045 max Si, 1.50–1.80	Annealed V	38.7– 45.7 42.2–126.5	....	b 55 000– 65 000 b 60 000–180 000	....	25–20 20– 5	45–30 40–10	....	....

* Footnotes on following page.

TABLE 4—Continued

Class of steel	Contents as given by analysis	Quenching temperature	Tensile strength: P limit	Tensile strength: Ultimate	Tensile strength: P limit	Tensile strength: Ultimate	Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness: Brinell at 3000 kg	Hardness: Scleroscope
	Per cent		kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
Chromium molybdenum steel [c]	C, 0.40; Cr, 1.00; Mo, .35	As rolled (1 inch round)	73.8	98.4	105 000	140 000	15. 0	32. 0	....	....
		Drawn at °C °F								
Do. [c]	C, .30; Cr, .70; Mo, .35	[d] 844 1550	110.1	113.2	156 625	160 925	18. 0	62. 2	....	....
		872 1600	105.3	109.5	149 925	155 850	17. 5	60. 2	....	....
		899 1650	102.5	109.9	145 775	156 375	17. 0	60. 2	....	....
		927 1700	99.5	107.9	141 570	153 450	17. 0	60. 1	....	....
		955 1750	100.3	108.5	142 500	154 350	18. 0	60. 0	....	....
		982 1800	101.3	109.0	144 000	154 900	17. 5	59. 0	....	....
Nickel-molybdenum steel [c]	C, .40; Ni, 1.50; Mo, .40	As rolled (1 inch round)	65.3	84.4	93 000	120 000	18. 0	39. 0	....	....

COMPRESSIVE STRENGTHS: For all steels approximately equal to yield point in tension (slightly above P limit).
DENSITY: Steel, about 7.85 g/cm³, or 490 lbs./ft.³
DUCTILITY, Erichsen values:
Low-carbon sheet, soft annealed, 0.75 mm, or 0.029 inch, thick, (B. S.) depth of indentation 12.0 mm, or 0.472 inch.
Low-carbon sheet, soft annealed, 1.30 mm, or 0.050 inch, thick, (B. S.) depth of indentation 12.5 mm, or 0.492 inch.
MODULUS OF ELASTICITY: In tension and compression, for all steels approximately 21 000 kg/mm² or 30 000 000 lbs./in.²
MODULUS OF ELASTICITY: In shear, for all steels approximately 8440 kg/mm² or 12 000 000 lbs./in.²
SCLEROSCOPE HARDNESS values shown are as determined with the Shore universal hammer.
STRENGTH IN SHEAR: P limit and ultimate strength each about 70 per cent of corresponding tensile values.

[a] The tables on steels are from the 11th report of the iron and steel division, standards committee, Society of Automotive Engineers (Inc.), revised August, 1919.
[b] These figures represent yield point.
[c] "Molybdenum as an alloying element in structural steels," by G. W. Sargent presented at the 23d meeting of the A. S. T. M., June 22–25, 1920.
[d] Drawing temperature 1000° F; quenching medium water; three-fourths inch round bar.

3. STEEL WIRE[a]

TABLE 5.—Tensile Strength of Commercial Steel Music Wire (Hardened)

[Data from tests at General Electric Co. laboratories]

Diameter		Ultimate tensile strength	
mm	Inch	kg/mm²	Lbs./in.²
12.95	0.051	226.0	321 500
11.70	.046	249.0	354 000
9.15	.036	253.0	360 000
7.60	.030	260.0	370 000
6.35	.025	262.0	372 500
4.57	.018	265.5	378 000

[a] See also "Wire rope."

TABLE 6.—Tinned High-Strength Steel Wire—Specification Values

[After I. A. S. B. specification 3S12, September, 1917, for high-strength steel wire. S. A. E. carbon steel, No. 1050 or higher number specified (see carbon steels above). Steel is to be manufactured by acid open-hearth process, to be rolled, drawn, and then uniformly coated with pure tin to solder readily.]

No. of wire (American or B. & S. wire gage)	Diameter		Required twists, in 203.2 mm (8 inches)	Weight		Required bends through 90°[a]	Breaking strength, specification minimum		Tensile strength	
	mm	Inch		kg/100 m	Lbs./100ft.		kg	Pounds	kg/mm²	Lbs./in.²
6	4.115	0.162	16	10.44	7.01	5	2040	4500	154	219 000
7	3.655	.144	19	8.28	5.56	6	1680	3700	161	229 000
8	3.275	.129	21	6.55	4.40	8	1360	3000	164	233 000
9	2.895	.114	23	5.21	3.50	9	1135	2500	172	244 000
10	2.590	.102	26	4.12	2.77	11	907	2000	172	244 000
11	2.305	.0907	30	3.28	2.20	14	735	1620	176	251 000
12	2.053	.0803	33	2.59	1.74	17	590	1300	177	252 000
13	1.828	.0720	37	2.05	1.38	21	470	1040	179	255 000
14	1.628	.0641	42	1.64	1.10	25	375	830	181	258 000
15	1.450	.0571	47	1.30	0.87	29	300	660	182	259 000
16	1.291	.0508	53	1.03	.69	34	245	540	186	264 000
17	1.150	.0453	60	0.82	.55	42	193	425	186	264 000
18	1.024	.0403	67	.64	.43	52	155	340	188	267 000
19	0.912	.0359	75	.51	.34	70	127	280	195	277 000
20	.812	.0320	85	.40	.27	85	102	225	197	280 000
21	.723	.0285	96	.33	.22	105	79	175	193	275 000

[a] Number of 90° bends specified above to be obtained by bending sample about 4.7 mm (0.188 inch) radius, alternately, in opposite directions. This specification corresponds to U. S. Navy Department specification 22W6, Nov. 1, 1916, for tinned, galvanized, or bright aeroplane wire.

4. STEEL WIRE ROPE

(*a*) Rope Wire and Types of Wire Rope—Specification Data

[After U. S. Navy specification 22R3, Sept. 1, 1914]

CAST STEEL WIRE: To be of hard crucible steel with minimum tensile strength of 155 kg/mm^2, or 220 000 $lbs./in.^2$, and minimum elongation of 2½ per cent in 254 mm, or 10 inches.
PLOW STEEL WIRE: To be of hard crucible steel with minimum tensile strength of 183 kg/mm^2, or 260 000 $lbs./in.^2$, and minimum elongation of 2½ per cent in 254 mm, or 10 inches.
ANNEALED STEEL WIRE: To be of crucible cast steel, annealed, with minimum tensile strength of 77.4 kg/mm^2, or 110 000 $lbs./in.^2$
TYPES OF WIRE ROPES OR CABLES (Construction):
- Type A.—6 strands with hemp core and 19 wires to a strand (=6 by 19), or 6 strands with hemp core and 18 wires to a strand, with jute, cotton, or hemp center.
- Type B.—6 strands with hemp core and 12 wires to a strand, with hemp center.
- Type C.—6 strands with hemp core and 14 wires to a strand, with hemp or jute center.
- Type AA.—6 strands with hemp core and 37 wires to a strand (=6 by 37), or 6 strands with hemp core and 36 wires to a strand, with jute, cotton, or hemp center.

TABLE 7.—Weight and Tensile Strength of Wire Rope—U. S. Navy Specification Values

Description	Diameter		Approximate weight		Minimum strength	
	mm	Inches	kg/m	Lbs./ft.	kg	Pounds
Galvanized cast steel, type A	9.5	⅜	0.31	0.21	3965	8740
	12.7	½	.55	.37	6910	15 230
	25.4	1	2.23	1.50	27 650	60 960
	38.1	1½	5.06	3.40	63 485	139 960
Galvanized cast steel, type AA	9.5	⅜	.33	.22	3840	8460
	12.7	½	.58	.39	7410	16 330
	25.4	1	2.23	1.50	27 650	60 960
	38.1	1½	5.28	3.55	59 735	131 690
Galvanized cast steel, type B	9.5	⅜	.25	.17	2995	6600
	12.7	½	.42	.28	5210	11 500
	25.4	1	1.68	1.13	20 890	46 060
	38.1	1½	3.94	2.65	47 965	105 740
Galvanized cast steel, type C	25.4	1	1.59	1.07	18 825	41 500
	41.3	1⅝	4.35	2.92	51 575	113 700
Galvanized plow steel, type A	9.5	⅜	.31	.21	4690	10 340
	12.7	½	.55	.37	8165	18 000
	25.4	1	2.23	1.50	32 675	72 040
	36.5	1 7/16	4.66	3.13	69 140	152 430
Galvanized plow steel, type AA	9.5	⅜	.33	.22	4540	10 000
	12.7	½	.58	.39	8750	19 300
	25.4	1	2.35	1.58	32 250	71 100
	41.3	1⅝	6.18	4.15	83 010	183 000

TABLE 8.—Minimum Strength of Plow Steel Hoisting Rope (Bright)—Panama Canal Specification Values

[After Panama Canal specification No. 302, 1912. Wire rope to be of best plow steel grade, and to be composed of 6 strands, 19 wires to the strand, with hemp center. Wires entering into construction of rope to have an elongation in 203.2 mm, or 8 inches, of about 2½ per cent.]

Diameter		Specified minimum strength		Diameter		Specified minimum strength	
mm	Inch	kg	Pounds	mm	Inches	kg	Pounds
9.5	⅜	5215	11 500	38.1	1½	74 390	164 000
12.7	½	9070	20 000	50.8	2	127 000	280 000
19.0	¾	20 860	46 000	63.5	2½	207 740	458 000
25.4	1	34 470	76 000	69.9	2¾	249 350	550 000

(b) Steel Wire Rope—Experimental Results

TABLE 9.—Size and Strength of Steel Wire Rope—Experimental Results [a]

[Wire rope purchased under Panama Canal specifications 302 and tested by U. S. Bureau of Standards, Washington, D. C.]

Description and analysis	Diameter		Ultimate strength		Ultimate strength (net area)	
	mm	Inches	kg	Pounds	kg/mm²	Lbs./in.²
Plow steel, 6 strands, 19 wires: C, 0.90; S, 0.034; P, 0.024; Mn, 0.48; Si, 0.172	50.8	2	137 900	304 000	129.5	184 200
Plow steel, 6 strands, 25 wires: C, 0.77; S, 0.036; P, 0.027; Mn, 0.46; Si, 0.152	69.9	2¾	314 800	694 000	151.2	214 900
Plow steel, 6 strands, 37 wires plus 6 strands, 19 wires: C, 0.58; S, 0.032; P, 0.033; Mn, 0.41; Si, 0.160	82.6	3¼	392 800	866 000	132.2	187 900
Monitor plow steel, 6 strands, 61 wires plus 6 strands, 19 wires: C, 0.82; S, 0.025; P, 0.019; Mn, 0.23; Si, 0.169	82.6	3¼	425 000	937 000	142.5	202 400

NOTE.—Recommended allowable working load for a wire rope running over a sheave is equal to one-fifth of specified minimum strength.

