

A11101 888516

NAT'L INST OF STANDARDS & TECH R.I.C.



A110188516

/Circular of the National Bureau of Stan
QC100 .U555 C447;1943 C.1 NBS-PUB-R 1934

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

MECHANICAL PROPERTIES OF METALS AND ALLOYS

CIRCULAR C447



UNITED STATES DEPARTMENT OF COMMERCE • Jesse H. Jones, Secretary

NATIONAL BUREAU OF STANDARDS • Lyman J. Briggs, Director

CIRCULAR OF THE NATIONAL BUREAU OF STANDARDS C447

MECHANICAL PROPERTIES OF METALS AND ALLOYS

by

JOHN L. EVERHART, W. EARL LINDLIEF, JAMES KANEGIS, PEARL G. WEISSLER
and FRIEDA SIEGEL



ISSUED DECEMBER 1, 1943

UNITED STATES GOVERNMENT PRINTING OFFICE • WASHINGTON • 1943

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, U. S. GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C. • PRICE \$1.50

FEB 7 1944

55212

Preface

Requests for information on the mechanical and related properties of metals and alloys are received frequently at the National Bureau of Standards from other departments of the Government, from industrial organizations, and from individuals engaged in research. Such information is rarely found in systematic form, and the sources may not be readily available to the individual seeking the data.

In response to a request in 1920 from the Smithsonian Institution for the assistance of the National Bureau of Standards in the revision of the Smithsonian Physical Tables, a compilation of the available information on the properties of materials was undertaken. It was found that many of the requests received at this Bureau for data on the mechanical properties of metals could be answered by reference to the tables compiled for the Smithsonian Institution and they were published as Physical Properties of Materials, Circular C101 of the National Bureau of Standards. The first edition was compiled by H. A. Anderson. In response to the continuing demand for information of this type, a second considerably expanded edition was prepared in 1924 by S. N. Petrenko.

The preparation of the present Circular was undertaken to bring the information up to date by the inclusion of data on the numerous new alloys which have been introduced since 1924. Because of the increasing importance of knowledge of the properties of metals at high and low temperatures, the tables dealing with materials under these conditions have been expanded. In response to requests for information on electrical and thermal conductivities and thermal expansion in connection with welding problems, tables dealing with these properties have been added. The tables have been rearranged to assist the engineer in locating, quickly, data on any desired alloy.

The entire manuscript was read by H. S. Rawdon, W. F. Roeser, and G. W. Quick, the portion on electrical properties by F. Wenner, the portion on thermal expansion by P. Hidnert, and the portion on thermal conductivity by M. S. Van Dusen. The definitions of mechanical properties were prepared by L. B. Tuckerman. The aluminum section was read by R. L. Templin of the Aluminum Company of America, the nickel section by W. A. Mudge and E. M. Wise of the International Nickel Co. Their many valuable contributions are gratefully acknowledged.

The cooperation of the technical societies and publishers who granted permission for the inclusion of material in this Circular is greatly appreciated. For each value of a property in this Circular the source is given in a literature reference.

LYMAN J. BRIGGS, *Director.*

MECHANICAL PROPERTIES OF METALS AND ALLOYS

by JOHN L. EVERHART, W. EARL LINDLIEF, JAMES KANEGIS, PEARL G. WEISSLER, and
FRIEDA SIEGEL

CONTENTS

	Page		Page
Preface.....	II	VII. Iron and steel—Continued	
I. Introduction.....	2	4. Approximate hardness conversion table for SAE car-	
II. Selection of the data.....	2	bon and alloy constructional steels (table 19)....	168
III. Organization of the data.....	3	5. Society of Automotive Engineers' summary charts....	169
IV. Definitions and discussion.....	4	6. Jominy end-quench test, definition.....	173
1. Stress.....	4	7. Normal-temperature properties (table 20).....	174
2. Strain.....	4	8. Damping capacity, definition.....	234
3. Stress-strain diagram.....	4	9. Calculation of freezing points of steels	
4. Yield point.....	4	(table 21).....	251
5. Yield strength.....	5	10. High-temperature properties (table 22).....	252
6. "Proportional limit".....	6	11. Low-temperature properties (table 23).....	271
7. Elastic limit.....	6	12. Thermal expansion (table 24).....	282
8. Tensile, compressive, or shear strength.....	6	13. Electrical and thermal properties (table 25).....	286
9. Elongation.....	6	14. Magnetic properties of permanent magnet alloys	
10. Reduction of area.....	7	(table 26).....	294
11. Modulus of elasticity.....	7	VIII. Lead and lead alloys.....	295
12. Poisson's ratio.....	7	1. Classification (table 27).....	297
13. Bending strength.....	8	2. Normal-temperature properties (table 28).....	298
14. Torsional strength.....	8	3. Properties of babbitts (table 29).....	307
15. Endurance limit.....	9	4. Properties of soft solders (table 30).....	308
16. Hardness.....	9	5. High-temperature properties (table 31).....	310
(a) Brinell number.....	9	6. Low-temperature properties (table 32).....	312
(b) Vickers number.....	9	7. Thermal expansion (table 33).....	313
(c) Rockwell number.....	9	8. Electrical and thermal properties (table 34).....	314
(d) Scleroscope number.....	10	IX. Magnesium and magnesium alloys.....	317
(e) Hardness conversion.....	10	1. Classification (table 35).....	319
17. Impact value.....	10	2. Normal-temperature properties (table 36).....	320
18. Erichsen value.....	11	3. High-temperature properties (table 37).....	335
19. Bend number.....	11	4. Low-temperature properties (table 38).....	340
20. Creep strength (long-time tensile strength).....	11	5. Thermal expansion (table 39).....	343
21. Coefficient of linear thermal expansion.....	11	6. Electrical and thermal properties (table 40).....	344
22. Electrical conductivity.....	12	X. Nickel and nickel alloys.....	347
23. Electrical resistivity or specific resistance		1. Classification (table 41).....	349
(reciprocal of conductivity).....	12	2. Normal-temperature properties (table 42).....	350
24. Temperature coefficient of electrical		3. High-temperature properties (table 43).....	363
resistivity.....	12	4. Low-temperature properties (table 44).....	368
25. Thermal conductivity.....	12	5. Thermal expansion (table 45).....	370
26. Temperature coefficient of thermal conductivity.....	12	6. Electrical and thermal properties (table 46).....	372
27. Heat-treating terms.....	12	XI. Tin and tin alloys.....	375
28. Powder metallurgy terms.....	15	1. Classification (table 47).....	377
V. Aluminum and aluminum alloys.....	17	2. Normal-temperature properties (table 48).....	378
1. Classification (table 1).....	19	3. Creep at room temperature (table 49).....	385
2. Heat-treatment and temper designation (table 2).....	21	4. High-temperature properties (table 50).....	386
3. Normal-temperature properties (table 3).....	22	5. Thermal expansion (table 51).....	387
4. High-temperature properties (table 4).....	48	6. Electrical and thermal properties (table 52).....	388
5. Low-temperature properties (table 5).....	53	XII. Zinc and zinc alloys.....	389
6. Thermal expansion (table 6).....	57	1. Classification (table 53).....	391
7. Electrical and thermal properties (table 7).....	60	2. Definitions.....	392
VI. Copper and copper alloys.....	65	(a) Dynamic ductility test.....	392
1. Nomenclature of the copper alloys, brass and		(b) Temper test.....	392
bronze.....	66	3. Normal-temperature properties (table 54).....	393
2. Classification of cast copper-base alloys		4. Creep properties (table 55).....	402
(table 8).....	67	5. Low-temperature properties (table 56).....	404
3. Classification of some wrought copper-base		6. Thermal expansion (table 57).....	405
alloys (table 9).....	69	7. Electrical and thermal properties (table 58).....	406
4. Temper designation for copper alloys		XIII. Miscellaneous metals and alloys.....	407
(table 10).....	71	1. Classification (table 59).....	409
5. Hardness conversion table for cartridge brass		2. Normal-temperature properties (table 60).....	410
(table 11).....	72	3. Low-melting alloys (table 61).....	432
6. Normal-temperature properties (table 12).....	73	4. Melting ranges of hard solders and brazing	
7. High-temperature properties (table 13).....	133	materials (table 62).....	433
8. Low-temperature properties (table 14).....	143	5. High-temperature properties (table 63).....	434
9. Thermal expansion (table 15).....	148	6. Low-temperature properties (table 64).....	445
10. Electrical and thermal properties (table 16).....	151	7. Thermal expansion (table 65).....	446
VII. Iron and steel.....	161	8. Electrical and thermal properties (table 66).....	450
1. Society of Automotive Engineers' steel		XIV. Appendix.....	457
numbering system.....	162	1. Physical properties of the elements (table 67).....	459
2. Combined standard steel lists of the American		2. Abbreviations used in this Circular.....	461
Iron and Steel Institute and the Society of		3. Conversion factors.....	461
Automotive Engineers (1942) (table 17).....	163	4. Temperature interconversion (table 68).....	463
3. Substitutes for constructional steels		XV. References.....	465
(table 18).....	167	XVI. Index.....	477

ABSTRACT

This Circular is a summary of the results of a comprehensive survey of the technical literature on the strength and related properties, thermal expansion, and thermal and electrical conductivities of ferrous and nonferrous metals and alloys at normal, high, and low temperatures. In general, the data are presented in tabular form, although graphical representation is often used to indicate the effects of changing composition or conditions on the properties. Data on aluminum, copper, iron and steel, lead, magnesium, nickel, tin, zinc, a number of miscellaneous metals, and their alloys are included. The Circular is not limited to conventional engineering materials but contains data on the properties of many materials not usually classed as such. Literature references to the sources of the data are included.

I. INTRODUCTION

Requests are received frequently at the National Bureau of Standards for information on the physical and mechanical properties of materials. In the past, many of these requests were answered by reference to Circular C101, which had been compiled for that purpose. The last edition of that Circular was issued in 1924. Since that time, metallurgical progress has resulted in the development of many new materials such as light alloys for aircraft, tungsten-carbide cutting tools, steels with low creep rates for high-temperature industrial equipment, etc.

With the entry of the United States into the war, it became necessary to develop quickly much new industrial and military equipment. In many cases the selection of materials could not be based on past experience, for there was none. Information on the properties of metals may serve as a guide to the designing engineer and the specification writer in the selection of suitable alloys and may assist in the pressing problem of the substitution of less critical materials in order to bring about conservation of those which are more critical.

This Circular is a summary of the results of a comprehensive survey of the technical literature and other sources on

the strength and related properties of metals and alloys. Other properties, such as electrical conductivity and thermal expansion, which are useful in the design of structures have been included. The Circular has not been limited to the metals and alloys usually considered engineering materials but includes data on many which, for economic or other reasons, are not ordinarily classed as such.

II. SELECTION OF THE DATA

In general, the data were selected from those published in the technical literature, and reference to the source is given. If available, the composition, size and shape of the material, and treatment have been included. As far as possible, data from actual tests are given rather than the specification or average properties which are available in numerous handbooks and manufacturers' catalogs. However, in some cases actual test data were not found in the recent literature, and it has been necessary to include average properties. These properties were obtained from engineering handbooks or trade magazines.

A word of caution should be directed to those using the values reported herein. Tensile and hardness-testing procedures at room temperature have been well standardized throughout the world, and direct comparison of these properties, regardless of by whom determined, may be made with some degree of confidence. However, impact, shear, and many other mechanical tests have not been standardized even within the United States. The validity of the comparison of such values obtained by different investigators for various materials is therefore somewhat uncertain.

A recent American Society for Testing Materials' symposium [1]¹ is of interest in

¹Figures in brackets appearing throughout the text and tables indicate the numbered references in the list at the end of this Circular.

the application of tensile-test results to design. The significance of the strength and ductility values is discussed by a number of engineers, and the ideas advanced are of particular value to the designer seeking to use materials in new applications. It was not practicable to summarize this information in a suitable form in this Circular. For further information on the subject, the original series of papers should be consulted.

The properties of engineering materials vary considerably, and the compilers have tried to select reliable sources of information and to reproduce accurately the values given in the original source. The selections are the most probable values that can be obtained under the given conditions and are intended to be representative of the material.

Specifications issued by the Government and various organizations usually present the minimum strengths which are acceptable. As most of the strength values given in this Circular are the results of actual tests, they will usually be higher than those given in specifications.

III. ORGANIZATION OF THE DATA

The Circular is divided into a number of sections, each devoted to the properties of one of the major industrial metals and its alloys with an additional section dealing with the less common metals and alloys. Each section is introduced by a table of the chemical compositions of some commercial materials, with applicable specification designations of various organizations. These tables are included to assist the engineer in locating specifications, but they should not be considered a complete listing of either commercial materials or specifications. Classification is made on the basis of composition, that is, alloys in which the major constituent is aluminum will be found in the aluminum section. Within each section, except in a few cases, the materials are arranged alphabetically in order of the predominating alloying

element, and the arrangement for a given predominating alloying element is in order of the increasing content of this element. No attempt has been made to include trade names of materials. Occasionally one is given if it is in general use or the composition is unknown. For a comprehensive list of trade names and corresponding compositions, reference should be made to "Engineering Alloys" by Woldman and Dornblatt [2].

The units of measurement selected comply with those which appear most frequently in American practice as determined by the inspection of numerous handbooks and other publications, with the exception of the kip (1 kip = 1,000 pounds).

Due to space limitations, it has been necessary to use a number of abbreviations, particularly in describing the condition of materials in the tables (see list on page 461). The arrangement of information is as follows: shape, size,² condition, and heat-treatment of the material tested.

Examples:

Bar, 1/2 in. diam, cold-rolled (50% red.) indicates a bar which has been reduced 50 percent in cold-rolling to a diameter of 1/2 in.

Bar, 1/2 in. diam, cast; ann 1 hr at 1,600°F indicates a cast bar, 1/2 in. in diameter, which has been annealed 1 hr at 1,600°F.

Graphical representation has been used in many cases to correlate the properties with composition, heat-treatment, or other factors. The curves have been redrawn from the original data to obtain uniformity and to assure the use of a minimum number of scales. Values may be read from the curves with sufficient accuracy for practical use.

The majority of test specimens used in the determination of the tensile data reported herein from American sources conformed to the recommendations of the American Society for Testing Materials [3].

²Not size of specimen.

The values have been rounded off somewhat, for example, stresses above 100 kips/in.² are reported to the nearest kip per square inch; similarly, elongation and reduction-of-area values above 10 percent are reported to the nearest 1 percent.

IV. DEFINITIONS AND DISCUSSION

The following definitions govern the use of terms in this Circular.

1. STRESS

The stress at a point in a body is the intensity of the internal force or component of force which acts on a given plane (area) through the point. Stress is expressed as force per unit of area (kips per square inch, etc.) and is usually referred to the original, unstressed area.

The stress or component of stress acting normal to a given area is called the tensile or the compressive stress on the area. The stress or component of stress acting tangential to a given area is called the shearing stress on the area.

In general, the values of six components of stress, three normal stresses, and three shearing stresses, referred to some definite set of coordinate axes, are necessary for the complete description of the state of stress at a point in a body.

2. STRAIN

A linear strain at a point in a body is the change per unit of length of a linear dimension through the point. A shearing strain at a point in a body is the change (expressed in radians) in a right angle at the point. Strain is a nondimensional quantity, but it is sometimes reported as "inches per inch," etc. When a linear strain is produced by forces acting on the body, it is called a tensile or compressive strain.

In general, the values of six components of strain, three linear strains, and three shearing strains, referred to some definite set of coordinate axes, are necessary for

the complete description of the state of strain at a point in a body. When conditions are such that the complete state of strain is known when one component of strain is known, it is usual to call that component of strain "the strain." This is the case in the ordinary tensile, compressive, and torsional test.

3. STRESS-STRAIN DIAGRAM

A stress-strain diagram is a diagram in which corresponding values of stress and strain are plotted against each other. It is the custom to plot values of strain as abscissas and corresponding values of stress as ordinates.

4. YIELD POINT

The yield point is a stress less than the maximum attainable stress, at which an increase in strain, or yielding, occurs without an increase in stress. Only certain materials exhibit this phenomenon, notably the mild steels. For some materials, as load is applied, first yielding is followed by a marked decrease in stress and considerable yielding at this approximately constant lower stress. For these materials a distinction may be made between "upper" and "lower" yield points.

There are three methods in general use for the determination of the yield points: The drop-of-the-beam method, the total-strain method with dividers, and the total-strain method with an extensometer. In materials having an upper and a lower yield point, it is usually the upper yield point that is determined by these methods.

Occasionally values for yield point have been reported in the literature for materials the stress-strain diagrams of which are smooth and of gradual curvature in the region of the yield point reported. The term, unless qualified as to the method of determination, is practically meaningless for such materials.

In the tables in this Circular, yield points have been listed in the column headed "Yield strength," but they have been identified as yield points.

5. YIELD STRENGTH

The yield strength is a stress less than the maximum attainable stress, at which the ratio of stress to strain has dropped well below its value at low stresses. It is not an inherent property of the material,³ like yield point, and it is necessary to specify the yield strength in an arbitrary manner. There are three common methods by which this has been done: The "set method," the "offset method," and the "extension-under-load method."

In the set method the yield strength is specified as the stress at which upon removal of load the material exhibits a specified permanent set, that is, permanent strain. In practice, the yield strength, when so specified, is determined with the aid of an extensometer. A suitable, small initial load is applied to a specimen of the material, and the extensometer is read. Higher loads are then applied in suitable steps, and after each such load the load is reduced to the initial load and the extensometer read again. When this extensometer reading exceeds the initial reading by an amount indicating the specified permanent set, the maximum stress produced prior to the final extensometer reading is recorded as the yield strength.

In the offset method the yield strength is specified as the stress at which strain exceeds by a specified amount the strain which would be produced if the ratio of stress to strain remained constant and equal to its value at low stresses. When so specified, the yield strength is determined from a stress-strain diagram, figure 1. At a specified offset, Om , (usually 0.1 or 0.2 percent) a line mn is drawn parallel to OA , the approximately straight, initial portion of the stress-strain diagram. The stress corresponding to the intersection r of mn with the stress-strain diagram is taken as the yield strength. In figure 1, Rr is parallel to the axis of strain, and OR is the yield strength.

In the extension-under-load method the yield strength is specified as the stress

³Except for materials having a yield point. For such materials the yield strength would be the yield point or lower yield point.

at which a specified strain is reached. In determining a yield strength so specified, the load is increased until the specified strain (most commonly 0.5 percent) is reached, and the corresponding stress is recorded as the yield strength.

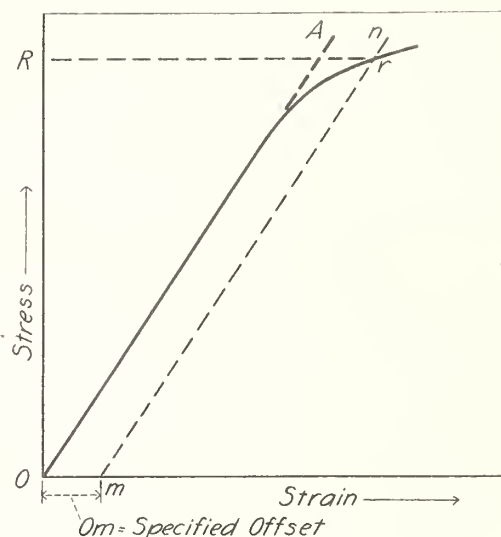


FIGURE 1.—Stress-strain diagram.

The American Society for Testing Materials [3] considers the yield strength to be "the stress at which a material exhibits a specified limiting permanent set." It has ordinarily been assumed that the stress producing a permanent set of the order of 0.2 percent or more was approximately equal to the stress corresponding to an offset of the same amount. However, Smith [5], has shown that for certain hard-drawn copper alloys the stress producing a 0.2-percent permanent set may be appreciably higher than the stress corresponding to an offset of 0.2 percent. It is known that for some materials, for very small values of set and offset, the stress producing a given set is not even approximately equal to the stress corresponding to an offset of the same value. If the extension-under-load method is used as a measure of permanent set, it is recognized as only approximate. This method is so used only for limited types of materials the stress-strain characteristics of which are well known from previous tests of similar material for which stress-strain diagrams were

plotted. Specifications for a number of copper alloys are written on this basis.

In this Circular the values reported for yield strength have been distinguished as determined by permanent set, offset, or extension-under-load, if this information was available. Where the method was not given specifically in the literature, the values were sometimes given as yield strength at a certain percentage, thus, yield strength (0.2%), and they are so reported here. In other cases, where no further information was given, they are reported simply as yield strength.

6. "PROPORTIONAL LIMIT"

The "proportional limit" is defined by the American Society for Testing Materials [3] as "the greatest stress which a material is capable of developing without a deviation from the law of proportionality of stress to strain (Hooke's Law)."

Many experiments have shown that for ordinary structural materials no such definite limit exists. All known structural metals have curved stress-strain diagrams, and the values of proportional limit determined from them will depend on the minimum departure from a straight line that can be detected by the methods used. Templin [4], for example, has shown how widely the proportional limit determined from stress-strain diagrams varies with the sensitivity and accuracy of the testing equipment used, the eccentricity of loading, the scale on which the stress-strain diagram is plotted, and other factors.

The proportional limit as usually determined may be regarded as a special value of the yield strength determined by the offset method for a low value of offset.

If particular importance is to be attached to values of the proportional limit, the original references should be consulted for the details of the method and the equipment used in determining them. If these details are not given, the values can only represent an indefinite upper limit beyond which the material definitely showed indications of departure from Hooke's Law.

7. ELASTIC LIMIT

The elastic limit is the greatest stress to which a material may be subjected without developing a permanent set upon removal of the load.

It is questionable whether such a definite limit exists in ordinary structural materials. The value determined by measuring the set may vary widely depending on the sensitivity and accuracy of the strain gage used to measure first permanent set.

The elastic limit as usually determined may be regarded as a special value of the yield strength determined by the set method for a low value of set.

Since practically no distinction between elastic limit and proportional limit can be made, the elastic limit has been reported in the column of proportional limits. If particular importance is to be attached to values of the elastic limit, the original references should be consulted for the details of the method and the equipment used in determining them. If these details are not given, the values can only represent an indefinite upper limit beyond which the material definitely showed indications of inelastic behavior.

8. TENSILE, COMPRESSIVE, OR SHEARING STRENGTH

The tensile, the compressive, or the shearing strength is the maximum stress that can be developed in the respective test, the load being referred to the original cross-sectional area.

9. ELONGATION

In tensile testing the elongation of a specimen is the increase in gage length, after rupture, referred to the original gage length. It is reported as percentage elongation.

The standard round tensile specimen used in the United States has a diameter of $0.500 \pm .01$ in. and a gage length of 2 in. Values of elongation determined on round specimens larger or smaller than this size are not directly comparable

unless they have gage lengths equal to 4 times the diameter, equivalent to $4.5\sqrt{\text{cross-sectional area}}$. Even when these dimensionally similar specimens are used, the values determined from undersized specimens may differ considerably from those determined on specimens of standard size. Tensile specimens used in foreign countries have different relationships between the gage length and the cross-sectional area, and values of elongation reported in this Circular are not comparable with values reported for American standard specimens. Specimens of sheet and plate usually have gage lengths of 2 or 8 in., and values of elongation obtained on these materials are seldom directly comparable.

In this Circular the gage length, if available, is given in the column of elongations, thus, $4\sqrt{\text{area}}$, which indicates a gage length equal to 4 times the square root of the original cross-sectional area. If no gage length is indicated, none appeared in the original reference.

10. REDUCTION OF AREA

In tensile testing the reduction of area of a specimen is the ratio of the difference between the original cross-sectional area of the specimen and the cross-sectional area after rupture, to the original cross-sectional area. It is reported as the percentage reduction of area.

Values of reduction of area on specimens of different sizes are more nearly comparable than are values of elongation. Measurement of reduction of area is difficult and uncertain on sheet and plate material and values are seldom reported.

11. MODULUS OF ELASTICITY

The tangent modulus of elasticity at any given stress is the slope of the stress-strain diagram at that stress.

The secant modulus of elasticity at any given stress is the ratio of that stress to the corresponding strain.

The moduli of elasticity ordinarily reported are either tangent moduli at zero

stress or secant moduli determined from the nearly straight, lower portion of the stress-strain diagram. These differ so little for ordinary engineering purposes that they may be considered identical and are commonly called "the modulus of elasticity." No distinction between them is made in this Circular.

Two different moduli of elasticity are ordinarily reported: The modulus of elasticity in tension or compression, also called Young's modulus; and the modulus of elasticity in shear, also called the modulus of rigidity. The moduli of elasticity in tension and compression are the same or not significantly different for most metals. The modulus of elasticity in shear is ordinarily determined from a torsional test on a round bar or tube. When so determined, the modulus of elasticity in shear is obtained from the formula

$$G = \frac{T}{J \theta},$$

where

G = modulus of elasticity in shear,

T = applied torque,

θ = angle of twist in radians, per unit of length,

J = torsional constant of the section, which in the case of a solid or hollow circular section is the polar moment of inertia of the cross-sectional area with respect to the axis of the specimen.

By plotting test values of T against θ , G is obtained as the slope of the nearly straight portion of the curve, divided by J .

12. POISSON'S RATIO

The elongation or shortening of a bar under axial stress is accompanied by a reduction or an increase, respectively, of the lateral dimensions. The ratio of the lateral strain to the corresponding axial strain is known as Poisson's ratio.

In an isotropic material, for small strains where the stress is practically

proportional to the strain, the following theoretical relation exists.

$$\mu = \frac{E}{2G} - 1,$$

where

μ = Poisson's ratio,

E = modulus of elasticity in tension or compression,

G = modulus of elasticity in shear.

13. BENDING STRENGTH

The strength of a material in bending is usually computed from the beam formula,

$$S = \frac{Mc}{I},$$

where

S = modulus of rupture,

M = maximum bending moment that can be sustained,

c = distance from the neutral axis to the extreme fiber,

I = moment of inertia of the cross-sectional area with respect to the neutral axis.

The modulus of rupture is thus a nominal stress, the nominal maximum stress in the specimen at failure, since the beam formula is based on the assumption that stress is proportional to strain, whereas this assumption is usually far from valid under conditions at failure. The actual maximum stress at failure may be much smaller than the modulus of rupture.

A bending test is frequently used in the testing of brittle materials. As applied to cast iron, specimens are cast, or cast slightly oversize and skin machined, to 0.875, 1.20, or 2.00 in. in diameter and tested under central loading between supports 12, 18, or 24 in. apart, respectively. For a round bar tested under central loading

$$\text{Modulus of rupture} = \frac{2.55 \times \text{maximum load} \times \text{span}}{(\text{diameter})^3}.$$

14. TORSIONAL STRENGTH

The strength of a material in torsion is usually determined from a torsional

test of a round solid or hollow specimen, and the strength is computed from the torsional formula for circular sections

$$S_t = \frac{M_t}{S_t},$$

where

S_t = modulus of rupture in torsion,

M_t = maximum torsional moment that can be sustained,

S_t = torsional section factor of the cross section, which in the case of a solid or hollow circular cylinder is equal to the polar moment of inertia divided by the radius or outer radius of the section.

As in the case of bending, the modulus of rupture in torsion is a nominal stress, the nominal maximum shearing stress in the specimen at failure, since the torsional formula is based on the assumption that stress is proportional to strain, whereas this assumption is usually far from valid under conditions at failure. The actual maximum shearing stress at failure may be much smaller than the modulus of rupture in shear. For a solid round bar

$$\text{Modulus of rupture in shear} = \frac{5.09 \times \text{maximum torque}}{(\text{diameter})^3}.$$

For round solid specimens of ductile materials a "torsional strength" is sometimes computed from the formula

$$S_T = 3/4 \frac{M_T c}{J},$$

where

S_T = "torsional strength,"

M_T = maximum torsional moment that can be sustained,

c = radius of the specimen,

J = polar moment of inertia of the cross-sectional area with respect to the axis of the specimen.

This formula assumes that at failure all the material in the specimen is equally stressed in shear. The "torsional strength" so computed will be smaller than the actual maximum shearing stress in the specimen at failure, but experiments indicate that it

differs less from the shearing strength determined by other methods than the modulus of rupture in shear determined from a solid specimen. This torsional strength may be expressed as

$$S_T = \frac{3.82 \times \text{maximum torque}}{(\text{diameter})^3}.$$

15. ENDURANCE LIMIT

The endurance limit is the stress below which a material will withstand an indefinitely large number of cycles of stress without failure. At present, it is generally believed that most ferrous materials have true endurance limits, that is, limits below which "fatigue-failure" will not occur. Most nonferrous metals are believed not to have true endurance limits, and the property may be expressed only as a function of the number of cycles to which the test has been carried. Generally, the minimum number of cycles used for endurance-limit determinations on ferrous materials reported in this circular was 10,000,000. If available, the number of cycles to which tests on nonferrous materials were carried has been included thus: (10⁶) indicates that the results are based on 100,000,000 cycles of stress.

Moore and Kommers [6] have classified the methods of performing endurance tests according to the type of stress as follows: (a) Flexural, (b) axial, and (c) torsional.

Unless otherwise stated, the endurance limits given in this Circular were determined for cycles of flexural stress on unnotched, polished specimens.

16. HARDNESS

The term "hardness" as used in this Circular is the resistance of a material under load to plastic deformation by indentation. Hardness numbers, which are measures of this type of hardness, are reported here in one of four systems, (a), (b), (c), (d), as follows:

(a) Brinell Number

The test for determining the Brinell number of metallic materials consists in

applying a known load for a specified time to the surface of the material to be tested through a hardened steel ball of known diameter. The diameter of the resulting permanent impression in the metal is measured. The Brinell number in kilograms per square millimeter is calculated as follows:

$$\text{Brinell number} = \frac{P}{\pi \frac{D}{2} (D - \sqrt{D^2 - d^2})},$$

where

P = applied load in kilograms,

D = diameter of the ball in millimeters,

d = diameter of the ball impression in millimeters.

A ball 10 mm in diameter and a load of 3,000 kg for hard materials and 500 kg for soft materials is standard practice. If other than a 10-mm ball or a load of 3,000 kg is used, it should be specifically stated.

(b) Vickers Number

The principles involved in testing by the Brinell and Vickers methods are practically identical. In the Vickers method, the indenter is a diamond, cut and polished to the shape of a square-based pyramid with an angle of 136° between pairs of opposite faces. The load applied for a specified time (usually 10 seconds) may be varied from 1 to 120 kg. For uniform (not case-hardened) materials, Vickers numbers are almost constant, regardless of the load applied. The Vickers and the 3,000-kg Brinell numbers on steels are practically identical up to a hardness number of about 300.

(c) Rockwell Number

The Rockwell hardness tester is essentially a machine that measures hardness by determining the difference of the depth of penetration under a minor and a major load of a steel ball or a spheroconical diamond point (Brale) into the specimen under certain arbitrary, fixed conditions of test. The hardness is expressed as a number that is derived by subtracting this difference

from an arbitrary constant. The following scales have been adopted by the American Society for Testing Materials [3]:

Scale	Penetrator	Major load	Scale used for readings
		kg	
A.....	Diamond (Brale)....	60	Black.
B.....	1/16-in. ball.....	100	Red.
C.....	Diamond (Brale)....	150	Black.
D.....	...do.....	100	Do.
E.....	1/8-in. ball.....	100	Red.
F.....	1/16-in. ball.....	60	Do.
G.....	...do.....	150	Do.
H.....	1/8-in. ball.....	60	Do.
K.....	...do.....	150	Do.
L.....	1/4-in. ball.....	60	Do.
M.....	...do.....	100	Do.
P.....	...do.....	150	Do.
R.....	1/2-in. ball.....	60	Do.
S.....	...do.....	100	Do.
V.....	...do.....	150	Do.

The Rockwell superficial hardness test is similar to the regular Rockwell test but is used where shallow penetration is desired, as on thin sheet, or to determine surface hardness. The scales are designated as follows:

Scale	Penetrator	Major load
		kg
15N.....	Diamond (N Brale).....	15
30N.....	...do.....	30
45N.....	...do.....	45
15T.....	1/16-in. ball.....	15
30T.....	...do.....	30
45T.....	...do.....	45

(d) Scleroscope Number

In the scleroscope test the height of rebound of a diamond-pointed hammer falling freely on the object from a fixed height is measured. The number is read on an empirical scale on which the average number of quenched high-carbon steel equals 100.

(e) Hardness Conversion

Since different distributions of stress and different amounts of cold-work are

produced by the different methods of determining hardness numbers, no conversion tables can be prepared that will accurately convert readings on all materials in one system under one load to readings on the same materials in another system or the same system under another load.

For some limited classes of materials, conversion tables between systems accurate enough for most practical purposes have been determined. Available conversion tables are listed later (see pages 72 and 168).

Petrenko [7] developed a number of equations for conversion from Brinell to Rockwell numbers that will give results with an error not greater than ± 10 percent. These equations are

$$\text{Brinell number} = \frac{7300}{130 - R_B}$$

for values of R_B greater than 40 and less than 100,

$$\text{Brinell number} = \frac{1,520,000 - 4500 R_C}{(100 - R_C)^2}$$

for values of R_C greater than 10 and less than 40,

$$\text{Brinell number} = \frac{25,000 - 10(57 - R_C)^2}{100 - R_C}$$

for values of R_C greater than 40 and less than 70,

$$\text{Brinell number} = \frac{3710}{130 - R_B}$$

for values of R_B greater than 30 and less than 100.

In this Circular, unless otherwise marked, the numbers are Brinell numbers. For numbers other than Brinell, the following abbreviations are used:

R_B , R_C , etc...Rockwell B number, Rockwell C number, etc.

S.....Scleroscope number.

V.....Vickers number.

17. IMPACT VALUE

Impact testing is used frequently to compare various materials or to determine the effects of temperature or other factors

on a metal. The test, which is an indication of the brittleness or notch-sensitivity of a material, consists usually of the determination of the energy absorbed in breaking a notched specimen by a single blow. The results of the test are stated only in terms of impact value, indicative of the total energy to break a standard specimen by a single blow under standard conditions and should not be generalized and applied quantitatively to other sizes of test specimens or other conditions. Although there are a number of methods of performing the impact test, those in general use are (a) simple-beam test (Charpy), and (b) cantilever-beam test (Izod).

Impact values are generally reported herein as determined by the Charpy method (unmarked) or by the Izod method (prefixed Iz) on standard notched specimens. A number of European tests are reported as notch-impact value in meter- or centimeter-kilograms per square centimeter and have not been converted to the customary American unit (foot-pounds).

18. ERICHSEN VALUE

The Erichsen test for forming quality is conducted by supporting a sample of sheet metal on a circular ring and deforming the sample at the center of the ring by a spherically pointed tool. The depth of the impression (or cup) in millimeters at fracture is the Erichsen value of the material and is indicative of the forming qualities.

19. BEND NUMBER

The bend number is the number of reversed bends through a specified angle (usually 90°) about a specified radius to which a specimen can be subjected without fracture.

In this Circular when bend numbers are reported without the radius of bend, this information was not available.

20. CREEP STRENGTH (LONG-TIME TENSILE STRENGTH)

The creep test is used to determine the combined effect of time, temperature,

and stress on the flow of a material. As usually conducted, the rate of flow is determined for a constant temperature and stress. A strain-time curve plotted for most metals shows three stages; an initial rapid but decreasing creep rate is followed by a period of approximately constant rate which eventually increases until failure occurs. In general, the rate during the second period is used to determine the "creep rate" for a given stress, and the test is usually discontinued after this rate has been established. In American practice, creep rates are commonly reported as percentage elongation per thousand hours based on a secondary period of at least several hundred hours. Although several short-time tests have been developed in Europe to determine creep rate, they have not been accepted in this country, and no results based on these tests are included in this Circular.

Creep characteristics may be influenced by many factors, among which are melting practice, chemical composition, heat-treatment, and grain size. Material of the same composition will not necessarily have the same creep characteristics. In using these data, the engineer should be particularly cautious in assuming that the rates will continue unchanged for periods as long as 10 or more times the test period and that the same rates of creep occur under conditions of combined stress as occur during a straight tensile test.

With the exception of the data for tin and zinc, the creep results reported herein are based on the rate per thousand hours and the duration of the test is usually given.

21. COEFFICIENT OF LINEAR THERMAL EXPANSION

The coefficient of linear thermal expansion of a substance is the ratio of the change of length per unit length to the change of temperature. For short ranges,

the following equation may be used to determine changes of length:

$$L_t = L_b [1 + \alpha(t-b)],$$

where

L_t = length at temperature t ,
 L_b = length at the base temperature b ,
 α = coefficient of expansion.

22. ELECTRICAL CONDUCTIVITY

The electrical conductivity is the quantity of electricity transferred across a unit area, per unit potential gradient, per unit of time. Electrical conductivities are reported in this Circular as percentage International Annealed Copper Standard (IACS).

An International standard of resistivity was adopted by the International Electrotechnical Commission in 1913, in which the standard resistivity of annealed copper is 0.15328 ohm per meter gram at 20°C (68°F), or based on the standard density of 8.89 grams per cubic centimeter at 20°C (68°F), 1.7241 microhm centimeters at 20°C (68°F). These are equivalent to a conductivity of 58.00×10^4 reciprocal ohm centimeters, or 100 percent IACS. Excepting for copper conductors, conductivities are generally expressed in terms of dimensions rather than weight. The values reported are volume conductivities based on the standard resistivity of copper at 20°C (1.7241 microhm centimeters). If the resistivity was determined at some temperature other than 20°C, the percentage IACS is reported thus, 25 percent (65°C). This indicates that although the conductivity is referred to the 20°C standard value, the resistivity was determined at 65°C.

23. ELECTRICAL RESISTIVITY OR SPECIFIC RESISTANCE (RECIPROCAL OF CONDUCTIVITY)

The electrical resistivity or specific resistance is the resistance of a unit cross section and a unit length of a material. It is reported in this Circular as microhm centimeters.

24. TEMPERATURE COEFFICIENT OF ELECTRICAL RESISTIVITY

The temperature coefficient of electrical resistivity is the ratio of the change in resistivity in a material due to a unit change in temperature to its resistivity at a base temperature. For short ranges the following equation may be used to determine changes in resistivity:

$$R_t = R_b [1 + \alpha(t-b)],$$

where

R_t = resistivity at a temperature t ,
 R_b = resistivity at a base temperature b ,
 α = coefficient of resistivity.

25. THERMAL CONDUCTIVITY

Thermal conductivity may be defined as the time rate of transfer of heat by conduction, through a unit thickness, across a unit area, for a unit difference in temperature. It is reported in this Circular as watts per centimeter for a difference in temperature of 1°C

$$\left(\frac{\text{watt-cm}}{\text{cm}^2 \text{ } ^\circ\text{C}} \right).$$

26. TEMPERATURE COEFFICIENT OF THERMAL CONDUCTIVITY

The temperature coefficient of thermal conductivity is the ratio of the change in thermal conductivity in a material due to a unit change in temperature to its thermal conductivity at a base temperature. For short ranges the following equation may be used to determine changes in thermal conductivity:

$$K_t = K_b [1 + \alpha(t-b)],$$

where

K_t = thermal conductivity at temperature t ,
 K_b = thermal conductivity at a base temperature b ,
 α = coefficient of thermal conductivity.

27. HEAT-TREATING TERMS

The following definitions were selected as being applicable to this Circular from

the glossary prepared by a joint committee on definitions, consisting of representatives of the American Society for Metals, Society of Automotive Engineers, American Foundrymen's Association, and the American Society for Testing Materials [8].

(a) *Aging*

A change in a metal by which its structure recovers from an unstable condition produced by quenching (quench aging) or by cold-working (strain aging). The change in structure consists in precipitation, often submicroscopic, and is marked by a change in physical properties. Aging which takes place slowly at room temperature may be accelerated by a slight increase in temperature. (See also *Precipitation Hardening*, p.14)

(b) *Annealing*

A process involving heating and cooling applied usually to induce softening. The term is also used to cover treatments intended to:

1. Remove stresses,
2. Alter mechanical or physical properties,
3. Produce a definite microstructure, and
4. Remove gases.

(c) *Austempering*

A trade name for a patented heat-treating process consisting in quenching an iron-base alloy from a temperature above the transformation range in a medium having a suitably high rate of heat abstraction, and maintained until transformation is complete, at a substantially uniform temperature which is below that of pearlite formation and above that of martensite formation.

(d) *Carburizing*

A process in which carbon is introduced into a solid iron-base alloy by heating above the transformation temperature range while in contact with a carbonaceous material which may be a solid, liquid, or gas.

Carburizing is frequently followed by quenching to produce a hardened case.

The term *Carbonizing* is sometimes used erroneously in place of *Carburizing*.

(e) *Case*

The surface layer of an iron-base alloy which has been suitably altered in composition and made substantially harder than the interior or core by a process of case-hardening.

(f) *Case-Hardening*

A process of surface hardening involving a change in composition of the outer layer of an iron-base alloy, followed by appropriate thermal treatment.

(g) *Core*

The interior portion of an iron-base alloy which, after case-hardening, is substantially softer than the surface layer or case.

(h) *Flame-Hardening*

A process of heating the surface layer of an iron-base alloy above the transformation temperature range by means of the flame of a high-temperature torch, followed by quenching.

(i) *Full-Annealing*

A softening process in which an iron-base alloy is heated to a temperature above the transformation range and after being held for a proper time at this temperature is cooled slowly to a temperature below the transformation range. The objects are ordinarily allowed to cool slowly in the furnace, although they may be removed from the furnace and cooled in some medium which reduces the rate of cooling.

(j) *Graphitizing*

An annealing process applied to certain iron-base alloys, such as gray cast iron or some steels with high carbon and silicon contents, by which the combined carbon is wholly or in part transformed to graphitic or free carbon.

(k) *Hardening*

Any process of increasing hardness by suitable treatment, usually involving heating and cooling.

(l) *Heat-Treatment*

A combination of heating and cooling operations applied to a metal or alloy in the solid state to obtain desired conditions or properties. Heating for the sole purpose of hot-working is excluded from the meaning of this definition.

(m) *Homogenizing*

A high-temperature heat-treatment process intended to eliminate or decrease chemical segregation by diffusion.

(n) *Hot-Quenching*

A process of quenching iron-base alloys in a medium, the temperature of which is substantially higher than atmospheric.

(o) *Inverse-Annealing*

A heat-treatment, analogous to *Precipitation Hardening*, applied to cast iron to increase its hardness and strength.

(p) *Malleablizing*

A process of annealing white cast iron in which the combined carbon is wholly or in part transformed to graphitic or free carbon, and, in some cases, part of the carbon is removed completely.

(q) *Nitriding*

A process of case-hardening in which an iron-base alloy of special composition is heated in an atmosphere of ammonia or in contact with nitrogenous material. Surface-hardening is produced by the absorption of nitrogen without quenching.

(r) *Normalizing*

A process in which an iron-base alloy is heated to a temperature above the transforming range and subsequently cooled in still air at room temperature.

(s) *Patenting*

A process of heat-treatment applied to medium or high-carbon steel in wire making between wire drawings. It consists in heating to a temperature above the transformation range, followed by cooling to a temperature below that range in air or in a bath of molten lead or salt maintained at a temperature appropriate to the carbon content of the steel and the properties required of the finished product.

(t) *Precipitation-Hardening*

A process of hardening an alloy by reheating it to allow a structural constituent to precipitate from a solid solution. (See also *Aging*.)

(u) *Process-Annealing*

A process commonly applied in the sheet and wire industries, in which an iron-base alloy is heated to a temperature close to, but below, the lower limit of the transformation range and subsequently cooled.

(v) *Quenching*

A process of rapid cooling from an elevated temperature, by contact with liquids, gases, or solids.

(w) *Solution Heat-Treatment*

A treatment in which an alloy is heated to a suitable temperature and held at this temperature for a sufficient length of time to allow a desired constituent to enter into solid solution, followed by rapid cooling to hold the constituent in solution. The material is left in a state of unstable equilibrium, and if reheated, may undergo *Precipitation-Hardening*.

(x) *Stress-Relieving*

A process to reduce internal residual stresses in a metal object by heating the object to a temperature below the transformation range and holding it for a proper time at that temperature. This treatment may be applied to relieve stresses induced

by casting, quenching, normalizing, machining, cold-working, or welding.

(y) *Tempering*

A process of reheating hardened or normalized steel to a temperature below the transformation temperature range, followed by any desired rate of cooling.

(z) *Transformation Range*

The transformation range on heating is the temperature interval in which austenite forms in an iron-carbon alloy. The transformation range on cooling is the temperature interval in which austenite disappears. Distinction must be made between the two ranges. They may overlap but never coincide. The limiting temperatures of the ranges depend on the composition of the alloy and, particularly for the cooling, on the rate of change of temperature.

28. POWDER METALLURGY TERMS

The following definitions of terms relating to powder metallurgy were selected from the glossary issued by the American Society for Metals [9] as being applicable to this Circular.

(a) *Compact*

An object produced by the compression of individual, mixed, or alloyed metal powders with or without the inclusion of non-metallic constituents.

(b) *Growth*

The increase in dimensions of a compact which occurs during sintering.

(c) *Hot-Pressing*

The simultaneous forming and heating of a compact.

(d) *Mesh*

The screen number of the finest screen of a specified standard screen scale through which all particles of a powder sample will

pass. Frequently, but not necessarily, a part of the sample may pass finer screens.

(e) *Mesh-Fraction*

That part of a metal powder passing a specified mesh screen and retained by some finer stated size.

(f) *Minus Mesh or Through*

The portion of a powder sample which passes through a stated screen. (See also *Plus Mesh*.)

(g) *Mixing*

The thorough intermingling of particles of two or more powders.

(h) *Particle Size*

The controlling lineal dimensions of an individual particle as determined by analysis with screens or other suitable instruments.

(i) *Particle-Size Distribution*

The percentages expressed in terms of weight of the various sizes of particles in a powder sample when classified in terms of size ranges and measured in terms of screen mesh or microns.

(j) *Plus Mesh or Oversize*

The particles of a powder sample retained on a screen of stated size. (See also *Minus Mesh*.)

(k) *Pore*

A minute cavity in a compact formed either intentionally or unintentionally.

(l) *Porosity*

A multiplicity of pores in a compact usually distributed uniformly.

(m) *Powder*

Particles of matter in which the size and characteristics are of such an order as to make the material of use in the formation of compacts.

(n) *Powder Metallurgy*

The art of producing metal powders and shaped objects from individual, mixed, or alloyed metal powders, with or without the inclusion of nonmetallic constituents, by pressing or forming objects which are simultaneously or subsequently heated to produce a coalesced, sintered, alloyed, brazed, or welded mass, characterized by the absence of fusion or the fusion of a minor component only.

(o) *Pressing*

The forming of a compact under pressure.

(p) *Shrinkage*

The decrease in the dimensions of a compact that occurs during sintering.

(q) *Sintering*

The heating of metal powders or compacts to convert them into coalesced, alloyed, brazed, or welded masses, under controlled conditions of time, temperature, and atmosphere.

V. ALUMINUM AND ALUMINUM ALLOYS

(17)

TABLE 1.—Classification of some aluminum alloys (1942)

[Specifications are changing frequently, the sponsoring organization should be consulted for the latest revision]

Designation		Nominal composition—percent							Serial numbers of corresponding alloys in the tables			
Federal ^a	Army ^a	Navy ^a	ASTM		SAE	Alcoa	Cu	Si		Mn	Mg	Other
			spec	alloy								
WROUGHT ALLOYS—BAR, ROD, WIRE, AND SHAPES												
Q-Q-A-411.....	Federal.....	46A3.....	.....	.....	25	2S	.....	.....	.....	.....	Al 99 (minimum).....	10 to 13, inclusive; 285, 411; figures 4, 18, 19.
Q-Q-A-356.....	do.....	46A6.....	.....	.....	29	3S	.....	.....	1.2	.....	.....	179 to 185, inclusive; figure 26.
Q-Q-A-351.....	Federal.....	46A4.....	B89-41T	.....	26	17S	4.0	5.5	0.5	0.5	Pb 0.5, Bi 0.5.....	39, 40.
25826 ^b	.....	43R5.....	.....	.....	.....	A17S	2.5	.....	.....	.....	.....	54, 76, 80, 81; figure 21.
Q-Q-A-354.....	Federal.....	46A9.....	Federal.....	.....	24	24S	4.5	.....	.....	1.5	Cr 0.25.....	75, 76, 80, 81; figure 21.
.....	.....	46A10.....	.....	.....	201	52S	.....	.....	.....	2.5	Cr 0.25.....	149, 150, 151.
Q-Q-A-331.....	Federal.....	46A10.....	.....	.....	.....	53S	.....	.....	0.7	.....	Cr 0.25.....	134 to 139, inclusive; figure 25.
WROUGHT ALLOYS—SHEET AND PLATE												
Q-Q-A-561.....	57-151-1.....	47A2.....	B25-41T	.....	25	2S	.....	.....	.....	.....	Al 99 (minimum).....	4 to 9, inclusive; 14, 329; figure 3.
Q-Q-A-359.....	Federal.....	47A4.....	{ B79-41T B12C-40T }	.....	29	3S	.....	.....	1.2	.....	.....	178, 319, 320, 367.
Q-Q-A-353.....	do.....	47A3.....	B78-41T	.....	26	17S	4.0	.....	0.5	0.5	.....	63, 64, 65, 287, 288, 290, 291.
Q-Q-A-355.....	do.....	47A10.....	.....	.....	24	24S	4.5	.....	.....	1.5	.....	82, 83, 85, 86, 302, 303.
Q-Q-A-318.....	do.....	47A11.....	B109-41T	.....	201	52S	.....	.....	.....	2.5	Cr 0.25.....	147, 311, 312.
Q-Q-A-334.....	do.....	47A12.....	.....	.....	.....	53S	0.25	0.6	0.7	.....	Cr 0.25.....	Properties similar to 53S above.
11326 ^b	.....	.....	.....	.....	.....	61S	.....	.....	.....	1.0	Cr 0.25.....	131, 132, 133.
FORGING ALLOYS												
Q-Q-A-367.....	Federal.....	46A7.....	.....	.....	.....	14S	4.4	0.8	0.8	0.4	.....	78, 79; figure 23.
Q-Q-A-367.....	do.....	46A7.....	.....	.....	26	17S	4.0	.....	.....	.....	.....	62, 73.
Q-Q-A-367.....	do.....	46A7.....	.....	.....	.....	18S	4.0	.....	.....	.....	Ni 2.0.....	98, 276.
Q-Q-A-367.....	do.....	46A7.....	.....	.....	27	25S	4.5	.....	.....	.....	.....	90, 92, 305, 423, 424.
Q-Q-A-367.....	do.....	46A7.....	.....	.....	.....	32S	0.9	12.5	.....	1.0	Ni 0.9.....	244, 282, 477, 478.
Q-Q-A-367.....	do.....	46A7.....	.....	.....	.....	A51S	.....	.....	1.0	.....	Cr 0.25.....	237, 453, 454.
Q-Q-A-367.....	do.....	.....	.....	.....	280	.....	.....	.....	.....	.....	.....	266.
SAND-CASTING ALLOYS												
Q-Q-A-601.....	AN-Q-Q-A-405.....	AN-Q-Q-A-405.....	B26-41T	JJ	35	43	.....	.....	5.0	.....	.....	203, 378, 457, 458.
Q-Q-A-601.....	.....	.....	B26-41T	.....	45	45	.....	.....	10.0	.....	.....	206, 383, 475.
Q-Q-A-601.....	.....	.....	B26-41T	K	37	47	.....	.....	12.5	.....	.....	208, 209, 387, 479.
Q-Q-A-601.....	.....	.....	B26-41T	.....	.....	108	4.0	3.0	.....	.....	.....	108, 109, 110, 345, 418, 419.
Q-Q-A-601.....	.....	.....	B26-41T	.....	33	112	7.0	.....	.....	.....	Zn 1.7, Fe 1.2.....	128, 431 to 434, inclusive.
Q-Q-A-601.....	.....	.....	B26-41T	F	34	122	10.0	.....	.....	0.2	Fe 1.2.....	46, 47, 48, 279.
Q-Q-A-601.....	AN-Q-Q-A-379.....	AN-Q-Q-A-379.....	B26-41T	H	39	142	4.0	.....	.....	1.5	Ni 2.0.....	59, 100, 101, 106, 274, 296, 344.
Q-Q-A-601.....	AN-Q-Q-A-390.....	AN-Q-Q-A-390.....	B26-41T	G	38	195	4.5	.....	.....	.....	.....	24 to 30, inclusive; 304, 415, 416.
Q-Q-A-601.....	.....	.....	B26-41T	CC	36	212	8.0	1.2	.....	.....	Fe 1.0.....	120, 121, 122.
Q-Q-A-601.....	AN-Q-Q-A-402.....	AN-Q-Q-A-402.....	B26-41T	I	320	214	.....	.....	.....	3.8	.....	154, 448.
Q-Q-A-601.....	AN-Q-Q-A-392.....	AN-Q-Q-A-392.....	B26-41T	.....	324	220	.....	.....	.....	10.0	.....	171, 176, 318, 450, 451.
Q-Q-A-601.....	.....	.....	B26-41T	.....	.....	A334	3.0	4.0	.....	0.3	.....	215, 456.
Q-Q-A-601.....	AN-Q-Q-A-376.....	AN-Q-Q-A-376.....	B26-41T	N	322	355	1.3	5.0	.....	.....	.....	219 to 223, inclusive; 322, 323, 461 to 464, inclusive.
Q-Q-A-601.....	.....	.....	B26-41T	.....	.....	A355	1.4	5.0	0.8	.....	Ni 0.8.....	227, 228.

^aRevisions not indicated.^bAir Corps specification.

TABLE 1.—Classification of some aluminum alloys (1942)—Continued

Designation			Nominal composition—percent							Serial numbers of corresponding alloys in the tables		
Federal ^a	Army ^a	Navy ^a	ASTM		SAE	Alcoa	Cu	Si	Mn		Mg	Other
			spec	alloy								
SAND-CASTING ALLOYS—Continued												
QQ-A-501.....	AN-QQ-A-394.....	AN-QQ-A-394.....	B26-41T.....	M.....	323.....	356.....	.....	7.0.....	0.3.....	.....	240, 241, 242, 325, 468 to 471, inclusive.	
.....	.....	.....	.....	.....	.....	406.....	.....	.....	2.0.....	.....	194.	
.....	.....	.....	.....	.....	31.....	645.....	2.5.....	.....	.....	Zn 11.0, Fe 1.2.....	267, 482.	
PERMANENT-MOLD CASTING ALLOYS												
QQ-A-596.....	.....	46A15.....	B108-41T.....	9A.....	35.....	43.....	.....	5.0.....	.....	.....	204, 459, 460.	
.....	.....	.....	B108-41T.....	3.....	.....	A108.....	4.5.....	5.5.....	.....	.....	230, 467.	
.....	.....	.....	.....	.....	.....	B113.....	7.0.....	1.7.....	.....	Fe 1.2.....	114, 425, 426, 427.	
.....	.....	.....	B108-41T.....	2.....	.....	C113.....	7.0.....	3.5.....	.....	Zn 2.0, Fe 1.2.....	118, 119, 429.	
.....	.....	.....	B108-41T.....	4.....	34.....	122.....	10.0.....	.....	0.2.....	Fe 1.2.....	49, 50, 51, 437, 438; figure 20.	
QQ-A-596.....	AN-QQ-A-386.....	AN-QQ-A-386.....	B108-41T.....	6.....	321.....	A132.....	0.8.....	12.0.....	1.0.....	Ni 2.5, Fe 0.2.....	249, 250, 481.	
.....	.....	.....	B108-41T.....	5.....	.....	138.....	10.0.....	4.0.....	0.2.....	Fe 1.0.....	125.	
.....	.....	.....	B108-41T.....	11.....	39.....	142.....	4.0.....	.....	1.5.....	Ni 2.0.....	102, 103, 104, 414, 417; figure 24.	
QQ-A-596.....	.....	.....	B108-41T.....	1A.....	.....	B495.....	4.5.....	2.5.....	.....	.....	112, 113.	
.....	.....	.....	.....	.....	.....	A214.....	.....	.....	3.8.....	Zn 1.8.....	156.	
QQ-A-596.....	AN-QQ-A-376.....	AN-QQ-A-376.....	.....	.....	322.....	355.....	1.3.....	5.0.....	.....	.....	224, 225, 226.	
.....	.....	.....	.....	.....	323.....	356.....	.....	7.0.....	.....	.....	243, 472, 473, 474.	
QQ-A-596.....	.....	46A15.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
DIE-CASTING ALLOYS												
QQ-A-591.....	AN-QQ-A-366.....	AN-QQ-A-366.....	B85-39T.....	V.....	305.....	13.....	.....	12.0.....	.....	.....	207, 480.	
.....	.....	.....	B85-39T.....	IV.....	304.....	43.....	.....	.....	.....	.....	205.	
.....	.....	.....	B85-39T.....	XII.....	312.....	81.....	7.0.....	3.0.....	.....	.....	117, 428.	
.....	.....	.....	.....	.....	.....	82.....	14.0.....	5.0.....	.....	.....	126.	
.....	.....	.....	B85-39T.....	VI.....	83.....	83.....	2.0.....	3.0.....	.....	.....	214, 455.	
QQ-A-591.....	AN-QQ-A-366.....	AN-QQ-A-366.....	B85-39T.....	VII.....	307.....	85.....	4.0.....	5.0.....	.....	.....	229, 465.	
.....	.....	.....	B85-39T.....	IX.....	309.....	93.....	4.0.....	2.0.....	.....	Ni 4.0.....	105, 420.	
.....	.....	.....	.....	.....	.....	218.....	.....	.....	8.0.....	.....	169, 449.	

^aRevisions not indicated.

TABLE 2.—*Symbols and conditions for heat-treatment and cold-working of aluminum alloys*

[Certain symbols are commonly used to designate tempers resulting from cold-work or heat-treatments for aluminum alloys. These symbols follow the alloy number and have been used in many cases in the tables and curves.]

Symbol	Condition	Approximate reduction by cold-work	Alloy	Solution heat-treatment		Precipitation heat-treatment	
				Temperature	Quench	Temper designation	Time of aging
0.....	Soft or annealed.....	Percent	17S.....	930 to 950	Cold water.....	.....	24 days
1/4H.....	1/4 hard.....	0	17S.....	930 to 950	...do.....	.....	24 days
1/2H.....	1/2 hard.....	21	24S.....	910 to 930	...do.....	.....	24 days
3/4H.....	3/4 hard.....	37	53S.....	960 to 980	...do.....	53S-W { 315 to 325	18 hr
H.....	Hard.....	60				or { 345 to 355	8 hr
		80	61S ^b	960 to 980	...do.....	61S-W { 315 to 325	18 hr
						or { 345 to 355	8 hr

^aMore than 90 percent of the maximum properties are obtained during the first day of aging.

^bPrecipitation heat-treatment at elevated temperatures is patented.

Other symbols used for aluminum alloys:

S Immediately following the alloy number indicates a wrought alloy.

T Indicates that the alloy is fully heat-treated and age-hardened either at room temperature or artificially aged above room temperature.

W is used only with alloys that require aging above room temperature to develop properties of the T temper, and indicates that the alloy has been subjected to the solution heat-treatment but not artificially aged.

RT Indicates that the alloy has been cold-worked after heat-treatment.

Certain modifications of the usual heat-treatments or strain-hardening processes are indicated by T and a number, as T3.

TABLE 3.—Aluminum and aluminum alloys, normal-temperature properties

[For a discussion of the indefiniteness of values reported for yield strength and particularly for "proportional limit," see pages 5 and 6. Hardness numbers are Brinell numbers unless prefixed R_p, R_c, etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed 12 (Izod method).]

Serial number	Composition	Condition	Tensile properties					Endurance Limit	Hardness number	Impact value	Miscellaneous	Reference	
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
PURE AND COMMERCIAL ALUMINUM (SEE ALSO FIGS. 2, 3, AND 4)													
1.....	Percent Si 0.0020, Cu 0.0010, Ca 0.0003, Mg 0.0003, Na 0.0003, Fe 0.0001	Sheet, 0.064 in., annealed at 390°F.	Kips/in. ²	Kips/in. ²	Kips/in. ² 1.8 (0.2% perm)	Kips/in. ² 6.9	Percent 49 (2 in.)	Percent	Kips/in. ²	17	ft-lb	Density (68°F).....2.6989.....	[12]
2.....	do.....	Sheet, 0.064 in., cold-rolled (75% red.).	.....	.....	15.4 (0.2% perm)	16.3	5.5 (2 in.)	.....	.....	27	.....	.....	[12]
3.....	Al 99.95.....	Annealed.....	.....	1.0	3.0 (0.2% offset)	9.0	60 (2 in.)	.....	.....	15	Iz 6.5	Shear str.....6.8 kips/in. ²	[13]
4.....	Cu 0.042, Si 0.0100, Fe 0.0065.....	Strip, 0.08 in., 8 hr at 660°F.	.....	.....	4.7 (0.2%)	9.2	41 (3 in.)	.....	.....	17	.....	Erichsen.....13.7 mm..... Bend No. (0.4 in. radius).....20.	[14]
5.....	do.....	Strip, 0.08 in., cold-rolled (33% red.).	.....	.....	12.1 (0.2%)	12.2	10 (3 in.)	.....	.....	26	.....	Erichsen.....11.9 mm..... Bend No. (0.4 in. radius).....13.	[14]
6.....	do.....	Strip, 0.08 in., cold-rolled (75% red.).	.....	.....	19.6 (0.2%)	20.5	6.1 (3 in.)	.....	.....	38	.....	Erichsen.....10.4 mm..... Bend No. (0.4 in. radius).....6.	[14]
7.....	Fe 0.27, Si 0.23, Cu 0.007.....	Strip, 0.08 in., 8 hr at 660°F.	.....	.....	6.1 (0.2%)	11.5	42 (3 in.)	.....	.....	20	.....	Erichsen.....13.1 mm..... Bend No. (0.4 in. radius).....17.	[14]
8.....	do.....	Strip, 0.08 in., cold-rolled (33% red.).	.....	.....	13.8 (0.2%)	15.4	14 (3 in.)	.....	.....	29	.....	Erichsen.....11.8 mm..... Bend No. (0.4 in. radius).....11.	[14]
9.....	do.....	Strip, 0.08 in., cold-rolled (75% red.).	.....	.....	23.5 (0.2%)	24.6	5.4 (3 in.)	.....	.....	47	.....	Erichsen.....9.4 mm..... Bend No. (0.4 in. radius).....4.	[14]
10.....	Al 99.5.....	Rod, 13/16 in. diam, cold-drawn and stabilized.	9,600	.....	.....	.....	.....	.....	.....	18	.....	.....	[15]
11.....	Fe 0.30, Si 0.22, Cu 0.12, Mn 0.005.....	Rod, rolled 1/2 hard.....	.....	7.5	12.0 (0.01% perm)	16.0	25 (2 in.)	75	7.3	.....	.....	.....	[17]
12.....	do.....	Rod, hard-rolled.....	.....	11.5	16.0 (0.01% perm)	20.4	18 (2 in.)	64	8.4	.....	.....	.....	[17]
13.....	Fe 0.49, Si 0.15, Cu 0.12.....	Rod, 3/4 in. diam, rolled.	10,100	11.3	.....	22.6	16 (2 in.)	65	10.5	45	19	Compressive str.....25.6 kips/in. ² Shear str.....13.8 kips/in. ² Mod-el (shear).....3,450 kips/in. ²	[19]
14.....	Fe 0.52, Si 0.15, Cu 0.12.....	Sheet, 0.020 in., hard-rolled (28-H).	9,100	12.4	.....	25.8	3.3 (2 in.)	.....	9.5 (10 ⁶)	.....	.....	.....	[20]
15.....	Al 99.0-99.5.....	Cast.....	10,000	.....	4-6	13-17 (10 diam)	18-25	40-55	.....	24-32	.....	Shear str.....10-11 kips/in. ² Mod-el (shear).....3,800 kips/in. ² Poisson's ratio.....0.36.	[21]
16.....	Al 99 +do.....	Extruded (2S)..... Wrought; annealed (2S-H).....	 10,300	..... .....	13 (0.2% perm) 5 (0.2% perm)	15 (2 in.) 13	25 (2 in.) 45 (2 in.)	..... .....	6 (5 × 10 ⁶) 5 (5 × 10 ⁶)	28 23	..... .....	Shear str.....10 kips/in. ² Comp yld str (0.2%).....5 kips/in. ² Shear str.....9.5 kips/in. ² Specific gravity.....2.71.	[22] [11]
18.....	do.....	Wrought; hard (28-H).....	10,300	.....	21 (0.2% perm)	24	15 (2 in.)	.....	8.5 (5 × 10 ⁶)	44	.....	Comp yld str (0.2%).....21 kips/in. ² Shear str.....13 kips/in. ²	[11]

ALUMINUM-COPPER ALLOYS (SEE ALSO FIGS. 5 AND 6)

19....	Cu 3.76.....	Cast.....	.....	.....	.....	12.1 (yld pnt)	21.5	10 (2 in.)	21	.....	.....	.....	[23]
20....	...do.....	Bar, 13/16 in. diam, hot-rolled.	.....	.....	.....	26.0 (yld pnt)	38.0	21 (2 in.)	50	.....	.....	.....	[23]
21....	Cu 4.0.....	Bar, sand-cast.....	10,500	.....	.....	17.5 (0.1%)	18.6	5.3 (4 $\sqrt{\text{area}}$)	.....	.....	.....	.....	[24]
22....	...do.....	Bar, sand-cast; 6 hr at 970°F, w-q, aged at r-t.	10,300	.....	.....	13.9 (0.1%)	32.7	8.7 (4 $\sqrt{\text{area}}$)	.....	.....	.....	.....	[24]
23....	Cu 4.28, Si 0.74, Fe 0.60, Mn 0.02.	Rod, 3/4 in. diam, sand-cast; 24 hr at 950°F, w-q, aged 2 hr at 212°-300°F.	9,800	.....	8.6	.....	24.4	4.0 (2 in.)	.....	.....	.....	.....	[24]
24....	Cu 4.35, Si 0.84, Fe 0.53.	Rod, 3/4 in. diam, cast; 16 hr at 960°F, w-q to 210°F (195-174).	.....	.....	.....	.....	33.5	4.5	6.5	R _E 82	.....	.....	[25]
25 ^a	Cu 4.5.....	Sand-cast; h-t (195-174).	10,300	.....	.....	16 (0.2% perm)	31	8.5 (2 in.)	.....	6	.....	.....	[11]
26 ^a	...do.....	Sand-cast; h-t and aged (195-176).	10,300	.....	.....	22 (0.2% perm)	36	5 (2 in.)	.....	6.5	.....	.....	[11]
27 ^a	...do.....	Sand-cast; h-t and aged (195-162).	10,300	.....	.....	31 (0.2% perm)	40	2 (2 in.)	.....	7	.....	.....	[11]
28....	...do.....	Sand-cast; aged 2 days at r-t.	.....	.....	.....	8.8 (yld pnt)	20.1	7.5 (2 in.)	.....	.....	46	.....	[13]
29....	...do.....	Sand-cast; 1 hr at 1,000°F, w-q, aged 2 days at r-t.	.....	.....	.....	22.6 (yld pnt)	32.2	5.5 (2 in.)	.....	.....	76	.....	[13]
30....	...do.....	Sand-cast; 8 hr at 1,000°F, w-q, aged 2 days at r-t.	.....	.....	.....	22.4 (yld pnt)	40.2	15 (2 in.)	.....	.....	74	.....	[13]
31....	Cu 4.9, Si 0.8, Fe 0.62, Mn 0.4.	Rod, 3/4 in. diam, sand-cast.	10,500	.....	4.9	.....	20.3	2.0 (2 in.)	.....	.....	.....	.....	[24]
32....	...do.....	Rod, 7/8 in. diam, sand-cast.	10,000	.....	4.7	.....	18.4	1.8 (2 in.)	.....	.....	.....	.....	[24]
33....	Cu 4.93, Si 0.84, Fe 0.62, Mn 0.03.	Rod, 7/8 in. diam, sand-cast; aged 5 days at r-t.	.....	.....	7.1	.....	28.0	3.7 (2 in.)	.....	.....	.....	.....	[24]
34....	...do.....	Rod, 7/8 in. diam, sand-cast; aged 2 hr at 300°F.	.....	.....	11.6	.....	31.1	3.0 (2 in.)	.....	.....	.....	.....	[24]
35....	...do.....	Rod, 7/8 in. diam, sand-cast; aged 20 hr at 300°F.	.....	.....	15.8	.....	35.8	1.3 (2 in.)	.....	.....	.....	.....	[24]
36....	Cu 8.0.....	Sand-cast.....	10,300	.....	.....	14 (0.2% offset)	19-22	0-2 (2 in.)	.....	7.5	.....	.....	[46]
37....	Cu 10.0, W ₂ 0.2.....	Sand-cast.....	.....	.....	.....	18	30	.....	.....	100	.....	.....	[104]
38....	Cu 11.0-13.5.....	...do.....	10,000	.....	.....	14 (0.2% perm)	24	2 (2 in.)	.....	10	.....	.....	[36]

^aReferences [10 and 11]—for all alloys, wrought and cast; modulus of elasticity (shear) 3,850 kips/in.², Poisson's ratio 0.33. ^bValues apply in general to all wrought forms except large sized extrusions; elongation applies to 1/2-in.-diameter test specimens. ^cCharpy specimen with 130° notch.

TABLE 3.—Aluminum and aluminum alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation					Reduction of area	Endurance limit
ALUMINUM-COPPER-BISMUTH-LEAD ALLOY											
39 ^a ...	Percent Cu 5.5, Bi 0.5, Pb 0.5.	Wrought; h-t and aged (11S-T3).	$k\text{tols/in.}^2$ 10,300	$k\text{tols/in.}^2$	$k\text{tols/in.}^2$ 42 (0.2% perm)	$k\text{tols/in.}^2$ 49	Percent b 14 (2 in.)	Percent t 12.5 (5 × 10 ⁶)	95	ft-lb	[11] Comp yld str (0.2%).....42 kips/in. ² Shear str.....30 kips/in. ² Specific gravity.....2.82.
40 ^a ...	...do.....	Forged; h-t and aged (11S-T).	10,300	.....	36 (0.2% perm)	57	15 (2 in.)	13 (5 × 10 ⁶)	110	.....	[11] Comp yld str (0.2%).....36 kips/in. ² Shear str.....31 kips/in. ²
ALUMINUM-COPPER-IRON ALLOYS											
41....	Cu 2.0, Fe 1.40, Ni 1.28, Mg 0.88, Si 0.64, Ti 0.095.	Cast; 2 hr at 985°F, w-q, aged 20 hr at 330°F.	.....	.....	.....	64.1	.....	23.7 (3 × 10 ⁷)	.....	.....	[37]
42....	Cu 4.0, Fe 2.1.....	Die-cast.....	.....	.....	.....	24	4	.....	53	.....	[18]
43....	Cu 8.0, Fe 1.6.....	...do.....	.....	.....	.....	32	2	.....	66	.....	[18]
44....	Cu 9.65, Fe 1.38, Si 0.39, Mg 0.28.	Rod, 7/8 in. diam, sand-cast at 1,290°F; aged 5 days at r-t.	.....	7.9	.....	20.9	1 (2 in.)	.....	.....	.....	[24]
45....	...do.....	Rod, 7/8 in. diam, sand-cast at 1,290°F; 5 hr at 925°F, w-q, aged 16 hr at 300°F and 5 days at r-t.	.....	15.0	.....	26.0	<1 (2 in.)	.....	.....	.....	[24]
46 ^a ...	Cu 10.0, Fe 1.2, Mg 0.2.	Sand-cast (122).....	10,300	.....	21 (0.2% perm)	25	0.5 (2 in.)	9.5 (5 × 10 ⁶)	85	0.6	[10] Shear str.....25 kips/in. ² Specific gravity.....2.85. Melting range.....1,005°-1,100°p.
47 ^a ...	...do.....	Sand-cast; ann (122-T2).	10,300	.....	20 (0.2% perm)	25	1 (2 in.)	9.5 (5 × 10 ⁶)	75	.....	[11] Comp yld str (0.2%).....20 kips/in. ² Shear str.....21 kips/in. ²
48 ^a ...	...do.....	Sand-cast; h-t and aged (122-T61).	10,300	.....	30 (0.2% perm)	36	1 (2 in.)	.....	100	.....	[11] Comp yld str (0.2%).....43 kips/in. ² Shear str.....29 kips/in. ²
49 ^a ...	...do.....	Chill-cast; aged (122-T52).	10,300	.....	31 (0.2% perm)	35	0.5 (2 in.)	.....	105	.....	[11] Comp yld str (0.2%).....31 kips/in. ² Shear str.....25 kips/in. ² Specific gravity.....2.89.
50 ^a ...	...do.....	Chill-cast; h-t and aged (122-T65).	10,300	.....	36 (0.2% perm)	45	0	8 (5 × 10 ⁶)	140	.....	[11] Comp yld str (0.2%).....36 kips/in. ² Shear str.....30 kips/in. ²
51 ^a ...	...do.....	Chill-cast; h-t and aged (122-T561).	10,300	.....	35	37	0	8.5 (5 × 10 ⁶)	115	.....	[11] Comp yld str (0.2%).....40 kips/in. ² Shear str.....27 kips/in. ²
ALUMINUM-COPPER-MAGNESIUM ALLOYS											
52....	Cu 1.2, Mg 0.92, Si 0.56, Mn 0.5, Ti 0.5, Fe 0.26.	Rod, 23/32 in. diam, wrought; 1 hr at 1,000°F, w-q, aged 25 hr at 295°F.	9,900	.....	40.3 (0.01% perm)	.....	.....	.....	.....	.....	[24]
53....	Cu 2.4, Mg 1.6, Ni 1.2, Si 0.7, Ti 0.06.	Extruded and aged.....	10,400	.....	26.9 (0.02%) 32.6 (0.2%)	49.7	8.5	.....	104	.....	[42]

54 ^a ...	Cu 2.5, Mg 0.3.....	Wrought; h-t and aged (A7S-T).	10,300	.....	24 (0.2% perm)	43	b ₂₇ (2 in.)	.....	13.5 (5 × 10 ⁸)	70	.....	Comp yld str (0.2%).....24 kips/in. ² Shear str.....26 kips/in. ² Specific gravity.....2.74.	[11]
55.....	Cu 3.25, Mg 0.70, Si 0.28, Fe 0.28.	Rod, 1/3 hr at 700°F, f-c.	.....	.....	6.8	25.2	25 (2 in.)	61	10.0 (10 ⁹)	50	17	.....	[38]
56.....	...do.....	Rod, 1/2 hr at 925°F, quenched and aged 2 hr in boiling water.	.....	.....	18.6	51.2	29 (2 in.)	48	12.0 (10 ⁹)	100	19	.....	[38]

ALUMINUM-COPPER-MAGNESIUM-MANGANESE ALLOYS (SEE ALSO FIGS. 7, 8, AND 9)

57.....	Cu 3.71, Mg 0.91, Mn 0.84, Fe 0.47, Si 0.42, Ti 0.01.	Rod, 19/32 in. diam, extruded.	.....	.....	.....	65.1	19 (10 diam)	.....	21.8 (2 × 10 ⁷)	.....	.....	.....	[26]
58.....	Cu 3.90, Mg 0.63, Mn 0.63, Si 0.46, Fe 0.29.	Plate, 1/2 in.; w-q from 940°F, cold- rolled 5 1/2% red. (17S-RT).	.....	.....	.....	64.5	21	29	.....	F _E 74	.....	.....	[25]
59 ^a ...	Cu 4.0, Mg 0.5, Mn 0.5.	Wrought; an (17S-0)...	10,300	.....	10	26	b ₂₂ (2 in.)	.....	11 (5 × 10 ⁹)	45	.....	Comp yld str (0.2%).....10 kips/in. ² Shear str.....16 kips/in. ² Specific gravity.....2.79.	[11]
60 ^a ...	...do.....	Wrought; h-t and aged at r-t (17S-T).	10,300	.....	40 (0.2% perm)	62	b ₂₂ (2 in.)	.....	15 (5 × 10 ⁸)	100	.....	Comp yld str (0.2%).....40 kips/in. ² Shear str.....36 kips/in. ²	[11]
61.....	...do.....	Rod, 3/4 in. diam, h-t (17S-T).	.....	32.0	.....	61.0	20 (2 in.)	37	17.0 (10 ⁸) 12.0 (10 ⁸)	118	.....	Torsion str.....45.3 kips/in. ²	[27]
62 ^a ...	...do.....	Forged; h-t and aged at r-t (17S-T).	10,300	.....	40 (0.2% perm)	62	22 (2 in.)	.....	15 (5 × 10 ⁸)	100	.....	Comp yld str (0.2%).....40 kips/in. ² Shear str.....36 kips/in. ²	[11]
63.....	...do.....	Sheet, 0.020 in., (17S-0).	9,800	10.8	.....	31.3	12 (2 in.)	.....	12.0 (10 ⁸)	F _E 60	.....	.....	[20]
64.....	...do.....	Sheet, 0.020 in., h-t and aged at r-t (17S-T).	9,000	35.3	.....	63.2	16 (2 in.)	.....	16.5 (10 ⁸)	F _E 95	.....	.....	[20]
65.....	...do.....	Sheet, 0.020 in., cold- worked (17S-H).	9,700	21.3	.....	38.2	2.5 (2 in.)	.....	15.0 (10 ⁸)	F _E 79	.....	.....	[20]
66.....	Cu 4.03, Fe 0.80, Mn 0.59, Mg 0.45, Si 0.24, Cr 0.10.	Sheet, 0.040 in., cold- rolled.	9,800	40.6	46.3 (yld pnt)	51.7	2.7 (4 in.)	13	.....	109	.....	.....	[28]
67.....	...do.....	Sheet, 0.040 in., rolled; 1/2 hr at 950°F, w-q.	8,700	14.1	.....	48.3	22 (4 in.)	28	.....	.....	.....	.....	[28]
68.....	...do.....	Sheet, 0.040 in., rolled; 1/2 hr at 950°F, w-q, aged 6 days at r-t.	10,500	28.5	.....	61.2	18 (4 in.)	27	.....	.....	.....	.....	[28]
69.....	...do.....	Sheet, 0.040 in., rolled; 1/2 hr at 950°F, w-q, aged 1 hr at 212°F.	10,300	20.7	.....	55.2	18 (4 in.)	27	.....	.....	.....	.....	[28]
70.....	Cu 4.10, Mg 0.63, Fe 0.57, Mn 0.55, Si 0.29.	Rod; h-t and aged at r-t.	.....	17.0	27.0 (0.01% perm)	56.0	27 (2 in.)	40	13.0	.....	.....	.....	[17]
71.....	Cu 4.22, Mn 0.65, Mg 0.54, Fe 0.42, Si 0.22.	Cu411-cast.....	.....	.....	20.6 (0.1%)	24.0	<1.0 (2 in.)	<1	.....	V 97	1z <1	.....	[43]

^a References [10 and 11]—For all alloys, wrought and cast; modulus of elasticity (shear) 3,850 kips/in.², Poisson's ratio 0.33. ^b Values apply in general to all wrought forms except large sized extrusions; elongation applies to 1/2-in.-diameter test specimens. ^c Reversed torsion.

TABLE 3.—Aluminum and aluminum alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
							Percent	Percent				
ALUMINUM-COPPER-MAGNESIUM-MANGANESE ALLOYS — Continued												
72....	Percent Cu 4.22, Mn 0.65, Mg 0.54, Fe 0.42, Si 0.22.	Chill-cast; 70 hr at 915°F, w-q, aged 4 days at r-t.	Kt/ps/in. ²	Kt/ps/in. ²	Kt/ps/in. ² 29.6 (0.1%)	Kt/ps/in. ² 41.2	Percent 1.8 (2 in.)	Percent 3.9	V 103	ft-lb Iz 3.6	.....	[43]
73....	...do.....	Forged; 70 hr at 915°F, w-q, aged 4 days at r-t.	.....	.....	29.6 (0.1%)	55.9	22 (2 in.)	28	V 118	Iz 15	.....	[43]
74....	Cu 4.26, Fe 0.67, Mn 0.63, Mg 0.63, Si 0.21.	Rod, h-t and aged at r-t.	.....	23.0	27.5 (0.01% perm)	53.0	22 (2 in.)	36	.....	.....	.....	[17]
75....	Cu 4.32, Mg 1.44, Mn 0.48, Fe 0.16, Si 0.14.	Plate, 1/2 in.; w-q from 920°F (24S-T).	.....	.....	48.5	65.5	20	26	R _E 74	.....	.....	[25]
76....	...do.....	Plate, 1/2 in.; w-q from 920°F, cold-rolled 5 1/2% red. (24S-RT).	.....	.....	55.5	70.0	17	27	R _E 77	.....	.....	[25]
77....	Cu 4.4, Fe 0.81, Mg 0.67, Mn 0.64, Si 0.22.	Rod, 3/4 in. diam, h-t and aged.	10,800	37.6	41.9 (0.1%)	59.6	19.7 (4 in.)	.....	.....	.....	.....	[24]
78 ^a ...	Cu 4.4, Mn 0.8, Si 0.8, Mg 0.4.	Forged; h-t and aged (14S-T).	10,300	.....	55 (0.2% perm)	70	14 (2 in.)	.....	135	.....	Comp yld str (0.2%).....55 kips/in. ² Shear str.....45 kips/in. ² Specific gravity.....2.80.	[11]
79....	...do.....	Forged, 5 x 5 in., h-t and aged (14S-T).	.....	.....	60.0	70.3	12 (2 in.)	24	.....	Iz 5.6	Compressive str.....74.7 kips/in. ² Shear str.....38.8 kips/in. ²	[39]
80 ^a ...	Cu 4.5, Mg 1.5, Mn 0.6.	Wrought; an (24S-0)...	10,300	.....	10 (0.2% perm)	26	^b 22 (2 in.)	.....	42	.....	Comp yld str (0.2%).....10 kips/in. ² Shear str.....18 kips/in. ² Specific gravity.....2.77.	[11]
81 ^a ...	...do.....	Wrought; h-t and aged at r-t (24S-T).	10,300	.....	45 (0.2% perm)	68	^b 22 (2 in.)	.....	105	.....	Comp yld str (0.2%).....45 kips/in. ² Shear str.....41 kips/in. ²	[11]
82 ^a ...	...do.....	Sheet, h-t and cold-worked (24S-RT).	10,300	.....	55 (0.2% perm)	70	13 (2 in.)	.....	116	.....	Comp yld str (0.2%).....55 kips/in. ² Shear str.....42 kips/in. ²	[11]
83....	...do.....	Plate, 3/4 in., h-t and aged at r-t (24S-T).	.....	.....	39.7	65.0	22 (2 in.)	21	.....	Iz 10	Shear str.....42.4 kips/in. ²	[39]
84....	...do.....	Sheet, 0.040 in., h-t and aged (Alclad 24S-T).	10,100	.....	49.9 (0.2% offset)	.....	.....	.....	.....	.....	Comp yld str (0.2%).....43.4 kips/in. ² Mod-el (comp).....10,200 kips/in. ²	[40]
85....	...do.....	Sheet, 0.040 in., h-t and cold-worked (Alclad 24S-RT).	10,000	.....	62.6 (0.2% offset)	.....	.....	.....	.....	.....	Comp yld str (0.2%).....53.4 kips/in. ² Mod-el (comp).....10,200 kips/in. ²	[40]
86....	...do.....	Sheet, 0.032 in., h-t and aged (24S-T).	.....	.....	44.0 (yld pt)	65.7	20 (2 in.)	.....	R _F 97	.....	.....	[41]
87....	...do.....	Sheet, 0.032 in., h-t aged (Alclad 24S-T).	.....	.....	43.0 (yld pt)	64.3	20 (2 in.)	.....	.....	.....	.....	[41]

ALUMINUM-COPPER-MANGANESE ALLOYS

88....	Cu 3.99, Si 0.81, Mn 0.79, Fe 0.36, Mg 0.01.	Plate, 1/2 in.; w-q from 965°F, aged 18 hr at 320°F.	.....	.....	48.5	61.0	13	25	.....	R _E 72	.....	[25]
89....	Cu 4.26, Mn 0.82, Si 0.70, Fe 0.50, Mg 0.03.	Plate, 1/2 in.; w-q from 965°F, aged 18 hr at 240°F (25S-T).	.....	.....	36.0	56.0	20	32	.....	R _E 65	.....	[25]
90....	Cu 4.36, Si 0.84, Mn 0.83, Fe 0.34.	Forged.....	.....	.....	30.0 (0.2% offset)	55.5	16 (4 diam)	22	13.0 (5 × 10 ⁶)	102 Iz 13	.....	[31]
91....	Cu 4.41, Mn 0.80, Si 0.73, Fe 0.48, Mg 0.02.	Plate, 1/2 in.; w-q from 965°F, aged 18 hr at 230°F, cold-rolled 5 1/2% red. (25S-R1).	.....	.....	45.0	57.0	16	29	.....	R _E 66	.....	[25]
92 ^a ...	Cu 4.5, Mn 0.8, Si 0.8.	Forged; h-t and aged (25S-T).	10,300	.....	35 (0.2% perm)	57	18 (2 in.)	.....	15 (5 × 10 ⁶)	110	.....	[11]
93....	Cu 12.33, Mn 0.95, Fe 0.40, Si 0.25.	Sand-cast.....	.....	8	20 (0.2% offset)	22	1 (2 in.)	.....	10 (5 × 10 ⁶)	75 Iz 0.2	.....	[13]

ALUMINUM-COPPER-NICKEL ALLOYS

94....	Cu 2.5, Ni 1.5, Fe 1.25, Si 1.2, Mg 0.75.	Heat-treated, quenched and aged.	.....	.....	39 (0.2%)	42	3 (11.3 √area)	.....	16 (2 × 10 ⁷)	129	.....	[18]
95....	Cu 2.5, Ni 1.5, Fe 1.2, Si 1.2, Mg 0.8, Ce 0.15.	Chill-cast; 5 hr at 975°F, w-q, 16 hr at 345°F.	.....	.....	47-51 (0.1%)	52-60	0-1	.....	18	130-140	.....	[44]
96....	Cu 3.90, Ni 2.22, Mg 1.60, Fe 0.38, Si 0.21.	Cast; 5 hr at 950°F, w-q, aged 5 hr at 375°F.	.....	26.0	.....	39.1	1.0 (2 in.)	.....	.....	108	.....	[45]
97....	Cu 3.91, Ni 2.22, Mg 1.66, Fe 0.35, Si 0.13.	Wrought; 5 hr at 950°F, w-q, aged 5 hr at 375°F.	.....	.....	52.8 (0.2% offset)	68.5	13 (2 in.)	.....	.....	138	.....	[45]
98 ^a ...	Cu 4.0, Ni 2.0, Mg 0.5.	Forged; h-t and aged (18S-T).	10,300	.....	47 (0.2% perm)	63	17 (2 in.)	.....	14.5 (5 × 10 ⁶)	115	.....	[11]
99 ^a ...	Cu 4.0, Ni 2.0, Mg 1.5.	Sand-cast (142).....	10,300	.....	24 (0.2% perm)	28	1 (2 in.)	.....	8 (5 × 10 ⁶)	80	0.6	[10]
100 ^a ...	do.....	Sand-cast; h-t and aged (142-761).	10,300	.....	32 (0.2% perm)	37	0.5 (2 in.)	.....	8 (5 × 10 ⁶)	100	.....	[11]
101 ^a ...	do.....	Sand-cast; aged (142-7571).	10,300	.....	28 (0.2% perm)	32	0.5 (2 in.)	.....	8 (5 × 10 ⁶)	65	.....	[11]
102 ^a ...	do.....	Chill-cast (142).....	10,300	.....	24 (0.2% perm)	34	1 (2 in.)	.....	.....	105	.....	[10]
103 ^a ...	do.....	Chill-cast; h-t and aged (142-761).	10,300	.....	42 (0.2% perm)	47	0.5 (2 in.)	.....	9.5 (5 × 10 ⁶)	110	.....	[11]
104 ^a ...	do.....	Chill-cast; aged (142-7571).	10,300	.....	34 (0.2% perm)	40	0 (2 in.)	.....	10.5 (5 × 10 ⁶)	105	.....	[11]
105....	Cu 4, Ni 4, Si 1.75.	Die-cast, 1/4 in. diam (89).	.....	.....	.....	31	1.5 (2 in.)	.....	.....	.....	2	[34]

^aReferences [10 and 11]—for all alloys, wrought and cast; modulus of elasticity (shear) 3,850 kips/in.², Poisson's ratio 0.33.
^bValues apply in general to all wrought forms except large sized extrusions; elongation applies to 1/2-in.-diameter test specimens.

TABLE 3.—Aluminum and aluminum alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Ref. cr- ence
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
ALUMINUM-COPPER-NICKEL ALLOYS—Continued												
106...	Percent Cu 4.02, Ni 1.94, Mg 1.61, Fe 0.56, Si 0.26.	Rod, 1/2 in. diam, sand-cast; 16 hr at 940°F, aged 2 hr at 300°F.	Ktpsi/in. ²	Ktpsi/in. ²	Ktpsi/in. ² 39.5	Percent 1.0	Percent	Ktpsi/in. ² 8.0 (10 ⁶)	ft-lb .....	.....	[25]	
107...	Cu 4.13, Ni 2.07, Mg 1.50, Fe 0.32, Si 0.29.	Cast; 2 hr at 970°F, boiling w-q, aged 3 weeks at r-t.	.....	.....	59.4	.....	.....	20.8 (3 × 10 ⁷)	.....	.....	[37]	
ALUMINUM-COPPER-SILICON ALLOYS												
108 ^a ...	Cu 4.0, Si 3.0.....	Sand-cast (108).....	10,300	.....	14 (0.2% perm)	21	2 (2 in.)	.....	8.5 (5 × 10 ⁶)	55	Comp yld str (0.2%).....14 kips/in. ² Shear str.....20 kips/in. ² Specific gravity.....2.75. Melting range.....970°-1,170°F.	[10]
109...	do.....	Sand-cast; 6 hr at 970°F, w-q, aged at r-t.	10,300	.....	23.1 (0.1%)	31.6	1.4 (4 /area)	.....	.....	.....	.....	[24]
110...	do.....	Sand-cast; 6 hr at 970°F, w-q, aged 48 hr at 300°F.	10,100	.....	31.6 (0.1%)	36.1	0.6 (4 /area)	.....	.....	.....	.....	[24]
111...	Cu 4.5, Si 1.2, Mn 0.3.	Sand-cast.....	.....	.....	18	32	3 (2 in.)	.....	9 (5 × 10 ⁶)	80	.....	[104]
112 ^a ...	Cu 4.5, Si 2.5.....	Chill-cast; h-t (B193-T4).	10,300	.....	22 (0.2% perm)	40	10 (2 in.)	.....	9.5 (5 × 10 ⁶)	75	Comp yld str (0.2%).....22 kips/in. ² Shear str.....30 kips/in. ² Specific gravity.....2.79.	[11]
113 ^a ...	do.....	Chill-cast; h-t and aged (B195-T6).	10,300	.....	33 (0.2% perm)	45	5 (2 in.)	.....	10 (5 × 10 ⁶)	90	Comp yld str (0.2%).....33 kips/in. ² Shear str.....32 kips/in. ²	[11]
114 ^a ...	Cu 7.0, Si 1.7, Fe 1.2.	Chill-cast (B113).....	10,300	.....	19 (0.2% perm)	28	2 (2 in.)	.....	.....	70	Comp yld str (0.2%).....19 kips/in. ² Shear str.....23 kips/in. ² Specific gravity.....2.86. Melting range.....1,005°-1,175°F.	[10]
115...	Cu 7.0, Si 2.0.....	Die-cast.....	10,300	.....	24 (0.2% offset)	27-32	0-1.5 (2 in.)	.....	16 (5 × 10 ⁶)	70-90	Specific gravity.....2.85. Melting range.....975°-1,165°F.	[46]
116...	Cu 7.0, Si 2.0, Zn 1.5, Fe 1.2.	Sand-cast.....	10,300	.....	14 (0.2% offset)	19-23	0-1.5 (2 in.)	.....	8.5 (5 × 10 ⁶)	55-80	Comp yld str (0.2%).....17 kips/in. ² Compressive str.....62 kips/in. ² Shear str.....20 kips/in. ² Specific gravity.....2.85. Melting range.....1,005°-1,175°F.	[46]
117 ^a ...	Cu 7.0, Si 3.0.....	Die-cast, 1/4 in. diam (S1).	.....	.....	24 (0.2% perm)	32	1.3 (2 in.)	.....	16 (5 × 10 ⁶)	.....	.....	[10]
118 ^a ...	Cu 7.0, Si 3.5, Zn 2.0, Fe 1.2.	Chill-cast (C113).....	10,300	.....	24 (0.2% perm)	30	1 (2 in.)	.....	9.5 (5 × 10 ⁶)	80	Comp yld str (0.2%).....24 kips/in. ² Shear str.....22 kips/in. ² Specific gravity.....2.85. Melting range.....975°-1,165°F.	[10]
119...	do.....	Chill-cast; run (C113-T2).	10,300	.....	14 (0.2% perm)	27	1.5 (2 in.)	.....	.....	70	Comp yld str (0.2%).....14 kips/in. ² Shear str.....19 kips/in. ²	[11]

120...	Cu 8.0, Si 1.2, Fe 1.0.	Sand-cast (212).....	10,300		14 (0.2%)	19-23	0-2 (2 in.)		7.5 (5 × 10 ⁴)	50-70	0.6	Comp yld str (0.2%).....16 kips/in. ² Compressive str.....57 kips/in. ² Shear str.....20 kips/in. ² Specific gravity.....2.83. Melting range.....975°-1,165°F.	[46]
121...	Cu 8.0, Si 1.7, Fe 1.0.	...do.....	10,100	.....	{ 9.5 (0.02%) 16.2 (0.2%) }	25.2	1	.....	.....	110	.....	[35]	
122...	...do.....	Sand-cast; ann (212)...	10,100	.....	{ 11.0 (0.02%) 18.6 (0.2%) }	27.1	0.9	.....	.....	109	.....	[35]	
123 ^a ...	Cu 8.0, Si 2.5.....	Sand-cast.....	10,300		15 (0.2% perm)	23	1 (2 in.)			65	0.6	Comp yld str (0.2%).....17 kips/in. ² Shear str.....20 kips/in. ² Specific gravity.....2.83. Melting range.....975°-1,165°F.	[10]
124...	Cu 8.0, Si 3.0, Fe 1.2.	Die-cast.....	.....	.....	.....	28	.....	.....	.....	67	.....	[18]	
125 ^a ...	Cu 10.0, Si 4.0, Fe 1.0, Mg 0.2.	Chill-cast (138).....	10,300	.....	24 (0.2% perm)	28	0.5 (2 in.)	.....	.....	100	.....	[11]	
126 ^a ...	Cu 14, Si 5.....	Die-cast, 1/4 in. diam (82).	10,300	.....	.....	44	0.2 (2 in.)	.....	.....	.....	.....	[11]	

ALUMINUM-COPPER-ZINC ALLOYS

127...	Cu 5.36, Zn 2.23, Mn 0.52, Fe 0.49, Si 0.11.	Rod, 5/8 in. diam, cast; 16 hr at 960°F, w-q, aged 6 hr at 320°F.	.....	.....	42.0 (0.1%)	51.0	3 (2 in.)	.....	10.0 (2 × 10 ⁸)	116	.....	[47]
128 ^a ...	Cu 7.0, Zn 1.7, Fe 1.2.	Sand-cast (112).....	10,300	.....	14 (0.2% perm)	23	1.5 (2 in.)	.....	9 (5 × 10 ⁸)	70	0.6	[11]

Comp yld str (0.2%).....17 kips/in.².....
Shear str.....20 kips/in.².....
Specific gravity.....2.85.
Melting range.....1,005°-1,175°F.

ALUMINUM-MAGNESIUM ALLOYS (SEE ALSO FIGS. 10, 11, AND 12)

129...	Mg 0.55, Fe 0.64, Si 0.56, Cu 0.15, Mn 0.006.	Heat-treated.....	.....	6.0	14.0 (0.01% perm)	36.0	38 (2 in.)	56	12.1	.....	.....	[17]
130...	Mg 0.61, Si 0.34, Fe 0.34, Cu 0.03, Mn 0.03.	Rod, 1 in. diam, extruded; h-t.	.....	.....	28.0 (0.1%)	34.3	25 (4 /area)	.....	12.8 (5 x 10 ⁷)	.....	.....	[48]
131 ^a ...	Mg 1.0, Si 0.6, Cr 0.25, Cu 0.25.	Wrought; ann (61S-4)...	10,300	.....	8 (0.2% perm)	18	b ₂₂ (2 in.)	.....	8 (5 x 10 ⁸)	30	.....	[11]
132 ^a ...	...do.....	Wrought; quenched (61S-W).	10,300	.....	21 (0.2% perm)	35	b ₂₂ (2 in.)	.....	12.5 (5 x 10 ⁸)	65	.....	[11]
133 ^a ...	...do.....	Wrought; h-t and aged (61S-T).	10,300	.....	39 (0.2% perm)	45	12 (2 in.)	.....	12.5 (5 x 10 ⁸)	95	.....	[11]
134...	Mg 1.2, Si 0.7, Cr 0.25.	Wrought; 1/2 hard (33S-1/2 H).	10,000	.....	21 (0.2% offset)	22	8 (2 in.)	.....	.....	40	.....	[49]
135...	...do.....	Wrought; hard (53S-H)...	10,000	.....	25 (0.2% offset)	28	6 (2 in.)	.....	.....	48	.....	[49]

^aReferences [10 and 11]—for all alloys, wrought and cast; modulus of elasticity (shear) 3,850 kips/in.², Poisson's ratio 0.33.
^bValues apply in general to all wrought forms except large sized extrusions; elongation applies to 1/2-in.-diameter test specimens.

TABLE 3.—Aluminum and aluminum alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation					Reduction of area
ALUMINUM-MAGNESIUM ALLOYS—Continued											
	Percent		$kips/in.^2$ 10,300	$kips/in.^2$	$kips/in.^2$ 7 (0.2% perm)	$kips/in.^2$ 16	Percent 35 (2 in.)	$kips/in.^2$ 7.5 (5 × 10 ⁶)	26	$ft-lb$	[11]
136 ^a ..	Mg 1.3, Si 0.7, Cr 0.25.	Wrought; am (53S-0)...									Comp yld str (0.2%).....7 kips/in. ² Shear str.....11 kips/in. ²
137 ^a ..	...do.	Wrought; quenched (53S-W).	10,300	.....	20 (0.2% perm)	33	30 (2 in.)	10 (5 × 10 ⁶)	65	.....	Comp yld str (0.2%).....20 kips/in. ² Shear str.....20 kips/in. ²
138 ^a ..	...do.	Wrought; h-t and aged (53S-I).	10,300	.....	34 (0.2% perm)	39	20 (2 in.)	11 (5 × 10 ⁶)	80	.....	Comp yld str (0.2%).....33 kips/in. ² Shear str.....24 kips/in. ²
139...	Mg 1.4, Mn 0.9, Si 0.7, Ti 0.3.	Sand-cast.....	.....	.....	17-21 (0.2%)	20-24	3-8 (2 in.)	.....	40-60	.....	.....
140...	...do.	Sand-cast; h-t.....	.....	.....	.....	23-33	0.5-5 (2 in.)	.....	70-120	.....	.....
141...	...do.	Chill-cast.....	.....	.....	.....	21-26	3-8 (2 in.)	.....	40-60	.....	.....
142...	...do.	Chill-cast; h-t.....	.....	.....	21-28 (0.2%)	26-36	0.5-5 (2 in.)	.....	70-120	.....	.....
143...	Mg 1.4, Mn 0.9, Si 0.7, Ti 0-0.2.	Sheet, h-t.....	.....	.....	26-36 (0.2%)	43-50	12-15 (2 in.)	.....	70-95	.....	.....
144...	...do.	Sheet, h-t and cold- rolled.	.....	.....	47-51 (0.2%)	50-57	2-10 (2 in.)	.....	100-120	.....	.....
145...	Mg 2.2, Mn 1.4.....	Sheet, soft.....	.....	.....	14-21 (0.2%)	31-36	16-20 (2 in.)	.....	50-65	.....	.....
146...	...do.	Sheet, hard-rolled.....	.....	.....	47-57 (0.2%)	51-60	2-5 (2 in.)	.....	85-100	.....	.....
147...	Mg 2.35, Cr 0.27, Fe 0.14, Si 0.12, Cu 0.05.	Plate, 1/2 in., rolled (52S).	.....	.....	21.0	31.5	22	62	R _e 68	.....	.....
148...	Mg 2.36, Cr 0.26, Fe 0.23, Si 0.20, Mn 0.01, Cu 0.01.	Rod, 1 in. diam, extruded.	.....	.....	8.4 (0.1%)	26.9	39 (4 /area)	17.0 (5 × 10 ⁷)	.....	.....	.....
149 ^a ..	Mg 2.5, Cr 0.25.....	Wrought; annealed (52S-0).	10,300	.....	14 (0.2% perm)	29	30 (2 in.)	17 (5 × 10 ⁶)	45	.....	Comp yld str (0.2%).....14 kips/in. ² Shear str.....18 kips/in. ² Specific gravity.....2.67.
150 ^a ..	...do.	Wrought; 1/2 hard (52S-1/2 H).	10,300	.....	29 (0.2% perm)	37	14 (2 in.)	19 (5 × 10 ⁶)	67	.....	Shear str.....21 kips/in. ²
151 ^a ..	...do.	Wrought; hard (52S-H)...	10,300	.....	36 (0.2% perm)	41	8 (2 in.)	20.5 (5 × 10 ⁶)	85	.....	Comp yld str (0.2%).....36 kips/in. ² Shear str.....24 kips/in. ²
152...	Mg 3.4, Mn 0.15.....	Sheet, soft.....	.....	.....	10-14 (0.2%)	28-36	15-20 (2 in.)	.....	50-60	.....	.....
153...	...do.	Sheet, hard.....	.....	.....	36-43 (0.2%)	43-50	2-6 (2 in.)	.....	85-100	.....	.....
154...	Mg 3.8.....	Sand-cast (214).....	10,300	.....	12 (0.2% perm)	25	9 (2 in.)	5.5 (5 × 10 ⁶)	50	3.8	Comp yld str (0.2%).....12 kips/in. ² Shear str.....20 kips/in. ² Specific gravity.....2.63. Melting range.....1,075°-1,185°F.

155 ^a ..	Mg 3.8, Si 1.8.....	Sand-cast.....	10,300.....	.....	13 (0.2% perm)	20	2 (2 in.)	.....	.....	50	6.7	Comp yld str (0.2%).....15 kips/in. ² Shear str.....17 kips/in. ² Specific gravity.....2.63. Melting range.....1,090°-1,170°F.	[10]
156 ^a ..	Mg 3.8, Zn 1.8.....	Chill-cast (A214).....	.....	.....	16 (0.2% perm)	27	5 (2 in.)	.....	.....	69	.....	Comp yld str (0.2%).....17 kips/in. ² Shear str.....22 kips/in. ² Specific gravity.....2.67.	[10]
157...	Mg 4.68, Fe 0.35, Mn 0.26, Si 0.15, Cu 0.03, Ti 0.007.	Rod, 19/32 in., extruded.	.....	.....	14.5 (0.2%)	36.7	24 (10 diam)	.....	19.2 (2 x 10 ⁷)	.....	.....	.....	[26]
158...	Mg 4.8, Fe 1.0, Cu 0.5, Ni 0.35, Si 0.25, Mn 0.2.	Hot-forged.....	.....	.....	23 (0.2%)	50	20-25 (2 in.)	.....	.....	95	.....	.....	[18]
159...	do.....	Cold-stamped.....	.....	.....	34-45 (0.2%)	57-64	10-12 (2 in.)	.....	.....	115-125	.....	.....	[18]
160...	Mg 4.97, Mn 0.25, Fe 0.20, Si 0.14, Ti 0.003.	Sheet, 7/16 in.....	.....	.....	38.0 (0.2%)	47.2	9.6	.....	.....	.....	1.7	.....	[26]
161...	Mg 5.95, Ni 1.49, Mn 1.00, Cu 0.37, Fe 0.28, Si 0.18.	Cast.....	.....	9.0	18.2	27.3	2.5 (2 in.)	.....	.....	74	.....	.....	[45]
162...	Mg 6.57, Fe 0.70, Mn 0.18, Si 0.11, Ti 0.007.	Rod, 19/32 in. diam, extruded.	.....	.....	37.3 (0.2%)	51.9	13 (10 diam)	.....	25.2 (2 x 10 ⁷)	.....	.....	.....	[26]
163...	Mg 7.0, Mn 0.45.....	Sheet, soft.....	.....	.....	21-26 (0.2%)	44-51	16-22 (2 in.)	.....	.....	.....	.....	.....	[18]
164...	do.....	Sheet, hard.....	.....	.....	43-51 (0.2%)	53-60	4-9 (2 in.)	.....	.....	100-115	.....	.....	[18]
165...	Mg 7.14, Fe 0.32, Mn 0.22, Si 0.15, Cu 0.01, Ti 0.003.	Sheet, 7/16 in.....	.....	.....	46.4 (0.2%)	59.6	11	.....	.....	.....	1.3	.....	[26]
166...	Mg 7.5, Mn 0.2-0.6...	Sheet, soft.....	.....	.....	21-28 (0.2%)	47-51	18-25 (2 in.)	.....	.....	75-90	.....	.....	[18]
167...	do.....	Sheet, hard-rolled.....	.....	.....	54-64 (0.2%)	64-78	3-10 (2 in.)	.....	.....	115-135	.....	.....	[18]
168...	Mg 7.73, Zn 0.98, Fe 0.40, Mn 0.16, Si 0.16, Cu 0.04, Ti 0.003.	Sheet, 7/16 in.....	.....	.....	23.5 (0.2%)	53.2	27	.....	.....	.....	1.9	.....	[26]
169 ^a ..	Mg 8.0.....	Die-cast (218).....	10,300.....	.....	23 (0.2% perm)	38	5 (2 in.)	.....	18 (5 x 10 ⁶)	.....	10	Specific gravity.....2.53..... Melting range.....1,000°-1,160°F.	[10]
170...	Mg 8.93, Fe 0.44, Mn 0.28, Si 0.12, Cu 0.04, Ti 0.01.	Rod, 19/32 in. diam, extruded.	.....	.....	23.6 (0.2%)	50.3	15 (10 diam)	.....	20.4 (2 x 10 ⁷)	.....	.....	.....	[26]
171 ^a ..	Mg 10.0.....	Sand-cast; n-t (220-04)	10,300.....	.....	25 (0.2% perm)	45	14 (2 in.)	.....	7 (5 x 10 ⁶)	75	.....	Comp yld str (0.2%).....26 kips/in. ² Shear str.....33 kips/in. ² Specific gravity.....2.56. Melting range.....840°-1,150°F.	[11]
172...	Mg 10.....	Mixed powders; compacted at 20 tons/in. ² ; 24 hr at 800°F in air; w-q.	.....	.....	.....	5.3	.....	.....	.....	.....	.....	Density.....2.27 g/cm ³ Porosity.....13%.	[52]
173...	do.....	Mixed powders; compacted at 30 tons/in. ² ; 24 hr at 800°F in air; w-q.	.....	.....	.....	17.7	.....	.....	.....	.....	.....	Density.....2.41 g/cm ³ Porosity.....7.5%.	[52]

^aReferences [10 and 11]—for all alloys, wrought and cast; modulus of elasticity (shear) 3,850 kips/in.², Poisson's ratio 0.33.

^bValues apply in general to all wrought forms except large sized extrusions; elongation applies to 1/2-in.-diameter test specimens.

^cNotch impact value in ft-lb/cm.²

TABLE 3.—*Aluminum and aluminum alloys, normal-temperature properties—Continued*

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Ref-er-ence
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
ALUMINUM-MAGNESIUM ALLOYS—Continued												
171...	Mg 10.....	Mixed powders; compacted at 56 tons/in. ² ; 24 hr at 800°F in air, w-q.	<i>k</i> tps/in. ²	<i>k</i> tps/in. ²	<i>k</i> tps/in. ²	<i>k</i> tps/in. ²	Percent.....	Percent.....	<i>k</i> tps/in. ²	<i>ft-lb</i>	Density.....2.52 g/cm ³ Porosity.....3.3%	[52]
175...	Mg 10.0, Mn 0.5, Si 0.2-1.5.	Sheet.....	.....	.....	28-34 (0.2%)	54-63	12-18 (2 in.)	.....	.....	90-95	.....	[18]
176...	Mg 10.49, Fe 0.13, Si 0.07, Cu 0.03.	Rod, 3/4 in. diam, cast; 16 hr at 810°F, o-q to 250°F (220-T4).	.....	.....	24.0	35.0	8	10	.....	R _E 86	ε 6	[25]
ALUMINUM-MANGANESE ALLOYS (SEE ALSO FIG. 13)												
177...	Mn 1.04, Fe 0.45, Si 0.14, Cu 0.12.	Plate, 1/2 in., rolled (3S).	.....	.....	15.5	19.5	30	64	.....	R _E 40	.....	[25]
178...	Mn 1.16, Fe 0.50, Si 0.20, Cu 0.11.	Sheet, 0.020 in., cold-worked (3S-H).	10,000	12.4	.....	27.8	5 (2 in.)	.....	10.0 (10 ⁵)	.....	.....	[20]
179 ^a ...	Mn 1.2.....	Wrought; anne (3S-0)....	10,300	.....	6 (0.2% perm)	16	10 (2 in.)	.....	7 (5 × 10 ⁶)	28	.....	[11]
180 ^a ...	...do.....	Wrought; 1/2 hard (3S-1/2 H).	10,300	.....	18 (0.2% perm)	21	16 (2 in.)	.....	9 (5 × 10 ⁶)	40	.....	[11]
181 ^a ...	...do.....	Wrought; hard (3S-H)...	10,300	.....	25 (0.2% perm)	29	10 (2 in.)	.....	10 (5 × 10 ⁶)	55	.....	[11]
182...	...do.....	Extruded (3S).....	.....	.....	15 (0.2% perm)	18	20 (2 in.)	.....	8 (5 × 10 ⁶)	35	.....	[22]
183...	Mn 1.22, Si 0.35, Fe 0.29, Cu 0.16.	Annealed.....	.....	1.5	2.5 (0.01% perm)	16.7	43 (2 in.)	68	7.0	.....	.....	[17]
184...	...do.....	1/2 hard.....	.....	8.5	17.0 (0.01% perm)	24.6	18 (2 in.)	58	10.1	.....	.....	[17]
185...	...do.....	Hard.....	.....	12.5	21.0 (0.01% perm)	29.6	12 (2 in.)	42	10.8	.....	.....	[17]
186...	Mn 1.25, Mg 1.0.....	Annealed.....	.....	.....	10	26	20 (2 in.)	.....	14	45	.....	[54]
187...	...do.....	1/2 hard.....	.....	.....	27	34	9 (2 in.)	.....	15	63	.....	[54]
188...	...do.....	Hard.....	.....	.....	34	40	5 (2 in.)	.....	16	77	.....	[54]
189...	Mn 1.32, Fe 0.35, Si 0.30, Cu 0.01.	Rod, 1 in. diam, extruded.	.....	.....	5.6 (0.1%)	15.1	46 (4 /area)	.....	8.7 (5 × 10 ⁷)	.....	.....	[48]
190...	Mn 1.33, Fe 0.60, Si 0.28, Cu 0.10.	Rod, 1 in. diam, hard-rolled.	.....	10.0	16.5 (0.01% perm)	27.6	11 (2 in.)	.....	.....	.....	.....	[24]
191...	Mn 1.35, Fe 0.59, Si 0.16, Cu 0.15.	Heat-treated.....	.....	9.0	17.5 (0.01% perm)	28.5	10 (2 in.)	34	10.7	.....	.....	[17]
192...	Mn 1.5.....	Sheet, soft.....	.....	.....	6-9 (0.2%)	14-17	30-40 (2 in.)	.....	.....	27-32	.....	[18]
193...	...do.....	Sheet, hard-rolled....	.....	.....	26-31 (0.2%)	27-33	3-6 (2 in.)	.....	.....	50-60	.....	[18]

194 ^a	Mn 2.0.....	Sand-cast (406).....	10,300.....	.....	9 (0.2% perm)	19	12 (2 in.)	5.5 (5 × 10 ⁶)	35	4	Comp yld str (0.2%)..... Shear str..... Specific gravity..... Melting range.....	[10]
ALUMINUM-NICKEL ALLOYS												
195...	Al 0.5, Mg 0.5, Cu 0.25, Mn + Cr + Mo 0.25.	Sheet, 1/16 in., ann...	.....	.....	6.5 (0.2% perm)	17	26 (2 in.)	.....	.....	.....	.....	[29]
196...	...do.....	Sheet, 1/16 in., hard..	.....	.....	32.5 (0.2% perm)	34.5	4 (2 in.)	.....	.....	.....	.....	[29]
197...	...do.....	Sheet, 1/16 in., h-t...	.....	.....	32 (0.2% perm)	40	13 (2 in.)	.....	.....	.....	.....	[29]
198...	Al 1.0, Cu 0.5, Mg 0.5, Mn + Cr + Mo 0.5.	Sheet, 1/16, ann.....	.....	.....	8.5 (0.2% perm)	21	20 (2 in.)	.....	.....	.....	.....	[29]
199...	...do.....	Sheet, 1/16 in., hard..	.....	.....	35.5 (0.2% perm)	38	4 (2 in.)	.....	.....	.....	.....	[29]
200...	...do.....	Sheet, 1/16 in., h-t...	.....	.....	51 (0.2% perm)	53	3 (2 in.)	.....	.....	.....	.....	[29]
201...	Al 2.2, Cu 2.0.....	Hot-rolled.....	10,400.....	.....	.....	.....	.....	.....	.....	.....	.....	[30]

ALUMINUM-SILICON ALLOYS (SEE ALSO FIGS. 14, 15, AND 16)

202...	Si 4.71, Fe 0.29, Cu 0.02.	Rod, 1/2 in. diam, sand-cast.	.....	.....	.....	18.7	11 (4 diam)	6.0 (2 × 10 ⁶)	45	.....	.....	[31]
203...	Si 5.0.....	Sand-cast (43).....	10,300.....	.....	9 (0.2% perm)	19	6 (2 in.)	6.5 (5 × 10 ⁶)	40	1	Comp yld str (0.2%)..... Shear str..... Specific gravity..... Melting range.....	[10]
204...	do.....	Chill-cast (43).....	10,300.....	.....	9 (0.2% perm)	24	6 (2 in.)	.....	40	2.1	Comp yld str (0.2%)..... Shear str..... Specific gravity..... Melting range.....	[10]
205...	do.....	Die-cast, 1/4 in. diam (43).	10,300.....	.....	13 (0.2% perm)	29	3.5 (2 in.)	.....	.....	4.5	Specific gravity.....	[10]
206 ^a ...	Si 10.0.....	Sand-cast (45).....	10,300.....	.....	10 (0.2% perm)	21	4.5 (2 in.)	6 (5 × 10 ⁶)	45	0.8	Comp yld str (0.2%)..... Shear str..... Specific gravity..... Melting range.....	[10]
207 ^a ...	Si 12.....	Die-cast, 1/4 in. diam (43).	10,300.....	.....	18 (0.2% perm)	33	1.8 (2 in.)	15 (5 × 10 ⁶)	.....	2	Specific gravity..... Melting range.....	[10]
208...	Si 12.39, Fe 0.45, Cu 0.01.	Rod, 1 in. diam, cast (47).	10,900.....	.....	.....	25.3	11 (2 in.)	.....	.....	.....	.....	[33]
209...	Si 12.5.....	Sand-cast (modified) (47).	10,300.....	.....	11 (0.2% perm)	26	8 (2 in.)	6 (5 × 10 ⁶)	50	3	Comp yld str (0.2%)..... Shear str..... Specific gravity..... Melting range.....	[10]
210...	Si 12.64, Mg 0.96, Ni 0.91, Cu 0.90, Fe 0.79, Mn 0.02.	Wrought; h-t.....	.....	28.0	44.4	52.8	6.0 (2 in.)	.....	126	.....	.....	[45]
211...	Si 13.....	Rod, 7/8 in. diam, sand- cast at 1,290°F (modi- fied); aged 3 months at r-t.	.....	3.7	.....	25.1	5.4 (2 in.)	.....	.....	.....	.....	[24]

^aReferences [10 and 11]—for all alloys, wrought and cast; modulus of elasticity (shear) 3,850 kips/in.², Poisson's ratio 0.33.
^bValues apply in general to all wrought forms except large sized extrusions; elongation applies to 1/2-in.-diameter test specimens.
^cCharpy specimen with Izod notch.