[a] For additional data on Strength and Other Properties of Wire Rope, see B. S. Tech. Papers, No. 121, by Griffith and Bragg, giving results of 275 tensile tests o wire-rope specimens ranging in diameter from one-fourth to 3¼ inches, and comprising five of the more common classes used in engineering practice.

5. SEMISTEEL [a]

TABLE 10.—Properties of Semisteel—Experimental Results

[Test results at Bureau of Standards on 155 mm shell, January, 1919. Microstructure: Matrix resembling pearlitic steel, embedded in which are flakes of graphite. Composition: Comb. C, 0.60–0.76; Mn, 0.88; P, 0.42–0.43; S, 0.077–0.088; Si, 1.22–1.23; graphitic C, 2.84–2.94.]

Metal	Tensile strength				Compressive strength				Hardness	
	P limit	Ultimate	P limit	Ultimate	P limit	Ultimate	P limit	Ultimate	Brinell at 3000 kg	Scleroscope
Semisteel:	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²		
Graph. C, 2.85; Comb. C, .76	7.9	19.8	11 200	28 200	24.3	72.6	34 500	103 300	176	....
Graph. C, 2.92; Comb. C, .60	4.2	14.9	6000	21 200	18.3	61.4	26 000	87 300	170	....

NOTE.—Tension specimens 12.7 mm, or 0.5 inch, diameter, 50.8 mm, or 2 inches, gage length; elongation and reduction of area negligible.

Compression specimens, 20.3 mm, or 0.8 inch, diameter, 61.0 mm, or 2.4 inches, long; failure occurred in shear.

MODULUS OF ELASTICITY in tension, 9560 kg/mm², or 13 600 000 lbs./in.²

[a] Semisteel—Gray iron to which steel has been added while in the molten condition. It may also be produced by other methods.

VII. NONFERROUS METALS AND ALLOYS

1. ALUMINUM [a] AND ALUMINUM ALLOYS

TABLE 11.—Composition and General Properties of Aluminum—Experimental Results

Metal	Approximate composition	Condition	Density		Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
					P limit	Ultimate	P limit	Ultimate			Brinell at 500 kg	Scleroscope [b]
	Per cent		g/cm³	Lbs./ft.³	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
Aluminum.	Av., Al, 99.3; Imp., Fe and Si.	Cast, sand at 700° C.	2.57	160.5	6.0– 7.0	8.4– 9.8	8500–10 000	12 000–14 000	29–15	36–22	25–26	4–5
		Cast, sand and heat treated, annealed 500° C, air cooled.	....	....	....	8.9– 9.6	....	12 600–13 600	28–18	30–22	25–27	4–5
		Cast, chill	2.57	160.5	6.3	9.1	9000	13 000	20.0	....	26	5
		Sheet, annealed	2.69	168.0	6.0	9.5	8500	13 500	23.0	25.0	....	(c)
		Sheet, hard	2.70	168.5	14.1	21.0	20 000	30 000	4.0	25.0	....	c 14
		Bars, hard	2.70	168.5	15.5	23.2	22 000	33 000	....	35.0	....	....
		Wire, hard	2.70	168.5	21.1	28.1	30 000	40 000	6.0	50.0	....	....

COMPRESSIVE STRENGTH: Cast, yield point, 12.7 kg/mm², or 18 000 lbs./in.²; ultimate strength, 47.1 kg/mm², or 67 000 lbs./in.²

MODULUS OF ELASTICITY: Cast, 6900 kg/mm², or 9 810 000 lbs./in.² at 17° C. (See B. S. Circular No. 76.) Landolt-Börnstein gives modulus of elasticity as 7200 kg/mm², or 10 230 000 lbs./in.²

[a] For further data, see B. S. Circular No. 76, Aluminum and Its Light Alloys.
[b] Magnifying hammer used; for conversion factor see definition.
[c] See Table 12.

TABLE 12.—Ductility and Hardness of Sheet Aluminum—Experimental Results

Aluminum sheet, Grade A (Al min., 99.0)

[From tests on No. 18 B. & S. gage, sheet rolled from 6.3 mm, or 0.25 inch, slab, Iron Age, 101, p. 950.]

Heat treatment, annealed	Thickness		Erichsen indentation		Scleroscope hardness
	mm	Inch	mm	Inch	
None (as rolled)	1.08	0.0425	6.83	0.269	14.0
At 200° C 2 hours	1.09	.0429	8.39	.349	10.0
At 300° C 2 hours	1.07	.0422	10.17	.401	4.5
At 400° C 2 hours	1.08	.0425	10.10	.370	4.5
At 200° C 30 min	1.07	.0422	7.97	.314	11.8
At 400° C 30 min	1.08	.0425	9.83	.386	4.5

TABLE 13.—Properties of Cast and Sheet Aluminum—Specification Values

[(1) Cast: U. S. Navy, 49Al, July 1, 1915. Al min., 94; Cu max., 6; Fe max., 0.5; Si max., 0.5; Mn max., 3; Minimum tensile strength, 12.7 kg/mm², or 18 000 lbs./in.², with minimum elongation of 8 per cent in 50.8 mm, or 2 inches. (2) Sheet: Grade A, A. S. T. M., B25-19 T. Al min., 99.0, minimum strengths and elongation.]

Gage (B & S)	Sheet	Thickness	Temper No.	Hardness	Tensile strength		Elongation in 50.8 mm (2 inches)
	mm	Inch			kg/mm²	Lbs./in.²	Per ct.
12-16, inclusive	2.052-1.293	0.0808-0.0509	[a] 1	Soft, annealed	8.8	12 500	30.0
			[b] 2	Half hard	12.7	18 000	7.0
			3	Hard	15.5	22 000	4.0
17-22, inclusive	1.152- .643	.0453- .0253	[a] 1	Soft, annealed	8.8	12 500	20.0
			[b] 2	Half hard	12.7	18 000	5.0
			3	Hard	17.6	25 000	2.0
23-26, inclusive	.574- .404	.0226- .0159	[a] 1	Soft, annealed	8.8	12 500	10.0
			[b] 2	Half hard	12.7	18 000	5.0
			3	Hard	21.1	30 000	2.0

NOTE.—Tension test specimen to be taken parallel to the direction of cold rolling of the sheet.

[a] Sheets of temper No. 1 to withstand being bent double in any direction and hammered flat.
[b] Sheets of temper No. 2 to bend 180° about radius equal to thickness without cracking.

TABLE 14.—Composition and General Properties of Aluminum Alloys—Experimental Results

Alloy and approximate composition, in per cent	Condition and per cent reduction	Density		Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
				P limit	Ultimate	P limit	Ultimate			Brinell at 500 kg	Scleroscope
Aluminum:		g/cm³	Lbs./ft.³	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per ct.	Per ct.		
Copper—											
Al, 98; Cu, 1; Imp. max., 1	Cast, chill			5.3	10.5	7500	15 000	24.0	34.0		
	Rolled, 70 per cent			19.0	21.1	27 000	30 000	4.0			
Al, 96; Cu, 3; Imp. max., 1	Cast, chill			8.1	13.7	11 500	19 500	12.0	21.0		
	Rolled, 70 per cent			24.6	28.8	35 000	41 000	5.5			
Al, 94; Cu, 5; Imp. max., 1	Cast, chill			10.2	15.1	14 500	21 500	7.0	14.0		
	Rolled, 70 per cent			23.2	26.7	33 000	38 000	6.0			
Al, 92; Cu, 8; Alloy "No. 12"	Cast, sand	2.88	180	7.7–10.5	10.5–16.2	11 000–15 000	15 000–23 000	4–0	3.5–0	50–65	13–18
Al, 90–92; Cu, 7–8.5; Imp. max., 1.7 [a]	Cast	2.9	181		12.7		18 000	1.0			
Copper, magnesium—											
Al, 95.2; Cu, 4.2; Mg, 0.6	Cast at 700° C.			3.2–4.6	9.6–13.3	4500–6500	13 600–18 900	2–0	.5–0	74–74	17–18
	Annealed, 500° C.			4.6	17.5	6500	24 900	3	1	80	21
Duralumin[b] or 17-S Alloy, Al, 94; Cu, 4; Mg, 0.5.	Annealed	2.8	174	24.7	41.8	35 100	59 500	21.1	29.5		
	Rolled, 70 per cent			53.0	56.0	75 400	79 600	4.0	13.2		
	Rolled, heat treated [c]			23.5	38.9	33 400	55 300	25.5	26.0		
Copper, manganese—											
Al, 96; Cu, 2; Mn, 2	Cast, chill			10.0	14.3	14 300	20 300	5.0			
	Rolled, 20 mm			19.0	26.9	27 100	38 200	16.0	38.0		
Al, 96; Cu, 3; Mn, 1	Cast, chill			11.4	19.0	16 200	27 000	14.0			
Al, 97; Cu, 1.5; Mn, 1, Naval Gun Factory [d]	Cast, sand	2.8	175		14.1		20 000	12.0			
	Forged			13.7	19.5	19 500	27 800	12.0	47.0		
Copper, nickel, magnesium, manganese—											
Al, 93.5; Cu, 3.5; Ni, 1.5; Mg, 1; Mn, 0.5	Cast at 700° C.			3.5–9.8	17.9–23.2	5000–14 000	25 500–33 000	6–1.5	8.5–1	54–86	9–25
Copper, nickel, manganese—											
Al, 94.2; Cu, 3; Ni, 2; Mn, 0.8	do				14.5–21.4		20 600–30 500	6–1	11–2	50–91	9–27
Magnesium—											
Magnalium, (1) Al, 95; Mg, 5	Cast, sand	2.5	156		12.0–21.1		17 000–30 000				
(2) Al, 77–98; Mg, 23–2	Cast, chill	2.40–2.56	150–160		29.5–45.0		42 000–64 000				