TABLE 3.—Aluminum and aluminum alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
ALUMINUM-SILICON ALLOYS—Continued												
212...	Si 13.....	Die-cast.....	$E_{tens}/in.^2$ 10,300	$E_{tens}/in.^2$	$E_{tens}/in.^2$ 18 (0.2% offset)	$E_{tens}/in.^2$ 33	Percent 2 (2 in.)	Percent (5 × 10 ⁶)	80	ft-lb 2	Specific gravity.....2.66..... Melting range.....1,070°-1,150°F.	[32]
ALUMINUM-SILICON-COPPER ALLOYS												
213...	Si 2.30, Cu 2.25, Fe 0.70, Mn 0.38, Ni 0.09, Zn 0.04, Mg 0.02.	Cast; 15 hr at 950°F, w-q, aged 3 hr at 320°F.	.....	.....	13	30	6.5 (2 in.)	.....	60	.....	.....	[50]
214 ^a ..	Si 3.0, Cu 2.0.....	Die-cast, 1/4 in. diam (83).	10,300	.....	14 (0.2% perm)	30	3.5 (2 in.)	 (5 × 10 ⁶)	.....	5	Specific gravity.....2.75.....	[10]
215 ^a ..	Si 4.0, Cu 3.0, Mg 0.3.	Sand-cast (A334).....	10,300	.....	16 (0.2% perm)	25	2 (2 in.)	 (5 × 10 ⁶)	65	0.7	Comp yld str (0.2%).....22 kips/in. ² Shear str.....24 kips/in. ² Specific gravity.....2.73..... Melting range.....940°-1,160°F.	[10]
216...	Si 4.61, Cu 1.18, Mg 0.58, Fe 0.26.	Cast; 16 hr at 980°F, w-q, aged 8 hr at 440°F.	.....	9.0	33.5 (0.2% offset)	36.3	1.5 (2 in.)	.....	86	.....	.....	[45]
217...	Si 5.0, Cu 0.75, Mg 0.40.	Sand-cast.....	9,800	.....	$\left\{ \begin{array}{l} 10.3 \\ (0.02\%) \\ 15.8 \\ (0.2\%) \end{array} \right\}$	$\left. \begin{array}{l} 24.2 \\ \end{array} \right\}$	1.5	.....	97	.....	.....	[35]
218...	do.....	Sand-cast; aged.....	10,300	.....	26.9 (0.02%)	34.8	1.0	.....	148	.....	.....	[35]
219...	Si 5.0, Cu 1.2, Mg 0.5.	Bar, 3/8 in., sand- cast; 16 hr at 980°F, aged 8 hr at 440°F.	.....	.....	.....	43.5	.....	..... (10 ⁶)	.....	.....	.....	[25]
220...	Si 5.0, Cu 1.3, Mg 0.5.	Sand-cast; h-t (355-14).	10,300	.....	20 (0.2% offset)	30	5 (2 in.)	.....	60	1.3	Comp yld str (0.2%).....23 kips/in. ² Shear str.....28 kips/in. ² Specific gravity.....2.68..... Melting range.....1,075°-1,160°F.	[406]
221...	do.....	Sand-cast; h-t and aged (355-161).	10,300	.....	33 (0.2% offset)	38	$\frac{4}{1}$ (2 in.)	.....	90	0.8	Comp yld str (0.2%).....36 kips/in. ²	[406]
222 ^a ..	do.....	Sand-cast; h-t and aged (355-16).	10,300	.....	25 (0.2% perm)	35	3.5 (2 in.)	 (5 × 10 ⁶)	90	.....	Comp yld str (0.2%).....29 kips/in. ² Shear str.....30 kips/in. ²	[11]
223 ^a ..	do.....	Sand-cast; aged (355-151).	10,300	.....	23 (0.2% perm)	28	1.5 (2 in.)	 (5 × 10 ⁶)	60	.....	Comp yld str (0.2%).....24 kips/in. ² Shear str.....22 kips/in. ²	[11]
224 ^a ..	Si 5.0, Cu 1.3, Mg 0.5.	Chill-cast; h-t (355-14).	10,300	.....	23 (0.2% perm)	38	6 (2 in.)	.....	.....	.....	.....	[11]
225 ^a ..	do.....	Chill-cast; h-t and aged (355-16).	10,300	.....	26 (0.2% perm)	43	4 (2 in.)	 (5 × 10 ⁶)	90	.....	Comp yld str (0.2%).....29 kips/in. ² Shear str.....30 kips/in. ² Specific gravity.....2.69.	[11]
226 ^a ..	do.....	Chill-cast; aged (355-151).	10,300	.....	24 (0.2% perm)	30	2 (2 in.)	.....	75	.....	Comp yld str (0.2%).....24 kips/in. ²	[11]
227 ^a ..	Si 5.0, Cu 1.4, Mn 0.8, Ni 0.8, Mg 0.5.	Sand-cast; aged (355-151).	10,300	.....	24 (0.2% perm)	28	1.5 (2 in.)	 (5 × 10 ⁶)	65	.....	Comp yld str (0.2%).....24 kips/in. ² Shear str.....22 kips/in. ² Specific gravity.....2.74.	[11]

228 ^a ..	...do.....	Sand-cast; aged (A355-T59).	10,300	.....	21 (0.2% perm)	25	2 (2 in.)	.....	8 (5 x 10 ⁶)	60	.....	Comp yld str (0.2%).....21 kips/in. ² Shear str.....21 kips/in. ² Specific gravity.....2.71.....	[11]
229 ^a ..	Si 5.0, Cu 4.0.....	Die-cast, 1/4 in. diam (85).	10,300	.....	19 (0.2% perm)	35	2.7 (2 in.)	.....	17 (5 x 10 ⁶)	.....	2.5	Specific gravity.....2.78.....	[10]
230 ^a ..	Si 5.5, Cu 4.5.....	Chill-cast (A108).....	10,300	.....	16 (0.2% perm)	28	2 (2 in.)	.....	.....	70	0.9	Comp yld str (0.2%).....16 kips/in. ² Shear str.....25 kips/in. ² Specific gravity.....2.77.....	[10]
231...	Si 12, Cu 0.8.....	Chill-cast.....	9,400	.....	5.0 (0.02%) 11.4 (0.2%)	20.9	1.0	.....	.....	80	.....	.....	[35]
232...	Si 20, Cu 1, Fe 0.7..	...do.....	.....	.....	18 (0.2%)	20	1.2 (2 in.)	.....	.....	85	.....	.....	[18]

ALUMINUM-SILICON-MAGNESIUM ALLOYS

233...	Si 0.70, Mg 0.60, Cr 0.15.	Extruded, aged.....	10,100	.....	35.9 (0.02%) 41.5 (0.2%)	48.7	10	.....	.....	104	.....	.....	[42]
234...	Si 1.0, Mg 0.6.....	Annealed.....	10,300	.....	6 (0.2% perm)	16	30 (2 in.)	.....	6.5 (5 x 10 ⁶)	28	.....	Shear str.....11 kips/in. ² Specific gravity.....2.69.....	[57]
235...	...do.....	Quenched.....	10,300	.....	20 (0.2% perm)	35	24 (2 in.)	.....	10.5 (5 x 10 ⁶)	64	.....	Shear str.....24 kips/in. ²	[57]
236...	...do.....	Heat-treated and aged..	.....	.....	40 (0.2% perm)	48	14 (2 in.)	.....	.....	95	.....	Shear str.....30 kips/in. ²	[57]
237 ^a ..	Si 1.0, Mg 0.6, Cr 0.25.	Forged, h-t, and aged (A518-T).	10,300	.....	40 (0.2% perm)	47	20 (2 in.)	.....	10.5 (5 x 10 ⁶)	100	.....	Comp yld str (0.2%).....40 kips/in. ² Shear str.....32 kips/in. ² Specific gravity.....2.69.....	[11]
238...	Si 1.20, Mg 0.05, Fe 0.31, Mn 0.02, Cu 0.01.	Roll, 1 in. diam, extruded, h-t.	.....	.....	41.0 (0.1%)	44.8	12 (4 /area)	.....	14.6 (5 x 10 ⁷)	.....	.....	.....	[48]
239...	Si 6.71, Fe 0.26, Mg 0.25, Cu 0.08.	Roll, 3/4 in. diam, cast; 16 hr at 1,000°F, w-q to 210°F (356-T4).	.....	.....	15.5	24.0	4.0	4.5	.....	R _g 66	c ₂	.....	[25]
240 ^a ..	Si 7.0, Mg 0.3.....	Sand-cast; h-t (356-T4).	10,300	.....	16 (0.2% perm)	28	6 (2 in.)	.....	.....	55	.....	Comp yld str (0.2%).....18 kips/in. ² Shear str.....22 kips/in. ² Specific gravity.....2.63.....	[11]
241 ^a ..	...do.....	Sand-cast; h-t and aged (356-T6).	10,300	.....	22 (0.2% perm)	32	4 (2 in.)	.....	8 (5 x 10 ⁶)	70	.....	Shear str.....27 kips/in. ²	[11]
242 ^a ..	...do.....	Sand-cast; aged (356-T51).	10,300	.....	20 (0.2% perm)	25	2 (2 in.)	.....	7.5 (5 x 10 ⁶)	60	.....	Comp yld str (0.2%).....22 kips/in. ² Shear str.....18 kips/in. ²	[11]
243 ^a ..	...do.....	Chill-cast; h-t and aged (356-T6).	10,300	.....	24 (0.2% perm)	40	5 (2 in.)	.....	.....	90	.....	Comp yld str (0.2%).....24 kips/in. ² Specific gravity.....2.63.....	[11]
244 ^a ..	Si 12.5, Mg 1.0, Cu 0.9, Ni 0.9.	Forged; h-t and aged (325-T).	10,300	.....	46 (0.2% perm)	56	8 (2 in.)	.....	14 (5 x 10 ⁶)	125	.....	Comp yld str (0.2%).....46 kips/in. ² Shear str.....38 kips/in. ² Specific gravity.....2.69.....	[11]
245...	Si 12.5, Mg 1.2, Ni 0.9, Cu 0.9.	Extruded, aged.....	11,200	.....	30.3 (0.02%) 38.7 (0.2%)	42.3	1.6	.....	.....	108	.....	.....	[42]

^a References [10 and 11]—for all alloys, wrought and cast; modulus of elasticity (shear) 3,850 kips/in.², Poisson's ratio 0.33.
^c Charpy specimen with Izod notch.

TABLE 3.—*Aluminum and aluminum alloys, normal-temperature properties—Continued*

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
ALUMINUM-SILICON-NICKEL ALLOYS												
246...	Percent Si 10, Ni 2.4, Mn 1.4, Cu 1.2.	Chill-cast, aged.....	kips/in. ² 11,700	kips/in. ²	kips/in. ² 24.6 (0.02%)	kips/in. ² 29.6	Percent	Percent	kips/in. ²	ft-lb 170	.....	[35]
247...	Si 12, Ni 1-2, Cu 1, Mg 1.	Cast; h-t and aged.....	10,300	.....	40 (0.2% offset)	46	0.5 (2 in.)	.....	.....	135	0.7	[56]
248...	do.....	Forged, solution h-t, and aged.	10,300	.....	43 (0.2% offset)	53	8 (2 in.)	.....	14 (5 × 10 ⁶)	118	1.3	[56]
249 ^a ...	Si 12, Ni 2.5, Mg 1.0, Cu 0.8, Fe 0.8.	Chill-cast; h-t (Al32-14).	10,300	.....	30 (0.2% perm)	38	1.5 (2 in.)	.....	.....	100	.....	[11]
250 ^a ...	do.....	Chill-cast; aged (Al32-T551).	10,300	.....	28 (0.2% perm)	36	0.5 (2 in.)	.....	.....	105	.....	[11]
251...	Si 13.18, Ni 3.08, Cu 2.96, Mg 1.04, Fe 0.53.	Wrought; h-t.....	.....	30.0	19.3 (0.2% offset)	59.3	4.0 (2 in.)	.....	.....	139	.....	[45]
ALUMINUM-TIN ALLOY												
252...	Sn 5.5-7.0, Ni 1.5- 1.8, Mn 0.7-1.0, Cu 0.6-0.9, Fe 0.2- 0.45, Si 0.15-0.3.	Die-cast.....	.....	.....	.....	.....	.....	.....	.....	45-50	.....	[59]
253...	do.....	Die-cast; 12 hr at 355°F.	.....	.....	.....	.....	.....	.....	.....	60-75	.....	[59]
ALUMINUM-ZINC ALLOYS (SEE ALSO FIG.17)												
254...	Zn 4.25, Mg 3.49, Mn 0.33, Fe 0.28, Si 0.14, V 0.05, Cu 0.02.	Sheet, 0.04 in., 1/2 hr at 840°F, w-q, aged 3 weeks at r-t.	.....	.....	35.3	61.9	20	.....	.....	.....	.....	[60]
255...	do.....	Sheet, 0.04 in., 1/2 hr at 840°F, a-c, aged 3 weeks at r-t.	.....	.....	.....	34.7	16	.....	.....	.....	.....	[60]
256...	Zn 4.38, Mg 3.47, Mn 0.32, Fe 0.30, Si 0.15, V 0.10, Cu 0.01.	Sheet, 0.04 in., 1/2 hr at 840°F, w-q, aged 3 weeks at r-t.	.....	.....	42.3	66.1	19	.....	.....	.....	.....	[60]
257...	do.....	Sheet, 0.04 in., 1/2 hr at 840°F, a-c, aged 3 weeks at r-t.	.....	.....	37.4	61.2	16	.....	.....	.....	.....	[60]
258...	Zn 5.0, Mg 2.5, Cu 2.3, Ni 1.0, Ti 0.1.	Wrought; ann.....	10,000	.....	9-18 (0.1%)	27-31	14-20	.....	.....	45-65	.....	[61]
259...	do.....	Wrought; h-t and aged at r-t.	10,000	.....	40-47 (0.1%)	65-72	16-21	.....	.....	130-140	.....	[61]

260...	...do.....	wrought; h-t and artificially aged.	10,000	.....	63-74 (0.1%)	72-85	10-16	.....	28-29 (2 x 10 ⁷)	160-180	.....	Comp yld str (0.1%).....60-67 kips/in. ² ..	[61]
261...	Zn 6.87, Mg 1.62, Mn 1.24, Si 0.29, Fe 0.28.	Bar, 23/32 in. diam, wrought; w-q from 930°F, aged 30 hr at 165°F.	10,100	.....	31.4 (0.001% perm) 52.6 (0.01% perm)	.....	.....	.....	.....	.....	.....	.....	[24]
262...	Zn 7, Mg 3.....	Mixed powders; compacted at 40 tons/in. ² ; 24 hr at 700°F in air, w-q.	.....	.....	.....	21.4	.....	.....	.....	.....	.....	.....	[52]
263...	...do.....	Mixed powders; compacted at 40 tons/in. ² ; 24 hr at 950°F in air, w-q.	.....	.....	.....	40.0	.....	.....	.....	.....	.....	.....	[52]
264...	Zn 10.....	Mixed powders; compacted at 40 tons/in. ² ; 24 hr at 700°F in air, w-q.	.....	.....	.....	10.9	.....	.....	.....	.....	.....	.....	[52]
265...	...do.....	Mixed powders; compacted at 40 tons/in. ² ; 24 hr at 950°F in air, w-q.	.....	.....	.....	15.5	.....	.....	.....	.....	.....	.....	[52]
266 ^a ...	Zn 10.0, Cu 1.0, Mn 0.7, Mg 0.4.	Forged; h-t (70S-1).....	.....	.....	40 (0.2% perm)	50	16 (2 in.)	.....	21 (5 x 10 ⁸)	85	.....	Shear str.....37 kips/in. ² Specific gravity.....2.91.	[11]
267 ^a ...	Zn 11.0, Cu 2.5, Fe 1.2.	Sand-cast (645).....	10,300	.....	20 (0.2% perm)	29	4 (2 in.)	.....	7.5 (5 x 10 ⁸)	70	2	Comp yld str (0.2%).....20 kips/in. ² Shear str.....22 kips/in. ² Specific gravity.....2.94. Melting range.....950°-1,165°F.	[10]
268...	Zn 12.0, Cu 3.0, Mn 0.6, Fe 0.27, Si 0.25, Al 0.1.	Rod, 23/32 in. diam, wrought; 3/4 hr at 895°F, w-q, aged at r-t.	9,800	.....	29.6 (0.001% perm) 40.3 (0.01% perm)	.....	.....	.....	.....	.....	.....	.....	[24]
269...	Zn 13.5, Cu 2.75.....	Sand-cast.....	.....	.....	11-18 (yld pnt)	20-27	2-4	.....	.....	60-65	1z 2-3	Specific gravity.....3.00..... Melting point.....1,130°F.	[62]
270...	...do.....	Chill-cast.....	.....	.....	13-20 (yld pnt)	25-34	4-8	.....	7.8 (2 x 10 ⁷)	65-70	1z 4-6	.....	[62]
271...	Zn 20.....	Sheet.....	.....	.....	.....	21	2 (2 in.)	.....	.....	80	.....	.....	[18]
272...	Zn 25.0, Cu 3.0.....	Bar, 1/2 in., hot- rolled.	10,000	.....	61.0 (yld pnt)	71.0	21 (2 in.)	38	.....	.....	.....	Specific gravity.....3.29.....	[23]
273...	...do.....	Sheet, 0.16 in., annealed.	10,000	.....	36.0 (yld pnt)	52.4	18 (2 in.)	.....	.....	.....	.....	.....	[23]

^aReferences [10 and 11]—for all alloys, wrought and cast; modulus of elasticity (shear) 3,850 kips/in.², Poisson's ratio 0.33.

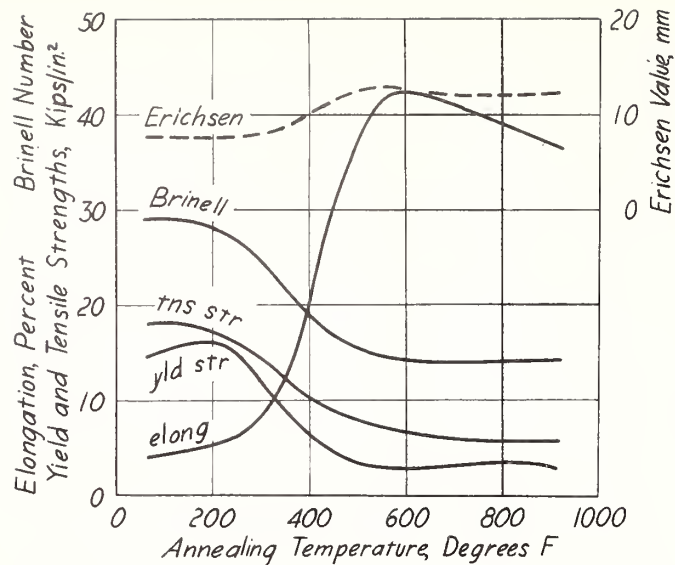


FIGURE 2.—Effect of annealing on the tensile properties, hardness, and Erichsen value of cold-rolled, high-purity aluminum sheet (Wolf and Tuxhorn [628]).

(Yield strength, 0.2%)

Si 0.0020%, Cu 0.0006%, Fe 0.0006%. Sheet, 0.04 in., cold-rolled (87% red.), annealed 1 hour.

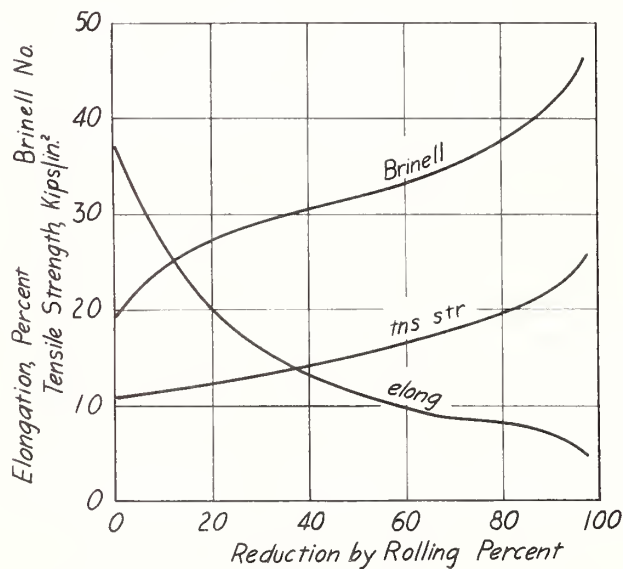


FIGURE 3.—Effect of cold-rolling on the tensile properties and hardness of aluminum sheet (Weiss [629]).

Al 99.7%

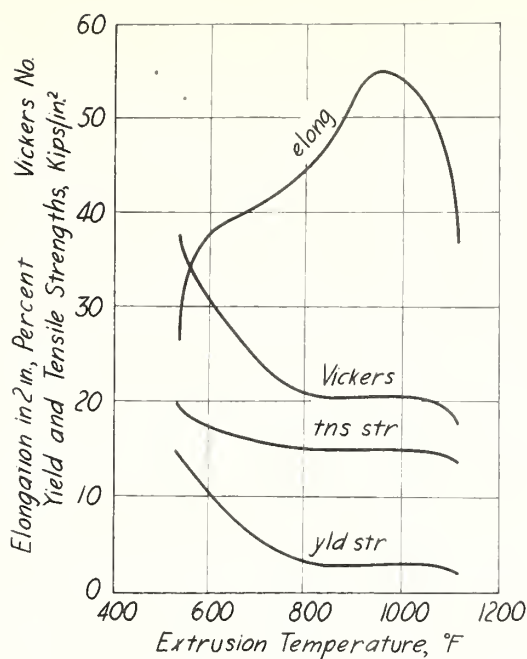


FIGURE 4.—Effect of extrusion temperature on the tensile properties and hardness of aluminum (Pearson [630]).

(Yield strength, 0.1%)

Fe 0.33%, Si 0.17%. Rod, extruded from 1 1/2 in. diameter to 1/2 in. diameter.

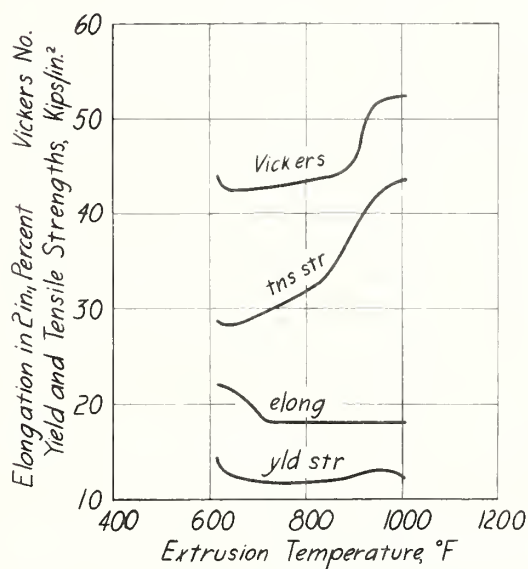


FIGURE 5.—Effect of extrusion temperature on the tensile properties and hardness of an aluminum-copper alloy (Pearson [630]).

(Yield strength, 0.1%)

Cu 5.31%, Fe 0.35%, Si 0.22%. Rod, extruded from 1 1/2 in. diameter to 1/2 in. diameter.

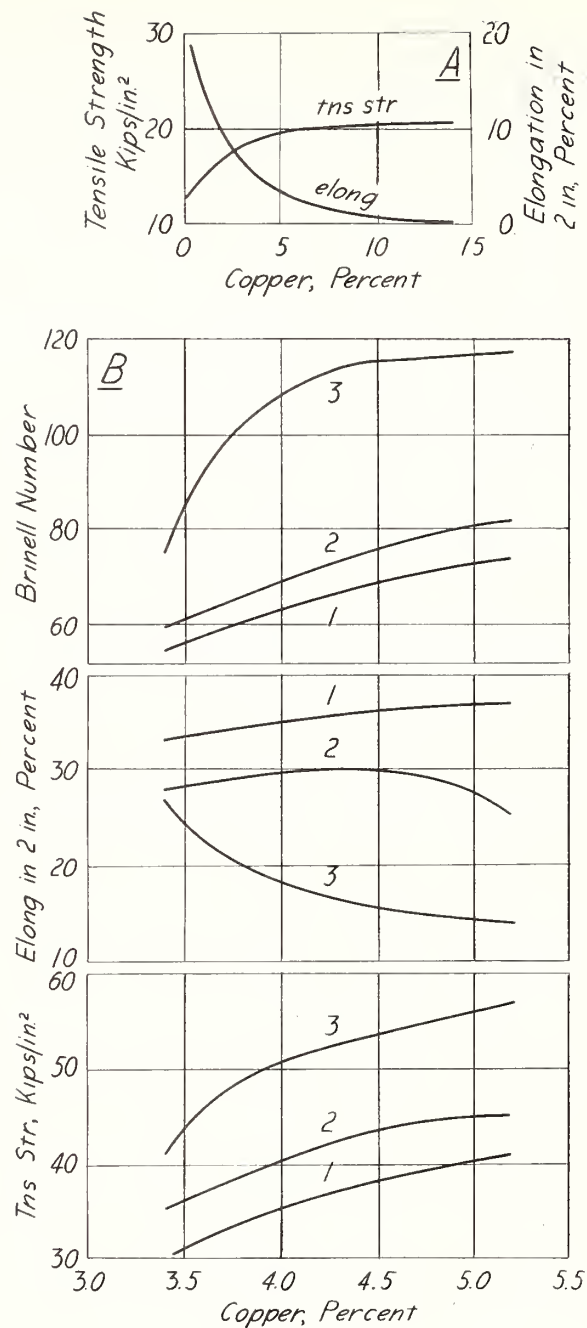


FIGURE 6.—Tensile properties and hardness of sand-cast and wrought aluminum-copper alloys (Dix and Bowman [631]).

A, Test bars, 1/2 in. diameter, cast in green sand; B, high-purity alloys, hot-rolled, annealed 1 hour at 1,000°F and quenched in water. Curves: 1, as quenched; 2, quenched and aged 11 days at room temperature; 3, quenched and aged 38 hours at 300°F.

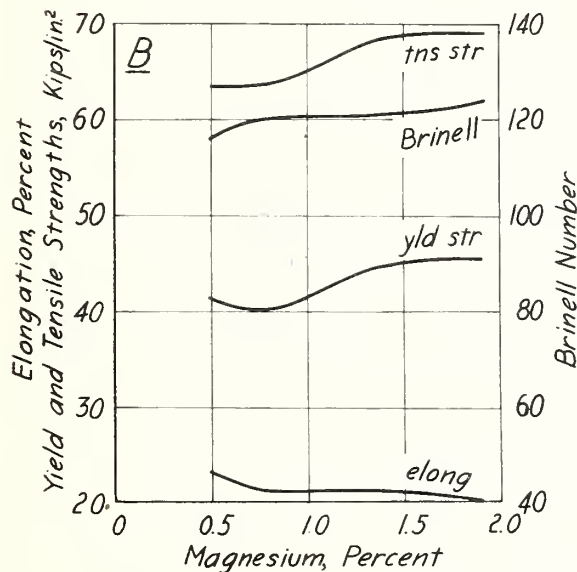
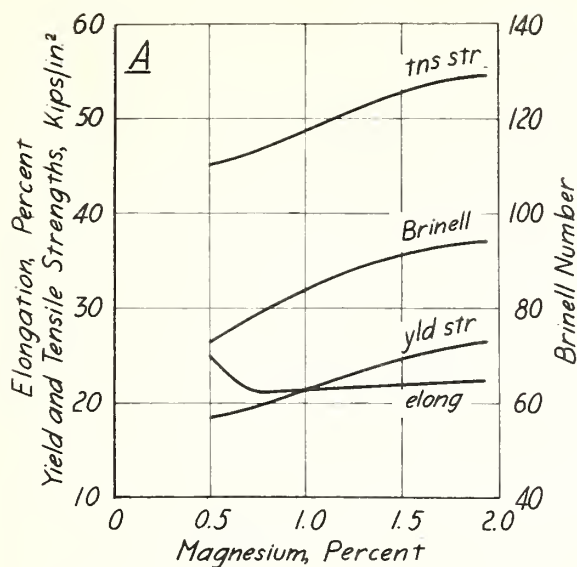


FIGURE 7.—Effect of magnesium on the tensile properties and hardness of an aluminum-copper alloy containing 4 percent of copper (Hansen and Dreyer [632]).

(Yield strength, 0.2%; elongation in $11.3 \sqrt{\text{area}}$.)

Alloys also contain Mn 0.6%, Fe 0.25%, Si 0.2%. Sheet, 0.08 in. A, Quenched; B, quenched and aged at room temperature.

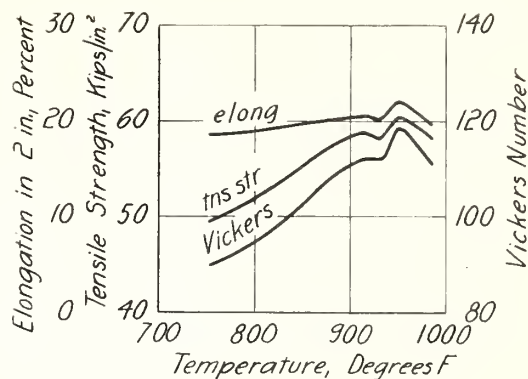


FIGURE 8.—Effect of temperature of solution heat-treatment on the tensile properties and hardness of Duralumin (Carpenter and Robertson [43]).

Quenched in cold water and aged 4 days at room temperature.

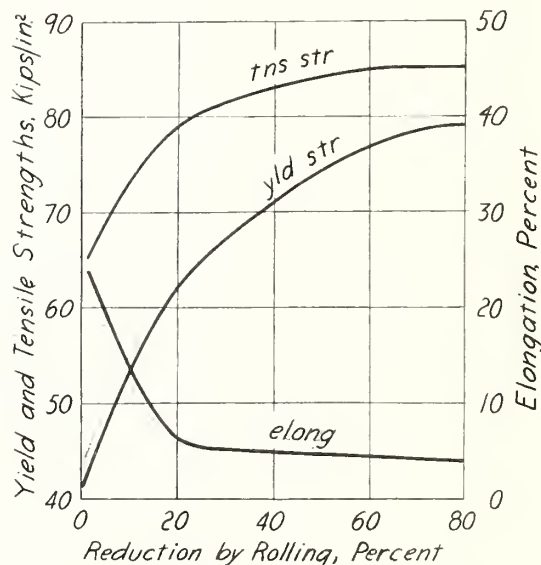


FIGURE 9.—Effect of cold-rolling on the tensile properties of aged Duralumin (Zeerleder [18]).

(Yield strength, 0.2%)

Aged 6 days at room temperature before rolling.

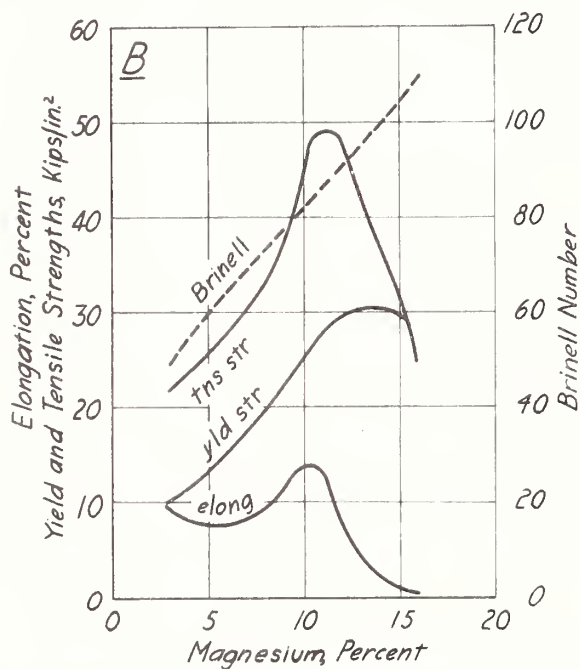
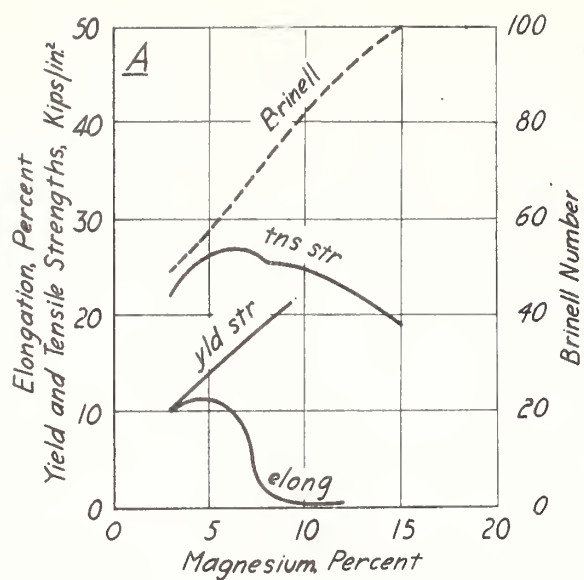


FIGURE 10.—Tensile properties and hardness of cast aluminum-magnesium alloys (Kempf and Keller [633]).

Fe and Si less than 0.25% each, Cu less than 0.15%.

A, Test bars, 1/2 in. diameter, cast in green sand; B, sand-cast and heat-treated.

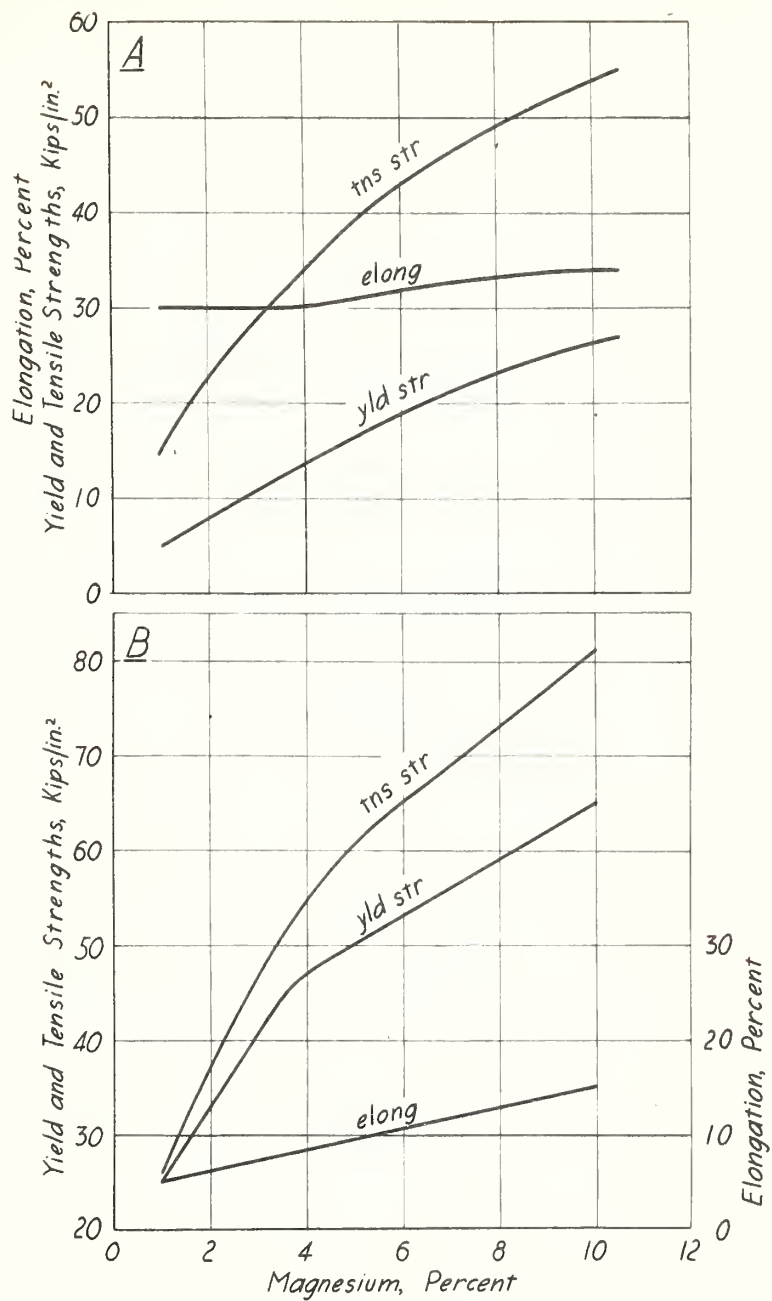


FIGURE 11.—Tensile properties of aluminum-magnesium alloy sheet (Kempf and Keller [633]).

A, Heat-treated; B, heat-treated and cold-rolled (75% red.)

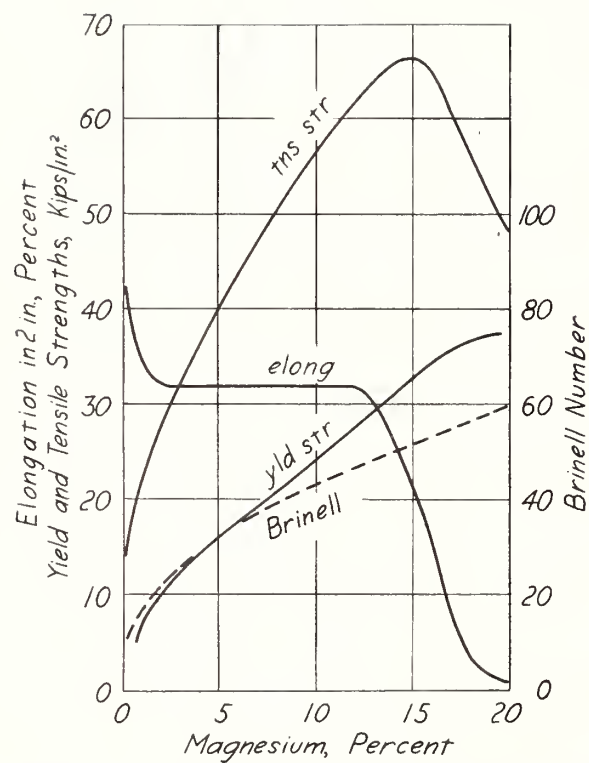


FIGURE 12.—Tensile properties and hardness of forged or extruded aluminum-magnesium alloys (Kempf and Keller [633]).

Cu, Fe, and Si less than 0.1% each.

Alloys containing up to 10% of Mg forged, others extruded; all annealed and quenched.

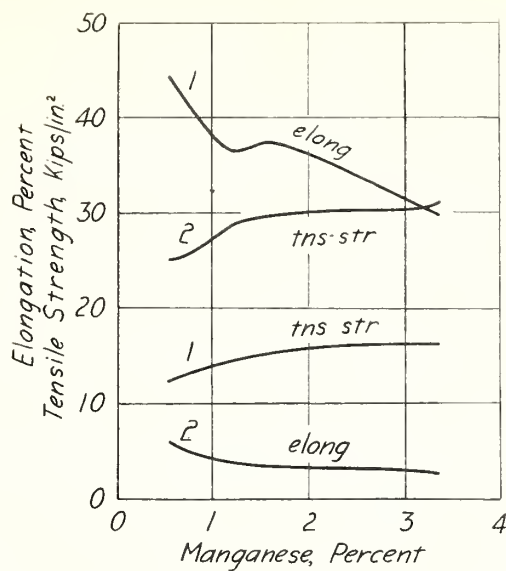


FIGURE 13.—Tensile properties of aluminum-manganese alloys (Bosshard [634]).

(Elongation in $11.3 \sqrt{\text{area}}$)

Sheet, 0.04-0.08 in. Curves: 1, annealed 8 hours at 750°F; 2, annealed at 790°F, rolled (80-90% red.).

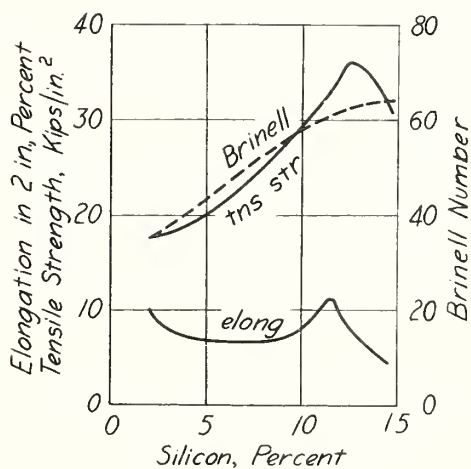


FIGURE 14.—Tensile properties and hardness of chill-cast aluminum-silicon alloys (Carpenter and Robertson [43]).

Fe 0.35%, Cu 0.15%

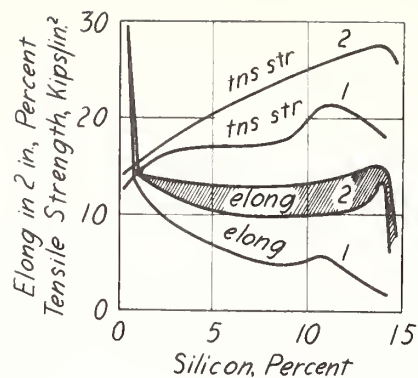


FIGURE 15.—Tensile properties of sand-cast aluminum-silicon alloys (Kempf [74]).

Test bars, 1/2 in. diameter. Curves: 1, normal; 2, modified by treatment with sodium fluoride before casting.

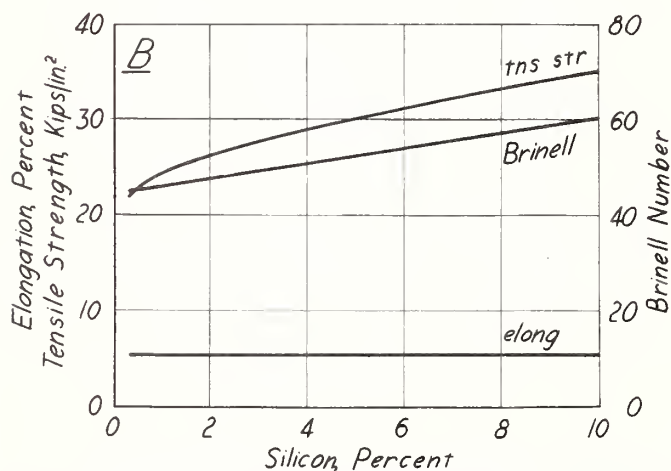
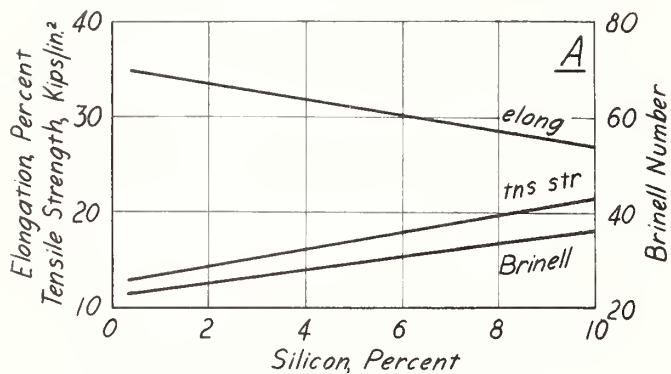


FIGURE 16.—Tensile properties and hardness of aluminum-silicon alloys (Kempf [74]).

Sheet, 0.08 in.

A, Annealed; B, hard-rolled.

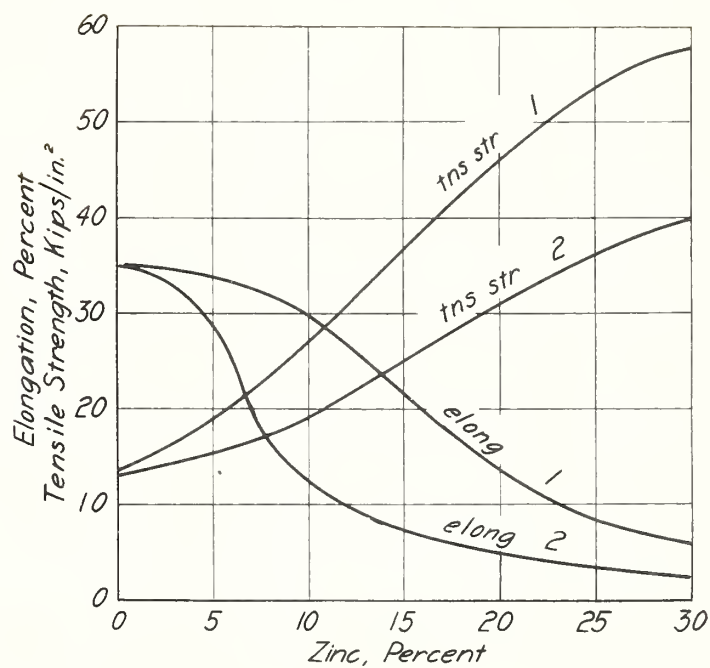


FIGURE 17.—Tensile properties of wrought and chill-cast aluminum-zinc alloys (Kempf [635]).

Curves: 1, rod, 3/4 in. square, forged; 1 hour at 880°F, water-quenched, aged 8 days at room temperature; 2, chill-cast.

TABLE 4.—*Aluminum and aluminum alloys, high temperature properties*

[For a discussion of the indefiniteness of values reported for yield strength and particularly for "proportional limit" see pages 5 and 6. Hardness numbers are Brinell numbers, unless prefixed R_c , R_p , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers).]

Serial number	Composition	Condition	Temperature	Short-time properties					Creep properties			Reference	
				"Proportional limit"	Yield strength ^a	Tensile strength	Elongation ^b	Reduction of area	Hardness number	Stress (kips/in. ²) for designated creep rate per 1,000 hours	Hours		
FOR PURE AND COMMERCIAL ALUMINUM, SEE FIGURES 18 AND 19													
ALUMINUM-COPPER ALLOYS (SEE ALSO FIGS. 20 TO 24, INCLUSIVE)													
274...	Cu 3.90, Al 2.22, Mg 1.60, Fe 0.36, Si 0.21.	Cast; 5 hr at 950°F, w-q, aged 5 hr at 375°F..	$\frac{op}{\text{Room}}$ $\frac{400}{\text{°400}}$ $\frac{600}{\text{°600}}$	26.0 13.5 4.9	39.1 31.5 13.4	1.0 1.2 6.0	..... ..... .....	108	0.01% 5.0 2.5 (0.28%)	..... ..... ..... ..... ..... .....	..... 312 293 [45]		
275...	Cu 3.91, Al 2.22, Mg 1.66, Fe 0.35, Si 0.13.	Wrought; 5 hr at 950°F, w-q, aged 5 hr at 375°F..	$\frac{op}{\text{Room}}$ $\frac{400}{\text{°400}}$ $\frac{600}{\text{°600}}$	 22.0	52.8 37.2	13 11 59	..... ..... .....	138	 15.0 (0.11%) 2.5 (0.69%)	..... ..... ..... ..... ..... .....	..... 556 317 [45]		
276...	Cu 4.06, Al 2.12, Fe 0.62, Mg 0.47, Si 0.21, Mn 0.01.	Wrought, h-t.....	$\frac{op}{\text{Room}}$ $\frac{400}{\text{°400}}$ $\frac{600}{\text{°600}}$	..... ..... .....	..... ..... .....	19 37 73	..... ..... .....	87	 5.0 (0.09%) 1.3 (0.4%)	..... ..... ..... ..... ..... .....	..... 576 308 [45]		
277...	Cu 4.25, Mn 0.63, Mg 0.44, Fe 0.52, Si 0.25.	Rod, 5/8 in. diam, wrought, aged.....	$\frac{op}{63}$ $\frac{302}{\text{°302}}$ $\frac{482}{\text{°482}}$ $\frac{662}{\text{°662}}$	28.4 23.3 7.2	59.0 31.8 19.7 4.7	23 22 24 80	32 34 67 90	110	 22.0 5.7 1.5	..... ..... ..... ..... ..... .....	..... 500 500 500 [63]		
278...	Cu 4.29, Si 0.66, Fe 0.50..	Cast; 24 hr at 960°F, w-q, aged 2 hr at 300°F..	$\frac{op}{\text{Room}}$ $\frac{400}{\text{°400}}$ $\frac{600}{\text{°600}}$	11.2 7.5 3.8	23.8	3.5 6.0 26	..... ..... .....	87	 5.0 (0.09%) 1.3 (0.13%)	..... ..... ..... ..... ..... .....	..... 535 308 [45]		
279...	Cu 9.64, Fe 1.08, Mg 0.23, Si 0.22.	Cast; 5 hr at 925°F, w-q, aged 5 hr at 375°F..	$\frac{op}{\text{Room}}$ $\frac{400}{\text{°400}}$ $\frac{600}{\text{°600}}$	34.0 12.0 2.8	..... ..... .....	0.5 1.5 12	..... ..... .....	130	 5.0 1.3	..... ..... ..... ..... ..... .....	..... 511 383 [45]		
ALUMINUM-MAGNESIUM ALLOY (SEE ALSO FIG. 25)													
280...	Mg 5.96, Al 1.49, Mn 1.00, Cu 0.37, Fe 0.28, Si 0.19.	Cast.....	$\frac{op}{\text{Room}}$ $\frac{400}{\text{°400}}$ $\frac{600}{\text{°600}}$	9.0 10.0	18.2 17.2	2.5 3.0 .....	..... ..... .....	74	 2.5 (0.15%) 1.3 (0.86%)	..... ..... ..... ..... ..... .....	..... 600 313 [45]		

FOR ALUMINUM-MANGANESE ALLOYS, SEE FIGURE 26

ALUMINUM-SILICON ALLOYS

281...	Si 4.61, Cu 1.18, Mg 0.68, Fe 0.26.	Cast; 16 hr at 980°F, w-q, aged 8 hr at 440°F..	Room °400	9.0 10.0	33.5	36.3 26.3	1.5 2.0	..... .....	86	..... .....	..... 10.0 (0.12%) 1.3 (0.15%)	..... ..... ..... .....	[45] 554 245
282...	Si 12.64, Mg 0.96, Ni 0.91, Cu 0.90, Fe 0.78, Mn 0.02.	Wrought, h-t.....	Room °400	28.0 16.0	44.4 29.2	52.8 35.2	6.0 4.0	..... .....	126	..... .....	..... 7.5 (0.09%)	..... ..... .....	[45] 578
283...	Si 13.18, Ni 3.08, Cu 2.96, Mg 1.04, Fe 0.53.	...do.....	Room °400	3.0 30.0	6.1 49.3	8.7 59.3 21.7	35 4.0 12	..... ..... .....	139	..... .....	..... 7.5 (0.07%) 1.3 (0.22%)	..... ..... .....	[45] 574 291

^a 0.2% offset.
^b 2-in. gage length.
^c 68 hr at indicated temperature before short-time test.
^d 20 hr at indicated temperature before short-time test.
^e 24 hr at indicated temperature before short-time test, short-time tensile tests on same type of alloy as creep tests but not from same lot.
^f 75 days at indicated temperature before short-time test, short-time tensile tests on same type of alloy as creep tests but not from same lot.
^g 30 days at indicated temperature before short-time test, short-time tensile tests on same type of alloy as creep tests but not from same lot.
^h Yield point.

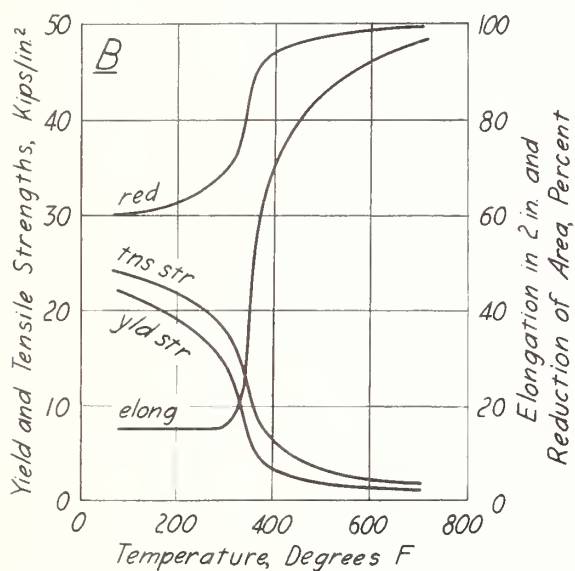
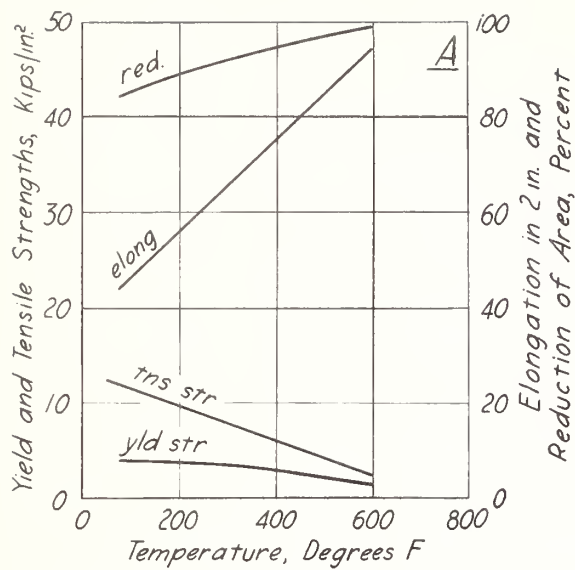


FIGURE 18.—Short-time tensile properties of wrought aluminum at high temperatures (Howell and Paul [636]).

(Yield strength, 0.2%)

Fe 0.53%, Si 0.13%, Cu 0.11%, Mn 0.02%. A, Annealed (2S-O); B, cold-rolled, 80% reduction (2S-H).

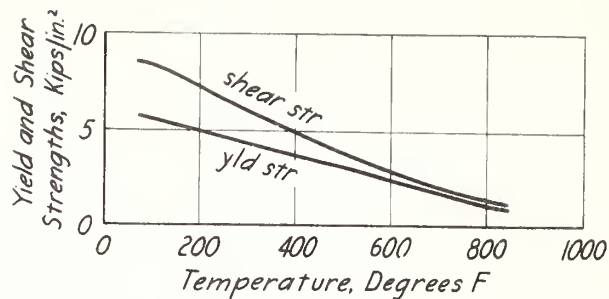


FIGURE 19.—Shear strength of aluminum at high temperatures (Irmann [637]).

Al 99.3%

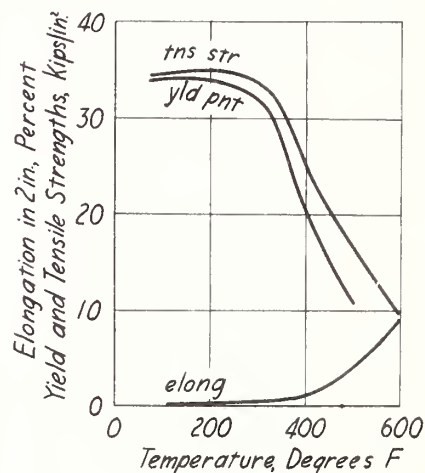


FIGURE 20.—Short-time tensile properties of an aluminum-copper-iron-magnesium alloy at high temperatures (Heil [??]).

Cu 10%, Fe 1.2%, Mg 0.2%. Chill-cast and aged (122-T52).

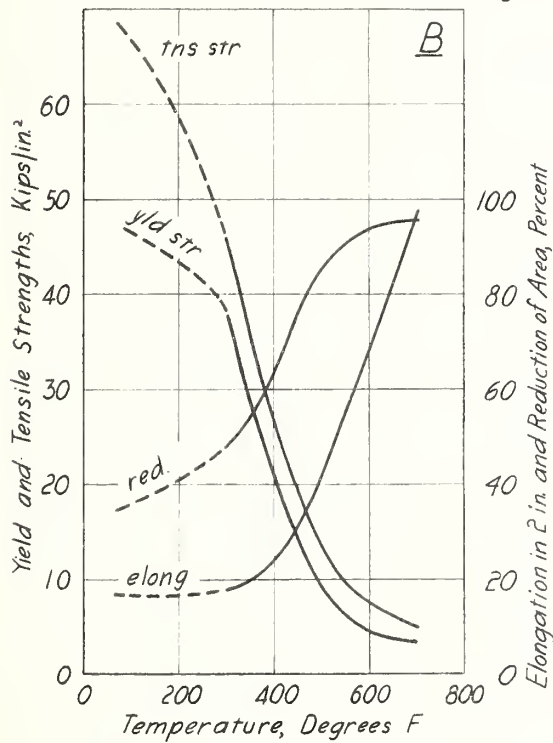
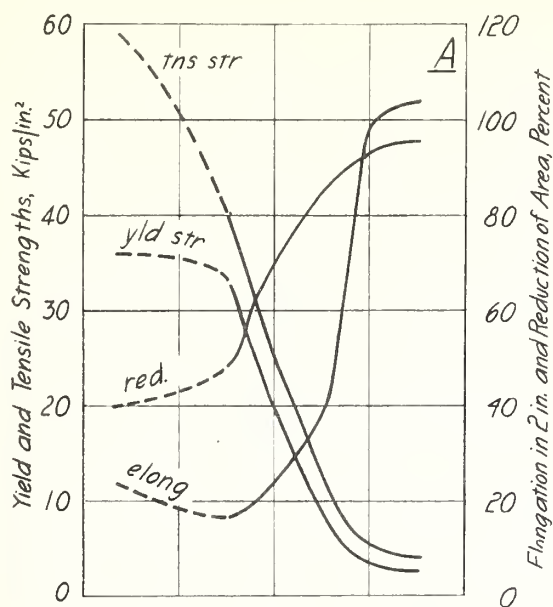


FIGURE 21.—Short-time tensile properties of wrought aluminum-copper-magnesium-manganese alloys at high temperatures (Howell and Paul [638]).