Nickel—											
Al, 97; Ni, 2	do			4.1	10.5	5800	14 900	21.0	36.0		
	Drawn, cold			13.9	16.0	19 700	22 700	13.0	37.0		
	Rolled, hot			8.4	12.8	11 900	18 200	28.0	52.0		
Al, 95; Ni, 5	Cast, chill			6.3	15.3	9000	21 700	9.0	11.0		
	Drawn, cold			16.1	19.6	22 900	27 900	8.0	24.0		
	Rolled, hot			9.5	15.7	13 500	22 300	22.0	36.0		
Nickel, copper—											
Al, 93.5; Ni, 5.5; Cu, 1	Cast, chill			7.5	17.4	10 700	24 800	6.0	8.0		
Al, 91.5; Ni, 4.5; Cu, 4	do			7.0	17.7	9900	25 200	4.0	5.0		
	Drawn, cold			22.3	26.6	31 700	37 800	8.0	15.0		
Al, 92; Ni, 5.5; Cu, 2	Rolled, hot			12.8	22.2	18 200	31 500	16.0	24.0		
Zinc, copper—											
Al, 88.6; Cu, 3; Zn, 8.4	Cast at 700° C.			4.7	18.5	6700	26 300	8.0	7.5	50	10
	Annealed, 500° C.			4.4	20.2	6200	28 800	8.0	7.5	50	10
Al, 81.1; Cu, 3; Zn, 15.9	Cast at 700° C.	3.09	193	9.8	24.7	14 000	35 100	2.0	2.0	74	15
	Annealed, 500° C.			9.8	29.0	14 000	41 200	4.0	4.0	70	15

[a] Specification values, alloy No. 12, A. S. T. M., B 26–19 T, tentative specified minimums for aluminum copper.

[b] Modulus of elasticity for duralumin averages 7030 kg/mm², or 10 000 000 lbs./in.²

[c] Quenched in water from 475° C after heating in a salt bath.

[d] Specification values, aluminum castings, U. S. Navy, 49Al, July 1, 1915: (impurities: Fe max., 0.5; Si max., 0.5) Al, 94; Cu max., 6; Mn max., 3; minimum, ultimate tensile strength, 12.7 kg/mm², or 18 000 lbs./in.² with 8.0 per cent elongation in 50.8 mm, or 2 inches.

2. COPPER [a] AND COPPER ALLOYS

TABLE 15.—Composition and General Properties of Copper—Experimental Results

Metal	Approximate composition, in per cent	Condition	Density		Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
					P limit	Ultimate	P limit	Ultimate			Brinell at 500 kg	Scleroscope
			g/cm^3	$Lbs./ft.^3$	kg/mm^2	kg/mm^2	$Lbs./in.^2$	$Lbs./in.^2$	Per cent	Per cent		
Copper [b]	Cu 99.9, electrolytic	Annealed at 200° C	8.89	555	6.0	26.7	8500	38 000	50	50	40	7
		Not annealed (96 per cent reduction) [b]	....	....	....	47.3	....	67 400	.8	64.5	....	....
		Annealed at 750° C, after drawing cold [b]	....	....	....	21.9	....	31 200	24.5	76.0	....	....
		Drawn hot (64 per cent reduction) [c]	....	....	....	32.9	....	46 800	4.3	70.5	....	....
	Cu 99.6, commercial	Cast	8.85	552	7.0	17.6	10 000	25 000	20	60	80	8
		Rolled hard (40 per cent reduction)	8.89	555	14.0	35.2	20 000	50 000	5	8	94	....
		Annealed at 500° C	8.90	556	(?)	24.6	(?)	35 000	50	60	42	6
	Cu 99.6, commercial	Drawn cold (50 per cent reduction)	....	....	26.0	35.2	37 000	50 000	9	....	....	18

COMPRESSION:
Cast copper, annealed cylinders, 15.9 mm, or 0.625 inch, diameter by 50.8 mm, or 2 inches, long.
Shortened 5 per cent at 22.0 kg/mm^2, or 31 300 $lbs./in.^2$ load.
Shortened 10 per cent at 29.0 kg/mm^2, or 41 200 $lbs./in.^2$ load.
Shortened 20 per cent at 39.0 kg/m^2, or 55 400 $lbs./in.^2$ load.
SHEARING STRENGTH: Cast copper 21.0 kg/mm^2, or 30 000 $lbs./in.^2$
MODULUS OF ELASTICITY:
Electrolytic .... 12 200 kg/mm^2, or 17 400 000 $lbs./in.^2$
Cast .... 7700 kg/mm^2, or 11 000 000 $lbs./in.^2$
Drawn, hard .... 12 400 kg/mm^2, or 17 600 000 $lbs./in.^2$

[a] For further data see B. S. Circular No. 73, Copper.
[b] Cu, 99.9 wire drawn cold from 3.18 mm, or 0.125 inch, to 0.64 mm, or 0.025 inch, Bull. Am. Inst. Min. Eng., February, 1919.
[c] Cu, 99.9 wire drawn at 150° C from 0.79 mm, or 0.031 inch, to 0.64 mm, or 0.025 inch (Jeffries, loc. cit.).

TABLE 16.—Properties of Rolled Copper—Specification Values

[U. S. Navy Department, 47C2, minimums for rolled copper, Cu min., 99.5]

Description	Temper	Thickness	Tensile strength		Elongation in 50.8 mm (2 inches)
			kg/mm²	Lbs./in.²	Per cent
Rods, bars, and shapes.	Soft		21.1	30 000	25
	Hard	To 9.5 mm (3/8 inch) inclusive	35.2	50 000	10
	...do	9.5 mm to 25.4 mm (1 inch)	31.6	45 000	12
	...do	25.4 mm to 50.8 mm (2 inches)	28.1	40 000	15
	...do	Over 50.8 mm (2 inches)	24.6	35 000	20
Sheets and plates	Soft		21.1–28.1	30 000–40 000	25–25
	Hard		24.6	35 000	18

TABLE 17.—Copper Wire (Hard-Drawn and Hard-Rolled)—Specification Values

[Specific gravity, 8.89 at 20° C (68° F). For copper wire and for hard-drawn and hard-rolled flat copper of thicknesses corresponding to diameters of wire. (A. S. T. M., B 1-15, and U. S. Navy Department, 22W3, Mar. 1, 1915)[a].]

Diameter		A. W. G. No.	Minimum tensile strength		Maximum elongation
mm	Inch		kg/mm²	Lbs./in.²	Per cent in 254 mm (10 inches)
11.68	0.460	0000	34.5	49 000	3.75
10.40	.410	000	35.9	51 000	3.25
9.27	.365	00	37.1	52 800	2.80
8.25	.325	0	38.3	54 500	2.40
7.35	.289	1	39.4	56 100	2.17
6.54	.258	2	40.5	57 600	1.98
5.83	.229	3	41.5	59 000	1.79
					Per cent in 1524 mm (60 inches)
5.19	.204	4	42.2	60 100	1.24
4.62	.182	5	43.0	61 200	1.18
4.12	.162	6	43.7	62 100	1.14
3.66	.144	7	44.3	63 000	1.09
3.26	.128	8	44.8	63 700	1.06
2.91	.114	9	45.2	64 300	1.02
2.59	.102	10	45.9	64 900	1.00
2.31	.091	11	46.0	65 400	.97
2.05	.081	12	46.2	65 700	.95
1.83	.072	13	46.3	65 900	.92
1.63	.064	14	46.5	66 200	.90
1.45	.057	15	46.7	66 400	.89
1.29	.051	16	46.8	66 600	.87
1.15	.045	17	47.0	66 800	.86
1.02	.040	18	47.1	67 000	.85

P limit of hard-drawn copper wire averages 55 per cent of ultimate tensile strength for four largest sized wires in table, and 60 per cent of tensile strength for smaller sizes.

[a] Column 1 gives the exact diameters to the number of places given. Some of the numbers in this column do not agree with the values in the American Society for Testing Materials table, since it was there assumed that the numbers in the second column are exact. The latter are not exact, but are simply the values to the nearest 0.001 inch, of the American wire gage (B. & S.) size. The third column, of A. W. G. sizes, is not given in the American Society for Testing Materials specifications.

TABLE 18.—Tensile Requirements of Copper Wire—(Medium Hard-Drawn and Soft Annealed)—Specification Values

Diameter		Medium hard-drawn, A. S. T. M., B 2-15[a]					Soft annealed, A. S. T. M., B 3-15		
		Ultimate tensile strength				Elongation (minimum) in 254 mm (10 inches)	Ultimate tensile strength		Elongation (minimum) in 254 mm (10 inches)
		Minimum		Maximum					
mm	Inch	kg/mm²	Lbs./in.²	kg/mm²	Lbs./in.²	Per ct.	kg/mm²	Lbs./in.²	Per ct.
11.70-7.37	0.460-0.290	31.0	44 000	35.9	51 000	3.3	25.3	36 000	35
7.34-2.62	.289- .103	34.3	48 800	39.3	55 900	[b] 1.2	26.0	37 000	30
2.59-0.53	.102- .021	36.4	51 800	41.4	58 800	[b] 1.0	27.1	38 500	25
0.51-0.08	.020- .003	....	....	....	....	....	28.2	40 000	20

NOTE.—Experimental results show tensile strength of concentric lay copper cable to approximate 90 per cent of combined strengths of wires forming the cable.

[a] Values shown from A. S. T. M. specifications, B 2-15, are averaged from strengths given for individual sizes. P limits of medium hard-drawn copper average 50 per cent of ultimate values shown.
[b] Elongation as measured in a 1524 mm, or 60 inches, gage length.

TABLE 19.—Tensile Requirements of Copper Plates—Specification Values [a]

Analysis	Ultimate tensile strength		Elongation in 203.2 mm (8 inches)
	kg/mm²	Lbs./in.²	Per ct.
Copper, arsenical, As, 0.25-0.50; impurities, max., 0.12	21.8	31 000	35
Copper, nonarsenical, impurities, max., 0.12	21.1	30 000	30

[a] A. S. T. M., B 11-18.