(Yield strength, 0.2%)

A, Cu 4%, Mg 0.5%, Mn 0.5%. Quenched and aged (17S-T); B, Cu 4.2%, Mg 1.5%, Mn 0.5%. Quenched and aged (24S-T).

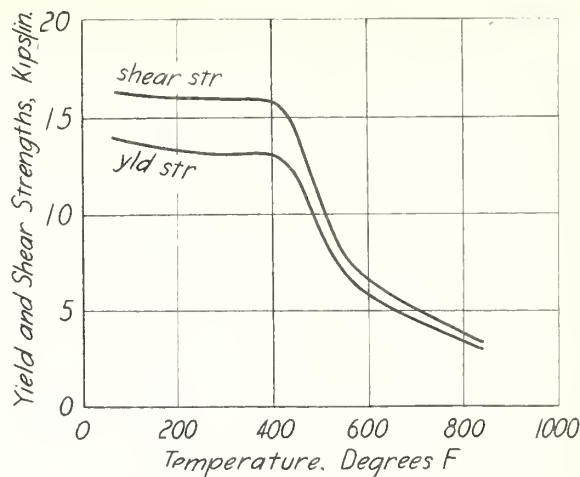


FIGURE 22.—Shear strength of an aluminum-copper-magnesium-manganese alloy at high temperatures (Irmann [637]).

Cu 4.3%, Mg 0.6%, Mn 0.5%, Si 0.4%.

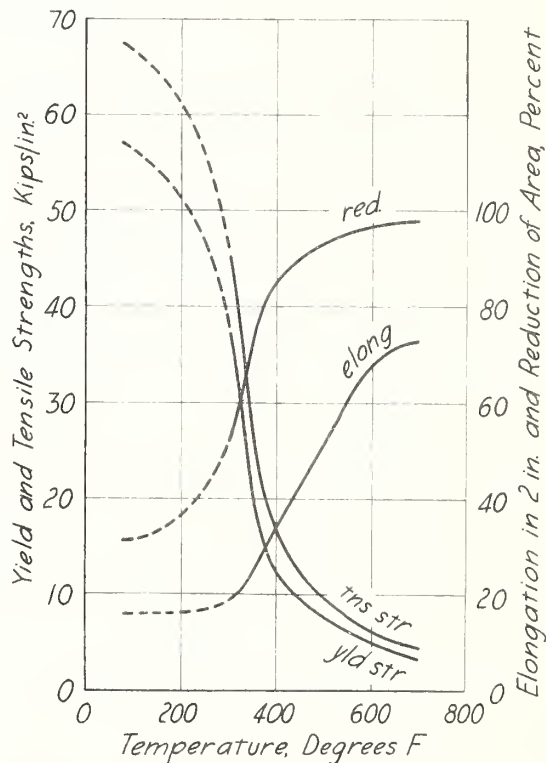


FIGURE 23.—Short-time tensile properties of a wrought aluminum-copper-magnesium-manganese alloy at high temperatures (Howell and Paul [638]).

(Yield strength, 0.2%)

Cu 4.4%, Mn 0.8%, Si 0.8%, Mg 0.4%. Quenched and aged (14S-T).

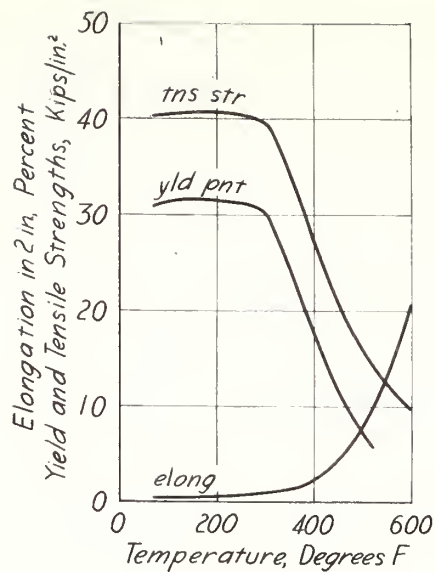


FIGURE 24.—Short-time tensile properties of an aluminum-copper-nickel-magnesium alloy at high temperatures (Heil [76]).

Cu 4%, Ni 2%, Mg 1.5%. Chill-cast and aged (142-T571).

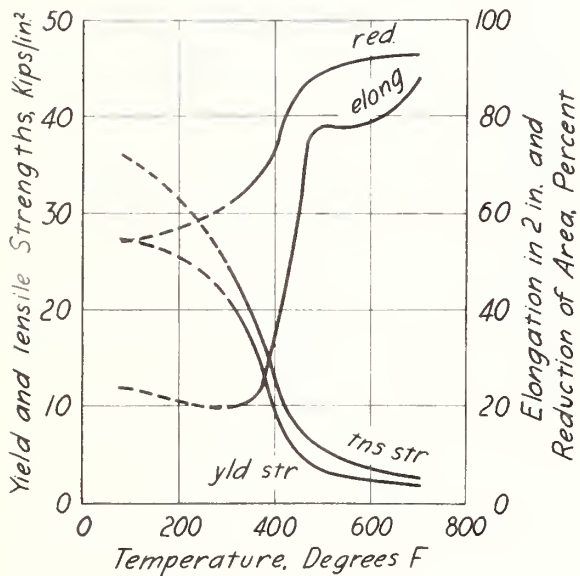


FIGURE 25.—Short-time tensile properties of a wrought aluminum-magnesium-silicon-chromium alloy at high temperatures (Howell and Paul [638]).

(Yield strength, 0.2%)

Mg 1.2%, Si 0.7%, Cr 0.25%. Heat-treated and aged (53S-T).

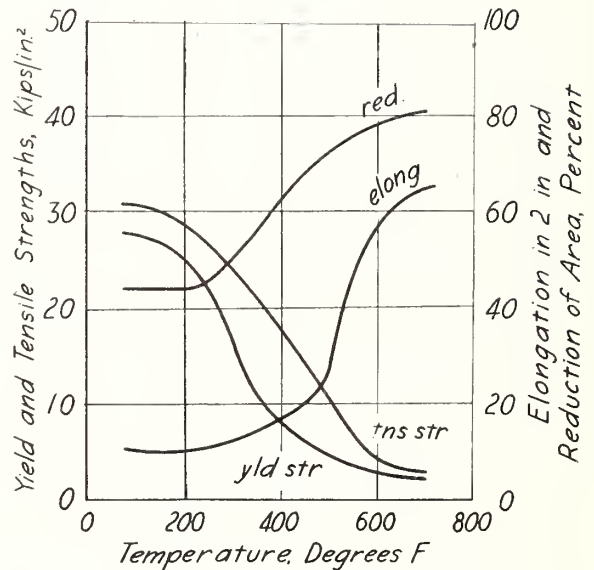


FIGURE 26.—Short-time tensile properties of a wrought aluminum-manganese alloy at high temperatures (Howell and Paul [636]).

(Yield strength, 0.2%)

Mn 1.2%, Fe 0.45%, Si 0.22%, Cu 0.1%, Hard-drawn, 30% reduction (3S-H).

TABLE 5.—*Aluminum and aluminum alloys, low temperature properties*

[For a discussion of the indefiniteness of values reported for yield strength see page 5. Hardness numbers are Brinell numbers unless prefixed R_B, R_C, etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed Iz (Izod method).]

Serial number	Composition	Condition	Temperature	Tensile properties				Endurance limit	Hardness number	Impact value	Remarks	Reference
				Yield strength	Tensile strength	Elongation	Reduction of area					
PURE AND COMMERCIAL ALUMINUM												
284...	Percent Fe 0.07, Si 0.054.....	Rod, 1 in. diam; rolled, annealed.....	Room temperature	4.4 (0.1% perm)	9.8 (2 in.)	36 (2 in.)	90	.....	.....	ft-lb Iz 19	Tensile specimens 0.25 in. diam.....	[64]
			14	3.8 (0.1% perm)	11.4 (2 in.)	36 (2 in.)	90	.....	.....	.....		
			-40	4.0 (0.1% perm)	11.6 (2 in.)	40 (2 in.)	92	.....	.....	Iz 19		
			-112	4.3 (0.1% perm)	11.9 (2 in.)	38 (2 in.)	92	.....	.....	Iz 20		
			-184	3.5 (0.1% perm)	14.1 (2 in.)	40 (2 in.)	90	.....	.....	Iz 21		
			-292	4.5 (0.1% perm)	20.8 (2 in.)	44 (2 in.)	87	.....	.....	Iz 27		
285...	Al (commercial).....	Hard-drawn (93% red.).....	77	.....	49.0 (2 in.)	2 (2 in.)	32	.....	.....	.....		[65]
			-301	.....	63.0 (2 in.)	6 (2 in.)	28	.....	.....	.....		
ALUMINUM-COPPER ALLOYS												
286...	Cu 3.46, Ni 1.86, Mg 0.76, Fe 0.45, Si 0.30, Mn 0.08.	Quenched from 970°F into boiling water, aged 1 hr at 212°F.	Room temperature	25.4 (0.1% perm)	47.9 (2 in.)	22 (2 in.)	34	.....	.....	Iz 7.0	Tensile specimens 0.25 in. diam.....	[64]
			-40	25.1 (0.1% perm)	49.3 (2 in.)	22 (2 in.)	33	.....	.....	Iz 7.5		
			-112	25.9 (0.1% perm)	50.4 (2 in.)	23 (2 in.)	31	.....	.....	Iz 7.5		
			-184	27.3 (0.1% perm)	55.3 (2 in.)	22 (2 in.)	25	.....	.....	Iz 8.0		
			-292	27.5 (0.1% perm)	62.3 (2 in.)	27 (2 in.)	28	.....	.....	Iz 8.0		
287...	Cu 3.72, Mg 0.62, Mn 0.59, Si 0.46, Fe 0.43.	Plate, 1/2 in.; w-q from 940°F (178-T).	Room temperature	41.5 (0.1% perm)	59.5 (2 in.)	22 (2 in.)	30	.....	R _E 66 R _E 70	15 18	Long. sample; Charpy impact bar with Izod notch.	[25]
288...	do.....	do.....	-105	43.0 (0.1% perm)	61.0 (2 in.)	21 (2 in.)	23	.....	R _E 66 R _E 70	8.5 10	Trans sample; Charpy impact bar with Izod notch.	[25]
289...	Cu 3.74, Mg 0.91, Mn 0.84, Fe 0.47, Si 0.42, Ti 0.01.	Rod, 19/32 in. diam; extruded.....	68	49.2 (0.2%)	65.1 (10 diam)	19 (10 diam)	.....	21.8 (2 x 10 ⁷)	.....	.....		[26]
			-31	.....	.....	.....	.....	22.2 (2 x 10 ⁷)	.....	.....		
			-85	.....	.....	.....	.....	25.6 (2 x 10 ⁷)	.....	.....		
290...	Cu 3.90, Mg 0.63, Mn 0.53, Si 0.46, Fe 0.29.	Plate, 1/2 in.; w-q from 940°F, cold-rolled 5 1/2% red. (178-T).	Room temperature	52.5 (0.1% perm)	64.5 (2 in.)	21 (2 in.)	29	.....	R _E 74 R _E 77	12 14	Long. sample; Charpy impact bar with Izod notch.	[25]
291...	do.....	do.....	-105	54.5 (0.1% perm)	67.0 (2 in.)	18 (2 in.)	23	.....	R _E 74 R _E 77	7.5 8	Trans sample; Charpy impact bar with Izod notch.	[25]
292...	Cu 3.90, Si 1.23, Mg 0.58, Mn 0.39, Fe 0.32.	Bar, 9/16 in., extruded; h-t (178-T).	Room temperature	50.5 (0.1% perm)	67.5 (2 in.)	15 (2 in.)	19	.....	139	.....		[25]
			-40	59.0 (0.1% perm)	67.0 (2 in.)	14 (2 in.)	51	.....	.....	.....		
293...	Cu 3.99, Si 0.81, Mn 0.79, Fe 0.36, Mg 0.01.	Plate, 1/2 in.; w-q from 965°F, aged 18 hr at 320°F.	Room temperature	58.0 (0.1% perm)	69.0 (2 in.)	13 (2 in.)	52	.....	R _E 72 R _E 77	6 7.5	Long. sample; Charpy impact bar with Izod notch.	[25]

TABLE 5.—Aluminum and aluminum alloys, low temperature properties—Continued

Serial number	Composition	Condition	Temperature	Tensile properties			Hardness number	Impact value	Remarks	Reference	
				Yield strength	Elongation	Reduction of area					
ALUMINUM-COPPER ALLOYS—Continued											
294...	Percent Cu 3.99, Si 0.81, Mn 0.79, Fe 0.36, Mg 0.01.	Plate, 1/2 in.; w-q from 965°F, aged 18 hr at 320°F.	{ Room -105	47.0 47.0	11 12	16 19	..... .....	R _E 72 R _E 77	4.5 5	Trans sample; Charpy impact bar with Izod notch.	[25]
295...	Cu 4.01, Mn 0.73, Mg 0.57, Fe 0.46, Si 0.23.	Bar, 9/16 in., extruded; 1 1/2 in at 950°F (178-T).	{ Room -40	12.0 14.5	23 24	42 42	..... .....	..... 112	.....	.....	[25]
296...	Cu 4.02, Si 1.94, Mg 1.61, Fe 0.56, Si 0.26.	Rod, 1/2 in. diam, sand-cast; 16 in at 940°F, aged 2 hr at 340°F.	{ Room -40	 39.5	1.0 1.0	.....	8.0 (10 ⁸) 9.0 (10 ⁸)	121 115	.....	.....	[25]
297...	Cu 4.1, Mn 0.75, Mg 0.57, Fe 0.42.	Rolled.....	{ Room -122	59.2 78.6	18 17 (10 diam)	34 20	..... .....	135	.....	.....	[66]
298...	Cu 4.26, Mn 0.82, Si 0.70, Fe 0.50, Mg 0.03.	Plate, 1/2 in.; w-q from 965°F, aged 18 hr at 240°F (258-T).	{ Room -105	36.0 37.0	20 22	32 31	.....	R _E 65 R _E 70	13 16	Long sample; Charpy impact bar with Izod notch.	[25]
299...	do.....	do.....	{ Room -105	34.0 34.5	17 18	22 22	.....	R _E 65 R _E 70	10 12	Trans sample; Charpy impact bar with Izod notch.	[25]
300...	Cu 4.26, Si 1.29, Fe 1.02.....	Rod, 3/8 in. diam, sand-cast; 12 in at 955°F, aged 2 hr at 300°F.	{ Room -40	 33.5	.....	.....	10.0 (5 x 10 ⁸) 11.0 (5 x 10 ⁸)	75 74	.....	.....	[25]
301...	Cu 4.27, Mg 1.22, Mn 1.21, Si 0.42, Fe 0.37.	Sheet, 7/16 in.....	{ 68 -31 -85	11.4 (0.2%)	13	.....	.....	.....	.....	.....	[26]
302...	Cu 4.32, Mg 1.44, Mn 0.19, Fe 0.16, Si 0.14.	Plate, 1/2 in.; w-q from 929°F (248-T).	{ Room -105	18.5 50.0	20 21	26 27	.....	R _E 74 R _E 77	12 12	Long sample; Charpy impact bar with Izod notch.	[25]
303...	do.....	do.....	{ Room -105	12.5 15.0	17 17	20 20	.....	R _E 74 R _E 77	7.5 7	Trans sample; Charpy impact bar with Izod notch.	[25]
304...	Cu 4.35, Si 0.81, Fe 0.53.....	Rod, 3/4 in. diam, cast; 16 in at 960°F, w-q to 210°F (135-T).	{ Room -105	24.5 25.5	4.5 5.0	6.5 5.5	.....	R _E 82 R _E 84	4 5	Charpy impact bar with Izod notch....	[25]
305...	Cu 4.36, Si 0.84, Mn 0.83, Fe 0.34.	Forged propeller blade; w-q from 950°F, aged 12 hr at 300°F (258).	{ Room -10	33.8 35.8	18 15	24 26	13.0 (5 x 10 ⁸) 16.0 (5 x 10 ⁸)	107 108	12 13 12 13	.....	[25]
306...	Cu 4.39, Mn 1.16, Mg 1.08, Si 0.63, Fe 0.46, Ti 0.01.	Rod, 19/32 in. diam, extruded.....	{ 68 -31 -85	59.5 (0.2%)	17 (10 diam)	.....	23.2 (2 x 10 ⁷) 29.5 (2 x 10 ⁷) 26.7 (2 x 10 ⁷)	.....	.....	.....	[26]
307...	Cu 4.41, Mn 0.80, Si 0.73, Fe 0.48, Mg 0.02.	Plate, 1/2 in.; w-q from 965°F, aged 18 hr at 240°F, cold-rolled 5 1/2% red. (258-RT).	{ Room -105	45.0 46.0	16 16	29 28	.....	R _E 59 R _E 74	10 12	Long sample; Charpy impact bar with Izod notch.	[25]
308...	do.....	do.....	{ Room -105	43.0 43.5	10 12	16 19	.....	R _E 68 R _E 74	7 8	Trans sample; Charpy impact bar with Izod notch.	[25]

309...	Cu 7.76, Fe 0.15, Si 0.10.....	Rod, 1/2 in. diam, sand-cast.....	Room { -40	.....	21.5	3.0	.....	7.0 (5 × 10 ⁶) 8.0 (5 × 10 ⁶)	65 72 .....	.....	[25]
310...	Cu 7.98, Si 0.98, Fe 0.59.....	do.....	Room { -40	.....	24.5	2.2	.....	7.0 (10 ⁶) 9.0 (10 ⁶)	82 89 .....	.....	[25]

ALUMINUM-MAGNESIUM ALLOYS

311...	Mg 2.35, Cr 0.27, Fe 0.14, Si 0.12, Cu 0.05.....	Plate, 1/2 in., rolled (FS).....	Room { -105	.....	21.0 22.0	22 29	62 65	.....	R _E 68 R _E 74	Long sample; Charpy impact bar with Izod notch.	[25]
312...	do.....	do.....	Room { -105	.....	21.5 22.0	21 25	60 64	.....	R _E 68 R _E 74	Trans sample; Charpy impact bar with Izod notch.	[25]
313...	Mg 3.66, Mn 0.50, Fe 0.15, Si 0.12, Cu 0.02.....	Rod, 1/2 in. diam, sand-cast.....	Room { -40	.....	.....	12	.....	6.0 (2 × 10 ⁶) 7.0 (2 × 10 ⁶)	58 59 .....	.....	[25]
314...	Mg 4.68, Fe 0.35, Mn 0.26, Si 0.15, Cu 0.03, Ti 0.007.....	Rod, 19/32 in. diam, extruded.....	68 { -31 -85	.....	14.5 (0.2%)	24 (10 diam) .....	.....	19.2 (2 × 10 ⁷) 23.9 (2 × 10 ⁷) 26.7 (2 × 10 ⁷)	..... ..... .....	.....	[26]
315...	Mg 6.57, Fe 0.70, Mn 0.18, Si 0.11, Ti 0.007.....	do.....	68 { -31 -85	.....	37.3 (0.2%)	13 (10 diam) .....	.....	25.2 (2 × 10 ⁷) 25.7 (2 × 10 ⁷) 25.3 (2 × 10 ⁷)	..... ..... .....	.....	[26]
316...	Mg 7.14, Fe 0.32, Mn 0.22, Si 0.15, Cu 0.01, Ti 0.003.....	Sheet, 7/16 in.....	68 { -31 -85	.....	46.4 (0.2%)	11	.....	.....	..... ..... .....	.....	[26]
317...	Mg 8.93, Fe 0.14, Mn 0.28, Si 0.12, Cu 0.04, Ti 0.01.....	Rod, 19/32 in. diam, extruded.....	68 { -31 -85	.....	23.6 (0.2%)	15 (10 diam) .....	.....	20.3 (2 × 10 ⁷) 19.6 (2 × 10 ⁷) 20.8 (2 × 10 ⁷)	..... ..... .....	.....	[26]
318...	Mg 10.49, Fe 0.13, Si 0.07, Cu 0.03.....	Rod, 3/4 in. diam, cast; 16 hr at 810°F, o-q to 250°F (220-14).....	Room { -105	.....	24.0 24.0	7.5 8	10 9	.....	R _E 86 R _E 85	Charpy impact bar with Izod notch.....	[25]

ALUMINUM-MANGANESE ALLOY

319...	Mn 1.04, Fe 0.45, Si 0.11, Cu 0.12.....	Plate, 1/2 in., rolled (FS).....	Room { -105	.....	15.5 17.0	30 34	64 66	.....	R _E 40 R _E 56	Long sample; Charpy impact bar with Izod notch.	[25]
320...	do.....	do.....	Room { -105	.....	15.0 16.5	30 33	66 66	.....	R _E 40 R _E 56	Trans sample; Charpy impact bar with Izod notch.	[25]

^aNotch impact value, m-kj/cm.²

TABLE 5.—Aluminum and aluminum alloys, low temperature properties—Continued

Serial number	Composition	Condition	Temperature	Tensile properties			Endurance limit	Hardness number	Impact value	Remarks	Reference
				Yield strength	Tensile strength	Elongation						Reduction of area
ALUMINUM-SILICON ALLOYS											
321...	Percent Si 4.71, Fe 0.29, Cu 0.02.....	Rod, 1/2 in. diam, sand-cast.....	$^{\circ}\text{F}$ { Room -40 }	Kips/in.^2	Kips/in.^2 18.5	Percent 11 8.5	Kips/in.^2 6.0 (2×10^8) 7.0 (2×10^8)	45 44	ft-lb} ..... .....	..... ..... .....	[25]
322...	Si 4.76, Cu 1.25, Mn 0.49, Fe 0.26.	Rod, 3/4 in. diam, cast; 16 hr at 980 $^{\circ}\text{F}$, w-q to 210 $^{\circ}\text{F}$ (335-14).	{ Room -105 }	25.0 26.5	29.0 31.0	1.5 2.0	..... .....	P _E 84 P _E 88	1.5 1.5	Charpy impact bar with Izod notch....	[25]
323...	Si 5.0, Cu 1.2, Mg 0.5.....	Rod, 3/8 in. diam, sand-cast; 16 hr at 980 $^{\circ}\text{F}$, aged 8 hr at 410 $^{\circ}\text{F}$.	{ Room -40 }	..... .....	43.5 43.0	..... .....	8.0 (10 ⁸) 10.0 (10 ⁸)	..... .....	..... .....	..... .....	[25]
324...	Si 5.11, Fe 1.89, Cu 0.24, Ni 0.22, Zn 0.11, Mn 0.04, Mg 0.01.	Die-cast.....	{ 70 32 0 }	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	5.7 4.9 4.8	..... ..... .....	[67]
325...	Si 6.71, Fe 0.26, Mg 0.25, Cu 0.08.	Rod, 3/4 in. diam, cast; 16 hr at 1,000 $^{\circ}\text{F}$, w-q to 210 $^{\circ}\text{F}$ (336-14).	{ Room -105 }	15.5 16.0	24.0 24.5	4 3.5	..... .....	P _E 66 P _E 70	2 2	Charpy impact bar with Izod notch....	[25]
326...	Si 11.58, Fe 1.25, Zn 0.28, Cu 0.12, Mn 0.08, Mg 0.03.	Die-cast.....	{ 70 32 0 }	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	3.8 3.7 3.5	..... ..... .....	[67]

TABLE 6.—*Aluminum and aluminum alloys, thermal expansion*

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade						Reference
			20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 500°C	20° to 600°C	
PURE AND COMMERCIAL ALUMINUM									
327 ^a	Al 99.997.....	Bar, full anneal.....	×10 ⁻⁶ 23.9	×10 ⁻⁶ 24.3	×10 ⁻⁶ 25.3	×10 ⁻⁶ 26.5	×10 ⁻⁶ 27.7	×10 ⁻⁶ 28.7	[68]
328.....	Cu 0.019, Fe 0.015, Si 0.014.....	Cast.....	23.8	24.7	25.7	26.7	27.7	28.7	[707]
329.....	Fe 0.36, Si 0.32, Cu 0.10, Mn 0.07.....	Sheet, 1/4 in., rolled.....	23.9	26.1	26.8	27.3	28.0	28.7	[707]
ALUMINUM-BERYLLIUM ALLOYS									
330.....	Be 4.2, Fe 0.12, Si 0.10, Cu 0.10, Mn 0.01.....	Cast.....	22.4	23.2	24.6	25.1	26.4	26.4	[70]
331.....	Be 10.1, Fe 0.19, Si 0.12, Cu 0.09, Mn 0.01.....	..do.....	21.6	22.5	23.2	24.0	25.2	25.2	[70]
332.....	Be 18.6, Fe 0.36, Si 0.12, Cu 0.11, Mn 0.05.....	..do.....	19.9	20.5	22.0	22.8	23.8	23.8	[70]
333.....	Be 27.5, Fe 0.58, Si 0.10, Cu 0.09, Mn 0.05.....	..do.....	19.0	20.0	21.1	21.9	22.9	22.9	[70]
334.....	Be 32.7, Fe 0.84, Si 0.11, Cu 0.09, Mn 0.06.....	..do.....	17.9	19.2	20.4	21.3	22.2	22.2	[70]
ALUMINUM-CALCIUM ALLOY									
335.....	Ca 7.62, Fe 0.15, Si 0.1, Cu 0.02.....	Cast; 20 hr at 225°C, a-c.....	20.3	21.0	21.7	.....	.....	.....	[71]
ALUMINUM-CHROMIUM ALLOY									
336.....	Cr 5.16, Fe 0.15, Si 0.1, Cu 0.02.....	Cast; 20 hr at 225°C, a-c.....	20.7	21.9	23.0	.....	.....	.....	[71]
ALUMINUM-COPPER ALLOYS									
337.....	Cu 1.91, Mn 1.08, Fe 0.51, Si 0.30.....	Sand-cast.....	23.6	25.2	26.9	26.8	27.5	27.5	[707]
338.....	Cu 2.47.....	Cast; stabilized at 225°C, a-c.....	22.8	23.6	24.2	24.2	25.0	25.0	[71]
339.....	Cu 3.66, Mg 0.52, Mn 0.51, Fe 0.37, Ca 0.20, Si 0.16.....	Wrought, w-q from 500°C.....	23.2	24.0	25.9	26.0	27.3	27.3	[707]
340.....	Cu 3.68, Mn 0.57, Mg 0.36, Fe 0.35, Si 0.25.....	Sand-cast.....	23.6	24.6	26.0	26.7	27.3	27.3	[707]
341.....	Cu 3.74, Mg 1.08, Fe 0.52, Si 0.30.....	Sheet, 1/4 in., hot-rolled.....	23.8	24.7	25.7	26.3	27.2	27.2	[707]
342.....	..do.....	Sheet, 0.09 in., w-q from 520°C, aged 2 days at 120°C.....	23.7	25.2	26.4	27.3	27.3	27.3	[707]
343.....	Cu 3.75, Fe 0.36, Si 0.30, Mn 0.18.....	Sand-cast.....	23.7	24.6	27.2	26.7	27.5	27.5	[707]
344.....	Cu 4.0, Al 2.0, Mg 1.5.....	Cast.....	22.5	23.4	24.4	24.4	25.4	25.4	[69]
345.....	Cu 4.41, Si 3.75, Fe 0.57.....	Sand-cast, f-c from 400°C.....	22.4	23.4	24.1	24.1	25.1	25.1	[707]
346.....	Cu 4.5, Mn 0.8, Mg 0.35.....	..do.....	22	23.5	25	25	26	26	[71]
347.....	Cu 4.82, Fe 0.41, Mn 0.13, Zn 0.096.....	Sand-cast.....	22.9	23.7	25.5	25.7	26.4	26.4	[69]
348.....	Cu 5.47, Si 0.04, Fe 0.03.....	Cast; stabilized at 225°C, a-c.....	22.3	23.2	23.8	23.8	24.8	24.8	[707]
349.....	Cu 5.81, Fe 0.42, Si 0.36.....	Sand-cast.....	23.8	24.9	27.8	27.8	28.0	28.0	[707]
350.....	Cu 6.08, Fe 0.79, Si 0.52, Zn 0.39, Si 0.25, Mn 0.22.....	..do.....	23.1	24.0	25.8	26.4	27.0	27.0	[69]
351.....	Cu 6.62, Si 4.08, Fe 0.64.....	Sand-cast, f-c from 400°C.....	21.8	22.9	23.6	23.6	24.6	24.6	[707]
352.....	Cu 7.75, Si 1.25, Fe 1.00.....	Sand-cast.....	23.5	24.6	26.0	26.6	27.2	27.2	[69]
353.....	Cu 7.87, Fe 0.45, Si 0.33, Mn 0.22.....	..do.....	23.4	24.4	25.0	25.0	26.0	26.0	[707]
354.....	Cu 7.88, Al 5.26, Fe 0.5, Mg 0.44, Si 0.3.....	Cast; 20 hr at 225°C, a-c.....	20.7	21.4	22.1	22.1	23.1	23.1	[71]
355.....	Cu 9.77, Fe 5.04, Si 0.16.....	Cast; stabilized at 225°C, a-c.....	19.9	20.8	21.5	21.5	22.5	22.5	[71]
356.....	Cu 9.78, Si 5.04.....	..do.....	20.5	21.5	22.2	22.2	23.2	23.2	[71]
357.....	Cu 9.86, Si 0.04, Fe 0.03.....	..do.....	21.2	21.9	22.7	22.7	23.7	23.7	[71]
358.....	Cu 9.88, Fe 1.06, Si 0.07.....	Sand-cast.....	22.4	23.1	23.8	23.8	24.8	24.8	[707]
359.....	Cu 11.88, Fe 0.43, Si 0.39.....	Cast; 1 hr at 400°C, a-c.....	19.6	20.1	20.6	20.6	21.6	21.6	[707]
360.....	Cu 13.14, Si 8.31, Fe 0.81.....	Cast; stabilized at 225°C, a-c.....	21.2	21.7	22.3	22.3	23.3	23.3	[71]
361.....	Cu 20.....	..do.....	19.7	20.2	20.8	20.8	21.8	21.8	[71]
362.....	Cu 33.20.....	..do.....	19.7	20.2	20.8	20.8	21.8	21.8	[71]

^a Additional values are 18.6 (-190° to 20°C); 21.3 (-100° to 20°C); 22.3 (-50° to 20°C); 23.9 (20° to 50°C).

^a Additional values are 18.6 (–190° to 20°C); 21.3 (–100° to 20°C); 22.3 (–50° to 30°C); 23.9 (30° to 50°C).

TABLE 6.—*Aluminum and aluminum alloys, thermal expansion—Continued.*

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade					Reference
			20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 600°C	
ALUMINUM-IRON ALLOYS								
363.... 364.... 365....	Percent Fe 0.70, Cu 0.05, Si 0.03..... Fe 3.59, Ni 3.26, Cu 0.064, Si 0.063..... Fe 8.45, Ni 3.09, Si 0.084, Cu 0.036.....	Cast; stabilized at 225°C, a-c..... .....do..... .....do.....	×10 ⁻⁶ 22.6	×10 ⁻⁶ 23.1	×10 ⁻⁶ 24.1	×10 ⁻⁶	×10 ⁻⁶	[71] [71] [71]
			19.5	20.3	21.2	.....	.....	
			ALUMINUM-MAGNESIUM ALLOY					
366....	Mg 8.98, Fe 0.15, Si 0.1, Cu 0.02.....	Cast; 20 hr at 225°C, a-c.....	23.3	24.1	24.6	.....	.....	[71]
ALUMINUM-MANGANESE ALLOYS								
367.... 368.... 369....	Mn 1.05, Fe 0.57, Si 0.41, Cu 0.19..... Mn 1.80, Fe 0.84, Si 0.40, Cu 0.23..... Mn 3.66, Fe 0.18, Si 0.10.....	Sweet, 1/4 in., rolled..... Sand-cast..... Cast; 20 hr at 225°C, a-c.....	23.8	25.7	25.9	25.5	27.5	[707] [707] [71]
			23.1	24.2	25.5	25.9	27.0	
			26.7	22.2	23.1	.....	.....	
ALUMINUM-NICKEL ALLOYS								
370.... 371.... 372....	Ni 1.5, Cr 1.5, Cu 1.0, Mn 0.5..... Ni 3.36, Cu 0.11, Fe 0.08, Si 0.06..... Ni 7.46, Mg 1.33, Fe 0.15, Si 0.1, Cu 0.02.....	Cast..... Cast; stabilized at 225°C, a-c..... .....do.....	23.2	24.2	25.8	.....	.....	[707] [71] [71]
			21.9	22.7	23.5	.....	.....	
			21.5	22.3	23.5	.....	.....	
373.... 374....	Ni 9.86, Cu 4.51..... Ni 19.53, Fe 0.08, Cu 0.07, Si 0.05.....	do..... .....do.....	19.9	20.9	21.6	.....	.....	[71] [71]
			18.2	18.9	19.5	.....	.....	
			ALUMINUM-SILICON ALLOYS					
375.... 376.... 377....	Si 3.12, Cu 2.4, Mn 0.93, Fe 0.55..... Si 3.33, Cu 2.2, Fe 0.55, Mn 0.01..... Si 4.15, Fe 0.52, Cu 0.33.....	Sand-cast; f-c from 400°C..... .....do..... .....do.....	22.2	23.4	23.8	.....	.....	[707] [707] [707]
			23.4	23.9	24.4	.....	.....	
			22.2	23.2	24.1	.....	.....	
378.... 379.... 380....	Si 4.71, Fe 0.06, Cu 0.035..... Si 6.61, Cu 4.53, Fe 0.57..... Si 7.25, Fe 0.47, Cu 0.27.....	Cast; stabilized at 225°C, a-c..... Sand-cast; f-c from 400°C..... .....do.....	21.8	22.4	23.5	.....	.....	[71] [707] [707]
			21.5	22.3	23.1	.....	.....	
			21.8	22.8	23.5	.....	.....	
381.... 382.... 383....	Si 7.42, Cu 2.43, Fe 0.53..... Si 9.45, Cu 6.29, Fe 0.53..... Si 9.81, Fe 0.50, Cu 0.22.....	do..... .....do..... .....do.....	21.7	22.5	23.4	.....	.....	[707] [707] [707]
			20.6	21.6	22.2	.....	.....	
			21.1	21.9	22.9	.....	.....	
384.... 385.... 386....	Si 10.18, Cu 2.47, Mn 1.17, Fe 0.70..... Si 10.23, Cu 9.78, Ni 3.91, Fe 0.42..... Si 10.28, Cu 4.58, Fe 0.51.....	Cast; 1 hr at 400°C, a-c..... Sand-cast; f-c from 400°C..... .....do.....	20.4	21.5	22.3	.....	.....	[707] [708] [707]
			18.8	19.1	20.2	.....	.....	
			20.4	21.3	22.1	.....	.....	
387.... 388.... 389....	Si 12.55, Fe 0.56, Cu 0.08..... Si 13.13, Cu 8.02, Ni 4.10, Fe 0.80..... Si 13.22, Ni 4.12, Cu 4.05, Fe 0.78.....	do..... Cast; 1 hr at 400°C, a-c..... .....do.....	19.4	18.7	19.3	.....	.....	[707] [708] [708]
			18.5	18.9	19.8	.....	.....	
			19.8	20.6	21.4	.....	.....	
390.... 391.... 392....	Si 13.34, Cu 4.03, Fe 0.82..... Si 13.35, Cu 7.59, Fe 0.74..... Si 13.51, Ni 1.93, Mg 0.99, Cu 0.85, Fe 0.5.....	do..... .....do..... .....do.....	19.4	20.1	20.9	.....	.....	[708] [708] [708]
			19.0	20.2	21.0	.....	.....	
			18.3	19.0	19.7	.....	.....	
393.... 394.... 395....	Si 14.0, Ni 4.12, Cu 2.08, Mg 1.32, Fe 0.5..... Si 14.83, Fe 0.12, Cu 0.09..... Si 19.30, Ni 4.18, Cu 3.14, Mn 1.08, Fe 0.84.....	do..... Cast; stabilized at 225°C, a-c..... Cast; 1 hr at 400°C, a-c.....	19.3	19.9	20.6	.....	.....	[71] [71] [708]
			16.6	17.0	17.8	.....	.....	
			18.7	18.7	19.0	.....	.....	
396.... 397.... 398....	Si 19.70, Fe 0.16, Cu 0.10..... Si 20.29, Cu 3.18, Mn 1.07, Fe 0.96..... Si 40.....	Cast; stabilized at 225°C, a-c..... Cast; 1 hr at 400°C, a-c..... Cast; stabilized at 225°C, a-c.....	17.4	18.0	18.8	.....	.....	[71] [71] [708]
			17.4	18.0	18.8	.....	.....	
			14.7	16.0	17.1	.....	.....	

		Hotted and drawn.....	24.3	28.1	27.9	27.6	[707]
Zn 12.17, Cu 1.47, Fe 0.31, Si 0.24, Mn 0.01.	399....	Cast.....	24.0		28.0		[69]
Zn 13.50, Cu 2.75..	400....		26.1	27.0	28.0	29.1	[72]
Zn 25.....	401....		26.6	27.5	30.3		[72]
Zn 37.5.....	402....		26.6		33.7		[72]
Zn 50.....	403....		26.5	27.6			

TABLE 7.—Aluminum and aluminum alloys, electrical and thermal properties

Serial number	Composition	Condition	Electrical properties		Thermal properties		Reference
			Volume conductivity	Resistivity	Conductivity	Temperature coefficient of conductivity	
PURE AND COMMERCIAL ALUMINUM (SEE ALSO FIG. 27)							
404 ^a ...	Percent Si 0.0020, Cu 0.0010, Ca 0.0003, Mg 0.0003, Na 0.0003, Fe 0.0001.	Sheet, 0.064 in., 1 hr at 200°C.	Percent IACS 54.94 (20°C)	Microhms cm 2.6548 (20°C)	Watts cm ⁻¹ °C ⁻¹	per °C x 10 ⁻⁴	[12]
405...	(Fe + Cu) <0.05, Si 0.02.	Sand-cast; 2 days at 495°C, cold w-q, 100 days at 200°C.	61.3	2.68	.....	.....	[74]
406...	Si 0.14, (Fe + Cu) <0.05.	Sand-cast; 2 days at 495°C, cold w-q.	60.95	2.847	.....	.....	[74]
407...	do.....	Sand-cast; 2 days at 495°C, cold w-q, 100 days at 200°C.	62.25	2.770	.....	.....	[74]
408...	Si 0.23, (Fe + Cu) <0.05.	Sand-cast; 2 days at 495°C, cold w-q.	58.50	2.947	.....	.....	[74]
409...	do.....	Sand-cast; 2 days at 495°C, cold w-q, 100 days at 200°C.	62.11	2.776	.....	.....	[74]
410...	Al 99.66.	.....	.....	.....	2.18 (50°C)	.....	[23]
411 ^b ...	Al 99.5.	Hard-drawn.	50.37 (20°C)	2.828 (20°C)	.....	.....	[73]
412...	Aluminum.	.....	.....	.....	2.11 (room) 2.11 (100°C) 2.22 (200°C) 2.29 (400°C)	.....	[73]
ALUMINUM-COPPER ALLOYS							
413...	Cu 3.79, Fe 0.96, Mn 0.59, Mg 0.49, Si 0.15.	Wrought; soln h-t, quenched, 2 hr at 370°C, slowly cooled.	45.7 (20°C)	3.77 (20°C)	1.79 (25°C) 1.88 (200°C)	3.0 (25°-200°C)...	[75]
414...	Cu 3.94, Ni 2.14, Mg 1.52, Fe 0.63, Si 0.55.	Chill-cast; 2 hr at 370°C, slowly cooled.	43.1 (20°C)	4.00 (20°C)	1.68 (25°C) 1.77 (200°C)	2.8 (25°-200°C)...	[75]
415...	Cu 4.0.	Sand-cast; h-t (195-T4).	34.6 (20°C)	4.99 (20°C)	1.38 (25°C)	.....	[75]
416...	do.....	Sand-cast; h-t (195-T4, ann).	50.7 (20°C)	3.40 (20°C)	1.93 (25°C)	.....	[75]
417...	Cu 4, Ni 2, Mg 1.5.	Chill-cast; soln h-t, quenched, aged (142-T6t).	33 (20°C)	5.2 (20°C)	1.30 (25°C)	.....	[76]
418...	Cu 4.0, Si 3.0.	Sand-cast (108).	30.7 (20°C)	5.62 (20°C)	1.21 (25°C)	.....	[75]
419...	do.....	Sand-cast; ann (108).	37.7 (20°C)	4.57 (20°C)	1.46 (25°C)	.....	[75]
420...	Cu 4, Ni 1, Si 2.	Die-cast (83).	26 (20°C)	6.6 (20°C)	1.05 (20°C)	.....	[10]
421...	Cu 4.39, Fe 0.73, Si 0.66.	Sand-cast; soln h-t, quenched, aged at r-t, 2 hr at 370°C, slowly cooled.	49.5 (20°C)	3.48 (20°C)	1.8 (25°C) 1.93 (200°C)	1.0 (25°-200°C)...	[75]
422...	Cu 4.45, Si 0.85, Mn 0.76, Fe 0.50.	Wrought; 2 hr at 370°C, slowly cooled.	52.6 (20°C)	3.28 (20°C)	1.98 (25°C) 2.03 (200°C)	1.3 (25°-300°C)...	[75]
423...	Cu 4.5, Mn 0.8, Si 0.8.	Forged; h-t (258-T)	38.6 (20°C)	4.47 (20°C)	1.5 (25°C)	.....	[75]
424...	do.....	Forged; h-t (258-T, ann).	52.2 (20°C)	3.30 (20°C)	2.01 (25°C)	.....	[75]
425...	Cu 7.0, Si 1.5, Fe 1.2.	Chill-cast (313).	28.9 (20°C)	5.96 (20°C)	1.17 (25°C)	.....	[75]
426...	do.....	Chill-cast; ann (313).	36.4 (20°C)	4.74 (20°C)	1.42 (25°C)	.....	[75]
427...	do.....	Chill-cast; h-t (313-T4).	29.5 (20°C)	5.84 (20°C)	1.17 (25°C)	.....	[75]
428...	Cu 7, Si 3.	Die-cast (81).	28 (20°C)	6.2 (20°C)	1.13 (20°C)	.....	[10]
429...	Cu 7.0, Si 3.0, Zn 2.0, Fe 1.2.	Chill-cast (313).	27 (20°C)	6.4 (20°C)	1.09 (25°C)	.....	[46]
430...	Cu 7.06, Zn 2.22, Fe 1.21, Si 0.75.	Sand-cast; 2 hr at 370°C, slowly cooled.	43.1 (20°C)	4.00 (20°C)	1.70 (25°C) 1.78 (200°C)	2.7 (25°-200°C)	[75]
431...	Cu 7.5, Zn 1.5, Fe 1.2.	Sand-cast (112).	29.9 (20°C)	5.77 (20°C)	1.21 (25°C)	.....	[75]
432...	do.....	Sand-cast; ann (112).	37.9 (20°C)	4.55 (20°C)	1.46 (25°C)	.....	[75]
433...	do.....	Sand-cast; soln h-t, quenched, (112-T4).	27.2 (20°C)	6.35 (20°C)	1.09 (25°C)	.....	[75]
434...	do.....	Sand-cast; h-t (112-T6).	28.7 (20°C)	6.00 (20°C)	1.17 (25°C)	.....	[75]
435...	do.....	Chill-cast (112).	32.1 (20°C)	5.37 (20°C)	1.30 (25°C)	.....	[75]
436...	Cu 8.0, Si 1.2, Fe 1.0.	Chill-cast (212).	30 (20°C)	5.7 (20°C)	1.26 (25°C)	.....	[46]
437...	Cu 10, Fe 1, Mg 0.25.	Chill-cast; soln h-t, quenched, aged (122-T65).	33 (20°C)	5.2 (20°C)	1.30 (25°C)	.....	[77]
438...	Cu 10.40, Fe 1.40, Si 0.59, Mg 0.29.	Chill-cast; 2 hr at 370°C, slowly cooled.	45.9 (20°C)	3.76 (20°C)	1.76 (25°C) 1.80 (200°C)	1.4 (25°-200°C)	[75]

139...	Cu 12.0.....	Sand-cast.....	35.8 (20°C)	1.81 (20°C)	51.42 (25°C)	[75]
140...	...do.....	Sand-cast; ann.....	14.9 (20°C)	3.84 (20°C)	51.72 (25°C)	[75]
441...	Cu 15.46.....	Chill-cast.....	.....	.....	{ 1.51 (30°-100°) 1.57 (60°-270°) }	[78]
442...	...do.....	Chill-cast; 24 hr at 500°C, f-c.....	.....	.....	{ 1.83 (30°-100°) 1.76 (60°-270°) }	[78]
443...	Cu 20.08.....	...do.....	.....	.....	{ 1.75 (30°-100°) 1.77 (60°-270°) }	[78]
444...	Cu 25.6.....	...do.....	.....	.....	{ 1.65 (30°-100°) 1.69 (60°-270°) }	[78]
445...	Cu 30.45.....	...do.....	.....	.....	{ 1.62 (30°-100°) 1.59 (60°-270°) }	[78]

ALUMINUM-MAGNESIUM ALLOYS

146...	Mg 2.5, Cr 0.25.....	Forged (528).....	47.2 (20°C)	3.65 (20°C)	51.40 (25°C)	[75]
147...	...do.....	Forged; ann (528).....	57.3 (20°C)	3.01 (20°C)	52.18 (25°C)	[75]
448...	Mg 4.....	Sand-cast (214).....	35 (20°C)	4.9 (20°C)	1.34 (25°C)	[108]
449...	Mg 8.0.....	Die-cast (218).....	25 (20°C)	6.9 (20°C)	1.00 (20°C)	[10]
450...	Mg 10.0.....	Sand-cast; ann (220).....	20.8 (20°C)	8.27 (20°C)	50.88 (25°C)	[75]
451...	...do.....	Sand-cast; h-t (220-T1).....	20.3 (20°C)	8.49 (20°C)	5.84 (25°C)	[75]

ALUMINUM-SILICON ALLOYS

452...	Si 0.91, Fe 0.58, Mg 0.50, Cu 0.50.....	Wrought; soln h-t, quenched, aged, 2 hr at 370°C, slowly cooled.....	56.2 (20°C)	3.07 (20°C)	{ 2.10 (25°C) 2.11 (200°C) }	[75]
453...	Si 1.0, Mg 0.6, Cr 0.25.....	Forged; h-t (A51S-T).....	16.7 (20°C)	3.69 (20°C)	51.90 (25°C)	[75]
454...	...do.....	Forged; h-t (A51S-T, ann).....	55.6 (20°C)	3.10 (20°C)	2.09 (25°C)	[75]
455...	Si 3, Cu 2.....	Die-cast (83).....	30 (20°C)	5.7 (20°C)	1.17 (20°C)	[10]
456...	Si 4, Cu 3, Mg 0.3.....	Sand-cast (43T).....	31 (20°C)	5.6 (20°C)	1.21 (20°C)	[10]
457...	Si 5.0.....	Sand-cast (43).....	36.4 (20°C)	4.74 (20°C)	1.12 (25°C)	[75]
458...	...do.....	Sand-cast; ann (43).....	11.7 (20°C)	4.22 (20°C)	51.53 (25°C)	[75]
459...	...do.....	Chill-cast (43).....	48.3 (20°C)	3.57 (20°C)	1.84 (25°C)	[75]
460...	...do.....	Chill-cast; ann (43).....	34.9 (20°C)	4.94 (20°C)	51.38 (25°C)	[75]
461...	Si 5.0, Cu 1.25, Mg 0.5.....	Sand-cast; h-t (755-T4).....	45.4 (20°C)	3.80 (20°C)	51.76 (25°C)	[75]
462...	...do.....	Sand-cast; h-t (755-T4, ann).....	35.5 (20°C)	4.85 (20°C)	51.38 (25°C)	[75]
463...	...do.....	Sand-cast; h-t (755-T6).....	37.2 (20°C)	4.64 (20°C)	51.46 (25°C)	[75]
464...	...do.....	Die-cast (85).....	28 (20°C)	6.2 (20°C)	1.13 (20°C)	[10]
465...	Si 5, Cu 4.....	Sand-cast; soln h-t, quenched, aged at h-t, 2 hr at 370°C, slowly cooled.....	47.0 (20°C)	3.67 (20°C)	{ 1.90 (25°C) 1.95 (200°C) }	[75]
466...	Si 5.04, Cu 0.95, Fe 0.36, Mg 0.31.....	Chill-cast (A108).....	37 (20°C)	4.7 (20°C)	1.12 (20°C)	[10]
467...	Si 5.5, Cu 4.5.....	Sand-cast; h-t (756-T4).....	38.3 (20°C)	4.50 (20°C)	51.51 (25°C)	[75]
468...	Si 7.0, Mg 0.3.....	Sand-cast; h-t (756-T4, ann).....	18.8 (20°C)	3.53 (20°C)	51.88 (25°C)	[75]
469...	...do.....	Sand-cast; h-t (756-T6).....	38.8 (20°C)	4.14 (20°C)	51.51 (25°C)	[75]
470...	...do.....	Sand-cast; h-t (756-T6).....	42.4 (20°C)	4.07 (20°C)	51.58 (25°C)	[75]
471...	...do.....	Sand-cast; h-t (756-T4).....	39.0 (20°C)	4.42 (20°C)	51.51 (25°C)	[75]
472...	...do.....	Chill-cast; h-t (756-T4).....	49.1 (20°C)	3.51 (20°C)	51.88 (25°C)	[75]
473...	...do.....	Chill-cast; h-t (756-T4, ann).....	40.5 (20°C)	4.26 (20°C)	51.59 (25°C)	[75]
474...	...do.....	Chill-cast; h-t (756-T6).....	30.7 (20°C)	5.62 (20°C)	51.21 (25°C)	[75]
475...	Si 10.0.....	Sand-cast (45).....	42.8 (20°C)	4.03 (20°C)	{ 1.78 (25°C) 1.75 (200°C) }	[75]
476...	Si 11.78, Mg 1.06, Ni 0.92, Cu 0.84, Fe 0.76.....	Forged; soln h-t, quenched, aged, 2 hr at 370°C, slowly cooled.....	35.8 (20°C)	1.82 (20°C)	51.42 (25°C)	[75]
477...	Si 12.0, Mg 1.0, Cu 0.8, Ni 0.8.....	Forged; h-t (725-T).....	12.6 (20°C)	1.05 (20°C)	51.63 (25°C)	[75]
478...	...do.....	Forged; h-t (725-T, ann).....	40 (20°C)	1.3 (20°C)	1.55 (25°C)	[109]
479...	Si 13.....	Sand-cast (47).....	36 (20°C)	4.8 (20°C)	1.08 (25°C)	[109]
480...	...do.....	Die-cast (13).....	.....	.....	.....	[109]

^a Constant mass temperature coefficient of electrical resistivity at 20°C is 42.9 x 10⁻⁴.

^b Conforms to the Am. Inst. Electrical Engrs. Standard No. 46 for hard-drawn aluminum conductors; temperature coefficient of electrical resistivity at 20°C is 40.3 x 10⁻⁴.

^c Calculated from electrical conductivity with a maximum error of +6%.

TABLE 7.—Aluminum and aluminum alloys, electrical and thermal properties—Continued

Serial number	Composition	Condition	Electrical properties		Thermal properties		Ref-er-ence
			Volume conductivity	Resistivity	Conductivity	Temperature coefficient of conductivity	
ALUMINUM-SILICON ALLOYS—Continued							
481...	Percent Si 13.80, Ni 2.45, Mg 1.18, Fe 1.09, Cu 0.75.....	Chill-cast; 2 hr at 370°C, slowly cooled.....	Percent IACS 27.2 (20°C)	Microhm cm 6.35 (20°C)	Watts cm ⁻¹ °C ⁻¹ $\left\{ \begin{array}{l} 1.35 \text{ (25°C)} \\ 1.39 \text{ (200°C)} \end{array} \right.$	per °C × 10 ⁻⁴ 1.2 (25°-200°C)...	[75]
ALUMINUM-ZINC ALLOY							
482...	Zn 11.0, Cu 2.5, Fe 1.2.....	Sand-cast (645).....	33 (20°C)	5.2 (20°C)	1.30 (20°C)	.....	[10]

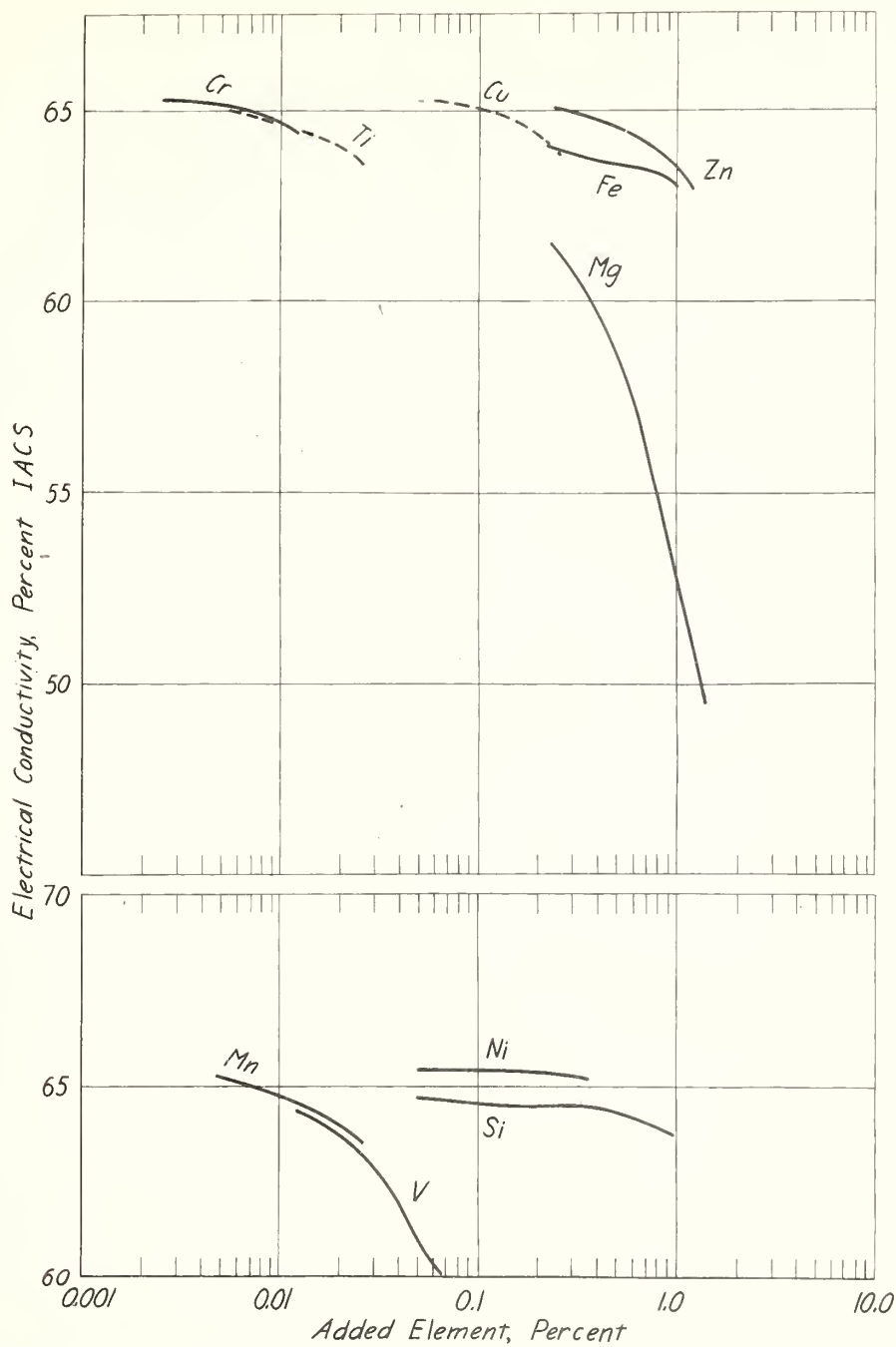


FIGURE 27.—Effect of various elements on the electrical conductivity of high-purity aluminum (Gauthier [639]).

Purity of base aluminum greater than 99.99%. Annealed at 610°F and slowly cooled.

VI. COPPER AND COPPER ALLOYS

(65)

NOMENCLATURE OF THE COPPER ALLOYS BRASS AND BRONZE

Brass and bronze have been companion materials for thousands of years. Originally, brass was an alloy of copper and zinc, whereas bronze was an alloy of copper and tin. However, it was found later that the addition of other elements frequently improved the properties or the appearance of the materials. At present, many nominal copper-tin alloys contain both tin and zinc and sometimes other metals, and it is often difficult to determine whether the tin or the zinc has a predominating effect.

The confusion resulting from the usage of the terms *brass* and *bronze* has led to a number of attempts at classification. The system developed by the American Society for Testing Materials for the classification of cast copper-base alloys [79] is the basis of table 8 in this Circular. For practical purposes, the majority of wrought copper-base alloys may be classified in this system also.

Some commercial materials are discussed briefly in the following paragraphs:

BRASS.—Alloys consisting essentially of copper (50 to 95 percent) and zinc (50 to 5 percent) are generally called brasses. Those containing less than 17 percent of zinc are known as *red brass*; those containing more than that quantity are called *yellow brass*. Some of the commoner brasses are *rich low brass* (85 percent of copper, 15 percent of zinc); *low brass* (80 percent of copper, 20 percent of zinc); *cartridge brass* (70 percent of copper, 30 percent of zinc); *high brass* (66 percent of copper, 34 percent of zinc); and *muntz metal* (60 percent of copper, 40 percent of zinc). Brasses are frequently modified by the addition of tin. Two well-known alloys of this type are *admiralty metal* (70 percent of copper, 29 percent of zinc, 1 percent of tin) and *naval brass* (60 percent of copper, 39.25 percent of zinc, 0.75 percent of tin). Copper-zinc alloys containing intentional additions of lead to improve the machining properties are called *leaded brasses*.