(a) Nomenclature of Copper Alloys

The general system of nomenclature employed has been to denominate (*a*) all simple copper zinc alloys as *brasses;* (*b*) all simple copper-tin alloys as *bronzes;* and (*c*) three or more metal alloys composed primarily of either of these two combinations as *alloy brasses* or *bronzes,* as for example, "Zinc bronze" for U. S. Government composition "G," Cu, 88 per cent; Sn, 10 per cent; Zn, 2 per cent. Alloys of the third type noted above, together with other alloys composed mainly of copper, have been called *copper alloys,* with the alloying elements other than minor impurities listed as modifying copper in the order of their relative percentages. In some instances the scientific name used to denote an alloy is based upon the deoxidizer used in its preparation, which may appear either as a minor element of its composition or not at all, as for example, phosphor bronze. Commercial names are shown below the scientific names. Care should be taken to specify the chemical composition of a commercial alloy, as the same name frequently applies to widely varying compositions.

Table	Alloy	Components
20	Brass	Copper-zinc.
21	Bronze	Copper-tin.
		Three or more components:
22		Alloy brasses.
23		Alloy bronzes.
24, 25, 26		Miscellaneous copper alloys.

TABLE 20.—Properties of Copper-Zinc Alloys (Brasses)—Experimental Results Unless Otherwise Noted

Alloy	Approximate composition in per cent	Condition	Density		Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
					P limit	Ultimate	P limit	Ultimate			Brinell at 500 kg	Scleroscope
			g/cm³	Lbs./ft.³	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
Brass	Cu, 90; Zn, 10 (red metal)	Cast, sand				20.4		29 000	22			
		Rolled, hard				38.7		[a]55 000	[a]5		60	20
		Rolled, soft	8.7	543		26.0		[a]37 000	[a]40	70	47	10
	Cu, 80; Zn, 20 (low brass)	Cast, sand				24.6		35 000	31	32		
		Rolled, hard				52.8		[a]75 000	[a]5		75	28
		Rolled, soft	8.6	537		29.5		[a]42 000	[a]50	85	46	12
	Cu, 70; Zn, 30	Cast, sand	8.4	524		28.2		40 000	35		37	
	(Cu, 66; Zn, 34; Std. sheet)	Rolled, hard	8.5	530		42.2		60 000	[a]5		[b]75	26
		Rolled, soft	8.4	524		33.8		[a]48 000	[a]50	85	45	12
	Cu, 60; Zn, 40 (Muntz metal or yellow brass)	Cast, sand			15.4	32.2	21 800	45 800	15	22		
		Rolled, hard	8.4	524	31.6	49.2	45 000	70 000	30	50		

COMPRESSIVE STRENGTHS:
- Brass, Cu, 90; Zn, 10; cast, 21.1 kg/mm², or 30 000 lbs./in.²
- Brass, Cu, 80; Zn, 20; cast, 27.4 kg/mm², or 39 000 lbs./in.²
- Brass, Cu, 70; Zn, 30; cast, 42.2 kg/mm², or 60 000 lbs./in.²
- Brass, Cu, 60; Zn, 40; cast, 52.8 kg/mm², or 75 000 lbs./in.²
- Brass, Cu, 50; Zn, 50; cast, 77.4 kg/mm², or 110 000 lbs./in.²

MODULUS OF ELASTICITY: Cast brass, average 9140 kg/mm², or 13 000 000 lbs./in.²

ERICHSEN VALUES:
- Soft slab, 1.3 mm, or 0.05 inch, thick, no rolling, depth of impression in standard sheet 13.9 mm, or 0.55 inch.
- Cu, 70; Zn, 30; hard sheet, 1.3 mm, or 0.05 inch, thick, rolled, 38 per cent reduction, depth of impression 7.4 mm, or 0.29 inch.
- Cu, 70; Zn, 30; hard sheet, 0.5 mm, or 0.020 inch, thick, rolled, 60 per cent reduction, depth of impression 3.8 mm, or 0.15 inch.

[a] Values are S. A. E. specification values. See S. A. E. Handbook, 1, p. 13 a; rev. December, 1913.
[b] A. S. T. M. specification B 19–18 T requires B. h. n. of 51–65 kg/mm² at 500 kg load for 70–30 annealed sheet brass.

TABLE 21.—Properties of Copper-Tin Alloys (Bronzes)—Specification Values

Alloy	Approximate composition in per cent	Condition	Density		Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
					P limit	Ultimate	P limit	Ultimate			Brinell at 500 kg	Scleroscope
			g/cm³	Lbs./ft.³	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
Bronze	Cu, 97.7; Sn, 2.3	Cast	...	...	5.98	19.7	8500	28 000	20	...	...	...
		Rolled	...	...	7.60	33.8	10 800	48 000	55	75	...	...
	Cu, 90; Sn, 10 (gun bronze or bell metal)	...	8.78	548	7.24	23.2	10 300	33 000	10	...	...	23
	Cu, 80; Sn, 20	Cast	8.81	550	7.10	22.5	10 100	32 000	1.5	...	...	...
	Cu, 70; Sn, 30	do	8.84	552	1.41	4.9	2000	7000	.5	...	...	...

COMPRESSIVE ULTIMATE STRENGTHS:

Cast, Cu, 97.7; Sn, 2.3 .... 23.9 kg/mm², or 34 000 lbs./in.²

Cu, 90; Sn, 10 .... 39.1 kg/mm², or 56 000 lbs./in.²

Cu, 80; Sn, 20 .... 83.0 kg/mm², or 118 000 lbs./in.²

Cu, 70; Sn, 30 .... 105.5 kg/mm², or 150 000 lbs./in.²

SPECIFICATION VALUE: A. S. T. M., B 22-18 T, for specimen (cylinder) 645 mm², or 1 inch², area, 25.4 mm, or 1 inch, long.

MINIMUM COMPRESSIVE ELASTIC LIMIT of Cu, 80; Sn, 20 cast is 16.9 kg/mm², or 24 000 lbs./in.² (=deformation limit or load required to produce 0.01 per cent set, A. S. T. M., B 22-18 T).

AVERAGE MODULUS OF ELASTICITY of bronzes varies from 7030 kg/mm², or 10 000 000 lbs./in.² to 10 900 kg/mm², or 15 500 000 lbs./in.²

TABLE 22.—Properties of Copper Alloys of Three or More Components (Alloy Brasses)—Experimental Results Unless Otherwise Noted

Constituent metals	Approximate composition in per cent	Condition	Density		Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
					P limit	Ultimate	P limit	Ultimate			Brinell at 500 kg	Scleroscope
			g/cm³	Lbs./ft.³	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
COPPER, ZINC:												
Aluminum	Cu, 57; Zn, 42; Al, 1	Cast				40.0		57 000	50.0			
	Cu, 55; Zn, 41; Al, 4					60.0		85 400	16.5			
	Cu, 62.9; Zn, 33.3; Al, 3.8					56.2		80 000				
	Cu, 70.5; Zn, 26.4; Al, 3.1				13.4	33.0	19 000	47 000	50.0			
Aluminum, manganese.[a]*	Cu, 64; Zn, 29; Al, 3.1; Mn, 2.5; Fe, 1.2.	Cast, tensilite			21.1	68.8	30 000	98 000	16.0	17.0	130	
Aluminum, vanadium.	Cu, 58.6; Zn, 38.5; Al, 1.5; V, 0.03.	Cold drawn			35.6	57.2	50 600	81 400	12.0	14.0		
Iron	Cu, 56; Zn, 41.5; Fe, 1	Cast				50.7–59.0		72 000–84 000	35.0–22.0	35.0–25.0	109–119	
	Cu, 60; Zn, 38.2; Fe, 1.8 (Aich's metal).	do	8.42	526		40.3		57 300				
	Cu, 57; Zn, 42; Fe, 1 (Delta metal).[b]	Cast, sand				31.7		45 000	10.0			
		Rolled, hard				42.2		60 000	17.0			
	Cu, 65; Zn, 30; Fe, 5	do				45.7		65 000				
Iron, manganese	Cu, 60; Zn, 38.5; Fe, 1; Mn, tr.	Cast	8.31	518	24.6	49.2	35 000	70 000	25			
		Rolled			31.6	63.2	45 000	90 000	25			
Iron, tin	Cu, 56.5; Zn, 40; Fe, 1.5; Sn, 1.0.[c]	Cast			23.2–26.0	49.2–52.8	33 000–37 000	70 000–75 000	35–20	35–22	104–119	
	Cu, 55; Zn, 42.4; Fe, 1.8; Sn, 0.8 (sterro metal).	do	8.4	524		42.5		60 500				
		Forged				53.6		76 200				
		Hard drawn				58.5		83 100				
Lead	Cu, 60–63.5; Zn, 35–33.5; Pb, 5.3 (yellow brass).	Cast	8.5	531		23.2–27.5		33 000–39 000	30.0–26.0	35.0–30.0		
		Sheet annealed				29.5		42 000	50.0			
		Sheet hard				42.9		61 000	30.0			
Lead, tin	Cu, 83; Zn, 7; Pb, 6; Sn, 4;[d] (red brass).	Cast	8.6	535	11.3	21.0	16 000	30 000	17.0	19.0		7.0
	Cu, 78; Zn, 9.5; Pb, 10; Sn, 2.	do	8.87	554	8.4	18.6	12 000	26 500	22.0	24.9		