The names applied to some compositions are very misleading. The alloys formerly known as *german silver* and now called *nickel silver*, because of their white color, are composed of copper, zinc, and nickel, and contain no silver. A more logical designation of these compositions is *nickel brass*. Similarly, *manganese bronze* is basically a copper-zinc alloy with small additions of

aluminum, iron, manganese, nickel, and tin to improve the mechanical properties or corrosion resistance. The name *high-strength brass* used in the American Society for Testing Materials classification is preferable for these alloys. Among other brasses improperly termed bronzes are *architectural bronze*, which is a simple leaded brass, and *commercial bronze*, which is a simple red brass.

BRONZE.—Alloys of copper and tin have been known for centuries as bronze. In these materials, the tin content is normally well below 20 percent. The use of simply binary alloys of copper and tin is quite limited; usually zinc and frequently lead are added to make these alloys, particularly in the cast form, more suitable for industrial use. Such compositions containing from about 8 to 30 percent of lead are known as *leaded bronzes*, regardless of the zinc content, and are used to a great extent as bearing materials.

Phosphor bronze is a term indicating that phosphorus was used to deoxidize the metal during melting. This treatment usually results in superior properties, although chemical analysis often fails to show more than a trace of phosphorus in the finished material.

The tendency to apply the name *bronze* to copper alloys other than those containing tin has resulted in a variety of bronzes, among which are *aluminum bronze*, *beryllium bronze*, and *conductivity bronze*.

Commercial aluminum bronze contains from 5 to 15 percent of aluminum and sometimes iron, manganese, and nickel. It lacks the characteristic bronze color but has superior corrosion resistance and high strength.

Beryllium bronze is the name applied to copper-beryllium alloys containing about 2 percent of beryllium or beryllium plus other metals, such as nickel, cobalt, or chromium. High strength and hardness can be developed in these alloys by heat-treatment.

Conductivity bronze is the term often used to designate alloyed copper for which a combination of superior tensile strength and relatively high electrical conductivity is required. Cadmium and tin are the preferred alloying elements for the purpose and are generally used in amounts somewhat below 2 percent.

Due to such loose terminology of the term *bronze*, alloys of copper and tin are known frequently as *tin bronze*.

TABLE 8.—Classification of cast copper-base alloys*

[Specifications are changing frequently, the sponsoring organization should be consulted for the latest revision]

Specifications			Designation		Serial numbers of corresponding alloys in the tables
Federal	ASTM	SAE	Class	Addition elements	
COPPER					
Q-Q-C-521a....	.....	.....	Copper ^b	Not over 2 percent total of other elements.....	430, 509, 512, 646, 656, 657, 658, 861, 929; figure 63.
BRASSES					
.....	.....	.....	Red brass.....	2 to 8 percent zinc; tin less than zinc; lead less than 0.5 percent.	1067, 1227.
Q-Q-B-691a....	B 62-41, B 145-41T, B 30-41T.	40	Leaded red brass.....	2 to 8 percent zinc; tin less than 6 percent, usually less than zinc; lead over 0.5 percent.	1064, 1065, 1066, 1067, 1100, 1110, 1148, 1228, 1376, 1377, 1378.
Q-Q-B-601.....	.....	41	Semi-red brass.....	8 to 17 percent zinc; tin less than 6 percent; lead less than 0.5 percent.	1229.
Q-Q-B-691a....	B 145-41T, B 30-41T..	.....	Leaded semi-red brass..	8 to 17 percent zinc; tin less than 6 percent; lead over 0.5 percent.	1009.
Q-Q-B-621.....	.....	45	Yellow brass.....	Over 17 percent zinc; tin less than 6 percent; less than 2 percent total aluminum, manganese, nickel, iron, or silicon; lead less than 0.5 percent.	965, 966, 974, 982, 987, 1002, 1003, 1004, 1031, 1081.
Q-Q-B-621.....	B 146-41T, B 30-41T..	41	Leaded yellow brass....	Over 17 percent zinc; tin less than 6 percent; less than 2 percent total aluminum, manganese, nickel, or iron; lead over 0.5 percent.	1012, 1013, 1016, 1019, 1230.
Q-Q-B-726b....	B 147-41T, B 30-41T..	43	High-strength yellow brass.	Over 17 percent zinc; over 2 percent total of aluminum, manganese, tin, nickel, and iron; silicon under 0.5 percent; lead under 0.5 percent; tin less than 6 percent.	982, 993, 995, 997, 999, 1001, 1007, 1008, 1025, 1026, 1028, 1077, 1078, 1125, 1233, 1236.
.....	B 132-41T, B 147-41T, B 30-41T.	.....	Leaded high-strength yellow brass.	Over 17 percent zinc; over 2 percent total of aluminum, manganese, tin, nickel, and iron; lead over 0.5 percent; tin less than 6 percent.	1015, 1396.
.....	.....	.....	Silicon brass.....	Over 0.6 percent silicon; over 3 percent zinc.....	1051 to 1055, inclusive; 1382.
.....	.....	.....	Tin brass.....	Over 6 percent tin; zinc more than tin.....	1073.
.....	.....	.....	Tin-nickel brass.....	Over 6 percent tin; over 4 percent nickel; zinc more than tin....	.....
.....	.....	42	Nickel brass (nickel silver).	Over 10 percent zinc; nickel in amounts sufficient to give white color; lead under 0.5 percent.	1046, 1047, 1048, 1232, 1234, 1235.
.....	B 149-41T, B 30-41T..	.....	Leaded nickel brass (leaded nickel silver).	Over 10 percent zinc; nickel in amounts sufficient to give white color; lead over 0.5 percent.	1032, 1383.
BRONZES					
Q-Q-B-691a....	B 60-41, B 143-41T, B 22-40, B 30-41T.	62, 64, 65, 640	Tin bronze.....	2 to 20 percent tin; zinc less than tin; lead less than 0.5 percent.	878, 882, 886 to 890, inclusive; 925 to 928, inclusive; 104 to 1107, inclusive; 1147, 1206, 1208, 1217, 1222, 1225, 1226, 1361, 1364.
Q-Q-B-691a....	B 61-41, B 143-41T, B 30-41T.	63, 660	Leaded tin bronze.....	Up to 20 percent tin; zinc less than tin; lead over 0.5 percent, under 6 percent.	908 to 910, inclusive; 923, 924, 1101, 1102, 1103, 1210, 1212, 1219, 1223, 1224.
Q-Q-B-691a....	B 144-41T, B 30-41T..	67	High-leaded tin bronze.	Up to 20 percent tin; zinc less than tin; lead over 6 percent.....	680 to 686, inclusive; 689, 1175, 1176, 1211, 1213, 1216, 1220, 1306.
.....	B 144-41T.....	48, 480, 481, 482	Lead bronze.....	Lead over 20 percent; zinc less than tin; tin less than 10 percent.	677, 678, 679, 687, 688, 1178, 1179.
.....	.....	.....	Nickel bronze.....	Over 10 percent nickel; zinc less than nickel; tin less than 10 percent; lead less than 0.5 percent.	722, 754, 770, 774, 791, 792, 1189, 1190, 1191, 1195.
.....	B 149-41T, B 30-41T..	.....	Leaded nickel bronze..	Over 10 percent nickel; zinc less than nickel; tin less than 10 percent; lead over 0.5 percent.	785, 786, 787, 791.
Q-Q-B-671a, Q-Q-B-726b.	B 148-41T, B 30-41T..	68	Aluminum bronze.....	5 to 15 percent aluminum; up to 10 percent iron with or without manganese or nickel; silicon less than 0.5 percent.	519, 526, 531 to 534, inclusive; 544, 545, 547, 548, 551, 553, 554, 560 to 564, inclusive; 568, 569, 575, 577, 578, 579, 585, 586, 591, 594, 595, 596, 1084, 1168, 1255, 1261, 1265, 1266, 1278.

*Adapted from The American Society for Testing Materials classification of cast alloys [79].

^b Includes alloys such as calcium copper (1.0% Cd) etc.

TABLE 8.—Classification of cast copper-base alloys^a—Continued

Specifications			Designation		Serial numbers of corresponding alloys in the tables
Federal	ASTM	SAE	Addition elements		
			Class		
BRONZES—Continued					
QC-C-503.....			Silicon bronze.....	Over 0.5 percent silicon; not over 3 percent zinc; not over 98 percent copper.	804, 810, 812, 823, 827, 828, 829, 835, 1201, 1344.
.....			Beryllium bronze.....	Over 2 percent beryllium or beryllium plus metals other than copper.	622, 623, 630, 659, 1272, 1273, 1274, 1279, 1280, 1281.

^a Adapted from The American Society for Testing Materials classification of cast alloys [79].

TABLE 9.—Classification of some wrought copper-base alloys (1942)

[Specifications are changing frequently, the sponsoring organization should be consulted for the latest revision]

Federal		ASTM		SAE		Nominal composition—percent								Serial numbers of corresponding alloys in the tables	
Spec	Alloy	Spec	Alloy	Spec	Alloy	Cu	Zn	Sn	Pb	Fe	Mn	Ni	Al	Other	
BARS, RODS, WIRE, AND SHAFTS															
Q Q-C-501.....	.....	E5-27	.....	.....	.....	99.9	.....	.....	.....	.....	.....	.....	.....	.....	84 to 189, inclusive; 191, 192, 196, 197, 198, 501 to 505, inclusive; 510, 511, 1082, 1081, 1127, 1163, 1164, 1213, 1241, figures 28 to 32, inclusive; 62, 64, 70, 71.
.....	.....	B105-39	.....	.....	.....	^a 94.0	.....	^b 5.0	.....	^b 0.75	^b 0.75	.....	^b 3.5	^b Si 1.5 ^b Si 3.0	545, 647, 665 to 668, inclusive; 694 to 697, inclusive; 797 to 802, inclusive; 857 to 860, inclusive; 862 to 865, inclusive; 870 to 876, inclusive; 940 to 903, inclusive; 1095, 1115, 1204, 1250 to 1254, inclusive; 1288 to 1294, inclusive; 1346, 1347, 1349, 1351, 1352.
Q Q-B-666.....	B	B150-41T	.....	701	.....	78-93	.....	^b 0.6	.....	^b 4.0	^b 2.0	^b 5.5	6.5-11	^b Si 2.25 ^b Be 2.0	535 to 538, inclusive; 542, 543, 546, 552, 555, 557, 558, 559, 573, 574, 584, 587, 1129, 1130, 1166, 1167, 1260, 1261, figures 37 and 38, 636 to 640, inclusive; 1131 to 1135, inclusive; 1170, 1282 to 1285, inclusive.
.....	.....	B120-41T	.....	.....	.....	rem	.....	.....	.....	.....	.....	.....	.....	.....	776, 777, 1326; figure 61.
Q Q-N-321.....	A	B151-41T	A	.....	.....	65	17	.....	.....	.....	.....	18	.....	.....	813 to 817, inclusive; 917, 918, 1340.
Q Q-C-591a.....	B	E98-41	B	.....	.....	96	^b 1.5	^b 1.6	.....	^b 0.8	^b 0.75	.....	.....	.....	866, 807, 821, 822, 1082, 1083, 1084, 1113.
.....	.....	B98-41	A	.....	.....	94.8	^b 1.5	^b 0.75	.....	1.6	^b 1.5	.....	.....	.....	.....
Q Q-C-591a.....	D	E98-41	D	.....	.....	94.0	^b 1.5	^b 1.5	.....	0.5	^b 1.5	.....	.....	.....	.....
Q Q-C-591a.....	A	E98-41	C	.....	.....	91.0	^b 4.5	^b 4.5	.....	^a 0.8	^b 1.25	.....	.....	.....	.....
Q Q-B-746.....	A	B139-41T	A	81	.....	rem	.....	5.0	.....	.....	.....	.....	.....	.....	.....
.....	.....	B139-41T	B1	.....	.....	rem	.....	5.0	1.0	.....	.....	.....	.....	.....	881, 1096, 1098, 1099, 1116, 1355 to 1358, inclusive; figures 48, 49, 66, 904, 1374.
Q Q-B-746.....	A	B139-41T	B2	.....	.....	rem	3.75	4.0	4.0	.....	.....	.....	.....	.....	887 to 890, inclusive; 1359, 1360.
.....	.....	B139-41T	C	.....	.....	rem	.....	8.0	.....	.....	.....	.....	.....	.....	893, 894, 1362, 1363, figure 48.
Q Q-B-746.....	B	B139-41T	D	.....	.....	rem	.....	10.0	.....	.....	.....	.....	.....	.....	1375.
.....	.....	B134-41T	1	.....	.....	95	5	.....	.....	.....	.....	.....	.....	.....	839, 940; figure 67.
.....	.....	B134-41T	2	.....	.....	90	10	.....	.....	.....	.....	.....	.....	.....	914, 947, 1105, 1109.
.....	.....	B134-41T	3	.....	.....	85	15	.....	.....	.....	.....	.....	.....	.....	1010, 1379, 1380.
.....	.....	B140-41T	B	.....	.....	89	rem	.....	1.75	.....	.....	.....	.....	.....	1011, 1381.
.....	.....	B140-41T	A	.....	.....	85	rem	.....	2.0	.....	.....	.....	.....	.....	.....
.....	.....	B134-41T	4	.....	.....	80	20	.....	.....	.....	.....	.....	.....	.....	948, 951, 952; figures 56 and 67.
Q Q-W-321.....	C	B134-41T	5	80	A	72	28	.....	.....	.....	.....	.....	.....	.....	955, 1236.
Q Q-W-321.....	C	B134-41T	6	.....	.....	70	30	.....	.....	.....	.....	.....	.....	.....	962, 963, 1113 to 1118, inclusive; 1151; figures 57 and 68.
Q Q-B-611.....	C	B131-41T	7	80	B	65	35	.....	.....	.....	.....	.....	.....	.....	970, 971, 975, 1237, 1383, 1394; figure 68.
Q Q-W-321.....	ANB	B131-41T	8	.....	.....	62	38	.....	.....	.....	.....	.....	.....	.....	979, 986, 981; figure 68.
.....	.....	B134-41T	B	.....	.....	65, 5	23.3	.....	.....	3.0	3.7	.....	4.3	.....	.....
Q Q-B-721a.....	B	B138-41T	C	.....	.....	62	19	.....	1.0	.....	.....	18	.....	.....	775.
Q Q-N-321.....	B	B151-41T	.....	.....	.....	60	rem	.....	.....	.....	.....	.....	.....	.....	1073, 1075, 1076, 1119, 1120, 1123, 1158, 1238.
Q Q-B-636.....	.....	B21-40T	.....	73	.....	60	rem	.....	.....	.....	.....	.....	.....	.....	1017, 1021, 1022, 1122, 1124.
Q Q-B-611a.....	B	B16-41	.....	72	.....	60	39	1.0	3.0	1.4	.....	.....	.....	.....	1006, 1080, 1156, 1387.
.....	.....	B138-41T	A	.....	.....	58.5	39	.....	.....	.....	.....	.....	.....	.....	776, 777.
.....	.....	B151-41T	B	.....	.....	55	27	.....	.....	.....	.....	18	.....	.....	.....
SHEET, STRIP, AND PLATE															
Q Q-C-501.....	.....	B152-41T	A	71	.....	99.9	.....	.....	.....	.....	.....	.....	.....	.....	430, 434, 495.
Q Q-C-501.....	.....	B152-41T	B	71	.....	99.9	.....	.....	.....	.....	.....	.....	.....	.....	.....
Q Q-C-501.....	.....	B152-41T	C	71	.....	99.9	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	B152-41T	E	.....	.....	99.45	.....	.....	.....	.....	.....	.....	.....	.....	.....
Q Q-C-591a.....	B	B120-41T	.....	.....	.....	rem	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	B120-41T	B	.....	.....	96.0	^b 1.5	^b 1.6	.....	^b 0.8	^b 0.75	.....	.....	.....	618 to 621, inclusive; 624, 641 to 644, inclusive.
Q Q-C-591a.....	A	B97-41	.....	.....	.....	94.8	^b 1.5	^b 0.75	.....	^b 1.6	^b 1.5	.....	.....	.....	803, 908, 909, 918, 919, 920, 924, 930.
Q Q-C-591a.....	A	B97-41	C	.....	.....	91.0	^b 4.5	^b 4.5	.....	^b 0.8	^b 1.25	.....	.....	.....	877, 882.
Q Q-B-716.....	A	.....	.....	77	A	rem	.....	5.0	.....	.....	.....	.....	.....	.....	881, 885.
.....	.....	B16-41T	1	.....	.....	95	5	.....	.....	.....	.....	.....	.....	.....	895 to 908, inclusive.
.....	.....	B16-41T	2	.....	.....	90	10	.....	.....	.....	.....	.....	.....	.....	943.
.....	.....	B16-41T	3	79	A	85	15	.....	.....	.....	.....	.....	.....	.....	945, 946.

^a Minimum.^b Maximum.^c If Ni is present, Si 0.25 percent maximum and vice-versa.^d Other addition elements added to improve properties, 0.5 percent maximum.

TABLE 10.—Temper designations for copper alloys¹

Temper	Increase in B&S gage number	Plate, sheet and strip (Reduction in thickness)	Wire (Reduction in area)	Temper	Increase in B&S gage number	Plate, sheet and strip (Reduction in thickness)	Wire (Reduction in area)
1/8 hard.....	1/2	Percent 5.5	Percent 10.9	Hard.....	4	Percent 37.1	Percent 60.5
1/4 hard.....	1	10.9	20.7	Extra hard.....	6	50.0	75.0
1/2 hard.....	2	20.7	37.1	Spring.....	8	60.5	84.4
3/4 hard.....	3	29.4	50.0	Extra spring.....	10	68.7	90.2

¹Adapted from ASTM Standards (1941 Supplement) [80].

TABLE 11.—Hardness conversion table for cartridge brass (Cu 70%, Zn 30%) [55]

Vickers number	Rockwell number		Rockwell superficial number		Brinell number	Vickers number	Rockwell number		Rockwell superficial number		Brinell number		
	B scale 100-kg load, 1/16-in. ball	F scale 60-kg load, 1/16-in. ball	15-T scale 15-kg load, 1/16-in. ball	30-T scale 30-kg load, 1/16-in. ball			45-T scale 45-kg load, 1/16-in. ball	15-T scale 15-kg load, 1/16-in. ball	30-T scale 30-kg load, 1/16-in. ball	45-T scale 45-kg load, 1/16-in. ball			
45.....		40.0	.....	.....	42	120.....	67.0	95.5	.....	.....	61.0	41.0	106
46.....		43.0	.....	.....	43	122.....	68.0	96.0	.....	83.0	62.0	42.0	108
47.....		45.0	.....	.....	44	124.....	69.0	96.5	.....	.....	63.0	43.0	110
48.....		47.0	.....	.....	45	126.....	70.0	97.0	.....	83.5	63.5	44.0	112
49.....		49.0	.....	.....	46	128.....	71.0	97.5	.....	.....	64.0	45.0	113
50.....		50.5	.....	.....	47	130.....	72.0	98.0	.....	84.0	64.5	45.5	114
52.....		53.5	.....	.....	48	132.....	73.0	98.5	.....	84.5	65.0	46.0	116
54.....		56.5	.....	.....	50	134.....	74.5	99.0	.....	85.0	65.5	47.0	118
56.....		58.8	.....	.....	52	136.....	75.0	99.5	.....	85.5	66.0	48.0	120
58.....		61.0	.....	.....	53	138.....	76.0	100.0	.....	.....	66.5	49.0	121
60.....		63.0	.....	.....	55	140.....	77.0	100.5	.....	85.5	67.0	50.0	122
62.....		65.0	.....	.....	57	142.....	77.5	101.0	.....	86.0	67.5	51.0	124
64.....		66.8	.....	.....	59	144.....	78.0	101.5	.....	86.5	68.0	51.5	126
66.....		68.5	.....	.....	61	146.....	79.0	102.0	.....	.....	68.5	52.0	128
68.....		70.0	.....	.....	62	148.....	80.0	102.5	.....	86.5	69.0	53.0	130
70.....		71.5	.....	.....	63	150.....	80.5	103.0	.....	.....	69.5	53.5	131
72.....		73.2	.....	.....	64	152.....	81.0	103.5	.....	87.0	70.0	54.0	133
74.....		74.8	.....	.....	66	154.....	81.5	104.0	.....	87.5	70.5	54.5	135
76.....		76.0	.....	.....	68	156.....	82.0	104.5	.....	.....	71.0	55.0	136
78.....		77.4	.....	.....	70	158.....	83.0	104.5	.....	87.5	71.5	56.0	138
80.....		78.6	.....	.....	72	160.....	83.5	105.0	.....	.....	72.0	57.0	140
82.....		80.0	.....	.....	74	162.....	84.0	105.5	.....	88.5	72.5	57.5	141
84.....		81.2	.....	.....	76	164.....	84.5	106.0	.....	89.0	73.0	58.0	143
86.....		82.3	.....	.....	77	166.....	85.0	106.5	.....	89.5	73.5	58.5	144
88.....		83.5	.....	.....	79	168.....	85.5	107.0	.....	90.0	74.0	59.0	146
90.....		84.4	.....	.....	80	170.....	86.0	107.5	.....	90.5	74.5	59.5	147
92.....		85.4	.....	.....	82	172.....	87.0	108.0	.....	91.0	75.0	60.0	149
94.....		86.3	.....	.....	83	174.....	87.5	108.5	.....	91.5	75.5	60.5	150
96.....		87.2	.....	.....	85	176.....	88.0	109.0	.....	92.0	76.0	61.0	152
98.....		88.0	.....	.....	86	178.....	88.5	109.5	.....	92.5	76.5	61.5	154
100.....		89.0	.....	.....	88	180.....	89.0	110.0	.....	93.0	77.0	62.0	156
102.....		89.8	.....	.....	90	182.....	89.5	110.5	.....	93.5	77.5	62.5	157
104.....		90.5	.....	.....	92	184.....	90.0	111.0	.....	94.0	78.0	63.0	159
106.....		91.2	.....	.....	94	186.....	90.5	111.5	.....	94.5	78.5	63.5	161
108.....		92.0	.....	.....	95	188.....	91.0	112.0	.....	95.0	79.0	64.0	162
110.....		92.6	.....	.....	97	190.....	91.5	112.5	.....	95.5	79.5	64.5	164
112.....		93.0	.....	.....	99	192.....	92.0	113.0	.....	96.0	80.0	65.0	166
114.....		94.0	.....	.....	101	194.....	92.5	113.5	.....	96.5	80.5	65.5	167
116.....		94.5	.....	.....	103	196.....	93.0	114.0	.....	97.0	81.0	66.0	169
118.....		95.0	.....	.....	105	.....	93.5	114.5	.....	97.5	81.5	66.5	171

TABLE 12.—Copper and copper alloys, normal-temperature properties

[For a discussion of the indefiniteness of values reported for yield strength and particularly for "proportional limit" see pages 5 and 6. Hardness numbers are Brinell numbers unless prefixed R_B, R_C, etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed Iz (Izod method).]

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
			ktds/in. ²	ktds/in. ²	ktds/in. ²	ktds/in. ²	Percent	Percent				
483...	Percent 3 Cu 99.999 minimum...	Wire, 0.24 in. diam; annealed 1 hr at 1,110°F.	.....	.....	.....	32	75 (2 in.)	.....	.....	ft-lb	Density (68°F).....8.9592 g/cm ³	[81]
484...	Oxygen-free copper (OFHC); Cu 99.997; S 0.0016.	Rod, 1/2 in. diam, cold-drawn (29% red.) from 0.125 mm grain size.	17,800	.....	49.4 (0.5% extn)	51.0	14 (2 in.)	88	17.0 (3 × 10 ⁶)	R _B 37		[82]
485...	Oxygen-free copper (OFHC); Cu 98.986; S 0.002, Fe 0.002.	Rod, 3/4 in. diam, annealed to 0.070 mm grain size.	16,200	.....	5.0 (0.5% extn)	30.9	60 (2 in.)	92	.....	.....		[83]
486...	...do.....	Rod, 3/4 in. diam, cold-drawn (36% red.) from 0.135 mm grain size.	17,500	.....	47.0 (0.5% extn)	47.5	20 (2 in.)	86	.....	.....		[83]
487...	Oxygen-free copper (OFHC); Fe 0.005, Ag 0.003, Pb 0.001, Al 0.0005.	Rod, hard-drawn.....	18,300	4.9	18.1 (0.01%)	11.4	29 (4/area)	.....	.....	.....		[24]
488...	...do.....	Rod, annealed 1 hr at 390°F.	18,700	7.6	20.2 (0.01%)	10.8	28 (4/area)	.....	.....	.....		[24]
489...	...do.....	Rod, annealed 1 hr at 930°F.	17,300	0.8	3.4 (0.01%)	30.7	62 (4/area)	.....	.....	.....		[24]
490...	Oxygen-free copper (OFHC).	Bar, 2 1/2 in. diam, cast from 2,075°F.	.....	.....	14	23	45 (2 in.)	57	.....	R _B 38 Iz 31	Comp str (65°F).....323 kips/in. ² , Specific gravity.....5.30.	[84]
491...	Tough-pitch copper: Cu 99.950, 0.043, Fe 0.002, S 0.002.	Rod, 3/4 in. diam, annealed to 0.060 mm grain size.	15,800	.....	5.5 (0.5% extn)	31.5	53 (2 in.)	71	.....	.....		[83]
492...	...do.....	Rod, 3/4 in. diam, cold-drawn (36% red.) from 0.075 mm grain size.	17,000	.....	46.0 (0.5% extn)	46.9	15 (2 in.)	58	.....	.....		[83]
493...	Cu 99.95.....	Sheet, 0.020 in., soft.	.....	6.8	.....	31.4	35 (2 in.)	.....	11.0 (10 ⁶)	.....		[20]
494...	...do.....	Sheet, 0.020 in., cold-worked (21% red.).	.....	15.9	.....	44.4	7.8 (2 in.)	.....	13.0 (10 ⁶)	R _B 33		[20]
495...	...do.....	Sheet, 0.020 in., cold-worked (50% red.).	.....	14.7	.....	52.6	2.2 (2 in.)	.....	14.0 (10 ⁶)	R _B 55		[20]
496...	Tough-pitch copper: Cu 99.948, 0.031, S 0.0029.	Rod, 1/2 in. diam, cold-drawn (36% red.) from 0.040 mm grain size.	17,800	.....	47.6 (0.5% extn)	48.8	9.8 (2 in.)	62	17.0 (3 × 10 ⁶)	R _B 47		[82]

^aDetermination of 11 elements spectrographically and 2 elements chemically showed no single impurity exceeding 0.0002%.

TABLE 12.—Copper and copper alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
PURE AND COMMERCIAL COPPER—Continued												
497...	Percent Cu 99.94, O ₂ 0.030, Pb 0.014, Fe 0.003.	Rod, annealed 1/2 hr at 1,200°F.	kips/in. ²	kips/in. ² < 0.9	kips/in. ²	kips/in. ² 31.1	Percent 50 (4 1/4 area)	Percent	kips/in. ²	ft-lb .....	.....	[24]
498...	...do.....	Rod, drawn (37% red.)...	17,200	4.9	14.3 (0.01%)	37.0	32 (4 1/4 area)	.....	.....	.....	.....	[24]
499...	Cu 99.895.....	Rod, 3/4 in. diam, annealed 1/2 hr at 1,200°F.	.....	3.2	.....	32.4	56 (2 in.)	72	10.0 (10 ⁶)	30	47	[38]
500...	...do.....	Rod, 1/2 in. diam, cold-drawn (56% red.).	.....	38.4	.....	56.2	6.5 (2 in.)	52	10.0 (10 ⁶)	16	104	[38]
501...	Electro tough-pitch copper: Fe 0.004.	Rod, hot-rolled, 1 hr at 1,200°F, f-c.	.....	.....	4.5 (0.01% perm)	31.2	52 (2 in.)	71	10.0	.....	.....	[17]
502...	Electro tough-pitch copper: Fe 0.0038, Pb < 0.002.	Rod, 1 in. diam, hot-rolled.	13,300	.....	6.5 (0.01% perm)	31.4	59 (2 in.)	72	4.0	.....	Torsion str.....29.9 kips/in. ² Shear str.....23.9 kips/in. ²	[93]
503...	Electro tough-pitch copper: Fe 0.02.	Rod, 1 in. diam, cold-drawn, 1 hr at 1,200°F, f-c.	.....	.....	4.2 (0.01% perm)	31.5	58 (2 in.)	76	9.5	.....	.....	[93]
504...	...do.....	Rod, 1 in. diam, cold-drawn.	16,600	.....	19.0 (0.01% perm)	40.4	27 (2 in.)	67	12.5 (5 × 10 ⁷)	74	Torsion str.....31.0 kips/in. ²	[93]
505...	Electro tough-pitch copper: Fe 0.008, Pb < 0.001.	Cold-rolled.....	.....	10.0	21.5 (0.01% perm)	52.0	13 (2 in.)	50	16.0	.....	Shear str.....28.4 kips/in. ²	[86]
506...	Electro copper powder (-325 mesh).	Compacted at 15 tons/in. ² , sintered 16 hr at 1,380°F in hydrogen.	.....	.....	.....	13.0	.....	.....	4.7 (4 × 10 ⁸)	.....	Porosity.....22.5%	[87]
507...	...do.....	Compacted at 50 tons/in. ² , sintered 16 hr at 1,380°F in hydrogen.	.....	.....	.....	23.2	.....	.....	9.5 (4 × 10 ⁸)	.....	Porosity.....7.0%	[87]
508...	...do.....	Compacted at 50 tons/in. ² , sintered 16 hr at 1,380°F in hydrogen; recompact at 50 tons/in. ² , re-sintered 16 hr at 1,380°F in hydrogen.	.....	.....	.....	30.0	.....	.....	13.0 (4 × 10 ⁸)	.....	Porosity.....4.5%	[87]
509...	Commercial copper...	Cast.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....5,000-6,800 kips/in. ² Poisson's ratio.....0.35.	[88]
510...	...do.....	Rod, 3/4 in. diam, hard-drawn.	.....	41.2	.....	48.7	15 (2 in.)	54	15.0 (10 ⁶) 10.0 (10 ⁶) 19.0 (10 ⁶)	96	Torsion str.....33.3 kips/in. ²	[27]

511...	Deoxidized copper: Li 0.006 (approx), Ca 0.008 (approx).	Rod, 5/16 in., ann at 1,050°F in saltwater.	.....	.....	.....	32-36	60-72 (2 in.)	.....	.....	.....	[89]
512...	Deoxidized copper: P 0.05 (added).	Sand-cast from 2,295°F.	.....	4.0	9.0 (0.2% perm)	25.9	57 (2 in.)	68	43	.....	[90]

COPPER-ALUMINUM ALLOYS (SEE ALSO FIGS. 34 TO 38, INCLUSIVE)

513...	Al 0.5.....	Rod, 1 in. diam, cold- drawn (10% red.).	.....	1.8	.....	35.2	50 (4/area)	.....	.....	.....	[24]
514...	...do.....	Rod, 1 in. diam, cold- drawn (10% red.), ann 2 hr at 570°F.	19,200	7.2	.....	35.2	51 (4/area)	.....	.....	.....	[24]
515...	...do.....	Rod, 1 in. diam, cold- drawn (50% red.).	19,400	8.1	.....	52.9	24 (4/area)	.....	.....	.....	[24]
516...	...do.....	Rod, 1 in. diam, cold- drawn (50% red.), ann 2 hr at 570°F.	20,100	12.5	.....	49.7	26 (4/area)	.....	.....	.....	[24]
517...	Al 3.96.....	Cast, annealed.....	.....	6.1	8.7 (0.5% extn)	34.7	84 (2 in.)	80	.....	.....	[91]
518...	...do.....	Forged, annealed.....	.....	8.2	12.5 (0.5% extn)	47.0	81 (2 in.)	80	.....	.....	[91]
519...	Al 5.25.....	Cast, annealed.....	.....	6.9	11.3 (0.5% extn)	41.0	79 (2 in.)	80	.....	.....	[91]
520...	...do.....	Forged, annealed.....	.....	7.7	12.3 (0.5% extn)	50.6	77 (2 in.)	70	.....	.....	[91]
521...	Al 5.62, Fe 0.065..	Rod, 1 in. diam, 1 hr at 1,200°F, f-c.	.....	10.0	14.5 (0.01% perm)	57.8	76 (2 in.)	72	15.2	.....	[90]
522...	...do.....	Rod, 1 in. diam, rolled.	16,600	.....	26.8 (0.01% perm)	71.9	43 (2 in.)	66	19.0 (10°)	.....	[90]
523...	Al 7.0.....	Sheet, 0.2 in., ann 1/2 hr at 1,200°F, a-c.	.....	14.7	.....	63.2	70 (2 in.)	69	.....	.....	[92]
524...	...do.....	Sheet, 0.2 in., rolled (50% red.).	.....	78.4	.....	106	10 (2 in.)	50	.....	.....	[92]
525...	Al 7.23.....	Cast, annealed.....	.....	8.0	11.7 (0.5% extn)	41.8	86 (2 in.)	60	.....	.....	[91]
526...	...do.....	Forged, annealed.....	.....	9.2	14.3 (0.5% extn)	54.1	96 (2 in.)	71	.....	.....	[91]
527...	Al 8.0.....	Sheet or plate, soft..	.....	.....	24 (0.5% extn)	60	60 (2 in.)	.....	R _h 30	.....	[94]
528...	...do.....	Sheet or plate, hard..	15,000	.....	60 (0.5% extn)	130	4 (2 in.)	.....	R _h 99	.....	[94]
529...	Al 8.5.....	Rollled; 1 hr at 1,300°F, f-c.	.....	.....	20.0 (0.01% perm)	65.5	74 (2 in.)	66	18.4	.....	[92]
530...	Al 9.10, Fe 0.002..	Rollled.....	15,000	.....	30.5 (0.01% perm)	86.8	34 (2 in.)	54	$\left\{ \begin{array}{l} 24.5 \\ (7 \times 10^7) \\ 10.0 \\ (8 \times 10^7) \end{array} \right\}$	.....	[90]
531...	Al 9.7.....	Round bar, die-cast at 2,120°F.	.....	.....	28.0 (0.15% perm)	58.9	9 (2 in.)	19	.....	.....	[95]
532...	Al 9.78.....	Cast.....	15,300	5.1	.....	59.3	20 (8 in.)	28	22.0 (5 x 10 ⁷)	6.3	[96]

^b Alternating torsion.

^c Zero to maximum torsion.

TABLE 12.—Copper and copper alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Hardness—number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
COPPER-ALUMINUM ALLOYS—Continued												
533...	Al 3.75	Cast; w-q from 1,650°F, 1/2 hr at 1,200°F, f-c.	19,400	24.9	kts/in. ²	kts/in. ²	Percent	Percent	kts/in. ²	142	ft-lb	[96]
534...	Al 10	Cast.....	12,000-15,000	10-11	20-25 (0.5% perm)	60-75	15-25 (2 in.)	15-25	26.0 (7 × 10 ⁷)	90-100	13	[97]
535...	...do.	Roll; 1 hr at 1,200°F, a-c.	.....	.....	21.8 (0.01% perm)	62.3	24 (2 in.)	23	20.0	.....	.....	[92]
536...	...do.	Roll; 1 hr at 1,200°F, f-c.	.....	.....	39.8 (0.01% perm)	89.0	37 (2 in.)	43	31.5	.....	.....	[92]
537...	Al 10.06, Fe 0.17..	Rod, 3 hr at 600°F, f-c.	.....	28.0	34.2 (0.01% perm)	74.0	18 (2 in.)	26	28.0	.....	.....	[17]
538...	Al 10.06, Fe 0.13..	Extruded to 1 9/32 in. diam, drawn to 1 1/4 in. diam, w-q from 1,650°F, 1/2 hr at 1,150°F, f-c.	26,660	16.9	.....	77.5	36 (8 in.)	34	34.0 (6 × 10 ⁷)	125	14	[96]
COPPER-ALUMINUM-IRON ALLOYS												
539...	Al 5.39, Fe 5.14...	Forged.....	.....	.....	48.1 (yld pnt)	86.5	32 (2 in.)	49	.....	119	12 42	[99]
540...	Al 7, Fe 1.....	Plate, 2 in., ann at 1,300°F.	.....	39.6	.....	81.2	45 (2 in.)	62	.....	.....	.....	[98]
541...	...do.	Plate, 2 in., cold-rolled (50% red.).	.....	92.9	.....	126	7.5 (2 in.)	35	.....	.....	.....	[98]
542...	Al 5, Fe 2.5.....	Rod, soft.....	.....	.....	29 (0.5% extn)	72	50 (2 in.)	.....	.....	R _B 52	.....	[94]
543...	...do.	Rod, hard.....	.....	.....	63 (0.5% extn)	125	5 (2 in.)	.....	.....	R _B 100	.....	[94]
544...	Al 8.6, Fe 2.9.....	Sand-cast.....	.....	14	22-27	60-70	22-27 (2 in.)	22-27	.....	109-124	60	[100]
545...	...do.	Centrifugally cast.....	.....	14	27-34	70-77	25-30 (2 in.)	25-30	.....	116-131	.....	[100]
546...	Al 9, Fe 0.5, Mn 0.10.	Drawn.....	.....	.....	.....	93.9	18	.....	31.3	157	4 3.7	[101]
547...	Al 9, Fe 3.....	Die-cast.....	.....	24.6	33.6 (0.5% extn)	85.1	40 (2 in.)	.....	.....	136	.....	[102]
548...	...do.	Sand-cast.....	.....	22.4	26.9 (0.5% extn)	71.7	30 (2 in.)	.....	.....	100	.....	[102]
549...	...do.	Forged.....	.....	17.9	33.6 (yld pnt)	85.1	42 (2 in.)	47	.....	130	12 35	[103]
550...	...do.	Bar, 3/4 in. diam, forged, h-t.	.....	25.8	50.0 (yld pnt)	87.4	32 (2 in.)	30	.....	135	12 30	[103]
551...	...do.	Wrought.....	.....	.....	40.0	80.0	15 (2 in.)	.....	25.0 (5 × 10 ⁶)	160	.....	[104]

TABLE 12.—Copper and copper alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation				
			kips/in. ²	kips/in. ²	kips/in. ²	kips/in. ²	Percent				
			18,800	5.4	73.5 (0.1%)	116	11 (4 in.)				
COPPER-ALUMINUM-IRON-NICKEL ALLOYS—Continued											
574...	Percent Al 9.73, Fe 5.42, Ni 4.97.	Rod, 3/4 in. diam, forged.	.....	.....	.....	.....	.....	.....	.....	.....	[24]
575...	Al 10, Fe 5, Ni 5.	Sand-cast.....	.....	26.9	56.0 (0.5% extn)	108	10 (2 in.)	.....	.....	.....	[102]
576...	Al 10.7, Fe 4, Ni 4.	Forged, h-t.....	.....	30	55-60	96-102	10-15 (2 in.)	.....	.....	.....	[100]
577...	Al 13.5, Fe 4, Ni 1, Mn 0.5.	Sand-cast.....	.....	35.8	44.8 (0.5% extn)	89.6	3 (2 in.)	.....	.....	.....	[102]
578...	Al 9.9, Ni 5.4, Mn 5.2, Fe 2.8.	Rod, 1 in. diam, chill-cast.	.....	.....	98.6 (0.15% perm)	112	1 (2 in.)	.....	.....	.....	[95]
COPPER-ALUMINUM-LEAD ALLOY											
579...	Al 10.3, Pb 1.9....	Round bar, die-cast at 2,095°F.	.....	.....	23.7 (0.15% perm)	53.5	8 (2 in.)	.....	.....	.....	[95]
COPPER-ALUMINUM-MANGANESE ALLOYS											
580...	Al 2.0, Mn 1.0....	Rod, 1 in. diam, chill-cast.	.....	.....	9.9 (0.15% perm)	36.5	46 (2 in.)	.....	.....	.....	[95]
581...	Al 7, Mn 1.....	Sheet, 0.2 in., cold- rolled (50% red.).	.....	76.9	.....	106	12 (2 in.)	.....	.....	.....	[92]
582...	...do.....	Sheet, 0.2 in., cold- rolled (50% red.), a-c. 1/2 hr at 600°F.	.....	84.1	.....	112	8.5 (2 in.)	.....	.....	.....	[92]
583...	...do.....	Sheet, 0.2 in., cold- rolled (50% red.), a-c. 1/2 hr at 1,200°F.	.....	17.4	.....	66.4	61 (2 in.)	.....	.....	.....	[92]
584...	Al 8.91, Mn 2.98...	Rod, 13/16 in., hot- rolled.	.....	.....	44.8 (yld pnt)	89.6	39 (2 in.)	.....	.....	.....	[96]
585...	Al 10, Mn 1.....	Chill-cast.....	.....	.....	35.8 (yld pnt)	89.4	25 (2 in.)	.....	.....	.....	[103]
586...	...do.....	Sand-cast.....	.....	.....	31.4 (yld pnt)	80.2	22 (2 in.)	.....	.....	.....	[103]
587...	Al 10.2, Mn 1.2....	Drawn.....	.....	.....	.....	96.1	17	.....	.....	.....	[101]
COPPER-ALUMINUM-NICKEL ALLOYS											
588...	Al 7, Ni 1.....	Sheet, 0.2 in., cold- rolled (50% red.).	.....	86.0	.....	113	6.0 (2 in.)	.....	.....	.....	[92]
589...	...do.....	Sheet, 0.2 in., cold- rolled (50% red.), a-c. 1/2 hr at 500°F.	.....	97.8	.....	124	4.5 (2 in.)	.....	.....	.....	[92]
590...	...do.....	Sheet, 0.2 in., cold- rolled (50% red.), a-c. 1/2 hr at 1,200°F.	.....	19.2	.....	66.2	62 (2 in.)	.....	.....	.....	[92]

591...	Al 10, Ni 5.....	Chill-cast.....	.....	.....	55.6 (yld pnt)	81.1	2 (2 in.)	5	.....	155	.....	.....	[103]
592...	...do.....	Forged.....	.....	.....	44.8 (yld pnt)	87.4	24 (2 in.)	.....	.....	143	Iz 19	.....	[103]
593...	...do.....	Forged, h-t.....	.....	.....	67.2 (yld pnt)	108	10 (2 in.)	.....	.....	218	Iz 8	.....	[103]
594...	Al 10.0, Ni 7.6....	Round bar, die-cast at 2,145°F.	.....	.....	50.2 (0.15% perm)	85.8	5 (2 in.)	7	.....	186	.....	Specific gravity.....	7.53..
595...	Al 9.4, Ni 7.4, Fe 4.1.	Rod, 1 in. diam, chill-cast.	.....	.....	57.3 (0.15% perm)	95.6	5 (2 in.)	9	.....	188	.....	Specific gravity.....	7.57..
596...	Al 10.1, Ni 7.6, Si 0.4.	Rod, 1 in. diam, chill-cast.	.....	.....	62.7 (0.15% perm)	90.5	2 (2 in.)	5	.....	.....	.....	Specific gravity.....	7.58..

COPPER-ALUMINUM-SILICON ALLOYS

597...	Al 7.20, Si 1.86, Fe 0.11.	Rod, 1 in. square, chill-cast from 2,055°F.	.....	.....	31.4 (yld pnt)	75.7	19 (1.3 in.)	25	.....	139	Iz 41	.....	[105]
598...	...do.....	Rod, 1 in. square, chill-cast; quenched from 1,470°F.	.....	.....	35.8 (yld pnt)	82.9	12 (1.3 in.)	18	.....	179	Iz 26	.....	[105]
599...	...do.....	Rod, 3/4 in. diam, forged.	.....	.....	59.4 (yld pnt)	99.0	25 (1.3 in.)	22	.....	186	Iz 24	.....	[105]
600...	...do.....	Rod, 3/4 in. diam, forged; ann at 1,470°F, a-c.	.....	.....	29.1 (yld pnt)	80.0	32 (1.3 in.)	32	.....	151	Iz 44	.....	[105]

COPPER-ALUMINUM-ZINC ALLOY

601...	Al 8.89, Zn 1.40, Fe 0.15.	Rod, 3/4 in. diam, extruded and drawn.	17,500	17.7	41.7 (0.1%)	80.0	37 (4√area)						[24]
--------	-------------------------------	---	--------	------	----------------	------	----------------	-------	-------	-------	-------	-------	------

COPPER-ARSENIC ALLOYS

602...	As 0.31, O ₂ 0.12...	Rod, 7/8 in. diam, drawn (7% red.).	.....	6.3	14.3 (0.01%)	33.6	46 (4√area)	.....	.....	.....	.....	.....	[24]
603...	...do.....	Rod, 7/8 in. diam, drawn (7% red.), ann 2 hr at 380°F.	.....	11.2	16.8 (0.01%)	31.4	41 (4√area)	.....	.....	.....	.....	.....	[24]
604...	...do.....	Rod, 7/8 in. diam, drawn (7% red.), ann 2 hr at 660°F.	.....	5.2	13.3 (0.01%)	32.9	50 (4√area)	.....	.....	.....	.....	.....	[24]
605...	As 0.33, Ag 0.10, O ₂ 0.001.	Rod, 7/8 in. diam, drawn (7% red.).	.....	2.9	11.0 (0.01%)	35.8	47 (4√area)	.....	.....	.....	.....	.....	[24]
606...	...do.....	Rod, 7/8 in. diam, drawn (7% red.), ann 100 hr at 340°F.	.....	14.8	.....	35.2	16 (4√area)	.....	.....	.....	.....	.....	[24]
607...	As 0.47, Fe 0.005, Sn 0.005.	Rod, 1 in. diam, drawn (10% red.).	.....	2.7	.....	34.9	47 (4√area)	.....	.....	.....	.....	.....	[24]
608...	...do.....	Rod, 1 in. diam, drawn (10% red.), ann 100 hr at 570°F.	18,840	5.4	.....	34.0	47 (4√area)	.....	.....	.....	.....	.....	[24]

^d Notch impact value, m-kg/cm.²

TABLE 12.—Copper and copper alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
			<i>kips/in.²</i>	<i>kips/in.²</i>	<i>kips/in.²</i>	<i>kips/in.²</i>	Percent	Percent				
			.....	9.9	.....	52.9	10 (4√area)	.....	.....	<i>ft-lb</i>		[24]
609...	As 0.17, Fe 0.005, Sn 0.005.	Rod, 1 in. diam, drawn (50% red.).	.....	.....	.....	.....	.....	.....	.....	.....		[24]
610...	...do.....	Rod, 1 in. diam, drawn (50% red.), 100 hr at 570°F.	19,400	1.8	.....	34.0	58 (4√area)	.....	.....	.....		[24]
COPPER-ARSENIC ALLOYS—Continued												
			<i>kips/in.²</i>	<i>kips/in.²</i>	<i>kips/in.²</i>	<i>kips/in.²</i>	Percent	Percent				
			.....	.....	.....	.....	10 (4√area)	.....	.....			
611...	Be 1.0.....	Quenched.....	.....	.....	21 (yld pnt)	43-50	50-55 (10 diam)	85-90	.....	65-70	.....	[106]
612...	...do.....	Quenched and h-t.....	13,700	.....	57 (yld pnt)	64-71	30-35 (10 diam)	80-85	.....	125-130	.....	[106]
613...	...do.....	Quenched and work- hardened.	.....	.....	102 (yld pnt)	107	6 (10 diam)	70	.....	200	.....	[106]
614...	...do.....	Quenched, work-hardened and h-t.	15,700	.....	93 (yld pnt)	121	12 (10 diam)	55	.....	230-240	.....	[106]
615...	Be 1.5.....	Cold-worked, 1 hr at 1,470°F, o-q.	16,800	.....	.....	95.4	45	.....	.....	86	.....	[107]
616...	...do.....	Cold-worked, 1 hr at 1,470°F, o-q, aged 4 hr at 610°F.	17,400	.....	.....	92.4	8	.....	.....	218	.....	[107]
617...	...do.....	Drawn, o-q from 1,470°F, aged at 570°F.	.....	.....	.....	88.2	26	.....	24.2	148	.....	[101]
618...	Be 2.0-2.25.....	Sheet, 0.050 in., soft..	18,600	8.0	31.0 (0.75% extn)	70.0	45 (2 in.)	.....	.....	110	.....	[108]
619...	...do.....	Sheet, 0.050 in., soft, h-t.	18,900	46.0	134 (0.75% extn)	175	6.3 (2 in.)	.....	.....	340	.....	[108]
620...	...do.....	Sheet, 0.050 in., hard..	17,200	39.0	105 (0.75% extn)	118	4.3 (2 in.)	.....	.....	220	.....	[108]
621...	...do.....	Sheet, 0.050 in., hard, h-t.	18,400	55.0	138 (0.75% extn)	193	2.0 (2 in.)	.....	.....	365	.....	[108]
622...	Be 2.2.....	Cast.....	.....	.....	42.6	62.7	14 (2 in.)	.....	.....	109	.....	[109]
623...	...do.....	Cast; quenched from 1,470°F, aged at 545°F.	.....	.....	94.1	119	1 (2 in.)	.....	.....	400	.....	[109]
624...	Be 2.25.....	Sheet, 0.040 in., w-q from 1,470°F, 2 hr at 525°F.	19,100	.....	.....	171	4.8 (2 in.)	.....	31.0 (10%)	8 _B 111	.....	[20]
625...	Be 2.4.....	Quenched.....	16,800	.....	47 (yld pnt)	81-88	30-35 (10 diam)	35-40	.....	110-130	Specific gravity.....8.2.....	[106]
626...	...do.....	Quenched and h-t.....	18,500	.....	149 (yld pnt)	171-185	3-5 (10 diam)	11	.....	340-370	.....	[106]
627...	...do.....	Quenched and work- hardened.	17,000	.....	129 (yld pnt)	135	3 (10 diam)	25	.....	230	.....	[106]

628...	...do.....	quenched, work-hardened, and h-t.	15,500	.....	159 (yld pnt)	192	4	45	.....	375	^a 1.3	.....	[106]
629...	Fe 2.5.....	wire, 0.157 in. diam, quenched, work-hardened, and h-t.	.....	.....	52.6 (yld pnt)	.....	.....	.....	^b 26.8	.....	.....	Mod-el (shear).....6,400 kips/in. ² ..	[106]

COPPER-BERYLLIUM-COBALT ALLOYS

630...	Be 1.75, Co 0.7, Si 0.25.	Cast; 3 hr at 750°F....	.....	.....	.....	140	3-C (2 in.)	.....	.....	.....	.....	.....	[110]
631...	Be 1.8, Co 0.13....	Bar, 1/2 in., cold-drawn (40% red.); h-t 3 hr at 700°F.	.....	.....	.....	158	20 (2 in.)	29	.....	R _c 83	.....	Specific gravity.....S.35.....	[111]
632...	Be 1.88, Co 0.25....	Bar, 1 in. diam, forged; 3 hr at 1,450°F, o-q, 3 hr at 635°F.	.....	.....	152 (0.2%)	173	3-5 (2 in.)	3-5	.....	R _c 39	.....	.....	[110]
633...	...do.....	Bar, 1 in. diam, forged; 3 hr at 1,450°F, o-q, 3 hr at 700°F.	.....	.....	124 (0.2%)	144	13 (2 in.)	14	.....	R _c 32	.....	.....	[110]
634...	Be 2, Co 0.2.....	Soft, annealed.....	15,000	18	26.0 (0.2%)	66	50 (2 in.)	.....	.....	.....	.....	.....	[111]
635...	...do.....	Heat-treated.....	19,000	86.5	146 (0.2%)	175	8 (2 in.)	.....	.....	.....	.....	.....	[111]
636...	...do.....	Rolled (2% red.), h-t..	18,100	118	173 (0.2%)	192	4 (2 in.)	.....	.....	.....	.....	.....	[111]
637...	...do.....	Rolled (37% red.), h-t..	17,900	105	179 (0.2%)	200	3 (2 in.)	.....	.....	.....	.....	.....	[111]

COPPER-BERYLLIUM-NICKEL ALLOYS

638...	Be 2.16, Ni 0.22, Fe 0.11.	Rod, 3/4 in. diam, quenched from 1,515°F, cold-drawn (15% red.).	16,900	.....	79.7 (0.5% extn)	110	11 (2 in.)	42	.....	.....	.....	.....	[83]
639...	...do.....	Rod, 3/4 in. diam, quenched from 1,515°F, cold-drawn (15% red.), 3 hr at 570°F.	18,500	.....	91.9 (0.5% extn)	213	2-8 (2 in.)	3-5	.....	.....	.....	.....	[83]
640...	Be 2.12, Ni 0.40, Fe 0.09.	Rod, 1/2 in. diam, cold-worked (21% red.), h-t 1 1/2 hr at 570°F.	18,800	.....	93.5 (0.5% extn)	187	5-0 (2 in.)	19	55.0 (3 × 10 ⁶)	R ₀ 48	.....	.....	[82]
641...	Be 2.14, Ni 0.28, Fe 0.06, Si 0.03.	Sheet, 0.040 in., w-q from 1,470°F, cold-rolled (37% red.), 2 hr at 525°F.	18,400	55.0	.....	193	2-0 (2 in.)	.....	28.0 (10 ⁶)	R ₀ 104	.....	.....	[20]
642...	Be 2.15, Ni 0.31, Fe 0.06, Si 0.03.	Sheet, 0.040 in., w-q from 1,470°F, 2 hr at 525°F.	18,900	46.0	.....	175	6-3 (2 in.)	.....	28.0 (10 ⁶)	R ₀ 102	.....	.....	[20]
643...	Be 2.25, Ni 0.50....	Sheet, 0.020 in., w-q from 1,470°F, cold-rolled (37% red.).	17,200	39.0	.....	118	4-3 (2 in.)	.....	27.0 (10 ⁶)	R ₀ 64	.....	.....	[20]
644...	...do.....	Sheet, 0.020 in., w-q from 1,470°F, cold-rolled (37% red.), 2 hr at 525°F.	18,400	55.0	.....	193	2-0 (2 in.)	.....	36.0 (10 ⁶)	R ₀ 104	.....	.....	[20]

^b Alternating torsion.