	Cu, 70; Zn, 27; Pb, 2; Sn, 1[e] (yellow brass).	do	8.4	524	7.38	20.7	10 500	29 500	25.0	28.5	53	
Manganese [f]	Cu, 58; Zn, 39; Mn, 0.05; impurities: Sn, Fe, Al, Pb (manganese bronze).	Cast,[g] sand			[h]21.1–24.6	49.2–52.7	[h]30 000–35 000	70 000–75 000	30–22	32–25	109–119	18–19
		Cast, chill			[h]22.5–26.0	52.7–56.3	[h]32 000–37 000	75 000–80 000	32–25	34–28	119–130	18–22
	Cu, 60; Zn, 39; Mn, tr.	Rolled	8.3	520	31.6	52.7	45 000	75 000	25.0	28.0		30
Manganese, vanadium.	Cu, 58.6; Zn, 38.5; Al, 1.5; Mn, 0.5; V, 0.03.	Cold drawn			35.6	57.2	50 600	81 400	12.0	14.0		
Nickel	Cu, 60.4; Zn, 31.8; Ni, 7.7 (nickel silver).[i]	Cast	8.5	530	10.8	25.3	15 400	36 000	40.5	42.0	46	
	Cu, 61.6; Zn, 17.2; Ni, 21.1 (German silver).[j]		8.7	544	13.2	28.8	18 800	40 900	28.5	25.1	80	
	Cu, 60.6; Zn, 11.8; Ni, 27.3.[k]		8.8	547	16.7	37.6	23 700	53 500	32.0	31.4	67	
	Cu, 58; Zn, 24; Ni, 18	Fine wire, drawn hard.	8.5	530		105.5		150 000				
Nickel, tungsten [l]	Cu, 60; Zn, 24; Ni, 14; W, 1–2 (platinoid).											
Tin[m]	Cu, 61; Zn, 38; Sn, 1 (naval brass).	Cast, sand			11.0	30.0	15 700	42 600	29.6	32.0		
		Annealed after rolling.			26.0	43.5	37 000	62 000	25.0	37.0		
	Cu, 58.2; Zn, 39.5; Sn, 2.3 (tobin bronze).	Cast	8.3	518	17.6	42.2	25 000	60 000				
		Rolled	8.4	524	38.0	55.6	54 000	79 000	35.0	40.0		
	Cu, 55; Zn, 43; Sn, 2	Cast				48.4		68 900	48.0	70.0		
Specification values.[n]		Rods, 0–12.7 mm (½ inch) diameter.[o]			19.0	42.2	27 000	60 000	35.0			
		12.7–25.4 mm (1 inch) diameter.[o]			18.3	40.8	26 000	58 000	40.0			
		Over 25.4 mm (1 inch) diameter.[o]			17.6	38.0	25 000	54 000	40.0			
		Shapes, all[o]			15.7	39.4	22 400	56 000	30.0			
		Plates to 12.7 mm (½ inch) thick, av.[o]			19.3	38.7	27 500	55 000	32.0			
		Over 12.7 mm (½ inch) thick.[o]			17.6	39.4	25 000	56 000	35.0			
		Tubing wall 0–3.2 mm (⅛ inch) thick.			21.1	42.2	30 000	60 000	28.0			
		3.2–6.4 mm (¼ inch).			19.7	38.7	28 000	55 000	32.0			

* Footnotes on following page.

TABLE 22—Continued

Constituent metals	Approximate composition in per cent	Condition	Density		Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
					P limit	Ultimate	P limit	Ultimate			Brinell at 500 kg	Scleroscope
			g/cm³	Lbs./ft.³	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
COPPER, ZINC—Con. Tin, specification values—Contd.	....	Over 6.4 mm (¼ inch).	....	....	18.3	35.1	26 000	50 000	35.0	....	....	....
Tin, lead........	Cu, 78; Zn, 16; Sn, 4; Pb, 3 (U. S. N. brass).	Cast........	....	....	11.3	20.3	16 100	28 900	19.0	23.2	....	....
Vanadium [p]........	Cu, 58.6; Zn, 38.5; Al, 1.5; Fe, 1.0; V, 0.03 (victor bronze).	Cold drawn........	....	....	56.5	64.5	80 000	92 000	11.5	29.0	....	....

[a] Cu, 67; Zn, 24; Al, 4.4; Mn, 3.8; P, 0.01; compressive P limit, 42.2 kg/mm², or 60 000 lbs./in.², and 1.33 per cent set for 70.3 kg/mm², or 100 000 lbs./in.² load.

[b] Modulus of elasticity, 11 700 kg/mm², or 16 600 000 lbs./in.²

[c] Compressive P limit, 20.0 to 28.2 kg/mm², or 28 500 to 40 000 lbs./in.²

[d] Compressive ultimate strength, 54.5 kg/mm², or 77 500 lbs./in.²

[e] Compressive P limit, 4.2 kg/mm², or 6000 lbs./in.², and 40 per cent set for 70.3 kg/mm², or 100 000 lbs./in.²

[f] Modulus of elasticity, sand cast, 9840 kg/mm², or 14 000 000 lbs./in.²

[g] Specification values: U. S. Navy 46B16a—cast, minimums, ultimate strength, 49.2 kg/mm², or 70 000 lbs./in.², with 20.0 per cent elongation in 50.8 mm, or 2 inches; U. S. Navy 46B15a—rolled, minimums, P limit, 24.6 kg/mm², or 35 000 lbs./in.²; ultimate strength, 49.2 kg/mm², or 70 000 lbs./in.², with 30.0 per cent elongation in 50.8 mm, or 2 inches. Cu, 57–60; Zn, 40–37; Fe max., 2.0; Sn, 0.5–1.5; (2.9 per cent increase in values for thicknesses 25.4 mm, or 1 inch, and under).

[h] Values shown thus are for yield points.

[i] Nickel silver (Ni, 9 per cent), B. h. n.=130 as rolled; B. h. n.=50 as annealed at 930° C.

[j] U. S. Navy Department specification, 46S3a, June 1, 1917: German silver, Cu, 60–67; Zn, 18–22; Ni min., 15; no mechanical requirements. For list of 30 German-silver alloys, see Brannt, Metallic Alloys, p. 314; "best" (Hiorns)="hard Sheffield," Cu, 46; Zn, 20; Ni, 34.

[k] Modulus of elasticity, 11 550 to 13 300 kg/mm², or 16 300 000 to 18 900 000 lbs./in.²

[l] High electric resistance alloy with mechanical properties as nickel brass.

[m] Specification values, naval brass castings, U. S. Navy 46B10b, Dec. 1, 1917: Normal proportions, Cu, 62; Zn, 37; Sn, 1. Min. tensile strength, 17.5 kg/mm², or 25 000 lbs./in.², with 15 per cent elongation in 50.8 mm, or 2 inches.

[n] Specification values, rolled naval brass, normal proportions, Cu, 62; Zn, 37; Sn, 1; min. properties. (After U. S., Navy specification, 46B6e, Feb. 1, 1918).

[o] Required to bend 120° cold about radius equal to diameter.

[p] Specification values, U. S. Navy 49B1b, Jan. 3, 1916: Vanadium bronze castings, Cu, 61; Zn, 38; Sn max., 1 (incl. V), min. values. P limit, 15.8 kg/mm², or 22 500 lbs./in.² ultimate strength, 38.7 kg/mm², or 55 000 lbs./in.², with 25 per cent elongation.

TABLE 23.—Properties of Copper Alloys of Three or More Components (Alloy Bronzes)—Experimental Results Unless Otherwise Noted

Constituent metals	Approximate composition in per cent	Condition	Density		Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
					P limit	Ultimate	P limit	Ultimate			Brinell at 500 kg	Scleroscope
			g/cm³	Lbs./ft.³	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
COPPER, TIN:												
Aluminum, see copper aluminum.												
Lead	Cu, 89; Sn, 10; Pb, 1 [a]*	Cast	.....	.....	.....	15.5	.....	22 000	.....	.....	.....	.....
	Cu, 88; Sn, 10; Pb, 2 [b]	...do	.....	.....	13.4–16.2	21.1–24.6	19 000–23 000	30 000–35 000	20–15	26–18	65–70	.....
	Cu, 80; Sn, 10; Pb, 10	Cast, sand	8.8	549	10.9	22.1	15 500	31 400	13.5	12.0	63	.....
		Cast, chill	.....	.....	12.8	24.7	18 200	35 200	4.5	3.5	85	.....
Lead, phosphorus	Cu, 80; Sn, 10; Pb, 10; P, tr.	Cast	9.1	570	11.3	21.1	16 000	30 000	6.0	3.5	65	12
Lead, zinc	[c] Cu, 76; Sn, 7; Pb, 13; Zn, 4 (red brass).	...do	.....	.....	13.8	18.8	19 600	26 800	11.0	11.5	.....	8.0
	[d] Cu, 81; Sn, 7; Pb, 9; Zn, 3.	...do	8.9	555	13.4–14.1	21.1–24.6	19 000–20 000	30 000–35 000	18–15	24–22	50–55	.....
	Cu, 88; Sn, 8; Pb, 2; Zn, 2	...do	.....	.....	.....	21.8–26.0	.....	31 000–37 000	20–16	.....	57–59	.....
Lead, zinc, phosphorus.[e]	Cu, 73.2; Sn, 11.3; Pb, 12.0; Zn, 2.5; P, 1.	...do	.....	.....	10.5	21.4	15 000	30 400	4.0	3.3	.....	11
Manganese	Cu, 88; Sn, 10; Mn, 2	...do	.....	.....	9.0	19.1	12 800	27 200	25.0	.....	.....	.....
Manganese bronze, see brass, manganese.												
Nickel, zinc	Cu, 88; Sn, 5; Ni, 5; Zn, 2 (1).[f]	...do	.....	.....	9.2	28.6	13 100	40 700	32.0	28.0	.....	.....
	Cu, 89; Sn, 4; Ni, 4; Zn, 3 (2).[g]	.....	.....	.....	8.1	27.9	11 500	39 700	31.0	31.0	.....	.....
Phosphorus [h, i]	Cu, 95; Sn, 4.9; P, 0.1	Rolled	8.6	535	28.2	45.7	40 000	65 000	30.0	.....	.....	37
	Cu, 89; Sn, 10.5; P, 0.5	Cast	.....	.....	11.2–14.1	21.8–24.6	16 000–20 000	31 000–35 000	6–10	.....	72–77	.....
Silicon	Cu, 70; Sn, 29.5; Si, 0.5	...do	.....	.....	.....	45.7	.....	65 000	.....	.....	.....	.....
		Drawn, hard	.....	.....	.....	73.8	.....	105 000	.0	.....	.....	.....
Vanadium, see brass, vanadium.												
Zinc (composition [j] "G").[k]	Cu, 88; Sn, 10; Zn, 2 (Government bronze.)	Cast, sand	8.6	535	8.58	27.4	12 200	38 900	25.0	21.0	64	13
Zinc [l] or Admiralty gun metal.	.....	Cast	8.7	543	[m] 12.7	34.2	[m] 18 000	48 700	48.2	.....	70	14
Commercial range [n]	.....	...do	.....	.....	5.6–8.4	22.5–26.7	8000–12 000	32 000–38 000	25–10	25–12	65–75	10–20
	Cu, 88; Sn, 8; Zn, 4 [o]	...do	8.5	530	7.73	27.5	11 000	39 200	30.5	24.0	58	11
	Cu, 85; Sn, 13; Zn, 2	...do	.....	.....	.....	26.7	.....	38 000	2.5	2.5	.....	25

* Footnotes on p. 43.

TABLE 23—Continued

Constituent metals	Approximate composition in per cent	Condition	Density		Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
					P limit	Ultimate	P limit	Ultimate			Brinell at 500 kg	Scleroscope
			g/cm³	Lbs./ft.³	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
COPPER, TIN—Con. Zinc, lead [p]	Cu, 90; Sn, 6.5; Zn, 2; Pb, 1.5.	Cast			8.4–11.2	23.9–28.1	12 000–16 000	34 000–40 000	33–25	34–26	50–60	
	Cu, 87; Sn, 7; Zn, 5; Pb, 1 (U. S. Navy valve bronze, 46B8a).	do			13.2	24.8	18 700	35 300	23.2	24.9		
	Cu, 85; Sn, 5; Zn, 5; Pb, 5.[q]	do			10.5–13.4	19.0–23.2	15 000–19 000	27 000–33 000	20–16	20–15	50–62	
	Cu, 83; Sn, 14; Zn, 2; Pb, 1.	do			10.5–13.4	16.2–19.0	15 000–19 000	23 000–27 000	4–0.5	4–0.5		20–24
Zinc, phosphorus	Cu, 86; Sn, 11; Zn, 3; P, tr. ("nongram").	do			13.4	24.6	19 000	35 000	9.0			
COPPER: Aluminum (or aluminum-bronze).	Cu, 90; Al, 10	Cast, sand [r]	7.5–7.45	468–465	13.9–23.3	51.1–60	19 800–33 200	72 700–85 500	28.8–21.7	30.0–22.4	102–106	25–26
	Cu, 92.5; Al, 7.2	Rolled, annealed			6.7	37.5	9600	53 500	91.0	72.9	81	19
Aluminum, iron	Cu, 86.4; Al, 9.7; Fe, 3.9 (Silliman bronze).	Wrought			9.84	59.3	14 000	84 400	11.5			
		Cast			8.08	55.4	11 500	78 850	14.5			
	Cu, 88.5; Al, 10.5; Fe, 1.0.	Cast, sand			14.06	54.1	20 000	77 000	24.5	25.0	100	
		Quenched, 850° C, drawn, 700° C.			28.1	64.6	40 000	92 000	14.0	18.5	140	
Specification values.[s]	Cu, 85–87; Al, 7–9; Fe, 2.5–4.5.[t]	Rods and bars up to 12.7 mm (½ inch).[u]			28.1	56.2	40 000	80 000	30.0			
		Over 12.7 mm to 25.4 mm (1 inch).[u]			26.4	52.7	37 500	75 000	30.0			
		Over 25.4 mm (1 inch).[u]			24.6	50.7	35 000	72 000	30.0			
		Shapes, all thicknesses.[u]			26.4	52.7	37 500	75 000	30.0			
		Shapes and plates 0 to 12.7 mm (½ inch).[u]			27.4	54.8	[v] 39 000	78 000	30.0			
		Over 12.7 mm (½ inch).[u]			26.4	52.7	37 500	75 000	30.0			

Aluminum, tin	Cu, 88.5; Al, 10.4; Sn, 1.2.	Cast, chill			25.8	47.8	36 700	68 000	4.5	5.5	189	32
Aluminum, titanium.	Cu, 90; Al, 10	Cast [w]			13.9	52.0	19 800	74 000	19.5	23.7	100	25
		Quenched, 800° C.			28.5	73.8	40 500	105 200	1.0	.8	262	
	Cu, 89; Al, 10; Fe, 1	Cast [x]	7.58	473	14.1–17.6	45.7–56.2	20 000–25 000	65 000–80 000	30–20	30–20	93–100	25–26
Lead	Cu, 71.9; Pb, 27.5; Sn, 0.5	Cast				4.2–4.6		6000–6600	3–3.2	4.2–6.7		
Nickel, aluminum	Cu, 82.1; Ni, 14.6; Al, 2.5; Zn, 0.7.	Forged [y]			44.5	90.0	63 300	128 000	10.0	12.0		
Specification values.[z]		Rods and bars up to 12.7 mm (½ inch).[u]			[aa] 42.2	56.2	[aa] 60 000	80 000	12.0			
		Over 12.7 mm to 25.4 mm (1 inch).[u]			[aa] 28.1	42.2	[aa] 40 000	60 000	20.0			
		Over 25.4 mm (1 inch).[u]			[aa] 21.1	38.7	[aa] 30 000	55 000	25.0			
		Sheets and plates, spring temper.				63.2		90 000				
		Medium temper [u]			[aa] 17.6	35.1	[aa] 25 000	50 000	25.0			

[a] Compressive P limit, 15.5 kg/mm², or 22 000 lbs./in.²
[b] Compressive P limit, 10.5 kg/mm², or 15 000 lbs./in.², and 28 per cent set for 70.3 kg/mm², or 100 000 lbs./in.²
[c] Ultimate compressive strength, 54.2 kg/mm², or 77 100 lbs./in.²
[d] Compressive P limit, 8.8 to 9.1 kg/mm², or 12 500 to 13 000 lbs./in.², and 34 to 35 per cent set for 70.3 kg/mm², or 100 000 lbs./in.²
[e] Compression, ultimate strength, 49.5 kg/mm², or 70 500 lbs./in.²
[f] Modulus of elasticity, (1) 12 200 kg/mm², or 17 300 000 lbs./in.²
[g] Modulus of elasticity, (2) 10 500 kg/mm², or 14 900 000 lbs./in.²
[h] Specification values, U. S. Navy, 46B5d, Mar. 1, 1917: Cu, 85 to 90; Sn, 6 to 11; Zn max., 4, cast.
Grade 1, Impurities max., 0.8. Min. tensile strength, 31.6 kg/mm², or 45 000 lbs./in.², with 20 per cent elongation in 50.8 mm, or 2 inches.
Grade 2, Impurities max., 1.6. Min. tensile strength, 21.1 kg/mm², or 30 000 lbs./in.², with 15 per cent elongation in 50.8 mm, or 2 inches.
[i] Cu, 80; Sn, 20; P max., 1, cast. Compressive P limit, 17.6 to 28.1 kg/mm², or 25 000 to 40 000 lbs./in.², and 6 to 10 per cent set for 70.3 kg/mm², or 100 000 lbs./in.² load.
[j] Specification values, cast, (minimums) (A. S. T. M. B 10 to 18) Cu, 87 to 89; Sn, 9 to 11; Zn, 1 to 3. Ultimate strength 21.1 kg/mm², or 30 000 lbs./in.², with 14 per cent elongation in 50.8 mm, or 2 inches.
[k] Values shown are averages for 30 specimens from 5 foundries tested at the Bureau of Standards.
[l] Values, A. S. T. M. Proc., **17**, 2, p. 186; 1917.
[m] Values are observed yield points.
[n] Compressive P limit, av. 10.5 kg/mm², or 15 000 lbs./in.², with 29 per cent set for 70.3 kg/mm², or 100 000 lbs./in.² load.
[o] Values from same series of tests as first values for "88–10–2." Averages for 26 specimens from 5 foundries tested at Bureau of Standards.
[p] Compressive P limit, 9.1 kg/mm², or 13 000 lbs./in.², with 34 per cent set for 70.3 kg/mm², or 100 000 lbs./in.² load.
[q] Compressive P limit, 8.4 kg/mm², or 12 000 lbs./in.², with 36 per cent set for 70.3 kg/mm², or 100 000 lbs./in.² load.
[r] High values are after Jean Escard, L'Aluminum dans l'industrie, Paris, 1918. Compressive P limit, 13.5 kg/mm², or 19 200 lbs./in.², with 13.5 per cent set for 70.3 kg/mm², or 100 000 lbs./in.² load.
[s] Specification minimums, U. S. Navy, 46B17, Dec. 2, 1918, for hot-rolled "aluminum-bronze."
[t] Specification values shown above under P limit are for yield point.
[u] Required to bend cold through 120° about radius equal to thickness.
[v] 2.6 per cent increase in strength up to 762 mm (30 inches) width.
[w] Compressive P limit, cast, 14.1 kg/mm², or 20 000 lbs./in.², with 11.4 per cent set at 70.3 kg/mm², or 100 000 lbs./in.² load.
[x] Compressive P limit, cast, 12.7 to 14.1 kg/mm², or 18 000 to 20 000 lbs./in.², with 13 to 15 per cent set at 70.3 kg/mm², or 100 000 lbs./in.² load.
[y] Modulus of elasticity, 14 900 kg/mm², or 21 150 000 lbs./in.²
[z] Specification values, U. S. Navy, 46B14b, Mar. 1, 1916: Cu min., 94; Sn min., 3.5; P, 0.05 to 0.50, rolled or drawn.
[aa] Minimum yield points specified. For P limits assume 66 per cent of values shown.

TABLE 24.—Composition and Tensile Strength of Bronze, Phosphor, Spring Wire—Specification Values

[Bronze, phosphor, spring wire, hard drawn or hard rolled, U. S. Navy specification, 22W5, Dec. 1, 1915: Cu, 94; Sn min., 4.5; Zn max., 0.3; Fe max., 0.1; Pb max., 0.2; P, 0.05–0.50; max. elong. in 203 mm, or 8 inches, is 4 per cent.]