^a Notch impact value, m-kg/cm.²

TABLE 12.—Copper and copper alloys, normal temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Ref-er-ence
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
COPPER-CADMIUM ALLOYS													
645...	Percent Cd 0.8.....	Wire, cold-drawn.....	$\frac{\text{kilops}}{\text{in.}^2}$ 19,000	$\frac{\text{kilops}}{\text{in.}^2}$	$\frac{\text{MPS}}{\text{in.}^2}$	$\frac{\text{kilops}}{\text{in.}^2}$ 101	Percent	Percent	$\frac{\text{kilops}}{\text{in.}^2}$ .....	.....	<i>ft-lb</i> .....	.....	[112]
646...	Cd 0.9, P 0.005....	Cast.....	.....	.....	4.5 (0.15%)	24.6	30 (2 in.)	.....	.....	35	.....	.....	[113]
647...	Cd 0.85, Zr 0.45, Si 0.05.	Rod, 5/8 in. diam, drawn.	.....	37.5	73.0 (0.2% perm)	78.0	11 (2 in.)	40	.....	R _B 85	.....	.....	[114]
648...	Cd 1.01.....	Strip, 0.022 in., cold- rolled (37% red.).	.....	26.5	.....	55.4	6.0	.....	.....	R _B 61	.....	.....	[115]
649...	...do.....	Strip, 0.032 in., cold- rolled (60% red.).	.....	28.0	.....	64.2	5.0	.....	.....	R _B 73	.....	.....	[115]
COPPER-CHROMIUM ALLOYS													
650...	Cr 0.45-0.55, Ag 0.06-0.12.	Heat-treated and cold- worked.	19,000- 20,000	.....	$\left\{ \begin{array}{l} 35-40 \\ (0.01\% \text{ perm}) \\ 64-65 \\ (0.2\% \text{ perm}) \end{array} \right\}$	75-80	20-25 (2 in.)	55-65	18-20 (10 ⁶)	140-160	.....	.....	[116]
651...	Cr 0.89, Si 0.09, Fe 0.07.	Rod, 1/2 in. diam; 1/2 hr at 1,875°F, at quenched, 3 hr at 930°F.	.....	.....	56.4 (0.5%)	72.3	20 (2 in.)	.....	.....	119	.....	.....	[117]
652...	Cr 0.88, Si 0.09, Fe 0.07.	Rod, 1/2 in. diam, cold-worked (92% red.).	19,900	.....	66.1 (0.5% extn)	72.8	7.5 (2 in.)	54	25.8 (3 x 10 ⁶)	R _B 73	.....	.....	[82]
653...	...do.....	Rod, 1/2 in. diam, cold-worked (92% red.), 3 hr at 815°F.	19,700	.....	70.0 (0.5% extn)	77.4	13 (2 in.)	54	28.0 (3 x 10 ⁶)	R _B 82	.....	.....	[82]
654...	Cr 0.93, Fe 0.10, Si 0.08.	Rod, 3/4 in. diam, quenched from 1,785°F, cold-drawn (84% red.), 3 hr at 840°F.	20,000	.....	74.1 (0.5% extn)	81.3	20 (2 in.)	55	.....	.....	.....	.....	[83]
655...	...do.....	Rod, 3/4 in. diam, quenched from 1,830°F, 3 hr at 820°F.	21,200	.....	46.5 (0.5% extn)	65.3	24 (2 in.)	60	.....	.....	.....	.....	[83]
COPPER-CHROMIUM-BERYLLIUM ALLOY													
656...	Cr 0.4, Be 0.1.....	Rod, 1 in. diam, cast; quenched from 1,700°F, aged 1 hr at 935°F.	.....	15-16	.....	30-35	10-15	.....	.....	86	.....	.....	[118]
657...	...do.....	Rod, 1 in. diam; quenched from 1,650°F, cold-worked (86% red.), aged 1 hr at 935°F.	.....	27.0	.....	46.2	20 (2 in.)	.....	.....	108	.....	.....	[118]
658...	...do.....	Rod, 1 in. diam; quenched from 1,650°F, aged 1 hr at 935°F, cold-swaged (86% red.).	.....	35.2	.....	49.4	12 (2 in.)	.....	.....	125	.....	.....	[118]

COPPER-COBALT-BERYLLIUM ALLOY

659...	Co 2.6, Be 0.4.....	Rod, 1 in. diam, cast; 1 hr at 1,650°F, w-q, 2 to 4 hr at 930°F.	17,000	45.0	.....	90.0	10 (2 in.)	20	.....	220	.....	Mod-el (shear).....7,200 kips/in. ²	[119]
660...	...do.....	Rod, forged; 1 hr at 1,650°F, w-q, 2 to 4 hr at 930°F.	17,000	45.0	.....	100	20 (2 in.)	24	.....	220	.....	Mod-el (shear).....7,200 kips/in. ²	[119]
661...	...do.....	quenched.....	.....	.....	21 (yld pnt)	43-50 (10 diam)	30-35 (10 diam)	65-80	.....	75-90	d 11	Specific gravity.....8.8.....	[106]
662...	...do.....	quenched, h-t.....	15,700	.....	71 (yld pnt)	85	15-18 (10 diam)	35-38	.....	185-200	d 7	.....	[106]
663...	...do.....	quenched, work- hardened.	.....	.....	75 (yld pnt)	78	6 (10 diam)	50	.....	150	d 8	.....	[106]
664...	...do.....	quenched, work-hardened, and h-t.	16,400	.....	82 (yld pnt)	107	15 (10 diam)	45	.....	210	d 7	.....	[106]

COPPER-IRON ALLOYS

665...	Fe 0.52.....	Rod, 1 in. diam, drawn (6% red.)	.....	2.7	.....	38.8	12 (4 1/2 area)	.....	.....	.....	.....	.....	[24]
666...	...do.....	Rod, 1 in. diam, drawn (6% red.), annealed 100 hr at 570°F.	19,800	14.3	.....	38.5	19 (4 1/2 area)	.....	.....	.....	.....	.....	[24]
667...	...do.....	Rod, 1 in. diam, drawn (29% red.)	.....	9.0	.....	45.7	26 (4 1/2 area)	.....	.....	.....	.....	.....	[24]
668...	...do.....	Rod, 1 in. diam, drawn (29% red.), annealed 100 hr at 570°F.	19,800	19.7	.....	44.8	35 (4 1/2 area)	.....	.....	.....	.....	.....	[24]
669...	Fe 25.....	Wire, 0.040 in. diam, cold-drawn (96% red.).	.....	.....	.....	138	.....	.....	.....	.....	.....	.....	[120]
670...	Fe 37.5.....	...do.....	.....	.....	.....	152	.....	.....	.....	.....	.....	.....	[120]
671...	Fe 50.....	...do.....	.....	.....	.....	193	.....	.....	.....	.....	.....	.....	[120]
672...	...do.....	Sand-cast.....	.....	.....	32.0 (yld pnt)	55.0	25 (2 in.)	42	.....	130	.....	.....	[121]
673...	...do.....	Forged.....	23,000	.....	65.0 (yld pnt)	69.0	28 (2 in.)	70	.....	132	37	.....	[121]

COPPER-LEAD ALLOYS

674...	Pb 11.68, Sn 0.16, Al 0.09, P 0.025.	Sand-cast from 2,010°F.	.....	.....	6.8 (yld pnt)	11.6	4.8 (2 in.)	6.1	.....	35	.....	.....	[122]
675...	Pb 12.66, Sn 0.16, Al 0.09, P 0.027.	Chill-cast from 2,010°F.	.....	.....	7.0 (yld pnt)	12.4	4.5 (2 in.)	4.9	.....	38	.....	.....	[122]
676...	Pb 19.26, Sn 0.07, Al 0.05.	Sand-cast from 2,010°F.	.....	.....	5.0 (yld pnt)	9.2	4.7 (2 in.)	7.6	.....	25	.....	.....	[122]
677...	Pb 20.94, Zn 0.15, Al 0.13, Sn 0.07.	Chill-cast from 2,010°F.	.....	.....	5.0 (yld pnt)	10.4	6.1 (2 in.)	7.6	.....	26	.....	.....	[122]
678...	Pb 24.40, Sn 0.12, Al 0.11, P 0.078.	Chill-cast from 2,100°F.	.....	.....	5.2 (yld pnt)	10.2	6.3 (2 in.)	6.9	.....	27	.....	.....	[122]
679...	Pb 26.33, Sn 0.24, Al 0.10, P 0.064.	Sand-cast from 2,100°F.	.....	.....	8.5 (yld pnt)	9.6	1.8 (2 in.)	5.3	.....	23	.....	.....	[122]

^aNotch impact value, m-kp/cm.²

TABLE 12.—Copper and copper alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
COPPER-LEAD-TIN ALLOYS													
680...	Percent Pb 8.61, Sn 5.36, Zn 0.82, Sb 0.34, Ni 0.14, Fe 0.04, P 0.04.	Cast from 2,040°F.....	Ktpsi/in. ² 10,900	Ktpsi/in. ²	Ktpsi/in. ² 14.7 (0.1% offset)	Ktpsi/in. ² 30.4	Percent 17 (2 in.)	Percent 20	.....	52	ft-lb	Comp yld str (0.12%).....14.5 kpsi/in. ² Comp str (12%).....34.5 kpsi/in. ² Specific gravity.....8.83.	[123]
681...	Pb 9.81, Sn 9.91, Zn 6.29, Sb 0.28, Ni 0.18, Fe 0.05, P 0.04.	Cast from 2,020°F.....	10,500	.....	17.4 (0.1% offset)	39.8	30 (2 in.)	27	.....	64	.....	Comp yld str (0.12%).....14.0 kpsi/in. ² Comp str (12%).....42.0 kpsi/in. ² Specific gravity.....8.82.	[123]
682...	Pb 10, Sn 10, P > 0.05.	Sand-cast from 1,750°- 1,900°F.	8,500	9.5-11.5	18.5-20	27-33	7-12 (2 in.)	8-13	.....	50-70	Iz 2-4	Comp yld str (0.1%).....12.5-15 kpsi/in. ² .. Comp str (10%).....35-47 kpsi/in. ² .. Specific gravity.....8.9.	[124]
683...	Pb 15, Sn 8, Zn 1.5.	Sand-cast from 1,900°F.	8,800	6-9	14-17	25-30	11-20 (2 in.)	11-15	.....	45-65	Iz 4-5	Comp yld str (0.1%).....12-15 kpsi/in. ² Comp str (10%).....38-40 kpsi/in. ² Specific gravity.....9.4.	[124]
684...	Pb 17.08, Sn 3.65, Zn 3.19.	Sand-cast from 2,100°F.	.....	.....	11.5 (yld pnt)	22.8	17 (2 in.)	22	.....	44	.....	.....	[122]
685...	Pb 17.50, Sn 3.52, Zn 3.43.	Cu11-cast from 2,010°F.	.....	.....	13.2 (yld pnt)	22.8	8.8 (2 in.)	12	.....	52	.....	.....	[122]
686...	Pb 20, Sn 6, Zn 1..	Sand-cast from 1,900°F.	.....	5-8	13-16	22-27	10-16 (2 in.)	9-14	.....	40-55	.....	Comp yld str (0.1%).....11-14 kpsi/in. ² Comp str (10%).....33-35 kpsi/in. ² Specific gravity.....9.6.	[124]
687...	Pb 20.10, Sn 9.76, Ni 0.62, Sb 0.14, P 0.03.	Cast from 2,020°F.....	9,000	.....	15.1 (0.1% offset)	31.3	16 (2 in.)	15	.....	60	.....	Comp yld str (0.12%).....14.5 kpsi/in. ² Comp str (12%).....41.0 kpsi/in. ² Specific gravity.....9.04.	[123]
688...	Pb 24.37, Sn 4.78, Sb 0.07.	Cast from 1,950°F.....	7,000	.....	10.1 (0.1% offset)	21.1	16 (2 in.)	16	.....	42	.....	Comp yld str (0.12%).....10.0 kpsi/in. ² Comp str (12%).....26.0 kpsi/in. ² Specific gravity.....8.90.	[123]
689...	Pb 35, Sn 2.....	Cast.....	.....	.....	5	12	5	.....	.....	28	.....	.....	[125]
COPPER-MAGNESIUM ALLOYS													
690...	Mg 0.71.....	Rod, 1 in. diam, rolled from 2 1/2 in. diam.	.....	20.2	29.6	51.3	34 (2 in.)	63	.....	95	.....	.....	[126]
691...	...do.....	Rod, 1 in. diam, rolled from 2 1/2 in., 1 hr at 1,290°F, slowly cooled.	.....	6.0	8.7	40.3	53 (2 in.)	76	.....	57	.....	.....	[126]
692...	Mg 1.42.....	Rod, 1 in. diam, rolled from 2 1/2 in. diam.	.....	19.9	27.1	58.0	32 (2 in.)	29	.....	110	.....	.....	[126]
693...	...do.....	Rod, 1 in. diam, rolled from 2 1/2 in. diam, 1 hr at 1,290°F, slowly cooled.	.....	8.3	10.3	46.8	45 (2 in.)	57	.....	65	.....	.....	[126]

COPPER-MANGANESE ALLOYS (SEE ALSO FIGS. 39 AND 10)

694...	Mn 0.37, Fe 0.07...	Rod, 1 in. diam, drawn (10% red.).	.....	3.6	.....	36.5	52 (1/area)	.....	.....	.....	.....	[24]
695...	...do.....	Rod, 1 in. diam, drawn (10% red.), 2 hr at 570°F.	19,700	8.1	.....	36.7	53 (1/area)	.....	.....	.....	.....	[24]
696...	...do.....	Rod, 1 in. diam, drawn (5% red.).	19,300	6.3	.....	51.4	19 (1/area)	.....	.....	.....	.....	[24]
697...	...do.....	Rod, 1 in. diam, drawn (50% red.), 2 hr at 570°F.	20,600	12.5	.....	51.5	23 (1/area)	.....	.....	.....	.....	[24]
698...	Mn 1.98, Si 1.39, Fe 0.07.	Bar, 1 in. diam, chill-cast.	14,100	5.4	14.8 (0.5% extn)	32.3	17 (2 in.)	.....	70	.....	.....	[127]
699...	Mn 3.0, Be 1.5....	Cold-worked, 1 hr at 1,470°F, 0-n.	17,500	.....	.....	76.8	25	.....	121	.....	.....	[107]
700...	...do.....	Cold-worked, 1 hr at 1,470°F, 0-n, aged 4 hr at 610°F.	19,100	.....	.....	149	4.5	.....	360	.....	.....	[107]
701...	Mn 4.49, Si 2.29, Fe 0.12.	Bar, 1 in. diam, chill-cast.	18,400	8.1	21.1 (0.5% extn)	34.7	15 (2 in.)	.....	76	.....	.....	[127]
702...	Mn 4.7, Al 1.9, Si 0.6.	Rod, 1 in. diam, chill-cast.	.....	.....	13.9 (0.15% perm)	32.9	18 (2 in.)	.....	73	.....	Specific gravity.....8.39.....	[95]
703...	Mn 4.8, Fe 1.9, Al 1.5.	Round bar, die-cast from 2,265°F.	.....	.....	28.2 (0.15% perm)	48.4	26 (2 in.)	.....	.....	.....	Specific gravity.....8.39.....	[95]
704...	Mn 4.8, Fe 2.0, Al 1.8.	Rod, 1 in. diam, chill-cast.	.....	.....	25.1 (0.15% perm)	49.1	33 (2 in.)	.....	92	.....	Specific gravity.....8.36.....	[95]
705...	Mn 5.....	Soft anne.....	.....	.....	.....	46-51	35-39	.....	71	.....	Specific gravity.....8.6..... melting point.....1,940°F.	[128]
706...	Mn 5, Si 2.....	Soft.....	.....	.....	.....	71	38	.....	110	.....	Specific gravity.....8.4.....	[128]
707...	Mn 13, Al 9.....	...do.....	.....	.....	.....	95	19	.....	300	.....	Specific gravity.....7.2.....	[128]
708...	...do.....	Hard-rolled.....	.....	.....	.....	136	1	.....	510	.....	.....	[128]
709...	Manganese: Mn 12, Ni 4.	Soft.....	17,900	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....6,700 kips/in. ² Poisson's ratio.....0.33.	[709]
710...	Mn 15, Si 2.....	Hard-rolled.....	.....	.....	.....	167	11	.....	205	.....	Specific gravity.....8.1.....	[128]

COPPER-NICKEL ALLOYS (SEE ALSO FIGS. 41, 42, AND 43)

711...	Ni 2.16, P 0.013...	Rod, cold-drawn, anne 1/2 hr at 1,200°F.	.....	3.6	.....	33.4	64 (1/area)	.....	.....	.....	.....	[24]
712...	...do.....	Rod, cold-drawn (14% red.).	.....	19.7	.....	51.7	25 (1/area)	.....	.....	.....	.....	[24]
713...	Ni 2.72, Fe 0.04, Mn 0.04, S 0.011.	Rod, 1 in. diam, cold-drawn.	.....	23.3	34.5 (0.01% perm)	47.0	20 (2 in.)	.....	.....	.....	.....	[24]
714...	Ni 19.23, Fe 0.27, Mn 0.12, C 0.03.	Rod, 1 in. diam, cold-rolled, 1 hr at 1,100°F, f-c.	.....	.....	9.0 (0.01% perm)	44.4	49 (2 in.)	.....	61	.....	.....	[98]
715...	...do.....	Rod, 1 in. diam, cold-rolled.	22,000	.....	30.0 (0.01% perm)	49.9	36 (2 in.)	.....	86	.....	Shear str.....35.3 kips/in. ² Torsion str.....41.7 kips/in. ²	[98]
716...	Ni 20.24.....	Sheet, 0.058 in., cold-rolled; 5 hr at 1,100°F.	.....	.....	18.9 (0.2% off-set)	15.1	27 (2 in.)	.....	V 70	.....	.....	[129]

TABLE 12.—Copper and copper alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
COPPER-NICKEL ALLOYS—Continued												
717...	Percent Ni 20.55, Ag 0.11...	Sheet, 0.063 in., cold-rolled; 6 hr at 1,100°F.	$kDsi/in.^2$	$kDsi/in.^2$	$kDsi/in.^2$ 30.2 (0.2% offset)	$kDsi/in.^2$ 51.0	Percent (2 in.) 25	Percent	V 107	ft-lb .....	.....	[129]
718...	Ni 21.24, Fe 0.51, Mn 0.29, C 0.031, Si 0.005.	Rod, cold-worked; 1 hr at 1,400°F, f-c.	.....	6.2	10.2 (0.01% perm)	48.0	48 (2 in.)	74 (10 ⁸)	.....	.....	.....	[17]
719...	...do.....	Rod, cold-worked; 3 hr at 400°F, f-c.	.....	25.0	45.0 (0.01% perm)	62.5	23 (2 in.)	68 (10 ⁸)	.....	.....	.....	[17]
720...	Ni 30.48, Mn 0.22, Fe 0.07, Mg 0.03.	Rod, 3/4 in. diam, cold-drawn (15% red.) from 0.030-mm grain size.	21,600	.....	63.8 (0.5% extn)	67.3	23 (2 in.)	71	.....	.....	.....	[83]
721...	...do.....	Rod, 3/4 in. diam, cold-drawn (15% red.) from 0.030-mm grain size, 2 hr at 840°F.	22,100	.....	53.7 (0.5% extn)	65.8	30 (2 in.)	72	.....	.....	.....	[83]
722...	Constantan Ni 45...	Sand-cast.....	.....	.....	21.0 (0.2% offset)	56	32 (2 in.)	34	80	30	Shear str.....13.0 kips/in. ² .. Specific gravity.....8.6. Melting range.....2,235°-2,325°F.	[130]
723...	Constantan: Ni 45.0, Mn 0.5-1.0, Fe 0.27, C 0.05, Si 0.02, S 0.006.	Rod, annealed 1 hr at 1,400°F.	24,800	20.2	27.1 (yld pnt)	66.6	46 (2 in.)	78	R _B 54	1z 64	Torsion str.....17.9 kips/in. ² .. Mod-el (shear).....9,200 kips/in. ² .. Poisson's ratio.....0.376.	[131]
724...	...do.....	Rod, hot-rolled.....	24,900	21.2	35.0 (yld pnt)	67.8	12 (2 in.)	76	R _B 62	1z 96	Torsion str.....18.8 kips/in. ² .. Mod-el (shear).....9,500 kips/in. ² .. Poisson's ratio.....0.376.	[131]
725...	Constantan: Ni 44.68, Mn 1.14, Fe 0.52, C 0.11.	Rod, 1 in. diam, hot-rolled.	25,000	14.5	28.0 (0.01% perm)	70.5	48 (2 in.)	78	400	.....	Shear str.....19.4 kips/in. ² .. Torsion str.....66.1 kips/in. ² ..	[83]
726...	Constantan Ni 44.77, Mn 0.89, Fe 0.66, C 0.078.	Rod, 1 hr at 1,450°F, f-c.	.....	21.0	25.4 (0.01% perm)	69.4	48 (2 in.)	79	56	.....	Shear str.....19.9 kips/in. ² .. Torsion str.....55.7 kips/in. ² ..	[83]
727...	...do.....	Rod, cold-rolled.....	.....	.....	54.7 (0.01% perm)	103	15 (2 in.)	70	159	.....	Shear str.....59.4 kips/in. ² .. Torsion str.....65.0 kips/in. ² ..	[93]
728...	Constantan: Ni 45.00, Mn 1.03, Fe 0.38, C 0.04, Si 0.02.	Rod, cold-rolled, 3 hr at 750°F, f-c.	.....	38.5	65.0 (0.01% perm)	95.5	23 (2 in.)	11	.....	.....	.....	[17]
COPPER-NICKEL-ALUMINUM ALLOYS												
729...	Ni 6.0, Al 1.5.....	Rod, 1 in. diam, extruded; cold-drawn (10% red.).	.....	20.2	49.7 (0.2%)	60.7	28 (2 in.)	.....	V 123	.....	.....	[132]
730...	...do.....	Rod, 1 in. diam, cold-drawn, 2 hr at 930°F.	.....	53.8	73.7 (0.2%)	106	15 (2 in.)	.....	V 224	.....	.....	[132]
731...	...do.....	Rod, 1 in. diam, quenched from 1,650°F.	.....	2.7	11.6 (0.2%)	49.3	48 (2 in.)	.....	V 68	.....	.....	[132]

732...	...do.....	Rod, 1 in. diam, quenched from 1,650°F, aged 2 hr at 1,020°F.	.....	40.1	76.2 (0.2%)	99.2	20 (2 in.)	.....	V 194	.....	[132]
733...	...do.....	Sheet, 1/8 in., cold-rolled (50% red.).	.....	33.2	68.3 (0.2%)	70.1	5 (2 in.)	.....	V 151	.....	[132]
734...	Ni 13.5, Al 1.5....	Rod, 1 in. diam, extruded, cold-drawn (10% red.).	.....	25.1	51.7 (0.2%)	64.5	28 (2 in.)	.....	V 146	.....	[132]
735...	...do.....	Rod, 1 in. diam, cold-drawn, 2 hr at 1,020°F.	.....	55.6	72.1 (0.2%)	124	15 (2 in.)	.....	V 254	.....	[132]
736...	...do.....	Rod, 1 in. diam, quenched from 1,650°F.	.....	3.1	9.4 (0.2%)	55.6	43 (2 in.)	.....	V 80	.....	[132]
737...	...do.....	Rod, 1 in. diam, quenched from 1,650°F, aged 2 hr at 1,110°F.	.....	45.7	67.6 (0.2%)	121	13 (2 in.)	.....	V 201	.....	[132]
738...	...do.....	Sheet, 1/8 in., cold-rolled (50% red.).	.....	31.8	78.6 (0.2%)	81.8	4 (2 in.)	.....	V 188	.....	[132]
739...	Ni 20.0, Al 1.95....	Rod, 7/8 in. diam, cold-drawn (25% red.), 1 hr at 1,020°F.	.....	93.2	.....	149	12 (2 in.)	24	.....	.....	[133]
740...	Ni 28.5, Al 1.5....	Sheet, 1/8 in., cold-rolled (50% red.).	.....	58.9	73.0 (0.1%)	93.4	1 (2 in.)	.....	V 200	.....	[132]
741...	...do.....	Sheet, 1/8 in., cold-rolled (50% red.), 2 hr at 1,020°F.	.....	97.0	118 (0.1%)	130	7 (2 in.)	.....	V 270	.....	[132]
742...	...do.....	Sheet, 1/8 in., quenched from 1,650°F.	.....	8.5	16.1 (0.1%)	58.7	36 (2 in.)	.....	V 97	.....	[132]
743...	...do.....	Sheet, 1/8 in., quenched from 1,650°F, aged 2 hr at 1,110°F.	.....	28.7	45.9 (0.1%)	100	17 (2 in.)	.....	V 206	.....	[132]
744...	Ni 43.17, Al 3.78, C 0.07.	1 hr at 1,540°F, w-q.	.....	20.5	46.0	90.8	48 (2 in.)	61	.....	.....	[134]
745...	...do.....	Water-quenched from 1,500°F, 7 hr at 1,100°F, slowly cooled.	.....	90.0	115	152	24 (2 in.)	38	.....	.....	[134]

COPPER-NICKEL-BERYLLIUM ALLOYS

746...	Ni 2.0, Be 0.2....	quenched from 1,650°F, cold-drawn (5% red.).	.....	.....	.....	66.6	4.3 (2 in.)	.....	.....	.....	[135]
747...	...do.....	quenched from 1,650°F, 1/2 hr at 930°F, cold-drawn (5% red.).	.....	.....	.....	122	2.5 (2 in.)	.....	.....	.....	[135]
748...	Ni 2.0, P 0.3, Be 0.2.	quenched from 1,470°F, cold-drawn (36% red.).	.....	.....	.....	99.1	4.4 (2 in.)	.....	.....	.....	[135]
749...	...do.....	quenched from 1,470°F, 1/2 hr at 930°F, cold-drawn (56% red.).	.....	.....	.....	120	2.0 (2 in.)	.....	.....	.....	[135]

COPPER-NICKEL-CHROMIUM ALLOY

750...	Ni 34.15, Cr 4.14, Mn 1.61, Fe 1.04, Si 0.13.	Rod, 1 in. diam, at 1,500°F, f-c.	.....	29.5	43.0 (0.01% perm)	100	27 (2 in.)	44	35.0	.....	[80]
751...	...do.....	Rod, 1 in. diam, forged.	25,000	31.0	54.0 (0.01% perm)	97.1	22 (2 in.)	47	31.0	.....	[80]

Shear str.....61.7 kips/in.²
Torsion str.....69.7 kips/in.²

TABLE 12.—Copper and copper alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation					Reduction of area
COPPER-NICKEL-IRON ALLOYS											
752...	Percent Ni 28.66, Fe 2.62, Mn 1.35, C 0.40, Si 0.002.	Rod, cold-rolled; 1 hr at 1,450°F, f-c.	kips/in. ²	kips/in. ² 12.5	kips/in. ² 24.5 (0.01% perm)	kips/in. ² 70.4	Percent 44 (2 in.)	Percent 70 (4 × 10 ⁷)	.....	ft-lb	[17]
753...	...do.....	Rod, cold-rolled; 3 hr at 850°F, f-c.	.....	55.0	74.0 (0.01% perm)	97.4	19 (2 in.)	54 (10 ⁶)	.....	.....	[17]
754...	Ni 30, Fe 1, Mn 1, Si 0.5.	Bar, cast.....	.....	18-22	32-35 (0.5% extn)	63-66 (2 in.)	35-40 (2 in.)	45-50	115-125	.....	[136]
COPPER-NICKEL-MANGANESE ALLOY											
755...	Ni 13.5, Mn 5, Al 1.5.	Rod, 1 in. diam, extruded, cold-drawn (10% red.).	.....	17.9	50.4 (0.2%)	69.2 (2 in.)	36 (2 in.)	.....	V 157	.....	[132]
756...	...do.....	Rod, 1 in. diam, cold- drawn, 2 hr at 1,110°F.	.....	69.9	85.1 (0.2%)	110	21 (2 in.)	.....	V 240	.....	[132]
757...	...do.....	Rod, 1 in. diam, quenched from 1,650°F.	.....	12.5	19.9 (0.2%)	57.1 (2 in.)	40 (2 in.)	.....	V 100	.....	[132]
758...	...do.....	Rod, 1 in. diam, quenched from 1,650°F, aged 2 hr at 1,110°F.	.....	49.3	62.7 (0.2%)	84.2 (2 in.)	7 (2 in.)	.....	V 221	.....	[132]
COPPER-NICKEL-SILICON ALLOYS											
759...	Ni 2.5, Si 0.6.....	Sand-cast; h-t at 840°F.	.....	.....	65.0 (0.15%)	76.2	8 (2 in.)	15	200	.....	[137]
760...	Ni 3.27, Si 0.82, Fe 0.087.	Rod, hard-drawn.....	.....	35.0	56.0 (0.01% perm)	69.5	18 (2 in.)	79	.....	.....	[17]
761...	...do.....	Rod, hard-drawn; 2 hr at 795°F.	.....	55.0	90.0 (0.01% perm)	122	6.0 (2 in.)	16	25.0	.....	[17]
762...	Cu 94.15, Ni 5.14, Si rem.	Sheet, 0.020 in., cold- soft.	16,400	53.2	.....	103	4.0 (2 in.)	.....	14.0 (10 ⁶)	.....	[20]
763...	...do.....	Sheet, 0.020 in., cold- worked (69% red.).	15,900	38.6	.....	133	1.0 (2 in.)	.....	24.0 (10 ⁶)	.....	[20]
COPPER-NICKEL-TIN ALLOYS											
764...	Ni 5, Sn 5.....	Sand-cast from 2,325°F.	.....	13.5	22.8 (0.2% perm)	48.8	44 (2 in.)	50	75	.....	[90]
765...	...do.....	Sand-cast, 10 hr at 1,400°F, w-q, aged 5 hr at 500°F.	.....	40.0	53.0 (0.2% perm)	74.0	28 (2 in.)	29	136	.....	[90]
766...	...do.....	Sand-cast, 10 hr at 1,400°F, w-q, aged 5 hr at 600°F.	.....	47.5	66.0 (0.2% perm)	84.0	16 (2 in.)	26	171	.....	[90]
767...	Ni 7.5, Sn 5.5.....	Sand-cast from 2,345°F.	.....	24.0	29.4 (0.2% perm)	56.5	36 (2 in.)	34	.....	.....	[90]

768...	...do.....	Sand-cast, 5 hr at 1,400°F, w-9, aged 10 hr at 500°F.	.....	50.0	64.5 (0.2% perm)	86.3	22 (2 in.)	34	.....	165	.....	[90]
769...	...do.....	Sand-cast, 5 hr at 1,400°F, w-9, aged 5 hr at 650°F.	.....	62.0	.....	104	5 (2 in.)	8	.....	213	.....	[90]
770...	Ni 20, Sn 7.....	Sand-cast, 7 hr at 1,600°F, w-9, aged 1 hr at 600°F.	.....	.....	64.5 (0.2% perm)	96.0	14 (2 in.)	24	.....	207	.....	[90]
771...	Ni 29.08, Sn 0.95, Fe 0.25, C 0.07.	Rod, 1 in. diam, cold-drawn.	21,400	.....	55.5 (0.01% perm)	87.3	3.8 (2 in.)	22	33.5 (5 × 10 ⁻⁷)	143	Shear str.....50.9 kips/in. ² ..	[98]
772...	...do.....	Rod, 1 in. diam, 1 hr at 1,800°F, f-c.	.....	.....	16.3 (0.01% perm)	57.8	33 (2 in.)	52	22.5	80	Shear str.....42.1 kips/in. ² .. Torsion str.....47.0 kips/in. ² ..	[99]
773...	Ni 29.36, Sn 1.33, Mn 0.32, Fe 0.25, C 0.048.	Sheet, 0.025 in., rolled (50% red.).	.....	.....	.....	97.9	2.5 (2 in.)	.....	27.0 (5 × 10 ⁻⁷)	R _g 90	.....	[149]

COPPER-NICKEL-ZINC ALLOYS (SEE ALSO FIG. 44)

774...	Ni 14.0, Zn 8.0, Sn 4.0.	Cast.....	.....	.....	33.6 (yld pnt)	49.3	19	.....	.....	.....	.....	[139]
775...	Cu 65.60, Ni 17.77, Pb 1.08, Fe 0.24, Mn 0.06, Zn rem.	Roller (53% red.).....	.....	.....	.....	94.2	2.2 (2 in.)	27	.....	S 37	.....	[140]
776...	Cu 65.44, Ni 17.83, Fe 0.34, Mn 0.08, Zn rem.	Roller (53% red.).....	.....	.....	.....	95.0	2.3 (2 in.)	31	.....	S 38	.....	[140]
777...	...do.....	Annealed at 1,300°F.....	.....	.....	29.4 (0.05% perm)	61.0	37 (2 in.)	45	.....	S 14	.....	[140]
778...	Ni 18.2, Zn 17.4, Mn 0.32, Fe 0.1.	Plate, 3/4 in., rolled..	.....	.....	58.8 (yld pnt)	64.8	18 (2 in.)	36	.....	Iz 17	.....	[141]
779...	Ni 19.75, Zn 5.17, Mn 0.75, Fe 0.34, C 0.07.	Rod, 1 in. diam, 1 hr at 1,400°F, f-c.	.....	.....	12.3 (0.01% perm)	51.1	47 (2 in.)	73	20.8	70	Shear str.....35.6 kips/in. ² .. Torsion str.....33.9 kips/in. ² ..	[90]
780...	...do.....	Rod, 1 in. diam, hot-rolled.	19,600	.....	32.0 (0.01% perm)	57.1	36 (2 in.)	70	23.0	89	Shear str.....38.3 kips/in. ² .. Torsion str.....35.3 kips/in. ² ..	[90]
781...	Ni 20, Zn 1, Se 1..	Soft.....	.....	.....	14.4 (0.5% extn)	44.8	48 (2 in.)	53	.....	.....	.....	[142]
782...	...do.....	Hard.....	.....	.....	62.7 (0.5% extn)	67.4	10 (2 in.)	33	.....	.....	.....	[142]
783...	Ni 20, Zn 5.....	Sheet or plate, soft..	.....	.....	20 (0.5% extn)	50	35 (2 in.)	.....	.....	R _g 25	Specific gravity.....8.86.....	[94]
784...	...do.....	Sheet or plate, hard..	19,000	.....	43 (0.5% extn)	85	5 (2 in.)	.....	.....	R _g 88	.....	[94]
785...	Ni 20, Zn 6, Pb 5..	Cast.....	.....	6.0	.....	26.3	13 (2 in.)	.....	.....	64	.....	[143]
786...	Ni 20, Zn 6, Pb 5, Sn 4.	...do.....	.....	19.9	.....	55.5	14 (2 in.)	.....	.....	114	.....	[143]
787...	Ni 20, Zn 6, Sn 4..	...do.....	.....	17.5	.....	65.4	22 (2 in.)	.....	.....	114	.....	[143]
788...	Ni 20.22, Zn 5.26, Mn 0.25, Fe 0.06, Mg 0.06.	Rod, 3/4 in. diam, annealed to 0.090-mm grain size.	20,200	.....	14.4 (0.5% extn)	49.0	50 (2 in.)	80	.....	.....	.....	[83]
789...	...do.....	Rod, 3/4 in. diam, cold-drawn (15% red.) from 0.090-mm grain size.	20,600	.....	58.1 (0.5% extn)	61.2	25 (2 in.)	76	.....	.....	.....	[83]

TABLE 12.—Copper and copper alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
COPPER-NICKEL-ZINC ALLOYS—Continued													
790...	Percent Ni 20.22, Zn 5.26, Mn 0.25, Fe 0.08, Mg 0.06.	Rod, 3/4 in. diam, cold-drawn (15% red.) from 0.060-mm grain size, 2 hr at 840°F.	Ktpsi/in. ² 20,800	Ktpsi/in. ²	Ktpsi/in. ² 45.6 (0.5% extn)	Ktpsi/in. ² 58.3	Percent 32 (2 in.)	Percent 78	Ktpsi/in. ² .....	.....	ft.-lb .....	.....	[83]
791...	Ni 20, Zn 10, Pb 5, Sn 4.	Sand-cast.....	.....	23.0	37.7 (yld pnt)	57.6	11 (2 in.)	.....	.....	120	.....	.....	[143]
792...	Ni 21.87, Zn 18.44, Mn 0.16.	Cast.....	.....	16.0	.....	41.8	57	.....	.....	57	.....	.....	[143]
COPPER-SELENIUM ALLOYS													
793...	Se 0.48.....	Rod, 1/2 in., drawn (36% red.).	.....	.....	50.9 (0.5% extn)	53.6	16 (1.4 in.)	.....	.....	.....	.....	.....	[142]
794...	...do.....	Rod, 1/2 in., ann 1 hr at 1,110°F.	.....	.....	8.0 (0.5% extn)	32.8	53 (1.4 in.)	.....	.....	.....	.....	.....	[142]
795...	Se 1.44.....	Rod, 1/2 in., drawn (36% red.).	.....	.....	52.0 (0.5% extn)	54.2	10 (1.4 in.)	.....	.....	.....	.....	.....	[142]
796...	...do.....	Rod, 1/2 in., ann 1 hr at 1,110°F.	.....	.....	10.1 (0.5% extn)	33.2	42 (1.4 in.)	.....	.....	.....	.....	.....	[142]
COPPER-SILICON ALLOYS (SEE ALSO FIG. 45)													
797...	Si 0.74.....	Rod, 1 in. diam, drawn (10% red.).	19,100	5.4	.....	41.7	45 (4√area)	.....	.....	.....	.....	.....	[24]
798...	...do.....	Rod, 1 in. diam, drawn (10% red.), 2 hr at 570°F.	19,700	14.3	.....	41.0	49 (4√area)	.....	.....	.....	.....	.....	[24]
799...	...do.....	Rod, 1 in. diam, drawn (23% red.).	.....	9.0	.....	48.8	29 (4√area)	.....	.....	.....	.....	.....	[24]
800...	...do.....	Rod, 1 in. diam, drawn (23% red.), 100 hr at 570°F.	19,600	25.1	.....	49.1	35 (4√area)	.....	.....	.....	.....	.....	[24]
801...	Si 2.5, Fe 0.5.....	Rod, 1 in., ann.....	15,000	.....	20 (0.5% extn)	55	75 (2 in.)	.....	.....	R _B 50	.....	Melting point.....1,875°F. Specific gravity.....8.66.	[145]
802...	...do.....	Rod, 1 in., hard.....	15,000	.....	55 (0.5% extn)	90	20 (2 in.)	.....	.....	R _B 90	.....	.....	[145]
803...	Si 2.51, Fe 0.26...	Sheet, 0.139 in., ann 1/2 hr at 1,380°F.	.....	.....	15.5 (yld pnt)	50.8	72 (2 in.)	58	.....	.....	.....	.....	[127]
804...	Si 3.0.....	Bar, 1 in. diam, chill- cast.	12,500	5.8	17.0 (0.5% extn)	33.4	24 (2 in.)	41	.....	71	.....	.....	[127]
805...	Si 3.15, Fe 2.1, Mn 0.1.	Wire.....	.....	.....	.....	56.9	40	.....	19.9	115	° 8	.....	[101]
806...	Si 3.2, Fe 1.2.....	Rod, 1 in., ann.....	15,000	.....	30 (0.5% extn)	60	75 (2 in.)	.....	.....	R _B 50	.....	Melting point.....1,870°F. Specific gravity.....8.55.	[145]
807...	...do.....	Rod, 1 in., hard.....	15,000	.....	65 (0.5% extn)	110	20 (2 in.)	.....	.....	R _B 90	.....	.....	[145]

808...	Si 3.23, Fe 0.29...	Sheet, 0.128 in., cold-rolled (5% red.)	.....	.....	38.1 (yld pnt)	107	9.0 (2 in.)	20	.....	.....	.....	[127]
809...	...do.....	Sheet, 0.128 in., ann 1/2 hr at 1,380°F.	.....	.....	17.5 (yld pnt)	67.4	56 (2 in.)	52	.....	.....	.....	[127]
810...	Si 4.5.....	Bar, 1 in. diam, chill-cast.	.....	.....	25.1 (0.5% extn)	40.5	11 (2 in.)	15	.....	100	.....	[127]
811...	Si 4.58, Fe 0.28...	Sheet, 0.137 in., hot-rolled.	.....	.....	38.8 (yld pnt)	86.5	11 (2 in.)	12	.....	174	.....	[127]
812...	Si 5.0.....	Sand-cast.....	.....	.....	.....	45.0	10 (11.3/area)	.....	.....	77	.....	[140]

COPPER-SILICON-MANGANESE ALLOYS

813...	Si 1.41, Mn 0.21, Fe 0.06.	Rod, 1/2 in. diam, cold-worked (72% red.).	17,000	.....	68.5 (0.5% extn)	88.0	10 (2 in.)	74	30.4 (3 x 10 ⁵)	R _B 86	.....	[82]
814...	Si 1.48, Mn 0.30, Fe 0.09.	Rod, 3/4 in. diam, cold-drawn (36% red.) from 0.14-mm grain size.	16,400	.....	53.7 (0.5% extn)	58.8	22 (2 in.)	82	.....	.....	.....	[83]
815...	...do.....	Rod, 3/4 in. diam, ann to 0.130-mm grain size.	17,900	.....	7.6 (0.5% extn)	37.4	62 (2 in.)	90	.....	.....	.....	[83]
816...	Si 1.49, Mn 0.40, Fe 0.04.	Rod, 3/4 in. diam, cold-drawn (64% red.), from 0.10-mm grain size.	15,800	.....	62.1 (0.5% extn)	84.6	17 (2 in.)	76	.....	.....	.....	[83]
817...	...do.....	Rod, 3/4 in. diam, ann to 0.110-mm grain size.	18,000	.....	7.6 (0.5% extn)	38.3	65 (2 in.)	92	.....	.....	.....	[83]
818...	Si 3, Mn 1.....	Sheet, 0.040 in., ann.	15,000	.....	24 (0.5% extn)	60	65 (2 in.)	.....	.....	R _F 45	.....	[145]
819...	...do.....	Sheet, 0.040 in., hard.	15,000	.....	100 (0.5% extn)	110	5 (2 in.)	.....	.....	R _B 95	.....	[145]
820...	Si 3.02, Mn 0.74, Zn 0.14, Fe 0.11, Ni 0.08.	Sheet, 0.020 in., soft.	16,800	9.4	.....	59.3	63 (2 in.)	.....	16.0 (10 ⁵)	R _B 41	.....	[30]
821...	Si 3.20, Mn 1.07, Fe 0.15.	Rod, 1/2 in. diam, cold-worked (39% red.) from 0.125-mm grain size.	14,600	.....	64.2 (0.5% extn)	97.1	13 (2 in.)	62	33.6 (3 x 10 ⁵)	R _B 101	.....	[82]
822...	...do.....	Rod, 1/2 in. diam, ann 1/2 hr at 1,290°F.	16,900	.....	16.0 (0.5% extn)	59.6	68 (2 in.)	78	18.8 (3 x 10 ⁵)	R _B 44	.....	[82]
823...	Si 3.22, Mn 2.01, Fe 0.08.	Bar, 1 in. diam, chill-cast.	17,700	5.8	14.8 (0.5% extn)	34.3	13 (2 in.)	18	.....	92	.....	[127]
824...	Cu 95.46, Mn 0.99, Si (rem).	Sheet, 0.020 in., cold-worked (60% red.).	12,400	26.0	.....	80.0	22 (2 in.)	.....	23.5 (10 ⁵)	R _B 91	.....	[30]
825...	Si 3.92, Mn 0.98, Fe 0.22.	Tubing, 3/8 in. o-d by 0.05 in. wall, ann.	.....	.....	.....	52.0	52 (2 in.)	.....	11.0 (10 ⁵)	.....	.....	[146]
826...	...do.....	Tubing, 3/8 in. o-d by 0.05 in. wall, cold-worked.	.....	.....	.....	67.0	49 (2 in.)	.....	18.0 (10 ⁵)	.....	.....	[146]
827...	Si 4, Mn 1.....	Sand-cast.....	15,000	.....	20 (0.75% extn)	50	20 (2 in.)	25	.....	90	.....	[147]
828...	Si 4.74, Mn 3.19, Fe 0.12.	Bar, 1 in. diam, chill-cast.	15,200	8.1	31.4 (0.5% extn)	55.1	4 (2 in.)	6	.....	133	.....	[127]
829...	Si 5.35, Mn 1.45, Fe 0.12.	...do.....	13,900	12.5	35.6 (0.5% extn)	41.4	1 (2 in.)	1	.....	118	.....	[127]

^a Notch impact value, m-kg/cm.²

TABLE 12.--Copper and copper alloys, normal-temperature properties--Continued

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
COPPER-SILICON-ZINC ALLOYS												
830...	Percent Si 3.12, Zn 0.22, Fe 0.16, Al 0.03.	Sheet, 0.025 in., rolled (50% red.).	$kts/in.^2$	$kts/in.^2$	$kts/in.^2$	$kts/in.^2$ 104	Percent 5.0 (2 in.)	Percent	$kts/in.^2$ 294.6 (5 x 16")	R _B 13	<i>ft-lb</i>	[149]
831...	Cu 95.70, Si 3.13, Zn 0.92, Fe rem.	Rod, 1/2 in. diam, annealed.	.....	.....	23.0 (0.5% extn)	62.0	53 (2 in.)	63	.....	R _F 86	12 99	[148]
832...	do.....	Rod, 1/2 in. diam, drawn (36% red.).	.....	.....	61.5 (0.5% extn)	101	12 (2 in.)	46	.....	R _T 110	12 24	[148]
833...	Cu 96.12, Si 3.11, Zn rem.	Rod, 1/2 in. diam, annealed.	.....	.....	24.0 (0.5% extn)	62.5	54 (2 in.)	71	.....	R _F 89	17 113	[148]
834...	do.....	Rod, 1/2 in. diam, drawn (36% red.).	.....	.....	62.0 (0.5% extn)	94.0	21 (2 in.)	65	.....	R _F 110	17 71	[148]
835...	Si 3.25, Zn 1.50, Sn 0.50.	Cast.....	.....	.....	.....	55.0	70	.....	.....	.....	Specific gravity.....8.34..... Melting point.....1,875° F.	[190]
COPPER-SILVER ALLOYS (SEE ALSO FIG. 46)												
836...	Ag 0.093, Fe 0.007.	Rod, 1 in. diam, drawn (10% red.).	.....	2.7	.....	34.5	51 (4 / area)	.....	.....	.....	.....	[24]
837...	do.....	Rod, 1 in. diam, drawn (10% red.), 2 hr at 570° F.	19,900	8.1	.....	34.3	51 (4 / area)	.....	.....	.....	.....	[24]
838...	do.....	Rod, 1 in. diam, drawn (5% red.).	.....	4.5	.....	50.6	22 (4 / area)	.....	.....	.....	.....	[24]
839...	do.....	Rod, 1 in. diam, drawn (50% red.), 2 hr at 570° F.	20,100	8.1	.....	49.1	22 (4 / area)	.....	.....	.....	.....	[24]
840...	Ag 5, Be 0.3.....	Wire, 0.039-0.078 in. diam, soft, quenched.	.....	.....	.....	46.7	29	.....	.....	.....	.....	[150]
841...	do.....	Wire, 0.039-0.078 in. diam, hard-drawn.	.....	.....	.....	101	0.5	.....	.....	.....	.....	[150]
842...	do.....	Wire, 0.039-0.078 in. diam, hard-drawn, aged.	.....	.....	.....	96.9	7.1	.....	.....	.....	.....	[150]
843...	Ag 5, Be 1.....	Wire, 0.039-0.078 in. diam, soft, quenched.	.....	.....	.....	59.7	.....	.....	.....	.....	.....	[150]
844...	do.....	Wire, 0.039-0.078 in. diam, hard-drawn.	.....	.....	.....	138	.....	.....	.....	.....	.....	[150]
845...	do.....	Wire, 0.039-0.078 in. diam, hard-drawn, aged.	.....	.....	.....	172	.....	.....	.....	.....	.....	[150]
846...	Ag 30, Be 0.5.....	Wire, 0.039-0.078 in. diam, soft, quenched.	.....	.....	.....	50.6	12	.....	.....	.....	.....	[150]
847...	do.....	Wire, 0.039-0.078 in. diam, hard-drawn.	.....	.....	.....	129	0.3	.....	.....	.....	.....	[150]
848...	do.....	Wire, 0.039-0.078 in. diam, hard-drawn, aged.	.....	.....	.....	98.1	6.0	.....	.....	.....	.....	[150]

COPPER-SULFUR ALLOYS

849...	S 0.54.....	Rod, 1/2 in., drawn (36% red.).	.....	.....	.....	52.5 (0.5% extn)	54.3	12 (1.4 in.)	.....	.....	.....	.....	[142]
850...	...do.....	Rod, 1/2 in., ann 1 hr at 1,110°F.	.....	.....	.....	9.0 (0.5% extn)	33.6	51 (1.4 in.)	.....	.....	.....	.....	[142]
851...	S 0.97.....	Rod, 1/2 in., drawn (36% red.).	.....	.....	.....	53.1 (0.5% extn)	56.7	8.6 (1.4 in.)	.....	.....	.....	.....	[142]
852...	...do.....	Rod, 1/2 in., ann 1 hr at 1,110°F.	.....	.....	.....	11.1 (0.5% extn)	34.9	46 (1.4 in.)	.....	.....	.....	.....	[142]

COPPER-TELLURIUM ALLOYS

853...	Te 0.45.....	Rod, 1/2 in., drawn (36% red.).	.....	.....	.....	50.7 (0.5% extn)	53.1	11 (1.4 in.)	.....	.....	.....	.....	[142]
854...	...do.....	Rod, 1/2 in., ann at 1,110°F.	.....	.....	.....	8.1 (0.5% extn)	33.0	51 (1.4 in.)	.....	.....	.....	.....	[142]
855...	Te 1.05.....	Rod, 1/2 in., drawn (36% red.).	.....	.....	.....	51.2 (0.5% extn)	53.3	11 (1.4 in.)	.....	.....	.....	.....	[142]
856...	...do.....	Rod, 1/2 in., ann at 1,110°F.	.....	.....	.....	8.3 (0.5% extn)	33.2	41 (1.4 in.)	.....	.....	.....	.....	[142]

COPPER-TIN ALLOYS (SEE ALSO FIGS. 47 TO 53, INCLUSIVE)

857...	Sn 0.48, Fe 0.003...	Rod, 1 in. diam, drawn (10% red.).	19,400	4.5	.....	.....	46.1	33 (4/area)	.....	.....	.....	.....	[24]
858...	...do.....	Rod, 1 in. diam, drawn, (10% red.), 2 hr at 570°F.	19,600	28.7	.....	.....	45.0	37 (4/area)	.....	.....	.....	.....	[24]
859...	...do.....	Rod, 1 in. diam, drawn (50% red.).	19,600	9.0	.....	.....	58.9	20 (4/area)	.....	.....	.....	.....	[24]
860...	...do.....	Rod, 1 in. diam, drawn, (50% red.), 2 hr at 570°F.	20,100	36.7	.....	.....	56.4	25 (4/area)	.....	.....	.....	.....	[24]
861...	Sn 1.0, P 0.03.....	Cast.....	.....	.....	.....	4.5 (0.15%)	22.4	25 (2 in.)	.....	.....	40	.....	[113]
862...	Sn 1.25, P 0.05.....	Rod, 13/32 in. diam, cold-worked (37% red.) from 0.015-mm grain size.	19,000	.....	.....	54.7 (0.5% extn)	59.2	14 (2 in.)	74	31.3 (3 x 10 ⁶)	R _B 70	.....	[82]
863...	Sn 1.58.....	Rod, 1/2 in. diam, ann..	.....	.....	.....	15.0 (0.5% extn)	43.5	50 (2 in.)	77	.....	R _F 69 Iz 84	.....	[148]
864...	...do.....	Rod, 1/2 in. diam, drawn (36% red.).	.....	.....	.....	53.5 (0.5% extn)	59.0	22 (2 in.)	70	.....	R _F 98 Iz 92	.....	[148]
865...	Signal bronze: Sn 1.58, P 0.03.	Rod, 13/32 in. diam, cold-worked (37% red.) from 0.015-mm grain size.	19,000	.....	.....	57.2 (0.5% extn)	62.4	15 (2 in.)	73	32.7 (3 x 10 ⁶)	R _B 71	.....	[82]
866...	Sn 2.99, P 0.48.....	Sheet, 1.04 in., rolled (30% red.).	16,900	30.2	.....	.....	64.7	14	.....	.....	.....	.....	[151]
867...	3.19, Fe 1.12, Sn 0.56, P 0.12.	Sheet, 0.04 in., cold- rolled (50% red.).	16,000	.....	.....	89.6 (0.2%)	93.9	4.0 (2 in.)	.....	.....	.....	.....	[151]
868...	Sn 3.86, Zn 0.03, P 0.068, Fe 0.04.	Sheet, 0.020 in., soft..	12,800	13.3	.....	.....	55.1	52 (2 in.)	.....	13.8 (10 ⁶)	R _B 14	.....	[30]

TABLE 12.—Copper and copper alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
COPPER-TIN ALLOYS—Continued													
869...	Percent Sn 3.86, Zn 0.09, P 0.068, Fe 0.04	Sheet, 0.020 in., cold-worked (60% red.).	kips/in. ² 14,800	kips/in. ² 54.4	kips/in. ²	kips/in. ² 90.2	Percent 1.8 (2 in.)	Percent	kips/in. ² 22.0 (10 ⁵)	R ₀ 57	ft-lb		[20]
870...	Sn 3.39, P 0.40....	Rod, 1/2 in., hard-drawn.	16,500	.....	82.5	87.0	30 (2 in.)	70	.....	178	12 46		[25]
871...	Sn 4.23, P 0.13....	Rod, 3/4 in., drawn; 1/2 hr at 525°F.	17,700	24.6	57.1 (0.1%)	61.8	33 (1/area)	78	22.0 (5 × 10 ⁷)	138	124		[152]
872...	Sn 4.27, P 0.21....	Wire, 0.065 in. diam, cold-drawn.	.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....6,200 kirs/in. ² ..	[153]
873...	Sn 4.28, P 0.29; Fe 0.02, Pb 0.003.	Rod, 3/4 in. diam, annealed to 0.010-mm grain size.	17,500	.....	18.7 (0.5% extn)	49.4	73 (2 in.)	82	.....	.....	.....		[83]
874...	Sn 4.32, P 0.38, Fe 0.025, Pb 0.003.	Rod, 1/2 in. diam, cold-worked (30% red.) from 0.030-mm grain size.	16,400	.....	60.0 (0.5% extn)	69.8	23 (2 in.)	79	29.0 (3 × 10 ⁵)	R _g 92	.....		[82]
875...	Sn 4.56, P 0.11, Fe 0.03.	Wire, 0.104 in. diam, cold-drawn.	.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....6,400 kirs/in. ² ..	[153]
876...	Sn 4.66, Fe 0.031, P 0.056, Pb 0.002.	Rod, cold-rolled.....	18,100	15.5	45.0 (0.01% perm)	58.6	32 (2 in.)	71	12.0 (7 × 10 ⁷)	.....	.....	Shear str.....37.0 kirs/in. ² .. Torsion str.....52.6 kirs/in. ² ..	[93]
877...	Sn 4.66, P 0.032....	Sheet, 0.025 in., rolled (30% red.).	.....	.....	.....	97.9	2.5 (2 in.)	.....	36.0 (5 × 10 ⁷)	R _g 91	.....		[149]
878...	Sn 5, P 0.05.....	Sand-cast from 2.25% Fe.	.....	7.0	18.0 (0.2% perm)	40.0	38 (2 in.)	34	.....	59	.....		[90]
879...	Sn 5.....	Mixed powders; cold-compacted at 9 tons/in. ² , hot-compacted at 5 tons/in. ² and 1,200%.	.....	.....	30.2 (yld pnt)	39.2	9	.....	.....	114	.....		[154]
880...	...do.....	Mixed powders; cold-compacted at 9 tons/in. ² , hot-compacted at 5 tons/in. ² and 1,470%.	.....	.....	26.9 (yld pnt)	50.4	47	.....	.....	.....	.....		[154]
881...	Sn 5.14, P 0.39, Fe 0.07.	Wire, 0.157 in. diam, cold-drawn.	.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....6,500 kirs/in. ² ..	[153]
882...	Sn 6.34, P 0.25....	Sheet, 0.04 in., cold-rolled (35% red.).	15,600	46.4	.....	83.6	26	.....	.....	.....	.....		[151]
883...	Sn 7.....	Mixed powders; cold-compacted at 9 tons/in. ² , hot-compacted at 5 tons/in. ² and 1,170%.	.....	.....	26.9 (yld pnt)	52.6	75	.....	.....	.....	.....		[151]
884...	Sn 7.68, Zn 0.16, P 0.066, Fe 0.02, Pb 0.01.	Sheet, 0.020 in., soft..	15,500	12.8	.....	51.8	78 (2 in.)	.....	17.2 (10 ⁵)	R _g 34	.....		[20]
885...	...do.....	Sheet, 0.020 in., cold-worked (60% red.).	15,100	56.1	.....	113	1.5 (2 in.)	.....	27.0 (10 ⁵)	R ₀ 80	.....		[20]

885...	Sn 8.20, Fe 0.07...	Rod, cold-drawn, ann 1 hr at 1,200°F, f-c	.....	18.0	20.5 (0.01% perm)	56.5	81 (2 in.)	73	21.0	.....	.....	[17]
887...	Sn 8.09, P 0.11, Fe 0.01, Pb 0.01.	Rod, 3/4 in. diam. ann to 0.070-mm grain size.	16,800	.....	20.7 (0.5% extn)	56.8	83 (2 in.)	82	.....	.....	.....	[88]
888...	Sn 8.10, P 0.08, Fe 0.013, Pb 0.002.	Rod, 1/2 in. diam. cold- worked (15% red.) from 0.100-mm grain size.	16,400	.....	49.1 (0.5% extn)	66.0	48 (2 in.)	81	30.0 (3 × 10 ⁶)	R _B 80	.....	[82]
889...	...do.....	Rod, 1/2 in. diam. cold- worked (30% red.) from 0.100-mm grain size.	15,000	.....	60.2 (0.5% extn)	81.0	27 (2 in.)	77	34.7 (3 × 10 ⁶)	R _B 96	.....	[82]
890...	...do.....	Rod, 1/2 in. diam. cold- worked (50% red.) from 0.100-mm grain size.	13,800	.....	65.3 (0.5% extn)	110	10 (2 in.)	69	30.0 (3 × 10 ⁶)	R _B 98	.....	[82]
891...	Sn 9.....	Mixed powders; cold- compact at 9 tons/in. ² , hot- compact at 5 tons/in. ² and 1,470°F.	.....	.....	33.6 (yld pnt)	47.0	17	.....	.....	.....	.....	[154]
892...	Cu 89.65, Sn 9.75, Pb 0.15, Sn 0.10, Zn rem.	Cast from 2,200°F.	12,600	.....	20.7 (0.5%)	47.3	42	21	.....	62	.....	[155]
893...	Sn 9.76, Zn 0.20, P 0.12, Fe 0.06.	Rod, 1/2 in. diam. cold- worked (30% red.) from 0.090-mm grain size.	14,100	.....	60.0 (0.5% extn)	92.1	23 (2 in.)	64	23.0 (3 × 10 ⁶)	R _B 91	.....	[82]
894...	Sn 9.96, P 0.12, Zn 0.10, Fe 0.02, Pb 0.01.	Rod, 3/4 in. diam. ann to 0.090-mm grain size.	16,200	.....	23.1 (0.5% extn)	61.8	76 (2 in.)	73	.....	.....	.....	[83]
895...	Sn 10.49, Ni 0.13, Fe 0.07.	Rod, cold-drawn, ann 1 hr at 1,200°F, f-c.	.....	15.0	18.5 (0.01% perm)	61.5	76 (2 in.)	72	20.5 (10 ⁶)	.....	.....	[17]
896...	Sn 10.....	Sand-cast from 2,230°F. ..	.....	10.0	20.0 (0.2% perm)	43.2	25 (2 in.)	.....	.....	74	.....	[90]
897...	Sn 11.2, P 0.23....	Chill-cast.....	.....	.....	29.1 (yld pnt)	49.3	11 (2 in.)	.....	.....	108	.....	[156]
898...	Sn 12.....	Cast.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[88]
899...	Sn 15.29, Zn 0.09, P 0.08, Pb 0.02, Fe 0.015.	Bar, 1 1/4 in. diam. sand-cast from 2,145°F.	.....	.....	28.2 (yld pnt)	32.3	1.5 (2 in.)	.....	.....	88	1z 26	[138]

COPPER-TIN-CADMIUM ALLOY

900...	Sn 0.82, Cd 0.30...	Rod, 1 in. diam. drawn (10% red.).	.....	6.3	.....	40.5	48 (4√area)	.....	.....	.....	.....	[24]
901...	...do.....	Rod, 1 in. diam. drawn (10% red.), 2 hr at 57°F.	19,400	11.6	.....	40.5	49 (4√area)	.....	.....	.....	.....	[24]
902...	...do.....	Rod, 1 in. diam. drawn (29% red.).	18,900	7.2	.....	48.6	27 (4√area)	.....	.....	.....	.....	[24]
903...	...do.....	Rod, 1 in. diam. drawn (29% red.), 2 hr at 570°F.	.....	8.1	.....	49.1	22 (4√area)	.....	.....	.....	.....	[24]

COPPER-TIN-LEAD ALLOYS

904...	Sn 4, Pb 4, Zn 4, P 0.15.	Rod, 1 in., hard.....	15,000	.....	15 (0.5% extn)	60	20 (2 in.)	.....	.....	R _B 75	.....	[145]
905...	Sn 5.0, Pb 1.0, P 0.10.	Sheet, 0.040 in., anne.	15,000	.....	20 (0.5% extn)	50	45 (2 in.)	.....	.....	R _B 25	.....	[145]

^aAlternating torsion.