Diameter (group limits)	Minimum tensile strength		Diameter (group limits)		Minimum tensile strength	
	kg/mm²	Lbs./in.²	mm	Inch	kg/mm²	Lbs./in.²
Up to 1.59 mm (0.0625 inch)	95.0	135 000	6.35	0.250	77.4	110 000
Over 1.59 to 3.17 mm (0.125 inch)	88.0	125 000	9.52	.375	73.8	105 000

3. MISCELLANEOUS METALS AND ALLOYS

TABLE 25.—Properties of Miscellaneous Metals and Alloys—Experimental Results Unless Otherwise Noted

Constituent metals	Approximate composition in per cent	Condition	Density		Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
					P limit	Ultimate	P limit	Ultimate			Brinell at 500 kg	Scleroscope
			g/cm³	Lbs./ft.³	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Per cent		
ANTIMONY a*	Sb	Drawn, hard	6.7	418								
COBALT b	Co, 99.7	Cast c	8.8	550	d 19.5	23.1	d 27 800	32 900	Less than 1		121	
		Annealed	8.9	556	d 22.2	26.0	d 31 600	36 900	Less than 1		48	
		Wrought, wire				62.7		89 200	3			
Molybdenum, chromium, etc. (or stellite).	Co, 59.5; Mo, 22.5; Cr, 10.8; Fe, 3.1; Mn, 2.0; C, 0.9; Si, 0.8.										512 (at 3000 kg)	
GOLD	Au, 100	Cast	19.3	1203		17.6		25 000	25.0			20
		Drawn, hard				26.0		37 000				
Copper	Au, 90; Cu, 10	do	17.2	1073		45.8		65 100			73 (at 200 kg)	
Copper, silver	Au, 58; Cu, 30; Ag, 12.	do				102.0		145 000				
LEAD f	Pb, commercial	Cast g	11.38	710		1.25		1780				3
		Rolled, hard	11.40	711		2.32		3300				
		Drawn, soft				1.70		2420				
		Drawn, hard				2.20		3130				
Antimony	Pb, 95.5; Sb, 4.5	Cast	10.5	655	2.81	4.5	4000	6400				
MAGNESIUM	Mg	do	1.70	106		21.1		30 000				
		Drawn, hard	1.75	109		23.2		33 000				
NICKEL h	Ni, 98.5	Cast	8.30	518	d 16.7	26.7	d 23 800	38 000	5.7	6.1	76	
	Ni, 99.95	Wrought, annealed	8.70	543	12.6	29.9	17 900	42 500	11.0			
	Ni 98.5	Wrought, commercial				45.7		65 000			83	35
		Rolled, hard, commercial				64.7		92 000	11.0			
		Rolled, annealed, commercial.				53.4		76 000	35.0			
		Drawn, hard, D=1.65 mm or 0.065 inch.				109.0		155 000				
Copper, iron i	Ni, 71; Cu, 27; Fe, 2	Drawn, hard				112.5		160 000				
Copper, iron, manganese j (or Monel metal).	Ni, 67; Cu, 28; Fe, 3; Mn, 2.	Rolled, hot	8.95	558							162	27
		Rods, diameter to 25.4 mm (1 inch).			d 44.4	66.6	d 63 100	94 600	40.0			
		Rods, 27.0–42.9 mm (1 1/16 inches).			d 43.6	65.5	d 62 000	93 100	39.0			

*Footnotes on p. 47.

TABLE 25—Continued

Constituent metals	Approximate composition in per cent	Condition	Density		Tensile strength				Elongation in 50.8 mm (2 inches)	Reduction of area	Hardness	
					P limit	Ultimate	P limit	Ultimate			Brinell at 500 kg	Scleroscope
			g/cm³	Lbs./ft.³	kg/mm²	kg/mm²	Lbs./in.²	Lbs./in.²	Per cent	Percent		
NICKEL—Contd. Copper, iron, manganese [j] (or Monel metal)—Contd.		Rods, 44.4–61.9 mm (2$\frac{7}{16}$ inches).			[d] 35.3	61.7	[d] 50 100	87 700	42.0			
		Rods, 63.5–88.9 mm (3½ inches).			[d] 30.8	60.0	[d] 43 800	85 300	44.0			
		Rods over 88.9 mm (3½ inches).			[d] 33.3	59.6	[d] 47 300	84 800	43.0			
		Rectangles			[d] 39.6	60.2	[d] 56 400	85 600	42.0			
		Hexagons			[d] 42.7	61.8	[d] 60 700	87 800	40.0			
Copper,[k] iron, silicon (or Monel metal[l]).	Ni, 67; Cu, 28; Fe, 2.5; Si, 1.5.	Cast, sand	8.83	551	26.1	50.9	37 100	72 300	34.0	32.0		20–23
PALLADIUM [m]	Pa	Drawn, hard	12.1	755		27.4		39 000				
PLATINUM [n]	Pt	do	21.5	1342		37.3		53 000	18.0			24
		Drawn, annealed				24.6		35 000	50.0			13
SILVER [o]	Ag, 100	Cast	10.5	655		28.1		40 000				
		Drawn, hard	10.57	660		36.0		51 200			59	32
Copper	Ag, 75; Cu, 25	do				77.0		109 500				
TANTALUM [p]	Ta	do	16.6	1035		91.4		130 000				
TELLURIUM [q]	Te	Drawn, wire	6.2	387								
TIN [r]	Sn, 99.8	Cast	7.3	456	1.13	2.81	1600	4000	35.0		14	8
		Rolled				3.73		5300				
		Drawn, hard				7.03		10 000				
Antimony, copper, zinc (Britannia metal).	Sn, 81; Sb, 16; Cu, 2; Zn, 1.											
ZINC, ALUMINUM, ETC.	Sn, 63; Zn, 18; Al, 13; Cu, 3; Sb, 2; Pb, 1 (aluminum solder).	Cast				10.2		14 500	1.9	1.5		
	Sn, 62; Zn, 15; Al, 11; Pb, 8; Cu, 3; Sb, 1.	do				9.1		13 000	1.6	1.3		
	Sn, 86; Zn, 9; Al, 5	Cast, chill				8.6		12 200	41.0	81.0		
Aluminum, zinc, cadmium.	Sn, 78; Al, 9; Zn, 8; Cd, 5.	do				10.1		14 300	18.0	41.0		
TUNGSTEN [s]	W, 99.2 [t]	Ingot sintered D=5.58 mm (0.22 inch).	18.0	1124		12.7		18 000	.0	.0		
		Rod swaged D=0.76 mm (0.03 inch).				151.0		215 000	4.0	28.0		

		Drawn, hard, D=0.029 mm (0.0014 inch).	....	....	....	415.0	....	590 000	....	65.0	....	....
		Drawn, hot, hard (after swaging) (1) 97.5 per cent reduction.	....	....	....	164.0	....	233 500	3.2	14.0	....	....
		u As (1) and equiaxed at 2000° C in H_2 v.	....	....	....	118.0	....	168 000	.0	.0	....	....
ZINC........	Zn, impurities Pb, Fe, Cd.	Cast, coarse, crystalline..	7.0	437	....	2.8–8.4	....	4000–12 000	....	....	42–48	8–10
		Cast, fine, crystalline....	....	....	....							
		Rolled w........	....	....	2.04	19.0	2900	27 000	....	....	....	....
		Rolled x........	....	....	4.08	25.3	5800	36 000	....	....	....	....
		Drawn, hard y........	7.1	443	....	7.03	....	10 000	....	....	....	....

a Modulus of elasticity, 7960 kg/mm^2, or 11 320 000 lbs./in.^{2} (Bridgman).

b Commercial composition: C, 0.06; cast tension, ultimate, 42.9 kg/mm^2, or 61 000 lbs./in.^{2} with 20 per cent elongation in 50.8 mm, or 2 inches. Compression, ultimate, 123.0 kg/mm^2, or 175 000 lbs./in.^{2}

c Compressive strength, cast and annealed, 85.8 kg/mm^2, or 122 000 lbs./in.^{2}

d Values are for yield point.

e Modulus of elasticity varies from 7000 to 9500 kg/mm^2, or 9 950 000 to 13 000 000 lbs./in.^{2}

f For compressive test data on lead-base babbitt metal, see table following zinc.

g Modulus of elasticity, cast or rolled, 492 kg/mm^2, or 700 000 lbs./in.^{2} drawn hard, 703 kg/mm^2, or 1 000 000 lbs./in.^{2}

h Modulus of elasticity, cast, 20 300 kg/mm^2, or 28 900 000 lbs./in.^{2}; drawn hard, 23 900 kg/mm^2, or 34 100 000 lbs./in.^{2}

i International Nickel Co. results. Average of tests over long period. Compressive P limit, 17.9 to 22.5 kg/mm^2, or 25 500 to 32 000 lbs./in.^{2}

j Modulus of elasticity, 15 500 to 16 200 kg/mm^2, or 22 000 000 to 23 000 000 lbs./in.^{2}

k Compression, P limit, 8.4 to 17.9 kg/mm^2, or 12 000 to 25 500 lbs./in.^{2}

l Specification values, U. S. Navy: Monel metal, Ni min., 60; Cu min., 23; Fe max., 3.5; Mn max., 3.5; C plus Si max., 0.8; Al max., 0.5.

46M1b: Cast (minimums) P limit, 22.8 kg/mm^2 yield point, or 32 500 lbs./in.^{2} yield point; ultimate strength, 45.7 kg/mm^2, or 65 000 lbs./in.^{2}, with 25 per cent elongation in 50.8 mm, or 2 inches.

46M7b: Rolled (minimums) rods and bars, P limit, 28.1 kg/mm^2 yield point, or 40 000 lbs./in.^{2} yield point; ultimate strength, 56.2 kg/mm^2, or 80 000 lbs./in.^{2}, with 32 per cent elongation in 50.8 mm, or 2 inches. Rolled (minimums) sheets and plates, P limit, 21.1 kg/mm^2 yield point, or 30 000 lbs./in.^{2} yield point; ultimate strength, 45.7 kg/mm^2, or 65 000 lbs./in.^{2}, with 15 per cent elongation in 50.8 mm, or 2 inches. Values shown are subject to slight modifications, depending on shapes and thicknesses.

m Modulus of elasticity, annealed, 9710 kg/mm^2, or 13 800 000 lbs./in.^{2}

n Modulus of elasticity varies from 16 000 to 17 500 kg/mm^2, or 22 800 000 to 24 900 000 lbs./in.^{2}

o Modulus of elasticity varies from 6000 to 8000 kg/mm^2, or 8 530 000 to 11 370 000 lbs./in.^{2}

p Modulus of elasticity, 19 000 kg/mm^2, or 27 000 000 lbs./in.^{2}

q Modulus of elasticity, 4180 kg/mm^2, or 5 950 000 lbs./in.^{2} (Bridgman).

r Compressive strength, cast, 4.5 kg/mm^2, or 6400 lbs./in.^{2} Modulus of elasticity, cast, av., 2810 kg/mm^2, or 4 000 000 lbs./in.^{2} Rolled, av., 4010 kg/mm^2, or 5 700 000 lbs./in.^{2} For compressive test data on tin-base babbitt metals, see table following zinc.

s After Z. Jeffries, Am. Inst. Min. Eng. Bull., 138, June, 1918.

t Commercial composition for incandescent electric lamp filaments containing thoria (ThO_2), approximately 0.75 per cent.

u Modulus of elasticity of drawn wire equals 362 kg/mm^2, or 514 000 lbs./in.^{2} (Dodge).

v Ordinary annealing treatment makes W brittle, and severe working below recrystallization or equiaxing temperature produces ductility. Tungsten rods which have been worked and recrystallized are stronger than sintered rods. The equiaxing temperatures of worked tungsten with a 5-minute exposure vary from 2200° C for a worked rod with 24 per cent reduction, to 1350° C for a fine wire with 100 per cent reduction. (Jeffries, loc. cit.)

w Tested with grain or direction of rolling.

x Tested across grain or direction of rolling.

y Compression, load on cylinder 25.4 mm, or 1 inch by 66.0 mm, or 2.6 inches, at 20 per cent deformation. For spelter (cast zinc) free from Cd, av., 17.3 kg/mm^2, or 24 500 lbs./in.^{2}. For spelter with Cd, 0.26, av., 27.4 kg/mm^2, or 39 000 lbs./in.^{2}. (See Proc. A. S. T. M., **13**, p. 688.) Modulus of rupture averages twice the corresponding tensile strength. Shearing strength, rolled, averages 13.6 kg/mm^2, or 19 400 lbs./in.^{2} Modulus of elasticity in tension, cast, 7750 kg/mm^2, or 11 025 000 lbs./in.^{2} Rolled, 8450 kg/mm^2, or 12 000 000 lbs./in.^{2} (Moore, Univ. of Ill., Eng. Exp. Sta. Bull. 52).