TABLE 12.—Copper and copper alloys, normal temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
COPPER-TIN-LEAD ALLOYS—Continued													
906...	Percent Sn 5.0, Pb 1.0, P 0.10.	Sheet, 0.010 in., hard..	kips/in. ² 15,000	kips/in. ²	kips/in. ² 60 (0.5% extn)	kips/in. ² 82	Percent 8 (2 in.)	Percent	kips/in. ²	R _B 90	ft-lb .....	.....	[145]
907...	Sn 6.91, Pb 7.14, Zn 2.73, Sb 0.30, Ni 0.24, P 0.04.	Cast from 2,080°F.....	10,400	.....	15.9 (0.1% offset)	33.9	23 (2 in.)	24	.....	53	.....	Comp yld str (0.12%).....14.0 kips/in. ² Comp str (12%).....36.5 kips/in. ² Specific gravity.....8.60.	[123]
908...	Electrical bronze: Sn 7, Pb 3, Zn 3.	Cast.....	.....	.....	.....	29-36	11-20 (2 in.)	.....	.....	50	Iz 2	.....	[137]
909...	do.....	do.....	.....	.....	17	35	15	.....	.....	60	.....	.....	[125]
910...	Sn 14, Pb 1, Zn 0.25.	do.....	.....	.....	15	40	10	.....	.....	85	.....	.....	[125]
COPPER-TIN-NICKEL ALLOYS													
911...	Sn 3.88, Ni 2.33, Si 0.58, P 0.37.	Sheet, cold-rolled; quenched from 1,470°F, aged 1 hr at 910°F.	17,500	37.9	.....	73.0	22 (2 in.)	.....	.....	R _B 80	.....	.....	[138]
912...	Sn 5.35, Ni 4.24, Si 0.79.	Mixed powders; cold- compacted at 9 tons/in. ² , hot- compacted at 5 tons/in. ² and 1,560°F.	.....	.....	35.8 (yld pnt)	50.4	13	.....	.....	.....	.....	.....	[154]
913...	Sn 5.4, Ni 5.3, Si 0.63.	do.....	.....	.....	49.3 (yld pnt)	58.2	5	.....	.....	.....	.....	.....	[154]
914...	Sn 7.76, Ni 2.37, Si 0.58, P 0.40.	Sheet, cold-rolled; quenched from 1,470°F, aged 1 hr at 909°F.	18,600	31.0	.....	74.1	22 (2 in.)	.....	.....	R _B 80	.....	.....	[158]
915...	Sn 8, Ni 7.5.....	Sand-cast from 2,300°F.	.....	25.0	34.0 (0.2% perm)	58.0	18 (2 in.)	18	.....	105	.....	.....	[90]
916...	do.....	Sand-cast, 5 hr at 1,400°F, w-q, 5 hr at 500°F.	.....	55.0	76.0 (0.2% perm)	89.6	18 (2 in.)	34	.....	179	.....	.....	[90]
COPPER-TIN-SILICON ALLOY													
917...	Sn 1.5, Si 1.0.....	Rod, 1 in. diam, ann..	15,000	.....	.....	40	35 (2 in.)	.....	.....	R _B 30	.....	Melting point.....1,905°F. Specific gravity.....8.77.	[145]
918...	do.....	Rod, 1 in. diam, hard..	15,000	.....	.....	70	10 (2 in.)	.....	.....	R _B 80	.....	.....	[145]
COPPER-TIN-TELLURIUM ALLOYS													
919...	Sn 1.33, Te 0.48..	Rod, 1/2 in. diam, ann..	.....	.....	17.0 (0.5% extn)	41.0	41 (2 in.)	47	.....	R _F 56	Iz 63	.....	[148]
920...	do.....	Rod, 1/2 in., drawn (36% red.).	.....	.....	51.5 (0.5% extn)	56.0	14 (2 in.)	42	.....	R _F 94	Iz 17	.....	[148]

921...	Sn 1.54, Fe 0.95...	Rod, 1/2 in. diam, ann.	.....	.....	14.5 (0.5% extn)	42.0	36 (2 in.)	39	.....	R _F 64	Iz 56	.....	[148]
922...	...do.....	Rod, 1/2 in., drawn (36% red.)	.....	.....	54.5 (0.5% extn)	58.5	11 (2 in.)	29	.....	R _F 97	Iz 9	.....	[148]

COPPER-TIN-ZINC ALLOYS

923...	Sn 6.33, Zn 1.85, Pb 1.75.	Plate, 12 in. x 4 in. x 1 in., cast.	.....	5.2	8.6	28.6	20 (2 in.)	17	.....	49	.....	.....	[159]
924...	Sn 6.84, Zn 4.70, Pb 1.15.	Rod, 13/16 in. diam, cast.	.....	.....	14.8	39.5	30 (2 in.)	27	.....	55	.....	.....	[159]
925...	Sn 9.89, Zn 2.09...	Cast.....	.....	5.8	12.2	30.1	22 (2 in.)	25	.....	55	.....	.....	[159]
926...	Sn 10, Zn 2.....	Bar, cast.....	15,000	11-14	18-21 (0.5% extn)	30-45	15-40 (2 in.)	.....	.....	60-80	Iz 7-14	Comp yld str (1.0%).....21-23 kips/in. ² Compressive str.....200-300 kips/in. ² Specific gravity.....8.5-8.8.	[160]
927...	Sn 10.16, Zn 1.88, Pb 0.28, As 0.041, Fe 0.03, Sb 0.013, P 0.007.	Bar, 1 in. square, cast from 2,100°F.	.....	.....	20.2 (yld pnt)	36.1	18 (2 in.)	.....	.....	61	Iz 10	.....	[161]
928...	Sn 11.86, Zn 1.29, Pb 0.17, Ni 0.09, Fe 0.01.	Cast.....	13,900	14.9	21.8 (yld pnt)	42.2	16 (2 in.)	19	.....	.....	.....	.....	[162]

COPPER-TITANIUM ALLOYS

929...	Ti 0.8, Si 0.3.....	Cast; h-t at 840°F.....	.....	.....	22.4 (0.15%)	44.8	16 (2 in.)	23	.....	78	.....	.....	[137]
930...	Ti 2.90, Al 0.09, Fe 0.06, Mn 0.04, Si 0.007.	Forged; quenched from 1,650°F.	.....	5.6	23.3 (yld pnt)	56.5	42 (2 in.)	44	.....	83	.....	.....	[163]
931...	...do.....	Forged; quenched from 1,650°F, aged 16 hr at 750°F.	.....	51.0	77.0 (yld pnt)	104	22 (2 in.)	30	.....	201	.....	.....	[163]

COPPER-ZINC ALLOYS (SEE ALSO FIGS. 54 TO 59, INCLUSIVE)

932...	Zn 0.48.....	Rod, 1 in. diam, drawn (10% red.)	19,800	1.8	.....	34.5	49 (4/area)	.....	.....	.....	.....	.....	[24]
933...	...do.....	Rod, 1 in. diam, drawn (10% red.), 2 hr at 570°F.	19,100	11.6	.....	34.5	52 (4/area)	.....	.....	.....	.....	.....	[24]
934...	...do.....	Rod, 1 in. diam, drawn (2% red.)	19,600	6.3	.....	42.3	28 (4/area)	.....	.....	.....	.....	.....	[24]
935...	Gilding metal: Zn 5.	Sheet, 0.040 in., soft..	.....	.....	.....	36	44 (2 in.)	.....	.....	R _F 45	.....	.....	[164]
936...	...do.....	Sheet, 0.040 in., cold-drawn (37% red.)	.....	.....	.....	55	4 (2 in.)	.....	.....	R _B 72	.....	.....	[164]
937...	...do.....	Sheet, 0.040 in., cold-drawn (60% red.)	.....	.....	.....	65	3 (2 in.)	.....	.....	R _B 77	.....	.....	[164]
938...	...do.....	Sheet, 0.040 in., ann 1 hr at 900°F.	15,000	5-9	.....	37	45 (2 in.)	.....	.....	R _F 58	.....	Melting point.....1,950°F. Specific gravity.....8.86.	[165]
939...	Cu 90.10, Zn rem...	Rod, 1/2 in. diam, ann..	.....	.....	11.5 (0.5% extn)	37.5	54 (2 in.)	85	.....	R _F 53	Iz 73	.....	[148]
940...	...do.....	Rod, 1/2 in. diam, drawn (36% red.)	.....	.....	47.5 (0.5% extn)	52.0	23 (2 in.)	83	.....	R _F 91	Iz 102	.....	[148]

960...	...do.....	Strip, cold-rolled (50% red.)	.....	34.7	67.6 (0.1%)	84.2	11 (2 in.)	49	.....	159	.....	[170]
961...	...do.....	Strip, cold-rolled (40% red.)	.....	42.8	79.5 (0.1%)	109	3 (2 in.)	47	.....	190	.....	[170]
962...	Zn 29.92, Pb 0.02, Fe 0.02	Rod, 3/4 in., 1 hr at 1,100°F, w-q.	14,900	9.2	.....	47.2	55 (8 in.)	75	22.5 (5 x 10 ⁷)	R _h 11	.....	[169]
963...	...do.....	Rod, 3/4 in., cold- drawn (27% red.)	15,500	17.8	.....	74.1	20 (2 in.)	58	22.0 (5 x 10 ⁷)	R _h 81	.....	[169]
964...	Zn 30.....	Mixed powders; cold- compacted at 9 tons/in. ² , hot- compacted at 5 tons/in. ² and 1,470°F.	.....	.....	24.6 (yld pnt)	42.6	16	.....	.....	110	.....	[154]
965...	Zn 30.2.....	Cast.....	.....	.....	14.5 (yld pnt)	37.4	58 (2 in.)	.....	.....	55	1z 41	[171]
966...	...do.....	Cast; ann.....	.....	.....	17.9 (yld pnt)	48.1	68 (2 in.)	.....	.....	57	.....	[171]
967...	Zn 32.8, Fe <0.1...	Plate, 3/4 in., rolled..	.....	.....	52.1 (yld pnt)	57.0	27 (2 in.)	50	.....	118	1z 28	[141]
968...	Zn 31.....	Sheet, hard.....	.....	.....	.....	85	4 (2 in.)	.....	.....	153	.....	[168]
969...	Cu 66.12, Zn rem...	Sheet, 0.025 in. (grain size 0.005 mm).	.....	.....	.....	50.8	62 (2 in.)	.....	.....	.....	.....	[172]
970...	Zn 34.23, Fe 0.15..	Wire, 0.064 in. diam, cold-drawn.	.....	.....	.....	.....	.....	.....	.....	.....	.....	[153]
971...	Zn 34.6, Fe <0.1...	Rod, rolled.....	.....	.....	41.6 (yld pnt)	52.5	40 (2 in.)	51	.....	101	1z 19	[141]
972...	Zn 34.86, Fe 0.03, Pb 0.02	Sheet, 0.020 in., ann at 1,110°F.	.....	.....	.....	46.0	58	.....	14.0 (10 ⁶)	.....	.....	[146]
973...	...do.....	Sheet, 0.020 in., rolled (69% red.).	.....	.....	.....	95.5	2	.....	21.5 (10 ⁶)	.....	.....	[146]
974...	Zn 34.38.....	Cold-worked.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[55]
975...	Zn 35.06, Fe 0.04..	Rod, cold-drawn, ann 1 hr at 1,200°F.	.....	9.0	11.0 (0.01% perm)	47.0	71 (2 in.)	73	18.0 (10 ⁷)	.....	.....	[17]
976...	Cu 64.78, Pb 0.04, Fe 0.02, Zn rem.	Sheet, 0.020 in., soft..	14,800	9.5	.....	46.6	57 (2 in.)	.....	13.5 (10 ⁶)	R _h 14	.....	[20]
977...	...do.....	Sheet, 0.020 in., cold- worked (37% red.).	15,600	31.9	.....	73.7	6.5 (2 in.)	.....	17.5 (10 ⁶)	R _h 79	.....	[20]
978...	Zn 36.96, Pb 0.03, Fe 0.01.	Rod, 1/2 in. diam, cold- worked (30% red.) from 0.060-mm grain size.	15,700	.....	53.9 (0.5% extn)	72.2	18 (2 in.)	62	22.7 (3 x 10 ⁶)	R _h 82	.....	[82]
979...	Zn 37.....	Wire, ann.....	.....	.....	.....	50	50 (2 in.)	.....	.....	.....	.....	[168]
980...	...do.....	Wire, hard-drawn.....	.....	.....	.....	125	2 (2 in.)	.....	.....	.....	.....	[168]
981...	Zn 37.53, Fe 0.07..	Wire, 0.241 in. diam, cold-drawn.	.....	.....	.....	.....	.....	.....	.....	.....	.....	[133]
982...	Zn 40.....	Die-cast.....	.....	.....	.....	56	45 (2 in.)	.....	.....	85	1z 30	[113]
983...	Zn 40.03, Pb 0.09, Fe 0.03, Sn 0.01.	Rod, 3/4 in., 1 hr at 1,300°F, w-q.	13,300	8.3	.....	59.5	41 (8 in.)	58	21.5 (5 x 10 ⁷)	R _h 51	.....	[169]

^b Alternating torsion.

TABLE 12.—Copper and copper alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
COPPER-ZINC ALLOYS—Continued													
984...	Percent Zn 40.03, Pb 0.09, Fe 0.03, Sn 0.01.	Rod, drawn (25% red.) ..	$\frac{\text{kips}}{\text{in.}^2}$ 15,300	$\frac{\text{kips}}{\text{in.}^2}$ 17.7	$\frac{\text{kips}}{\text{in.}^2}$ 77.6	Percent (2 in.) 24	Percent (2 in.) 52	$\frac{\text{kips}}{\text{in.}^2}$ (5 x 10 ⁷) 27.7	R _B 82	ft-lb	.....	.....	[169]
985...	Muntz metal: Zn 40.11, Pb 0.20, Fe 0.164, Sn 0.10.	Rod, hot-rolled, cooled in ice brine, reheated to 480°F.	17,800	26.0	49.5 (0.01% perm)	76.6 (2 in.)	2.2 (2 in.)	5.2 (10%) 5.5 (5 x 10 ⁶)	.....	.....	.....	Shear str.....55.3 kips/in. ² ... Tension str.....54.8 kips/in. ² ...	[93]
986...	...do.....	Rod, hot-rolled, cooled in ice brine, reheated to 840°F.	16,000	20.0	27.4 (0.01% perm)	55.6 (2 in.)	34 (2 in.)	42 (10%) 8.5 (5 x 10 ⁷)	.....	.....	.....	Shear str.....41.0 kips/in. ² ... Tension str.....45.3 kips/in. ² ...	[93]
987...	Zn 41.04.....	Cast.....	.....	.....	19.7 (yld pnt)	55.8 (2 in.)	45 (2 in.)	50	90	.....	.....	.....	[171]
988...	Zn 50.....	Mixed powders; cold- compacted at 9 tons/in. ² , hot- compacted at 5 tons/in. ² and 1,425°F.	.....	.....	.....	23.5	0	.....	114	.....	.....	.....	[154]
COPPER-ZINC-ALUMINUM ALLOYS													
989...	Zn 16.35, Al 6.16, Mn 4.39, Fe 2.30.	Sand-cast.....	.....	22.9	.....	91.2 (2 in.)	28 (2 in.)	33	.....	.....	.....	.....	[174]
990...	...do.....	Chill-cast.....	.....	30.6	.....	97.0 (2 in.)	23 (2 in.)	26	.....	.....	.....	.....	[174]
991...	Cu 79.00, Al 2.52, Fe 0.02, Pb 0.01, Zn rem.	Rod, cold-rolled (45% red.)..	.....	.....	.....	80.1 (2 in.)	10 (2 in.)	36	.....	.....	.....	.....	[173]
992...	Cu 63.35, Al 4.12, Mn 2.74, Fe 1.73, Pb 0.25, Ni 0.20, Zn rem.	Cast from 2,100°F.....	14,000	.....	59.5 (0.5%)	99.0	10	12	179	.....	.....	Specific gravity.....7.90.....	[155]
993...	Zn 31.45, Al 4.10, Ni 3.00, Fe 1.45.	Bar, 2 1/2 in. square, cast.	.....	.....	52.4 (0.5% perm)	99.7 (2 in.)	12 (2 in.)	15	159	Iz 11	.....	.....	[175]
994...	...do.....	Bar, 1 in. square, forged.	.....	.....	54.4 (0.5% perm)	103 (2 in.)	16 (2 in.)	18	185	Iz 19	.....	.....	[175]
995...	Zn 33.57, Al 3.96, Ni 3.13.	Bar, 2 1/2 in. square, cast.	.....	.....	56.2 (0.5% perm)	95.2 (2 in.)	6.0 (2 in.)	8.4	185	Iz 7	.....	.....	[175]
996...	...do.....	Bar, 1 in. square, forged.	.....	.....	61.4 (0.5% perm)	105 (2 in.)	11 (2 in.)	12	200	Iz 7	.....	.....	[175]
997...	Zn 34.66, Al 3.28, Ni 2.83, Sn 0.75, Fe 0.15.	Bar, 2 1/2 in. square, cast.	.....	.....	52.9 (0.5% perm)	82.9 (2 in.)	4.5 (2 in.)	8.4	154	Iz 9	.....	.....	[175]
998...	...do.....	Bar, 1 in. square, forged.	.....	.....	55.6 (0.5% perm)	98.1 (2 in.)	20 (2 in.)	23	165	Iz 39	.....	.....	[175]
999...	Zn 35.96, Al 3.02, Fe 1.87.	Bar, 2 1/2 in. square, cast.	.....	.....	41.9 (0.5% perm)	96.3 (2 in.)	20 (2 in.)	18	154	Iz 22	.....	.....	[175]

1000..	...do.....	Bar, 1 in. square, forged.	.....	.....	44.8 (0.5% perm)	85.1	35 (2 in.)	47	.....	154	Iz 67	.....	[175]
1001..	Cu 57.05, Al 0.97, Fe 0.35, Mn 0.82, Sn 0.46, Zn rem.	Bar, chill-cast from 1,755°-1,870°F.	.....	21.5	35.3 (yld pnt)	87.6	30 (2 in.)	28	.....	R _e 73	.....	.....	[176]
COPPER-ZINC-ARSENIC ALLOYS													
1002..	Zn 29.41, As 0.49..	Cast.....	.....	.....	11.9 (yld pnt)	32.9	36 (2 in.)	36	.....	58	.....	.....	[171]
1003..	...do.....	Cast; annealed.....	.....	.....	24.6 (yld pnt)	51.5	75 (2 in.)	67	.....	57	.....	.....	[171]
1004..	Zn 40.54, As 0.48, Fe 0.07.	Cast.....	.....	.....	20.2 (yld pnt)	50.6	22 (2 in.)	24	.....	80	.....	.....	[171]
1005..	...do.....	Hot-forged.....	.....	.....	26.9 (yld pnt)	58.2	24 (2 in.)	20	.....	101	.....	.....	[171]
COPPER-ZINC-IRON ALLOYS													
1006..	Zn 38.18, Fe 1.21, Sn 0.72, Al 0.10, Pb 0.09.	Rod, 1/2 in., hard- drawn.	15,500	.....	81.0	88.0	12 (2 in.)	36	.....	178	Iz 10	.....	[25]
1007..	Zn 40.11, Fe 1.72, Pb 0.49, Al 0.44, Sn 0.10.	Cast.....	.....	11.6	22.2 (yld pnt)	60.4	16 (2 in.)	23	.....	.....	.....	.....	[162]
1008..	Cu 56.85, Fe 1.50, Sn 0.32, Al 0.23, Mn 0.20, Zn rem.	...do.....	14,200	13.0	.....	70.0	33 (8 in.)	41	17.0 (2.5 x 10 ⁶)	93	21	Shear str.....43.2 kips/in. ² .. Mod-el (shear).....4,600 kips/in. ² .. Specific gravity.....8.26.	[96]
COPPER-ZINC-LEAD ALLOYS													
1009..	Zn 9.5, Pb 7, Sn 3..	Cast.....	.....	.....	15-20 (yld pnt)	30-36	15-25 (2 in.)	15-25	.....	55-65	.....	Specific gravity.....8.6.	[177]
1010..	Zn 10, Pb 1.5.....	Rod, hard.....	15,000	.....	.....	60	8 (2 in.)	.....	.....	R _p 58	.....	Melting point.....1,900°p.. Specific gravity.....8.83.	[178]
1011..	Zn 13.25, Pb 1.75..	...do.....	.....	.....	.....	60	10 (2 in.)	.....	.....	.....	.....	Melting point.....1,877°p.. Specific gravity.....8.77.	[178]
1012..	Zn 24.5, Pb 3, Sn 1.5.	Cast.....	.....	.....	.....	30-35	25-35 (2 in.)	25-35	.....	50-60	.....	Specific gravity.....8.5.	[177]
1013..	Zn 30.52, Pb 0.52, Sn 0.26, Fe 0.24.	Sand-cast.....	.....	.....	15-20 (yld pnt)	32.7	37	.....	.....	R _p 14	.....	.....	[174]
1014..	Zn 34.8, Pb 1.75, Fe <0.10.	Hard-drawn.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....4,800 kips/in. ²	[16]
1015..	Zn 33.20, Pb 1.68, Sn 1.52, Mn 0.84, Fe 0.76, Al 0.44, Ni 0.21.	Chill-cast.....	.....	.....	22.0 (0.2%)	42.8	4.4 (2 in.)	.....	.....	94	.....	.....	[180]
1016..	Zn 35, Pb 2.....	Cast.....	15,000	.....	18-25 (yld pnt)	35-45	15-25 (2 in.)	20-30	.....	55-65	.....	Specific gravity.....8.5.	[177]
1017..	Cu 62, Pb 2.6, Zn rem.	Rod, 3/4 in. diam.....	.....	32.0	.....	60.4	23 (2 in.)	47	18.0 (10%) 14.0 (10%) 26.0 (10%)	124	.....	Torsion str.....42.2 kips/in. ²	[27]

^a Alternating torsion.

^c Zero to maximum torsion.

TABLE 12.—Copper and copper alloys, normal temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
COPPER-ZINC-LEAD ALLOYS—Continued												
1018..	Percent Zn 37, Pb 1.5.....	Sheet, hard.....	Kt/psi/in. ²	Kt/psi/in. ²	Kt/psi/in. ²	Kt/psi/in. ²	Percent 4 (2 in.)	Percent	Kt/psi/in. ²	142	ft-lb.....	[168]
1019..	Zn 37.65, Pb 1.53, Fe 0.12, Al 0.06.	Chill-cast.....	.....	.....	19.3 (0.2%)	47.2	20 (2 in.)	.....	.....	76	.....	[190]
1020..	Zn 40, Pb 2.....	Drawn.....	.....	.....	.....	59.4	5	.....	23.5	141	.....	[101]
1021..	Architectural bronze: Zn 40, Pb 2.5, Sn 0.34, Fe 0.16.	Extruded, hard.....	14,000	.....	35 (0.5% extn)	70	10 (2 in.)	.....	.....	.....	Specific gravity.....8.44.	[94]
1022..	do.....	Extruded, soft.....	.....	.....	18 (0.5% extn)	50	20 (2 in.)	.....	.....	.....	.....	[94]
1023..	Zn 40.11, Pb 0.08, Fe 0.03.	Rod, 3/4 in. diam., annealed 1/2 hr at 1,020°F.	.....	15.6	16.8 (yld pnt)	54.2	56 (2 in.)	31	22.0 (10 ⁶)	72	30	[38]
1024..	do.....	Rod, 1/2 in. diam., cold-drawn (56% red.).	.....	43.2	49.9 (yld pnt)	96.7	13 (2 in.)	52	26.0 (10 ⁶)	179	19	[38]
COPPER-ZINC-MANGANESE ALLOYS												
1025..	Zn 33.1, Mn 4.2, Al 3.5.	Round bar, die-cast from 1,480°F.	.....	.....	62.5 (0.13% perm)	93.6	7 (2 in.)	16	.....	187	.....	[95]
1026..	Cu 56.62, Mn 2.20, Fe 1.76, Al 1.72, Zn rem.	Bar, chill-cast from 1,705°-1,870°F.	.....	24.2	39.8 (yld pnt)	92.4	22 (2 in.)	23	.....	.....	.....	[176]
1027..	Zn 38.85, Mn 1.43, Pb 1.25, Fe 1.08, Sn 0.90.	Forged.....	.....	.....	.....	73.9	36	.....	.....	12 20	.....	[181]
1028..	Cu 56.50, Mn 2.11, Fe 1.69, Al 0.49, Zn rem.	Bar, chill-cast from 1,795°-1,870°F.	.....	16.1	26.5 (yld pnt)	72.8	34 (2 in.)	31	.....	.....	.....	[176]
COPPER-ZINC-NICKEL ALLOYS (SEE ALSO FIGS. 60 AND 61)												
1029..	Zn 9.79, Ni 2.10, Si 0.45.	Sheet, 0.040 in., hard-rolled.	15,700	31.0	.....	108	1.0 (2 in.)	.....	.....	R _B 98	.....	[156]
1030..	Zn 9.89, Ni 2.32, Si 0.37.	Sheet, 0.020 in., quenched from 1,470°F., aged 1 hr at 300°F.	19,800	44.5	.....	90.0	14 (2 in.)	.....	18.5 (10 ⁶)	R _B 86	.....	[20]
1031..	Zn 10.3, Ni 3.97, Sn 2.51.	Mixed powders; cold-compact at 9 tons/in. ² , hot-compact at 5 tons/in. ² and 1,650°F.	.....	.....	20.2 (yld pnt)	43.7	32	.....	.....	.....	.....	[154]
1032..	Zn 17.5, Ni 15, Pb 7, Sn 2.5, Fe 1.0.	Cast.....	.....	.....	19.0 (yld pnt)	33.6	30	.....	.....	56	.....	[139]
1033..	Zn 19.89, Ni 2.37, Si 0.37.	Sheet, 0.020 in., quenched from 1,470°F., aged 1 hr at 300°F.	17,200	37.2	.....	85.8	22 (2 in.)	.....	16.0 (10 ⁶)	R _B 85	.....	[20]

COPPER-ZINC-NICKEL ALLOYS (SEE ALSO FIGS. 60 AND 61)

1034..	Zn 20.0, Ni 6.0, Al 1.5.	Sheet, 1/8 in., cold- rolled (50% red.).	.....	24.9	59.0 (0.1%)	88.9	6 (2 in.)	.....	.....	V 198	.....	.....	[132]
1035..	do.....	Sheet, 1/8 in., cold- rolled (50% red.), aged 2 hr at 530°F.	.....	56.0	59.4 (0.1%)	104	11 (2 in.)	.....	.....	V 246	.....	.....	[132]
1036..	Cu 65.82, Ni 6.17, Pb 1.27, Fe 0.23, Mn 0.06, Zn rem.	Annealed at 1,200°F....	.....	.....	21.6 (0.05% perm)	53.2	54 (2 in.)	55	.....	S 12	.....	Ericksen.....11.6 mm.....	[140]
1037..	do.....	Roller (50% red.).....	.....	.....	.....	95.1	4.0 (2 in.)	28	.....	S 40	.....	Ericksen.....2.4 mm.....	[140]
1038..	Zn 26.2, Ni 15.5, Mn 0.17, Fe 0.15.	Annealed at 1,200°F....	.....	.....	.....	60.5	48 (2 in.)	.....	.....	R ₅ 53	.....	Mod-el (shear).....6,200 kips/in. ² ..	[16]
1039..	Zn 26.30, Ni 18.55, Mn 0.11, Fe 0.04, Pb 0.01.	Sheet, 0.020 in., am. rolled (37% red.).	.....	.....	.....	95.4	1.5 (2 in.)	.....	.....	R ₀ 66	.....	.....	[20]
1040..	do.....	Sheet, 0.020 in., rolled (37% red.).	.....	.....	.....	118	1.2 (2 in.)	.....	.....	R ₀ 79	.....	.....	[20]
1041..	do.....	Sheet, 0.020 in., rolled (69% red.).	.....	.....	.....	53.8	62 (2 in.)	56	.....	S 12	.....	Ericksen.....12.5 mm.....	[182]
1042..	Cu 64.68, Ni 6.73, Fe 0.19, Mn 0.06, Zn rem.	Sheet, 0.060 in., am at 1,200°F.	.....	.....	22.6 (yld pnt)	99.2	3.5 (2 in.)	30	.....	S 42	.....	Ericksen.....3.3 mm.....	[182]
1043..	do.....	Sheet, 0.060 in., hard-rolled.	.....	.....	.....	114	2.5 (2 in.)	.....	.....	R ₅ 98	.....	.....	[158]
1044..	Zn 30.12, Ni 2.36, Si 0.66.	Sheet, 0.040 in., hard-rolled.	14,000	48.0	.....	85.4	28 (2 in.)	.....	.....	R ₅ 79	.....	.....	[20]
1045..	do.....	Sheet, 0.020 in., quenched from 1,470°F, aged 1 hr at 900°F.	16,500	38.0	.....	51.3	31 (2 in.)	34	.....	94	.....	Specific gravity.....8.52.....	[95]
1046..	Zn 31.1, Ni 19.5....	Rod, 1 in. diam, chill-cast.	.....	.....	26.4 (0.15% perm)	76.6	4 (2 in.)	13	.....	.....	.....	Specific gravity.....8.37.....	[95]
1047..	Zn 32.7, Ni 18.0, Al 1.1.	do.....	.....	.....	67.2 (0.15% perm)	67.2	43	52	.....	97	.....	.....	[175]
1048..	Zn 39.74, Ni 3.35..	Cast; am 2 hr at 1,380°F.	.....	.....	.....	75.9	33	51	.....	144	.....	.....	[175]
1049..	do.....	Rod, cold-drawn.....	.....	.....	.....	90.5	17-27 (2 in.)	.....	.....	V 150	Iz 20-28	.....	[183]
1050..	Zn 44.4, Ni 9.4, Pb 1.55.	Rod, extruded.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

COPPER-ZINC-SILICON ALLOYS

1051..	Zn 10, Si 5, Al 1, Mn 1.	Die-cast.....	.....	.....	83.7 (0.2% offset)	116	4.0 (2 in.)	.....	.....	182	.....	.....	[185]
1052..	do.....	Chill-cast; w-q from 1,425°F.	.....	.....	.....	79.0	5.5 (2 in.)	.....	.....	Iz 19	.....	Melting range.....1,513°-1,566°F....	[185]
1053..	do.....	Chill-cast; w-q from 1,425°F., aged 1/4 hr at 570°F.	.....	.....	.....	87.2	7.5 (2 in.)	.....	.....	207	.....	.....	[185]
1054..	Zn 15, Si 4.....	Die-cast.....	.....	.....	65-70 (yld pnt)	85-95	8-12 (2 in.)	10-15	.....	160-180	.....	Specific gravity.....8.15.....	[186]
1055..	Zn 34, Si 1.....	do.....	.....	.....	35-40 (yld pnt)	65-70	20-30 (2 in.)	15-20	.....	120-130	.....	Specific gravity.....8.50.....	[186]

^a Notch Impact value, m-kg/cm.²

TABLE 12.—Copper and copper alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
COPPER-ZINC-SILVER ALLOYS													
1056..	Percent Zn 22.5, Ag 25.0...	Chill-cast.....	<i>k</i> lps/in. ²	<i>k</i> lps/in. ²	<i>k</i> lps/in. ²	<i>k</i> lps/in. ²	Percent	Percent			<i>ft-lb</i>		[184]
1057..	Zn 30, Ag 20, Cd 5..	...do.....	.....	.....	.....	53.0	12 (2 in.)	.....	.....	.....	.....	Specific gravity.....8.94..... Specific gravity.....8.80..... Melting range.....1,400°-1,485°.	[184]
1058..	Zn 35, Ag 20.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Melting range.....1,400°-1,510°.	[184]
1059..	Zn 40, Ag 9.....	Chill-cast.....	.....	.....	.....	18.8	16 (2 in.)	.....	.....	.....	.....	Specific gravity.....8.55.....	[184]
COPPER-ZINC-TELLURIUM ALLOYS													
1060..	Cu 99.87, Te 0.99, Zn rem.	Rod, 1/2 in. diam, ann.	.....	.....	12.0 (0.5% extn)	37.5	36 (2 in.)	37	.....	R _F 54	Iz 56	.....	[148]
1061..	Cu 89.97, Te 0.25, Zn rem.	...do.....	.....	.....	12.5 (0.5% extn)	39.0	46 (2 in.)	62	.....	R _F 58	Iz 72	.....	[148]
1062..	...do.....	Rod, 1/2 in. diam, drawn (36% red.).	.....	.....	19.5 (0.5% extn)	54.0	16 (2 in.)	54	.....	R _F 96	Iz 33	.....	[148]
1063..	Cu 60, Te 0.98, Zn rem.	...do.....	.....	.....	.....	83.5	14 (2 in.)	31	.....	.....	Iz 10	.....	[187]
COPPER-ZINC-TIN ALLOYS													
1064..	Zn 5, Sn 5, Pb 5...	Cast.....	11,000	8	14-20 (yld pnt)	30-38	20-30 (2 in.)	25-29	.....	55-65	Iz 9	Specific gravity.....8.6.....	[177]
1065..	Zn 5.10, Sn 5.99, Pb 2-33, Ni 0.23, Fe 0.06.	...do.....	12,900	9.0	16.0 (yld pnt)	34.0	20 (2 in.)	22	.....	.....	.....	.....	[162]
1066..	Cu 84.65, Pb 4.80, Sn 4.67, Ni 0.36, Fe 0.23, Sn 0.17, Zn rem.	Cast from 2,150°.	12,800	.....	16.0 (0.5%)	34.0	23	25	.....	56	.....	Specific gravity.....8.73.....	[155]
1067..	Zn 6, Sn 6.....	Sand-cast.....	.....	.....	16-18 (yld pnt)	36-43	30-60	.....	.....	50-55	120	Specific gravity.....8.6-8.7.....	[188]
1068..	Zn 10.49, Sn 1.02, Fe 0.02.	Rod, 1/2 in. diam, cold-worked (30% red.) from 0.035-mm grain size.	17,000	.....	59.9 (0.5% extn)	££.2	12 (2 in.)	77 (3 x 10 ⁶)	.....	R _B 80	.....	.....	[82]
1069..	Zn 10.56, Sn 3.66..	Mixed powders; cold-compacted at 9 tons/in. ² , hot-compacted at 5 tons/in. ² and 1,650°.	.....	.....	20.2 (yld pnt)	42.6	53	.....	.....	.....	.....	.....	[154]
1070..	Zn 11.48, Sn 1.10, P 0.37, Fe 0.02, Pb 0.01.	Rod, 1/2 in. diam, cold-drawn (30% red.) from 0.040-mm grain size.	15,800	.....	££.9 (0.5% extn)	78.8	13 (2 in.)	64	.....	R _B 89	.....	.....	[82]
1071..	Admiralty brass: Zn 27.36, Sn 0.97.	Rod, 5/8 in. diam, cold-drawn (31% red.).	.....	31.8	.....	68.5	35 (2 in.)	64	.....	.....	.....	.....	[169]

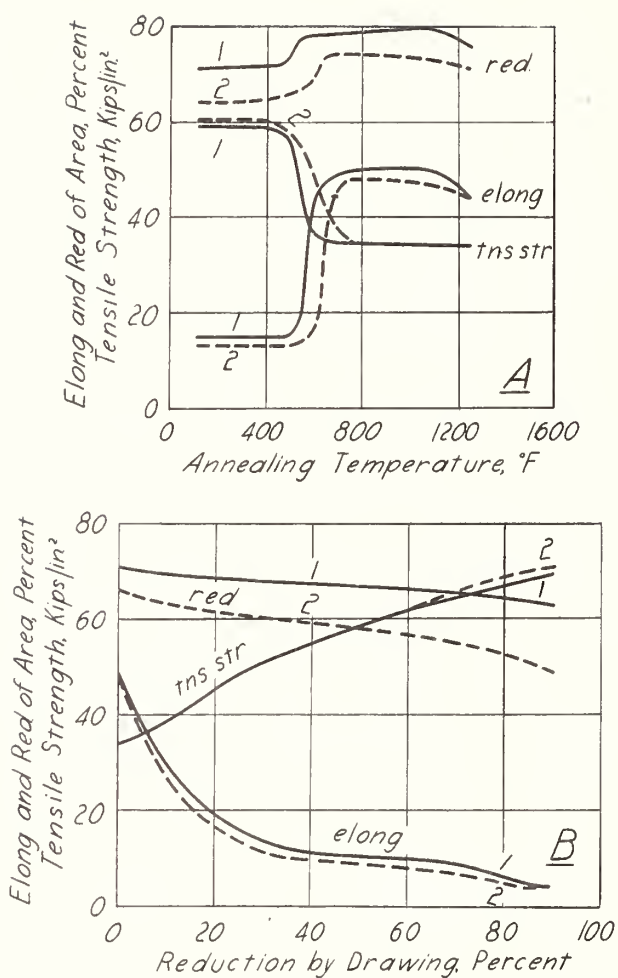


FIGURE 28.—Effect of annealing and cold-drawing on the tensile properties of oxygen-free and phosphorized copper (Rolle and Schleicher [640]).

(Elongation in 2 in.)

A, Effect of annealing; rod, 1/2 in. diameter, cold-drawn (62% red.), annealed 1 hour; B, effect of cold-drawing; rod, annealed 2 hours at 930°F and drawn.

Curves: 1, oxygen-free (OFHC); 2, phosphorized, P 0.02%.

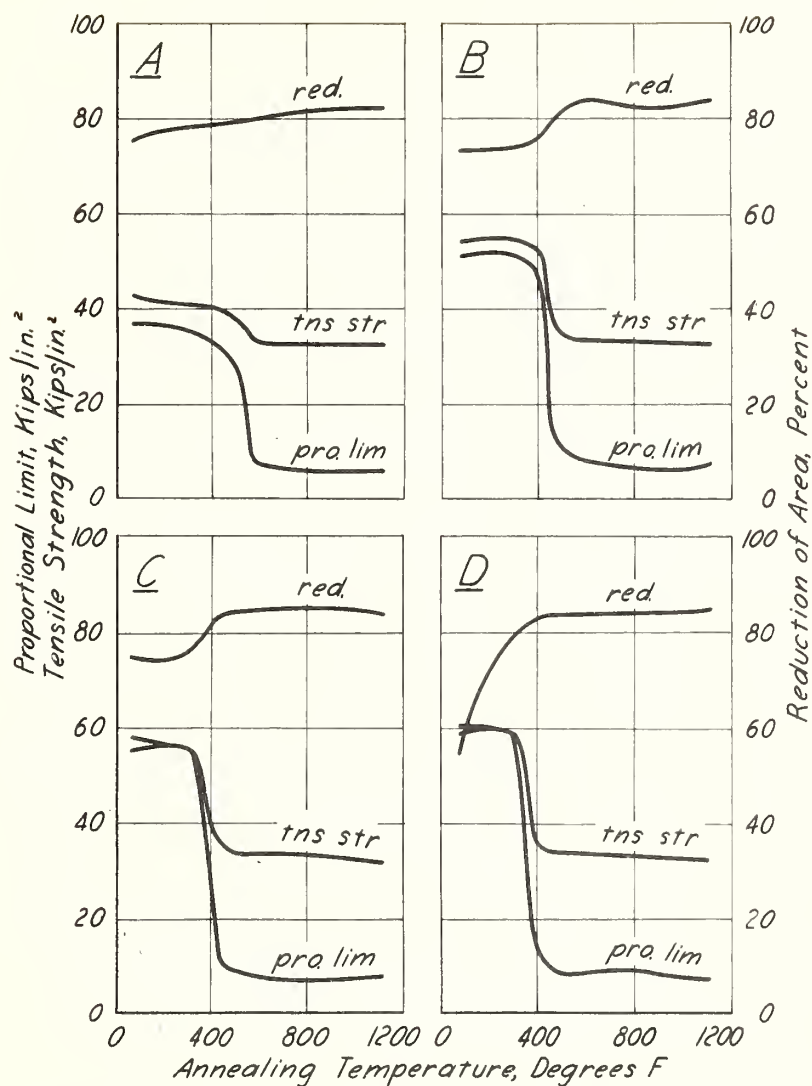


FIGURE 29.—Effect of annealing on the tensile properties of copper cold-worked various amounts (Krupkowski and Balicki [641]).

Annealed 1/2 hour after cold-working:

A, 21% red.; B, 49% red.; C, 72% red.; D, 95% red.

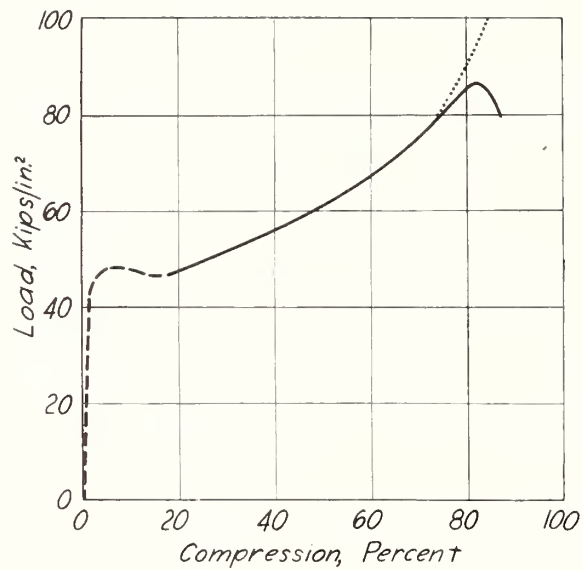


FIGURE 30.—Compressive strength of cold-drawn copper (Crane [642]).

The hardness of the sample was Scleroscope number 73. The dotted curve at loads greater than 80 kips/in.² indicates the normal upward trend; the drop actually obtained and shown by the solid line is due to fracture occurring in the periphery of the test piece.

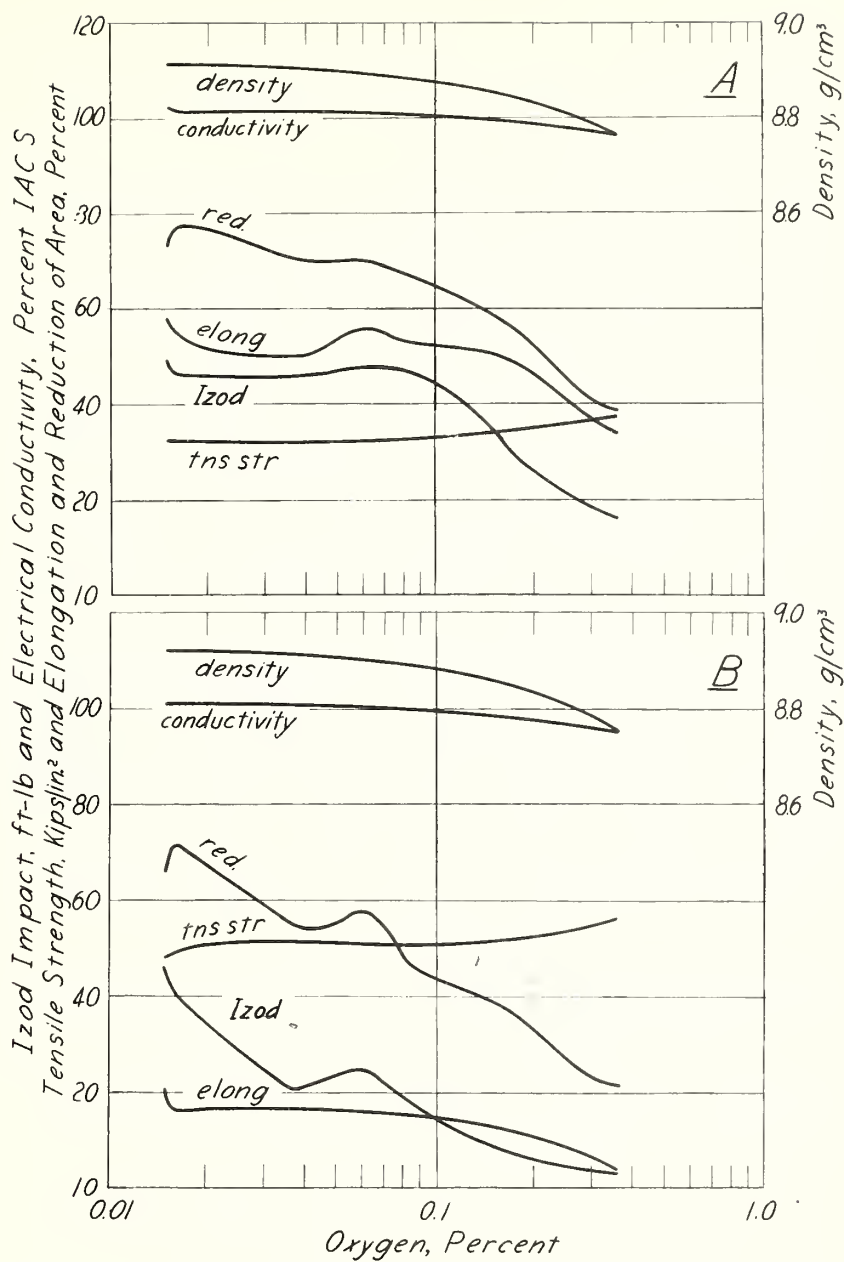


FIGURE 31.— Effect of oxygen on the tensile properties, impact value, density, and electrical conductivity of copper (Hanson, Marryat and Ford [643]).

(Elongation in $4\sqrt{\text{area}}$)

A, Rod, 5/8 in. diameter, annealed 1/2 hour at 1,290°F, air-cooled; B, rod, 5/8 in. diameter, cold-rolled (49% red.).

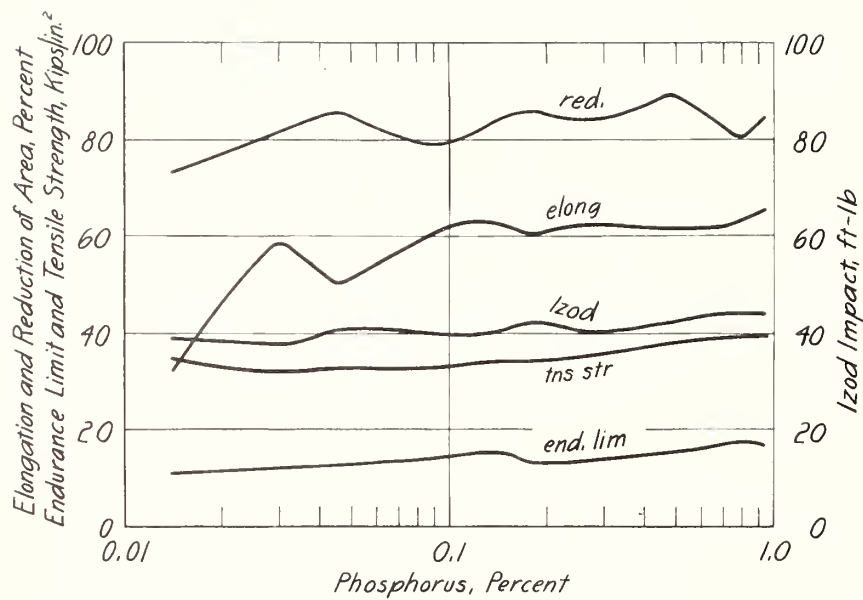


FIGURE 32.—Effect of phosphorus on the tensile properties, endurance limit, and impact value of copper (Hanson, Archbutt, and Ford [644]).

(Elongation in $4\sqrt{\text{area}}$; endurance limit at 2×10^7 cycles)

Rod, 5/8 in. diameter, annealed 1/2 hour at 1,200°F, air-cooled.

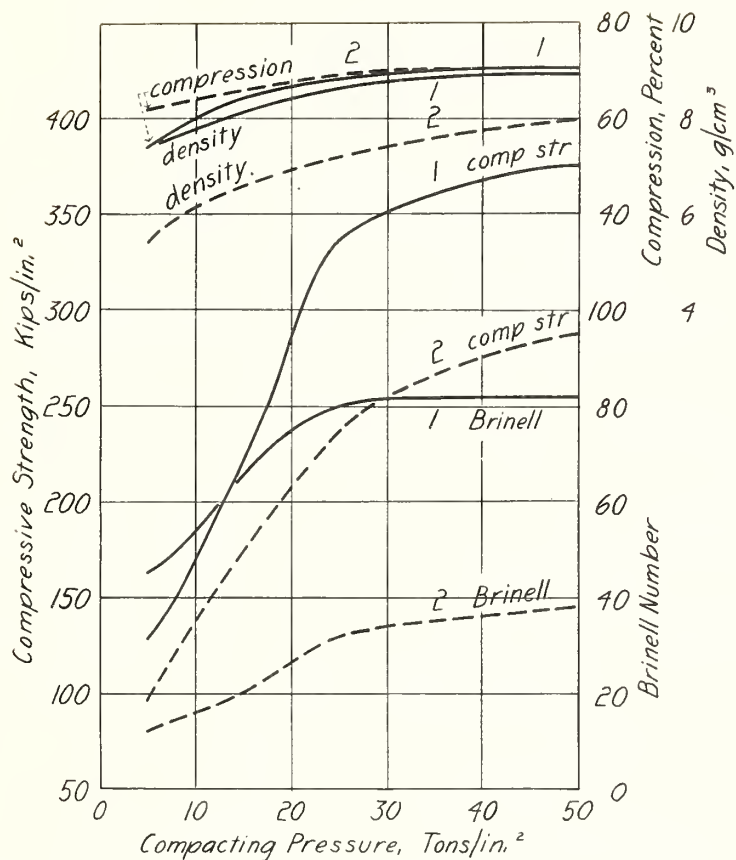


FIGURE 33.—Compressive properties, hardness, and density of copper powder compacts (Goetzel [52]).

(Compression is the reduction in thickness at the point where edge fracture first occurred)

Curves: 1, hot-pressed under hydrogen at 930°F; 2, cold-pressed and sintered 1 hour in hydrogen at 1,470°F.

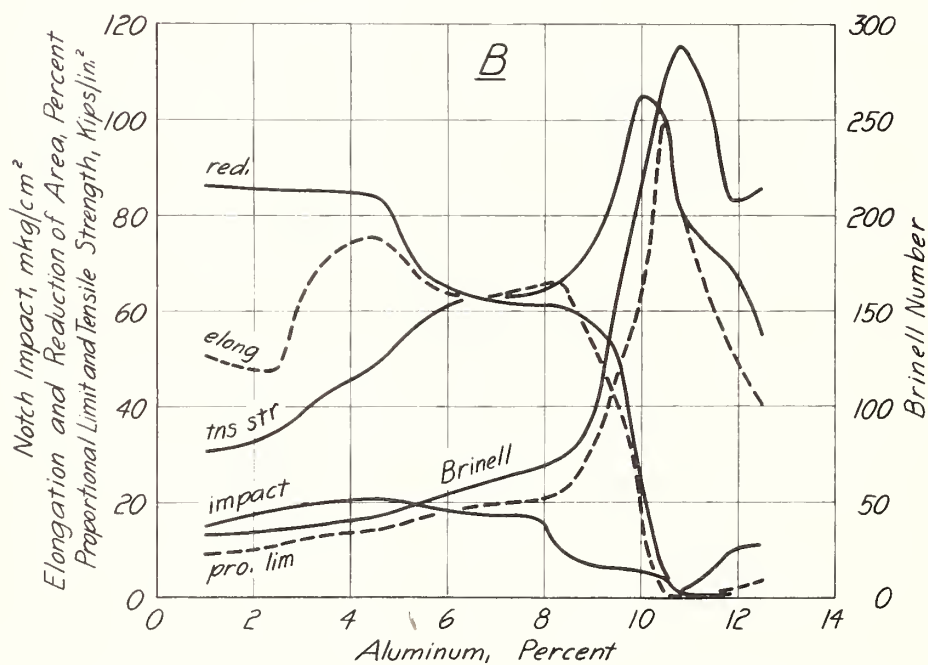
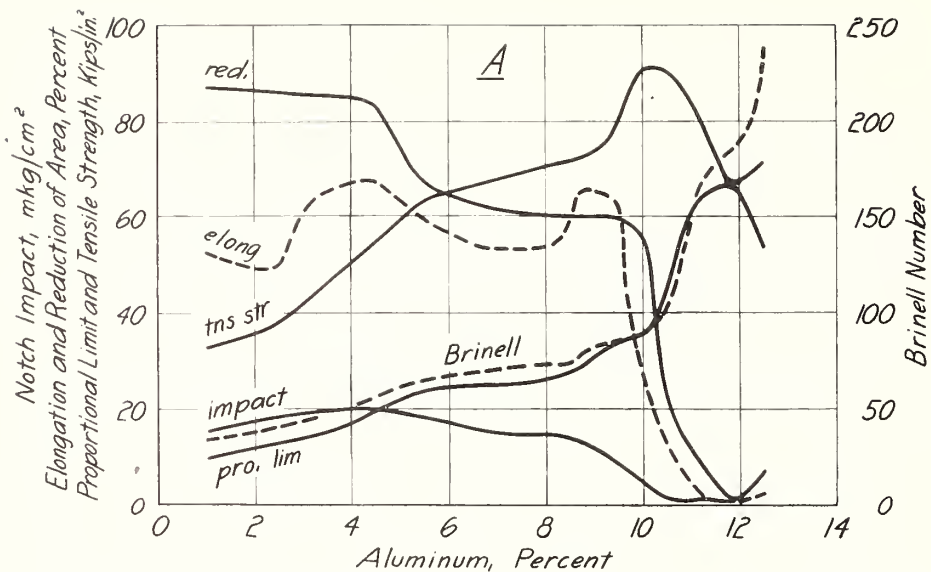


FIGURE 34.—Tensile properties, impact value, and hardness of wrought copper-aluminum alloys (Broniewski [645]).

(Elongation in 10 diam)

A, Annealed at 1,200°F and slowly cooled; B, 1 hour at 1,650°F, quenched, reheated 1/2 hour at 570°F, air-cooled.

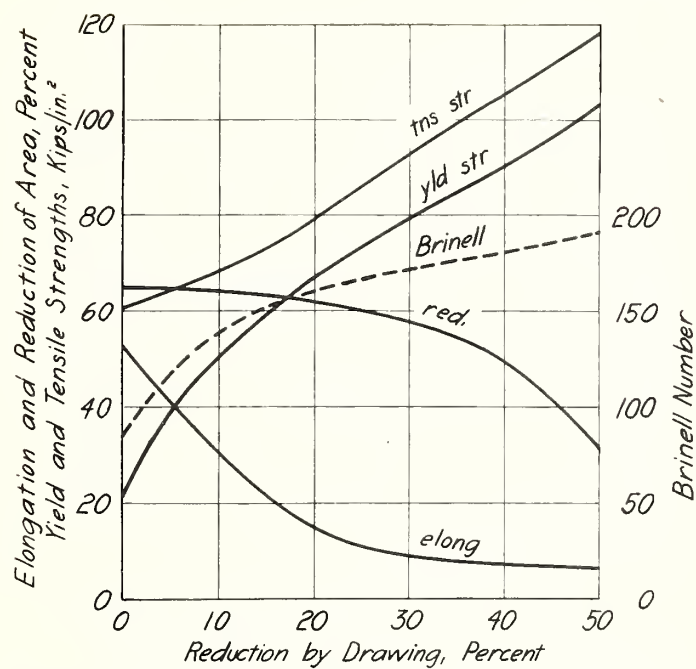


FIGURE 35.—Effect of cold-drawing on the tensile properties and hardness of a copper-aluminum alloy containing 4 percent of aluminum (Lay [646]).

(Yield strength, 0.2%)

Rod, 5/8 in. diameter, annealed at 1,200°F and drawn.

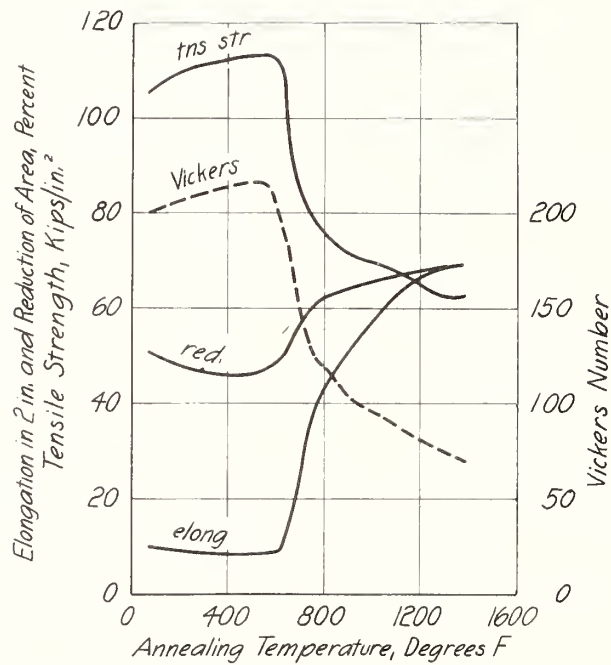


FIGURE 36.—Effect of annealing on the tensile properties and hardness of a cold-worked copper-aluminum alloy containing 7 percent of aluminum [103].

Cold-rolled (50% red.) and annealed.

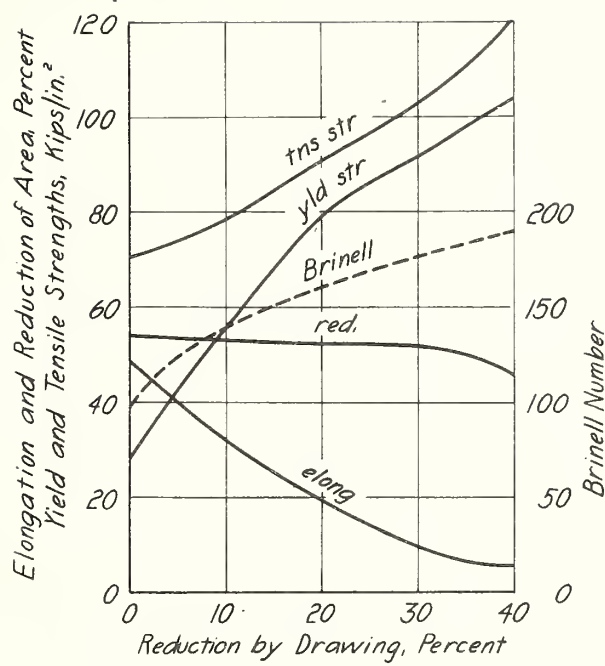


FIGURE 37.—Effect of cold-drawing on the tensile properties and hardness of a copper-aluminum alloy containing 8 percent of aluminum (Lay [646]).