TABLE 26.—Properties of White Metal Bearing Alloys [a]—Experimental Results Unless Otherwise Noted

Alloy No.	Formula				Pouring temperatures		Density		Permanent deformation at 21° C						Hardness, Brinell at 500 kg	
	Sn	Sb	Cu	Pb					At 454 kg=1000 pounds		At 2268 kg=5000 pounds		At 4536 kg=10 000 pounds		At 21° C	At 100° C
	Per cent	Per cent	Per cent	Per cent	°C	°F	g/cm³	Lbs./ft.³	mm	Inch	mm	Inch	mm	Inch		
	Tin base															
1	91.0	4.5	4.5	....	440	824	7.34	458	0.000	0.0000	0.025	0.0010	0.380	0.0150	28.6	12.8
2 [b]	89.0	7.5	3.5	....	432	808	7.39	461	.000	.0000	.038	.0015	.305	.0120	28.3	12.7
3	83.3	8.3	8.3	....	491	916	7.46	465	.025	.0010	.114	.0045	.178	.0070	34.4	15.7
4	75.0	12.0	3.0	10.0	360	680	7.52	469	.013	.0005	.064	.0025	.229	.0090	29.6	12.8
5	65.0	15.0	2.0	18.0	350	661	7.75	484	.025	.0010	.076	.0030	.229	.0090	29.6	11.8
	Lead base															
6	20.0	15.0	1.5	63.5	337	638	9.33	582	.038	.0015	.127	.0050	.457	.0180	24.3	11.1
7	10.0	15.0	....	75.0	329	625	9.73	607	.025	.0010	.127	.0050	.583	.0230	24.1	11.7
8	5.0	15.0	....	80.0	329	625	10.04	627	.051	.0020	.229	.0090	1.575	.0620	20.9	10.3
9	5.0	10.0	....	85.0	324	616	10.24	640	.102	.0040	.305	.0120	2.130	.0840	19.5	8.6
10	2.0	15.0	....	83.0	329	625	10.07	629	.025	.0010	.254	.0100	3.910	.1540	17.0	8.9
11	....	15.0	....	85.0	329	625	10.28	642	.025	.0010	.254	.0100	3.020	.1190	17.0	9.9
12	....	10.0	....	90.0	334	634	10.67	666	.064	.0025	.432	.0170	7.240	.2850	14.3	6.4

(NOTE.—For other bearing alloys see brass, lead (yellow brass); brass, lead-tin (red brass); bronze, phosphor; etc., under copper alloys.)

[a] Babbitt metal, A. S. T. M., 18, 1, p. 491. Experimental permanent deformation values from compression tests on cylinders 31.8 mm or 1¼ inches diameter by 63.5 mm or 2½ inches long, tested at 21° C (70° F). (Set readings after removing loads.)

[b] U. S. Navy specification 46M2b (Cu, 3-4.5; Sn, 88-89.5; Sb, 7.0-8.0) covers manufacture of antifriction metal castings (composition W).

VIII. NONMETALLIC MATERIALS

1. RUBBER

TABLE 27.—Rubber, Sheet [a]—Experimental Results

Grade	Ultimate strength				Ultimate elongation		Set [b]	
	Longitudinal [c]		Transverse		Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse
	kg/mm²	Lbs./in.²	kg/mm²	Lbs./in.²	Per cent	Per cent	Per cent	Per cent
1	1.92	2730	1.81	2575	630	640	11.2	7.3
2	1.45	2070	1.43	2030	640	670	6.0	5.0
3	.84	1200	.89	1260	480	555	22.1	16.3
4	1.30	1850	1.20	1700	410	460	34.0	24.0
5	.48	690	.36	510	320	280	27.5	25.0
6	.62	880	.48	690	315	315	34.3	25.9

The specific gravity of rubber averages from 0.95 to 1.25, corresponding to an average density of 59.4 to 78.2 lbs./ft.³

Four-ply rubber belts show an average ultimate tensile strength of 0.63 to 0.65 kg/mm², or 890 to 930 lbs./in.) Benjamin). A working tensile stress of 0.070 to 0.105 kg/mm², or 100 to 150 lbs./in.², is recommended (Bach).[8]

[a] Data from B. S. Circular No. 38.
[b] Set measured after 300 per cent elongation for 1 minute with 1 minute rest.
[c] Longitudinal indicates direction of rolling through the calendar.

2. LEATHER, BELTING—EXPERIMENTAL RESULTS

Oak-tanned leather from the center or back of the hide:
- MINIMUM TENSILE STRENGTHS of belts (Marks, p. 622)—
  - Single, 2.81 kg/mm², or 4000 lbs./in.²; double, 2.53 kg/mm², or 3600 lbs./in.²
- MAXIMUM ELONGATION for one hour's application of 1.58 kg/mm², or 2250 lbs./in.² stress—
  - Single, 13.5 per cent; double, 12.5 per cent.

Modulus of elasticity of leather varies from an average value of 12.5 kg/mm², or 17 800 lbs./in.², to 22.5 kg/mm², or 32 000 lbs./in.²

Chrome leather has a tensile strength of 5.97 to 9.07 kg/mm², or 8500 to 12 900 lbs./in.²

The specific gravity of leather varies from 0.86 to 1.02, corresponding to a density of 53.7 to 63.8 lbs./ft.³

3. WOOD

For data on mechanical and other physical properties of woods grown in the United States, see Bulletin 556, Forest Service, U. S. Department of Agriculture, containing data on 130 000 tests of woods in both green and air-dry condition. For mechanical properties (metric units) of woods grown in the United States, tested in a green condition, see table in 1919 edition of Smithsonian Physical Tables, showing values as converted from Forest Service Bulletin (English values) to corresponding metric values.

See also any good text on wood, for example, Snow, The principal species of wood, their characteristic properties, 1910, New York; Record, Mechanical properties of wood, 1914, New York; Baterden, Timber, Westminster series, containing bibliography, pages 333 and 334, 1908, London; Boulger, Wood, A manual of the natural history and industrial applications of the timbers of commerce, 1908, London; and Charpentier, Timber, translation from French by Joseph Kennell, 1902, London.

4. MANILA ROPE

TABLE 28.—Weight and Strength of Different Sizes of Manila Rope—Specification Values

[From U. S. Government Standard Specifications adopted April 4, 1918, and formulated jointly by cordage manufacturers and Government representatives. Rope to be made of manila or Abaca fiber, with no fiber of grade lower than U. S. Government Grade I, to be three strand,[a] medium laid, with maximum weights and minimum strengths shown in the table below, lubricant content to be not less than 8 nor more than 12 per cent of the weight of the rope as sold.]

Approximate diameter		Circumference		Maximum net weight		Minimum breaking strength	
mm	Inches	mm	Inches	kg/m	Lbs./ft.	kg	Pounds
6.3	1/4	19.1	3/4	0.029	0.0196	317	700
7.9	5/16	25.4	1	.042	.0286	544	1200
9.5	3/8	28.6	1 1/8	.061	.0408	657	1450
11.1	7/16	31.8	1 1/4	.080	.0539	793	1750
11.9	15/32	34.9	1 3/8	.095	.0637	952	2100
12.7	1/2	38.1	1 1/2	.109	.0735	1110	2450
14.3	9/16	44.5	1 3/4	.153	.1029	1430	3150
15.9	5/8	50.8	2	.195	.1307	1810	4000
19.1	3/4	57.2	2 1/4	.241	.1617	2220	4900
20.6	13/16	63.5	2 1/2	.284	.1911	2680	5900
22.2	7/8	69.8	2 3/4	.328	.2205	3170	7000
25.4	1	76.2	3	.394	.2645	3720	8200
27.0	1 1/16	82.6	3 1/4	.459	.3087	4310	9500
28.6	1 1/8	88.9	3 1/2	.525	.3528	4990	11 000
31.8	1 1/4	95.2	3 3/4	.612	.4115	5670	12 500
33.3	1 5/16	101.6	4	.700	.4703	6440	14 200
34.9	1 3/8	108.0	4 1/4	.787	.5290	7260	16 000
38.1	1 1/2	114.3	4 1/2	.875	.5879	7940	17 500
39.7	1 9/16	120.7	4 3/4	.984	.6615	8840	19 500
41.2	1 5/8	127.0	5	1.094	.7348	9750	21 500
44.5	1 3/4	139.7	5 1/2	1.312	.8818	11 550	25 500
50.8	2	152.4	6	1.576	1.059	13 610	30 000
52.4	2 1/16	165.1	6 1/2	1.823	1.225	15 420	34 000
57.2	2 1/4	177.8	7	2.144	1.441	17 460	38 500
63.5	2 1/2	190.5	7 1/2	2.450	1.646	19 730	43 500
66.7	2 5/8	203.2	8	2.799	1.881	22 220	49 000
73.0	2 7/8	215.9	8 1/2	3.136	2.107	24 940	55 000
76.2	3	228.6	9	3.543	2.381	27 670	61 000
79.4	3 1/8	241.3	9 1/2	3.936	2.645	30 390	67 000
82.5	3 1/4	254.0	10	4.375	2.940	33 110	73 000

[a] Four-strand medium-laid rope when ordered may run up to 7 per cent heavier than three-strand rope of the same size, and must show 95 per cent of the strength required for three-strand rope of the same size.

IX. ALPHABETICAL INDEX

This list gives in alphabetical order the names of materials, including metals and certain alloys, by their commercial names, but does not list all alloys by components, for which see tabular matter following the chief component as listed below.