(Yield strength, 0.2%)

Rod, 1 in. diameter, annealed at 1,200°F and drawn.

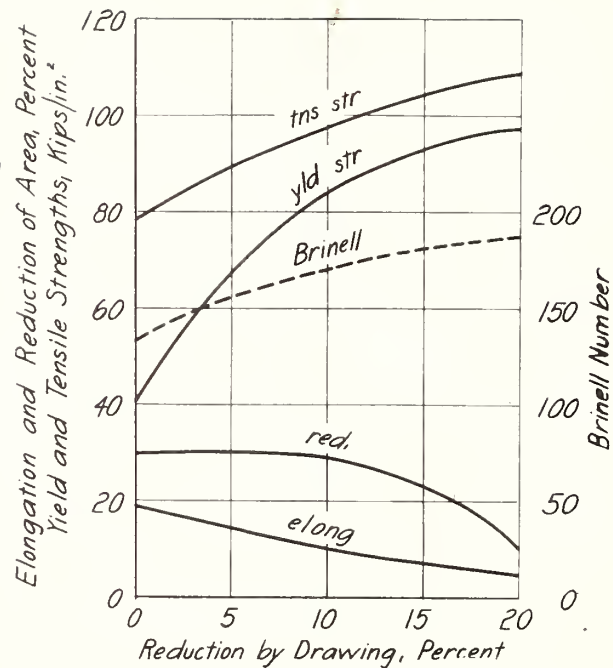


FIGURE 38.—Effect of cold-drawing on the tensile properties and hardness of a copper-aluminum alloy containing 10 percent of aluminum (Lay [846]).

(Yield strength, 0.2%)

Rod, 1 in. diameter, annealed at 1,200°F and drawn.

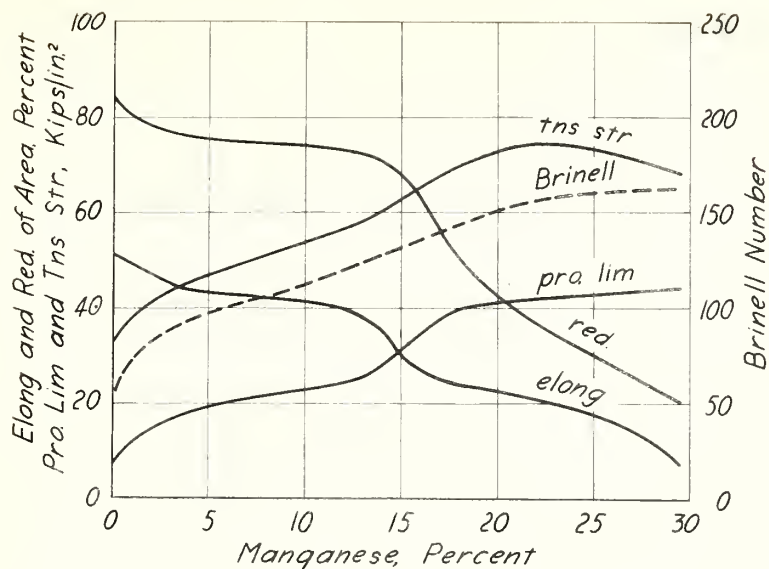


FIGURE 39.—Tensile properties and hardness of wrought copper-manganese alloys (Broniewski and Jaslan [647]).

(Elongation in 10 diam)

Annealed 1 hour at 930°F.

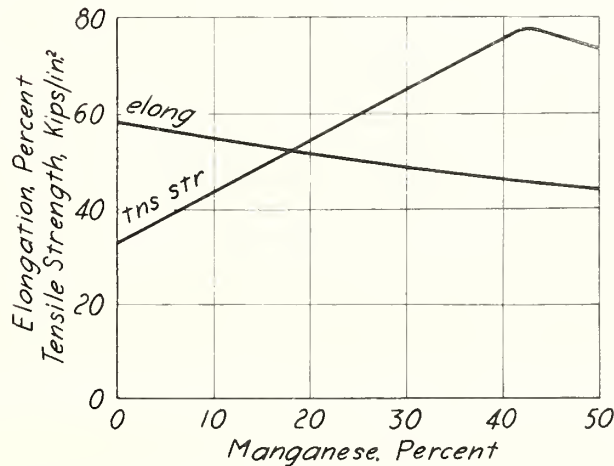


FIGURE 40.—Tensile properties of forged copper-manganese alloys (Hesse and Myskowski [572]).

(Elongation in 4 diam)

Alloys made with electrolytic manganese.

Annealed 2 hours at 1,380°F, quenched.

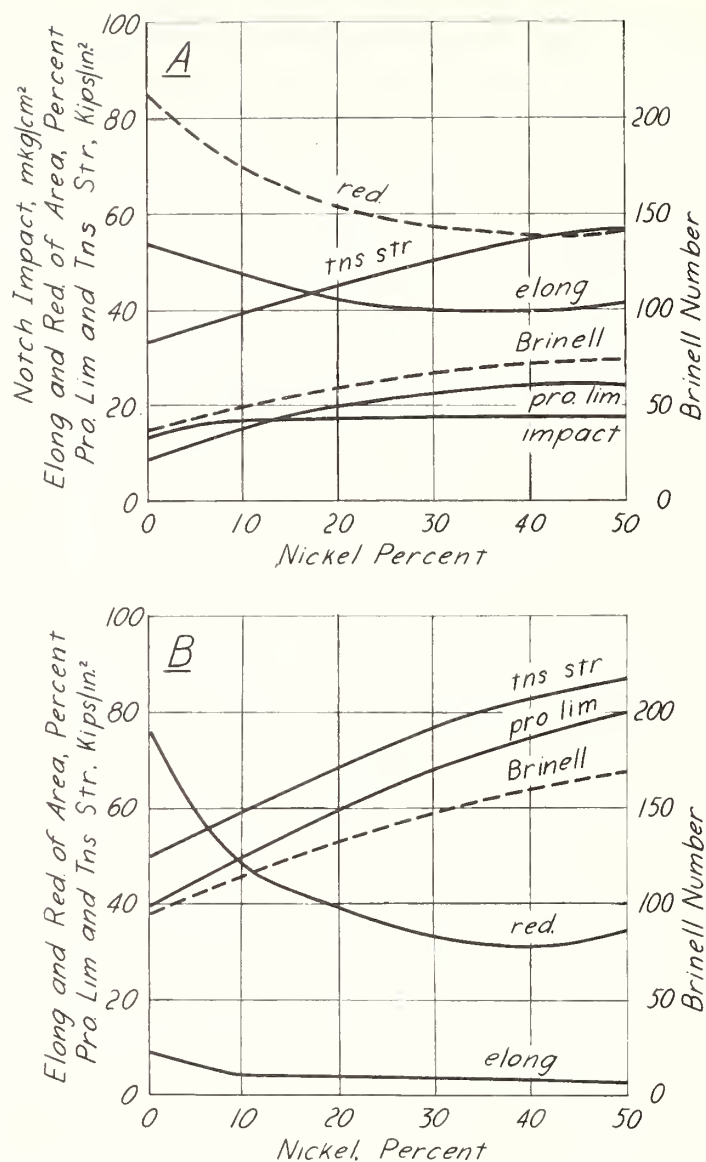


FIGURE 41.—Tensile properties, impact value, and hardness of wrought copper-nickel alloys (Broniewski and Kulesza [648]).

(Elongation in 10 diam)

A, Annealed 1/4 hour at 1,020°F; the impact tests on samples forged at 2,010°–1,470°F; B, cold-worked (40% red.).

Note—These tests were made on samples from small experimental melts and the properties are somewhat different from those of commercial alloys. See figure 42.

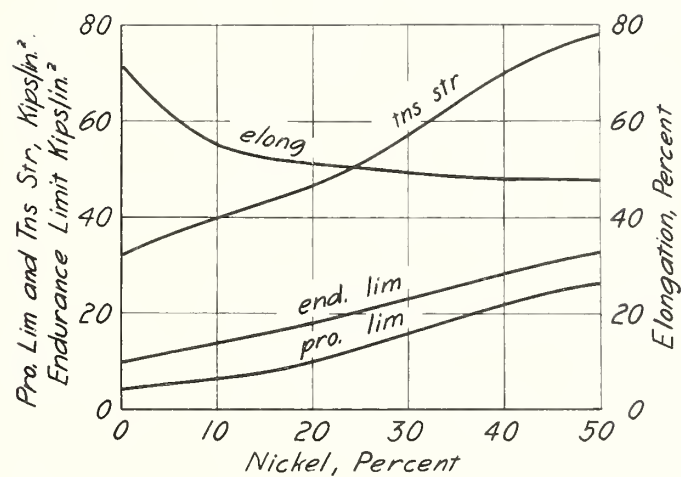


FIGURE 42.—Tensile properties and endurance limit of wrought, annealed commercial copper-nickel alloys (Wise [649]).

(Endurance limit at 10^8 cycles)

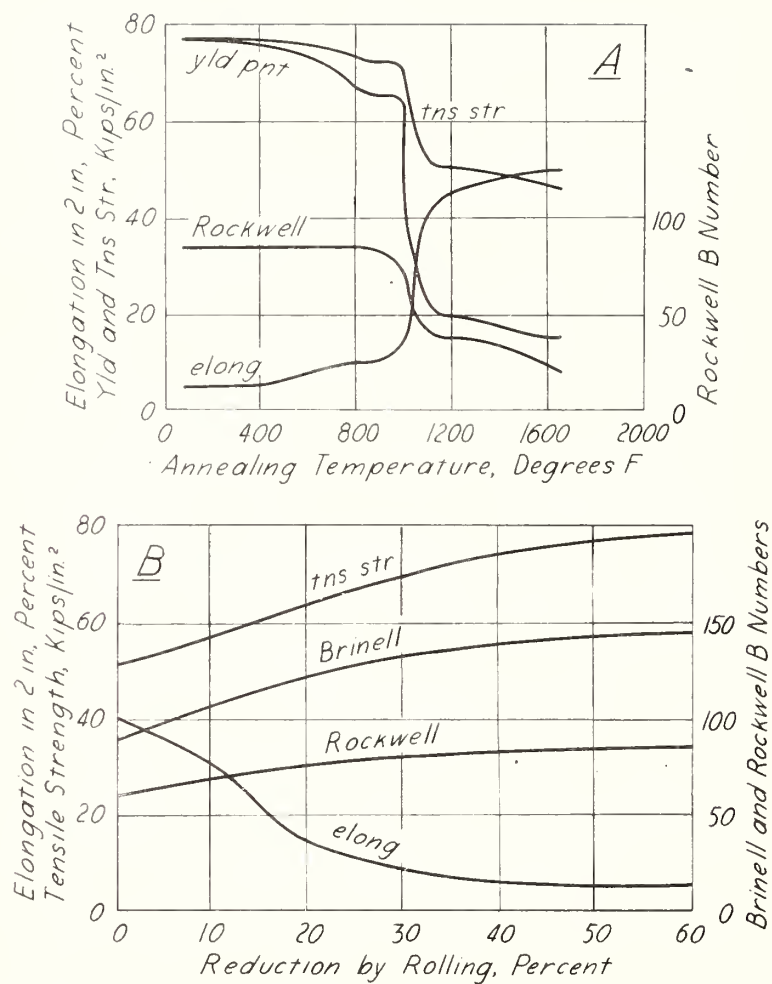


FIGURE 43.—Effect of annealing and cold-rolling on the tensile properties and hardness of a copper-nickel alloy containing 30 percent of nickel (Jennison and Girvin [216]).

A, Effect of annealing; sheet, 0.04 in., cold-rolled (44% red.), annealed 1/2 hour; B, effect of cold-rolling.

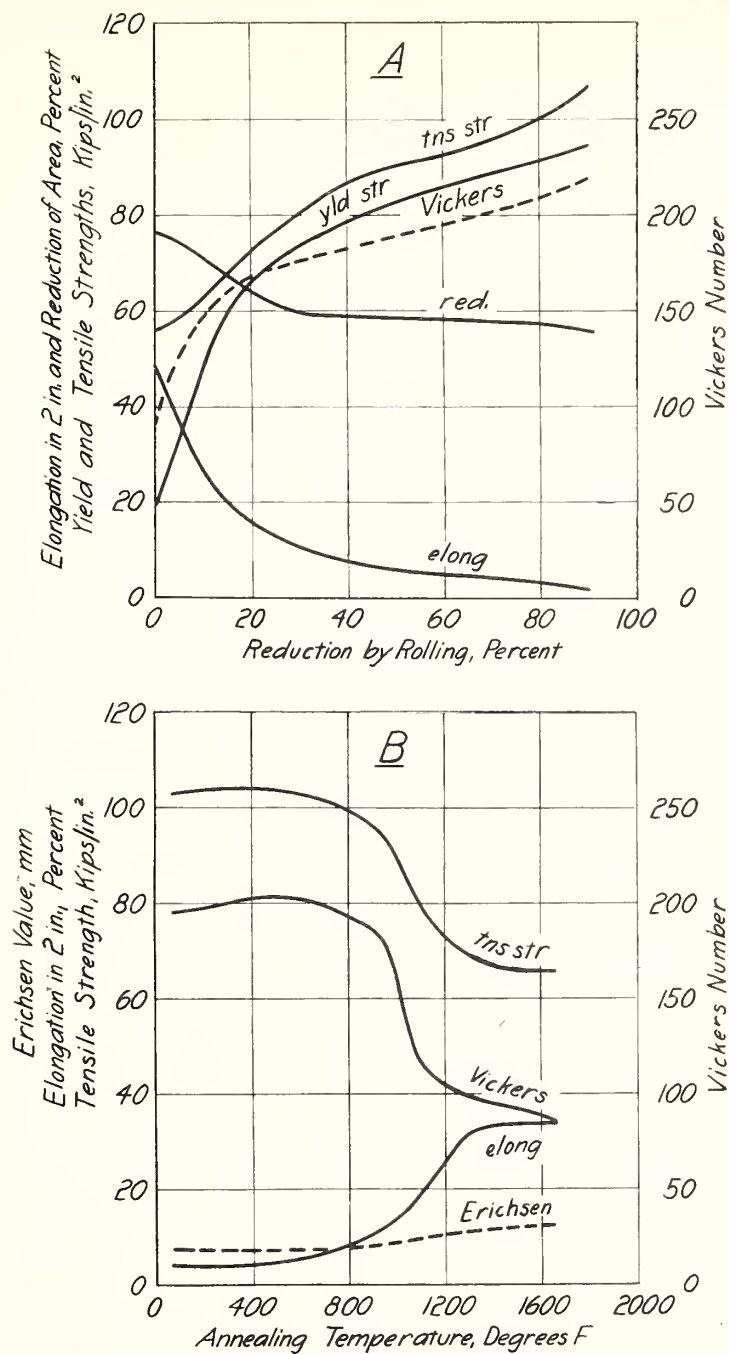


FIGURE 44.—Effect of annealing and cold-rolling on the tensile properties, hardness, and Erichsen value of a copper-nickel-zinc alloy (Cook [203]).

(Yield strength, 0.1% offset)

Ni 29.77%, Zn 7.93%, Mn 0.14%, Fe 0.09%, C 0.019%, Si 0.007%, Pb 0.003%, S 0.002%.

A, Effect of cold-rolling; B, effect of annealing; sheet. 0.07 in., cold-rolled (60% red.), annealed 1/2 hour.

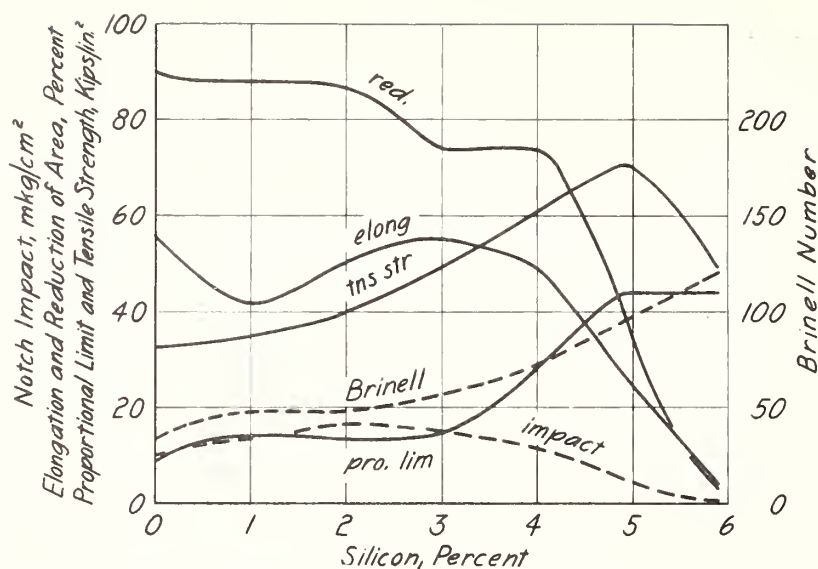


FIGURE 45.--Tensile properties, impact value, and hardness of wrought copper-silicon alloys (Broniewski [645]).

(Elongation in 10 diam)

Annealed 1 hour at 1,380°F, slowly cooled.

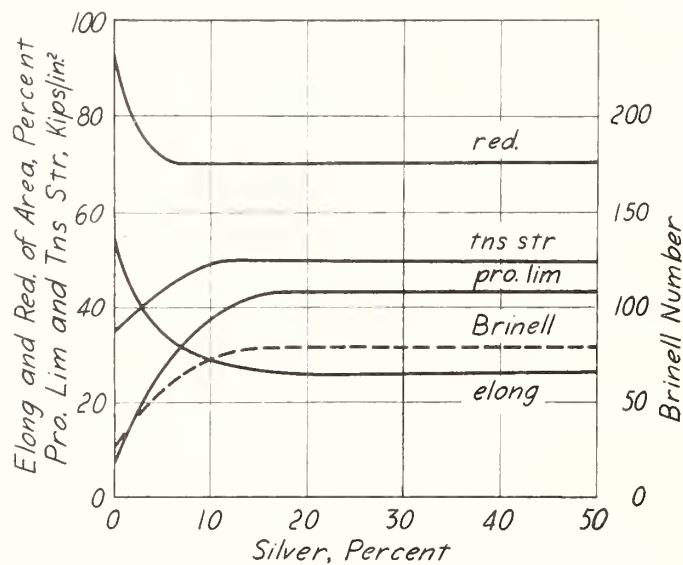


FIGURE 46 --Tensile properties and hardness of wrought copper-silver alloys (Broniewski [651]).

(Elongation in 10 diam)

Annealed 12 hours at 1,200°F, air-cooled.

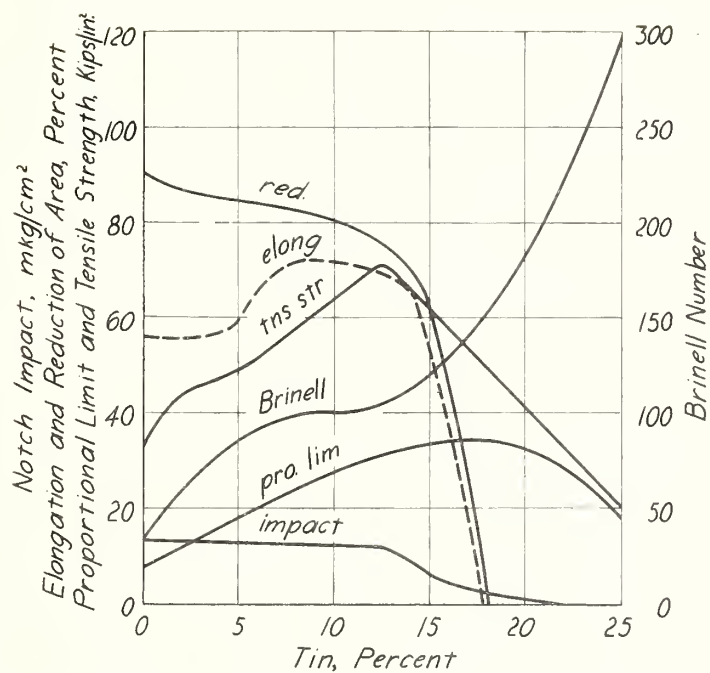


FIGURE 47.—Tensile properties, impact value, and hardness of wrought copper-tin alloys (Broniewski and Wawrzynkiewicz [652]).

(Elongation in 10 diam)

Annealed at 840°F.

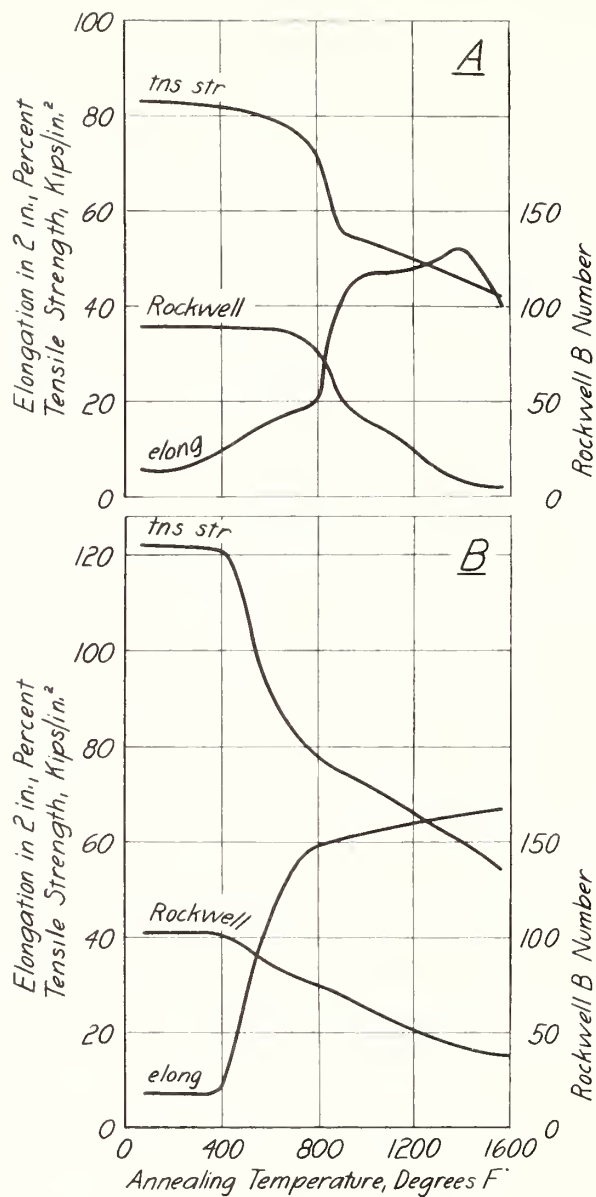


FIGURE 48.—Effect of annealing on the tensile properties and hardness of cold-rolled copper-tin alloys (Jennison and Girvin [650]).

Sheet, 0.04 in., cold-rolled (50% red.), annealed 1/2 hour.

A, Sn 4.5%, P 0.05%; B, Sn 10.5%, P 0.05%.

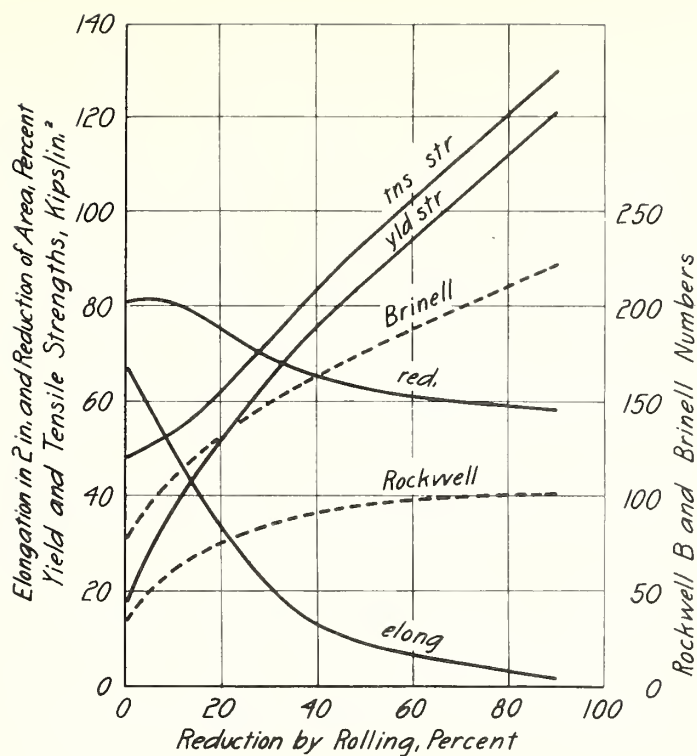


FIGURE 49.—Effect of cold-rolling on the tensile properties and hardness of a copper-tin alloy (Cook and Tallis [653]).

(Yield strength, 0.1% offset)

Sn 5.27%, P 0.09%, Fe less than 0.01%, Pb less than 0.005%.
Annealed at 1,155°F and rolled.

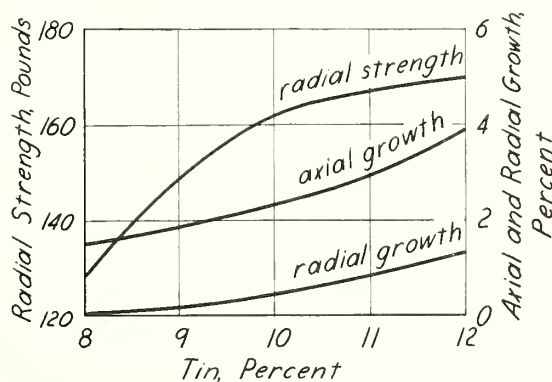


FIGURE 50.—Effect of tin content on the properties of sintered copper-tin-graphite compacts (Koehring [52]).

Base mixture, 90 parts copper and 2 parts graphite. Compacts sintered at 1,500°F.

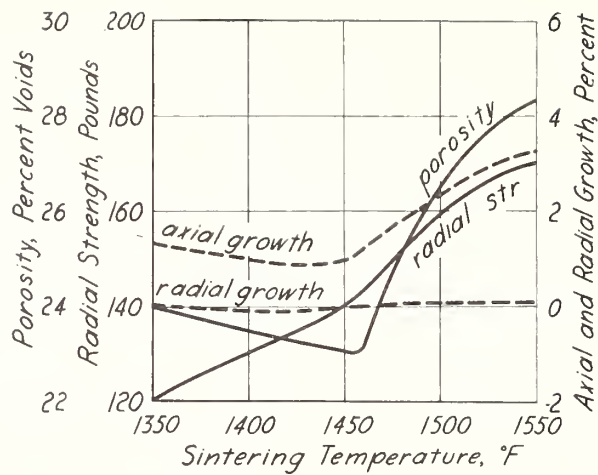


FIGURE 51.—Effect of sintering temperature on the properties of sintered copper-tin-graphite compacts (Koehring [52]).

Cu 90 parts, Sn 10 parts, graphite 2 parts.

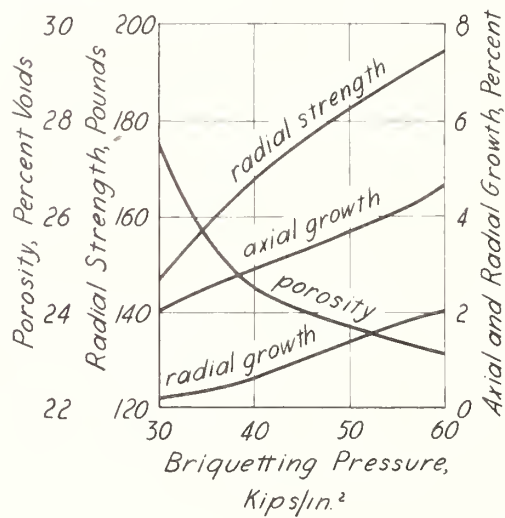


FIGURE 52.—Effect of briquetting pressure on the properties of sintered copper-tin-graphite compacts (Koehring [52]).

Cu 90 parts, Sn 10 parts, graphite 2 parts.
Sintered at about 1,500°F.

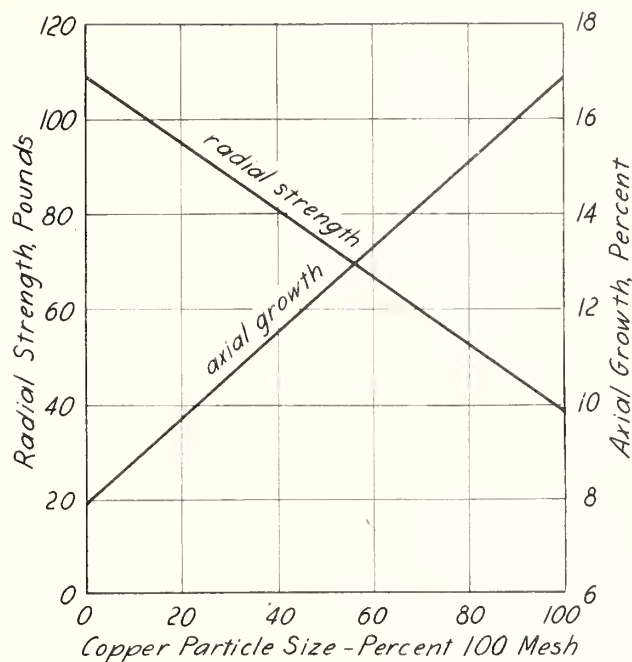


FIGURE 53.—Effect of particle size on the properties of sintered copper-tin-graphite compacts (Koehring [52]).

Cu 90 parts, Sn 10 parts, graphite 6 parts.

The screen analyses of the copper powders were:

Mesh	Percent					
+100	0	20.0	40.0	60.0	80.0	100
-100 +200	6.5	5.2	3.9	2.6	1.3	0
-200 +325	24.5	19.6	14.7	9.8	4.9	0
-325	69.0	55.2	41.4	27.6	13.8	0

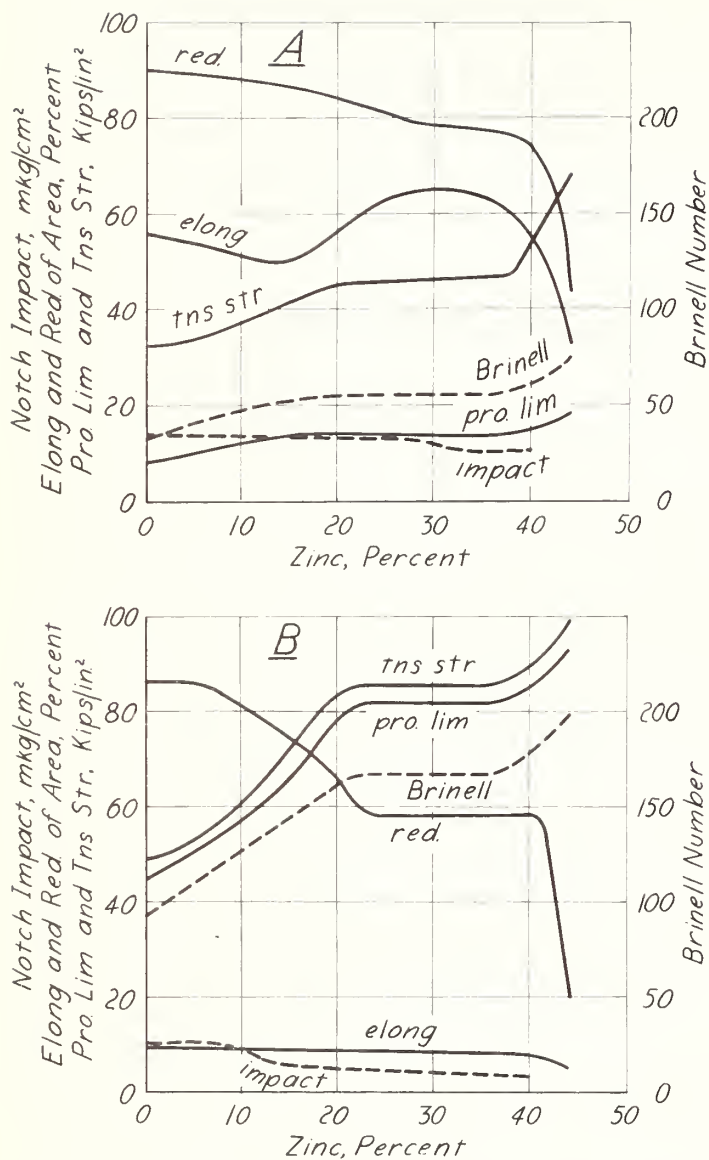


FIGURE 54.—Tensile properties, impact value, and hardness of wrought copper-zinc alloys (Broniewski and Trzebski [354]).

(Elongation in 10 diam)

A, Annealed 2 hours at 1,020 F; B, cold-rolled (40% red.).

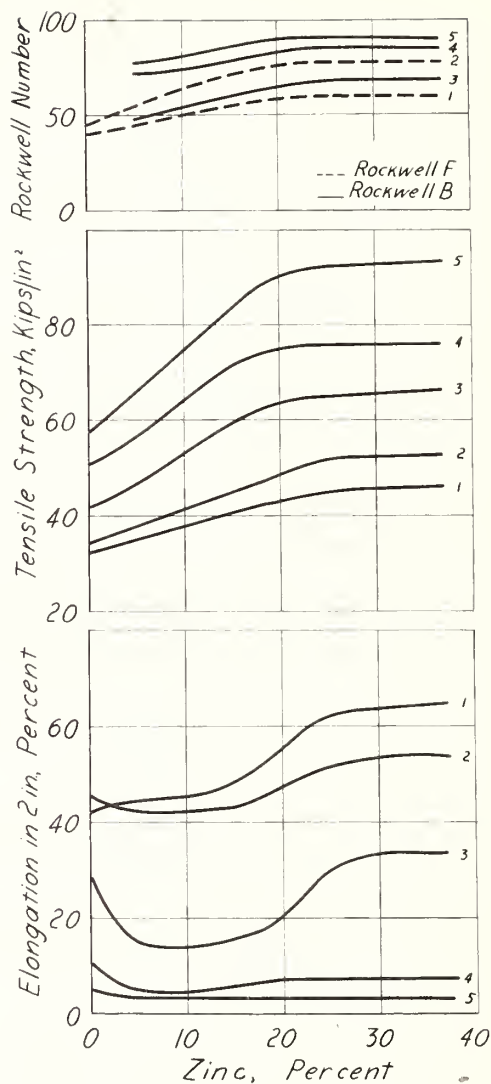


FIGURE 55.—Tensile properties and hardness of copper-zinc alloys (Crampton [184]).

Sheet, 0.04 in. Curves: 1, soft anneal; 2, light anneal; 3, rolled (21% red.); 4, rolled (37% red.); 5, rolled (60% red.).

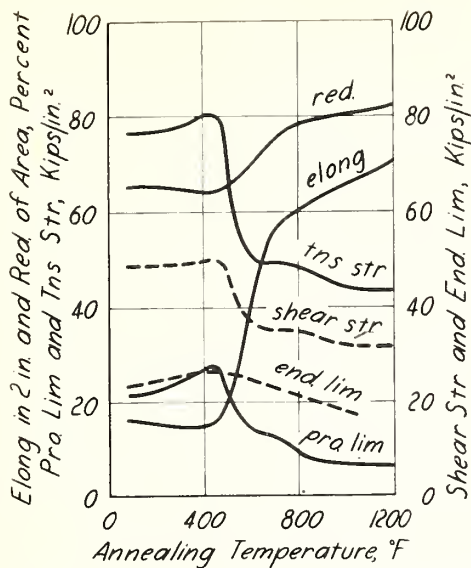


FIGURE 56.—Effect of annealing on the tensile properties, endurance limit, and shear strength of a cold-drawn copper-zinc alloy (McAdam [86]).

Zn 19.06%, Fe 0.05%, Pb less than 0.01%.

Annealed 1 hour.

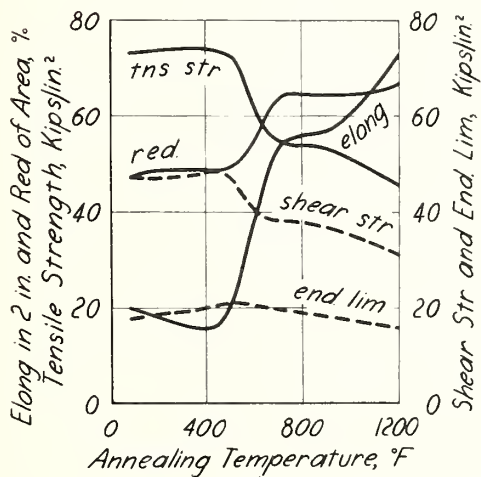


FIGURE 57.—Effect of annealing on the tensile properties, endurance limit, and shear strength of a cold-drawn copper-zinc alloy (McAdam [86]).

Zn 29.99%, Fe 0.05%, Pb less than 0.01%.

Annealed 1 to 1 1/2 hours.

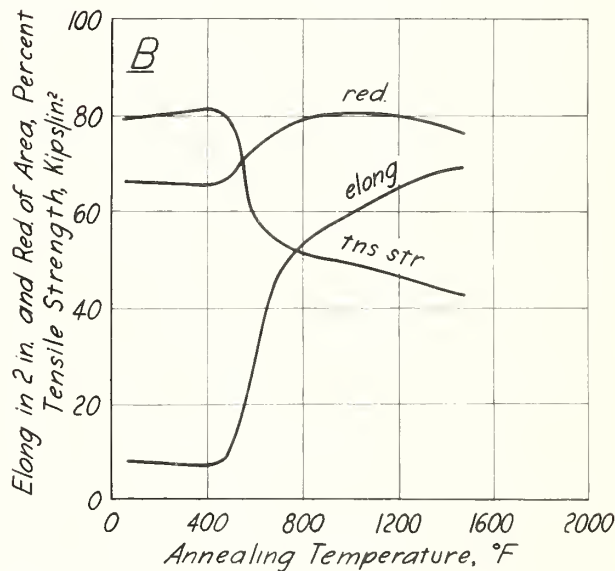
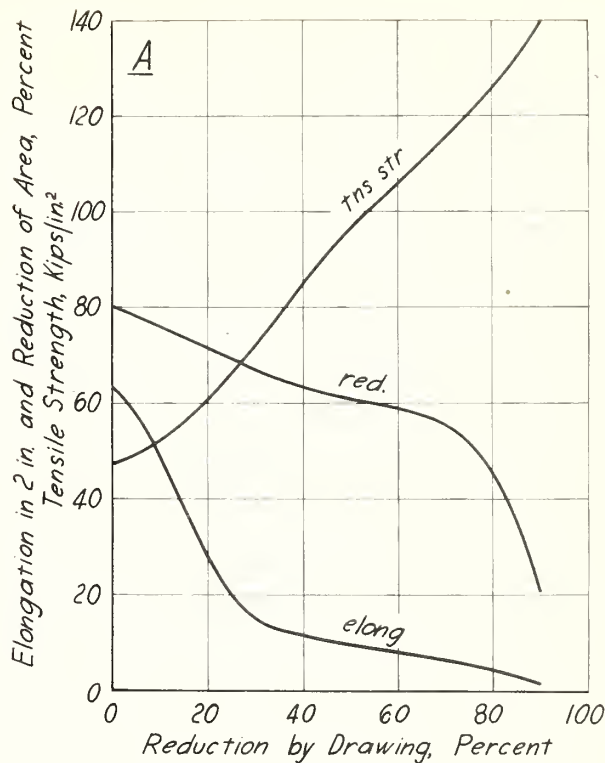


FIGURE 58.—Effect of annealing and cold-drawing on the tensile properties of a copper-zinc alloy containing 34 percent of zinc (Pratt [855]).

A, Effect of cold-drawing; B, effect of annealing the cold-worked alloy.

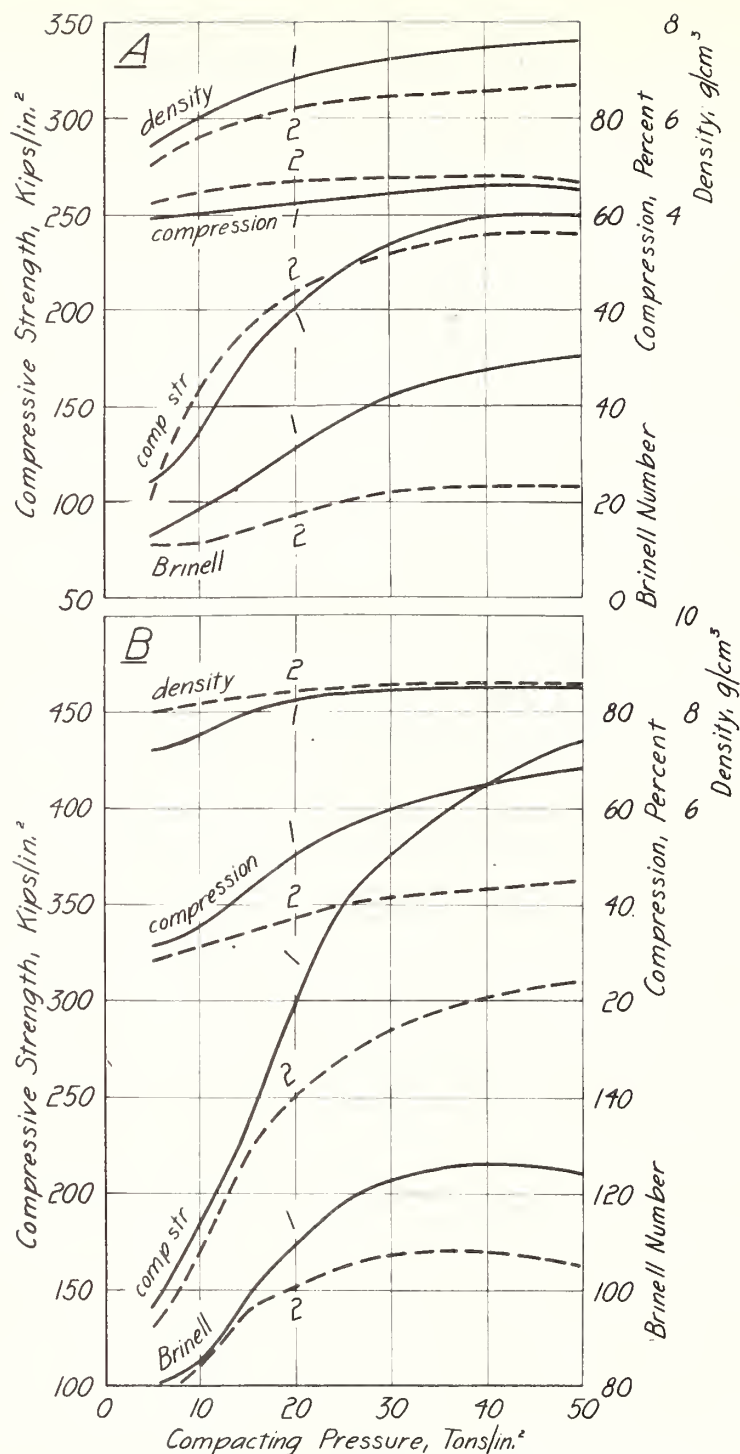


FIGURE 59.—Compressive properties, hardness, and density of copper-zinc powder compacts containing 25 percent of zinc (Goetzal [52]).

(Compression is the reduction in thickness at the point where edge fracture first occurred)

A, Cold-pressed and sintered at 1,470°F; B, hot-pressed under hydrogen at 930°F.

Curves: 1, test pieces prepared from pre-alloyed powder; 2, test pieces prepared from mixed powders.

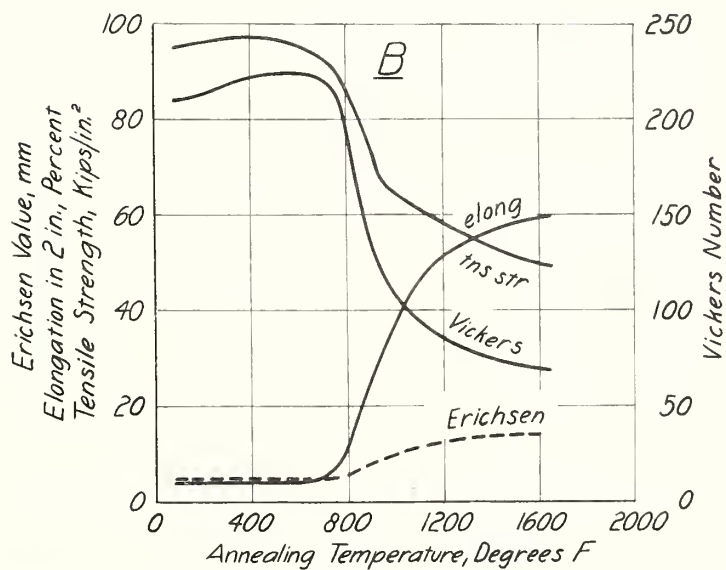
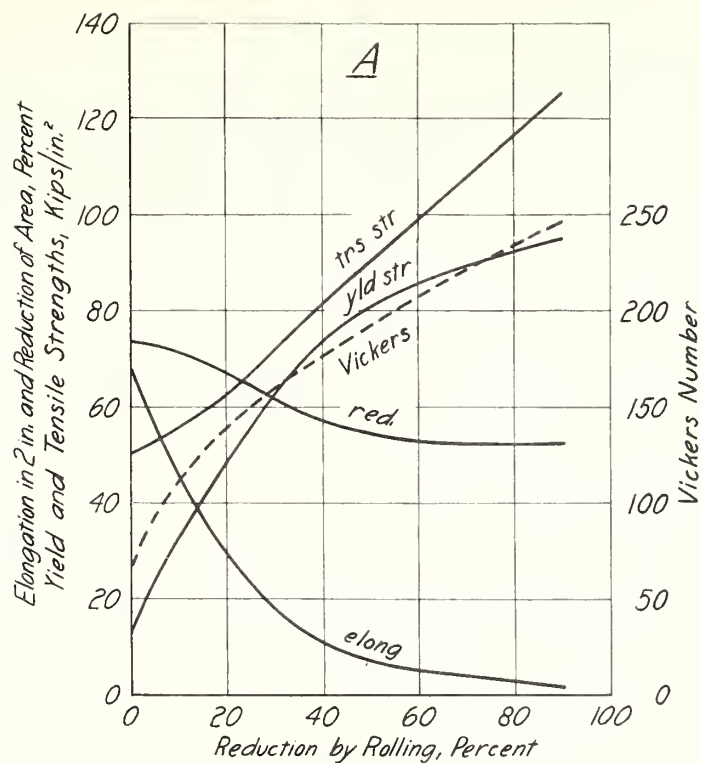


FIGURE 80.—Effect of annealing and cold-rolling on the tensile properties, hardness, and Erichsen value of a copper-zinc-nickel alloy (Cook [203]).

(Yield strength, 0.1% offset)

Zn 27.14%, Ni 10.05%, Mn 0.13%, Fe 0.04%, Si 0.009%, C 0.007%,
Pb 0.005%, S 0.003%.

A, Effect of cold-rolling; B, effect of annealing; sheet, 0.07 in., cold-rolled (60% red.), annealed 1/2 hour.

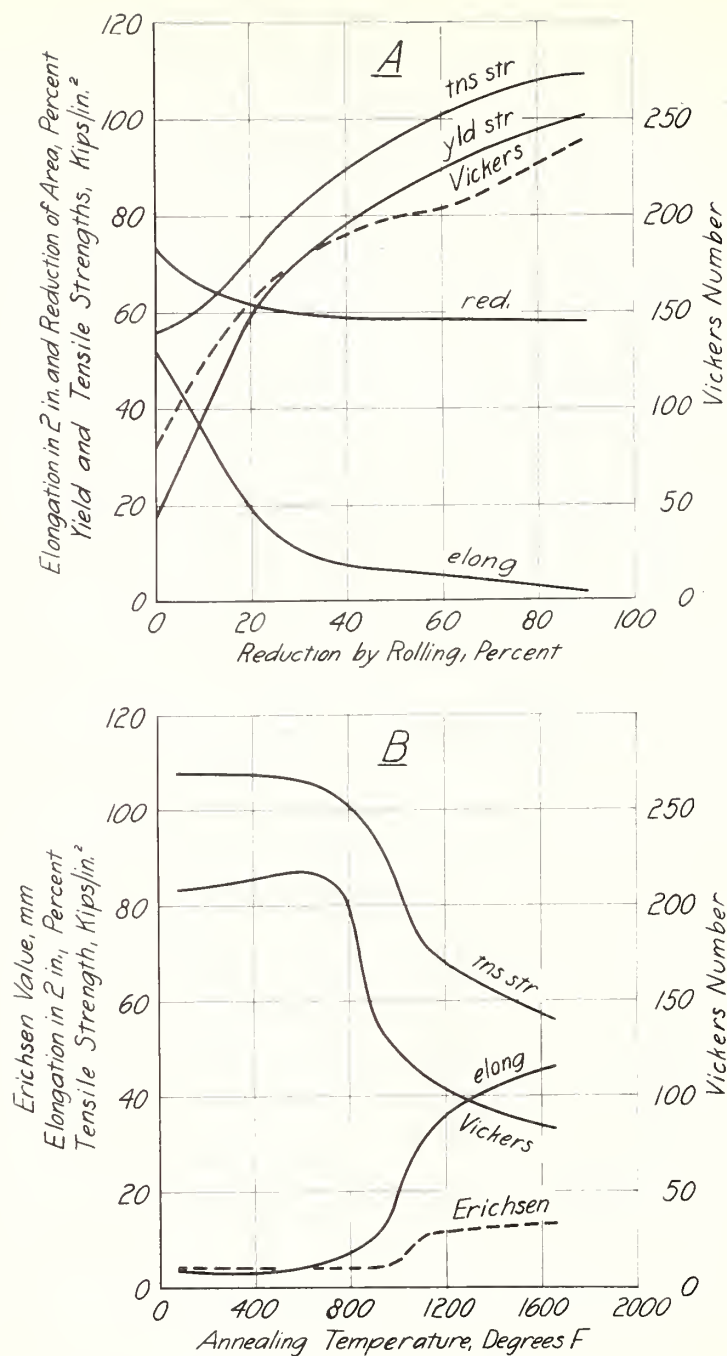


FIGURE 61.—Effect of annealing and cold-rolling on the tensile properties, hardness, and Erichsen value of a copper-zinc-nickel alloy (Cook [203]).

(Yield strength, 0.1% offset)

Zn 19.36%, Ni 18.40%, Mn 0.12%, Fe 0.07%, C 0.008%, Pb 0.004%,
Si 0.004%, S 0.003%.

A, Effect of cold-rolling; B, effect of annealing; sheet, 0.07 in., cold-rolled (60% red.), annealed 1/2 hour.

TABLE 13.—Copper and copper alloys, high-temperature properties

[For a discussion of the infiniteness of values reported for yield strength and particularly for "proportional limit" see pages 5 and 6. Hardness numbers are Brinell numbers unless prefixed R_B , R_C , etc. (Rockwell C, etc.); S (Scleroscope); V (Vickers).]

Serial number	Composition	Condition	Temperature	Short-time properties					Creep properties				Reference	
				"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Stress (kips/in. ²) for designated creep rate per 1,000 hours	Duration			
PURE AND COMMERCIAL COPPER (SEE ALSO FIGS. 62, 63, AND 64)														
1062....	Electro copper.....	Wrought, full anneal.....	T_p 400	kips/in. ²	kips/in. ²	kips/in. ²	Percent	Percent .....	.....	0.001%	0.01%	0.1%	Hours 1,135	[63]
1083....	Deoxidized copper: Cu 99.97, P 0.015.	Rod, 3/4 in., cold-drawn, annealed.....	85 400	18.4 12.5	42.0 (0.5%)	43.3 36.8	31 21 (2 in.)	81 83	88	.....	.....	.....	.....	[63]
COPPER-ALUMINUM ALLOY														
1081....	Al 7.08, Fe 0.55, Sn 0.08, P 0.01.	Die-cast.....	70 200 400 600 700 800 900 1,000	9.0 11.0 10.6 6.5	19.2 13.6 (yld mt) 16.2 (yld mt) 14.4 (yld mt) 15.9 (yld mt) 16.1 (yld mt) 16.1 (yld mt) 10.1 (yld mt)	55.8 52.5 48.3 37.7 26.9 26.4 22.2 15.4	72 71 (2 in.) 63 (2 in.) 33 (2 in.) 17 (2 in.) 8.5 (2 in.) 5.0 (2 in.) 4.8 (2 in.)	60 56 45 32 18 14 7.7 7.0	R_B 24	.....	.....	.....	.....	[63]
1085....	Ni 20.0, Zn 5.08, Mn 0.69.....	Rod, 3/4 in., cold-drawn, annealed at 1,200°F.	85 900	11.0 12.5	18.2 (0.5%)	50.4 45.0	51 28 (2 in.)	75 72	74	.....	.....	.....	.....	[63]
1086....	Ni 30.06, Mn 0.80, Fe 0.03, Pb 0.005.	Wire, 0.125 in. diam, annealed to 0.020-mm grain size.	Room 300 500	..... ..... .....	21.0 (0.5% extn)	59.0	40 (2 in.) .....	.....	.....	.....	.....	.....	.....	[191]
1087....	do.....	Wire, 0.125 in. diam, drawn (84½ red.).	Room 500	..... .....	80.0 (0.5% extn)	90.5	9 (2 in.) .....	.....	.....	.....	.....	.....	.....	[191]
1088....	Ni 30.32, Mn 0.65, Zn 0.15.....	Rod, 3/4 in., cold-drawn, annealed at 1,020°F.	85 750	37.5 17.5	48.3 (0.5%)	64.7 17.6	37 22 (2 in.)	65 48	127	.....	.....	.....	.....	[63]
COPPER-SILICON ALLOYS														
1089....	Cu 96.34, Si 2.80, Fe 0.06, Pb 0.005, Zn rem.	Wire, 0.125 in. diam, annealed to 0.100-mm grain size.	Room 400 500	..... ..... .....	8.0 (0.5% extn)	49.5	65 (2 in.) .....	.....	.....	.....	.....	.....	.....	[191]

TABLE 13.—Copper and copper alloys, high-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Short-time properties				Creep properties			Reference			
				"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Stress (kips/in. ²) for designated creep rate per 1,000 hours		Duration		
COPPER-SILICON ALLOYS—Continued														
1090....	Cu 86.34, Si 2.80, Fe 0.06, Pb 0.005, Zn rem.	Wire, 0.125 in. diam, annealed, 0.008-mm grain size.	$\left\{ \begin{array}{l} \text{Room} \\ 300 \\ 400 \\ 500 \end{array} \right\}$	$\left\{ \begin{array}{l} \text{kips/in.}^2 \\ 25.0 \\ (0.5\% \text{ extn}) \end{array} \right\}$	$\left\{ \begin{array}{l} \text{kips/in.}^2 \\ 64.5 \\ (2 \text{ in.}) \end{array} \right\}$	$\left\{ \begin{array}{l} \text{Percent} \\ 61 \\ (2 \text{ in.}) \end{array} \right\}$	.....	$\left\{ \begin{array}{l} 0.001\% \\ 10.0 \\ 1.6 \\ 0.7 \end{array} \right\}$	$\left\{ \begin{array}{l} 0.01\% \\ 20.0 \\ 5.0 \\ 1.7 \end{array} \right\}$	$\left\{ \begin{array}{l} 0.1\% \\ 15.0 \\ 4.2 \end{array} \right\}$	$\left\{ \begin{array}{l} 1.0\% \\ 5,000 \\ 5,000 \end{array} \right\}$	$\left\{ \begin{array}{l} \text{Hours} \\ 5,000 \\ 5,000 \end{array} \right\}$	[191]	
1091....	do.....	Wire, 0.125 in. diam, drawn (84% red.).	$\left\{ \begin{array}{l} \text{Room} \\ 300 \\ 400 \\ 500 \end{array} \right\}$	$\left\{ \begin{array}{l} \text{kips/in.}^2 \\ 68.5 \\ (0.5\% \text{ extn}) \end{array} \right\}$	$\left\{ \begin{array}{l} \text{kips/in.}^2 \\ 143 \\ (2 \text{ in.}) \end{array} \right\}$	$\left\{ \begin{array}{l} \text{Percent} \\ 53 \\ (2 \text{ in.}) \end{array} \right\}$	.....	.....	.....	.....	.....	.....	[191]	
1092....	Si 2.81, Mn 1.25, Zn 0.20, Fe 0.15.	Wrought, fully annealed.....	400	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1093....	do.....	Rod, 3/4 in., cold-drawn, annealed at 840°F.	$\left\{ \begin{array}{l} 85 \\ 550 \end{array} \right\}$	$\left\{ \begin{array}{l} 22.0 \\ 10.0 \end{array} \right\}$	$\left\{ \begin{array}{l} 38.7 \\ (0.5\%) \\ 48.4 \end{array} \right\}$	$\left\{ \begin{array}{l} 53 \\ (2 \text{ in.}) \\ 80 \\ (2 \text{ in.}) \end{array} \right\}$	$\left\{ \begin{array}{l} 64 \\ 119 \end{array} \right\}$	.....	.....	.....	.....	.....	[63]	
1094....	Si 3.40, Mn 1.21, Fe 0.10.....	Rod, 3/4 in., hot-rolled.....	$\left\{ \begin{array}{l} 70 \\ 550 \\ 700 \end{array} \right\}$	$\left\{ \begin{array}{l} 38.0 \\ 43.8 \end{array} \right\}$	$\left\{ \begin{array}{l} 86.5 \\ (\text{yld pnt}) \\ 71.6 \\ (\text{yld pnt}) \end{array} \right\}$	$\left\{ \begin{array}{l} 102 \\ (2 \text{ in.}) \\ 82.9 \\ (2 \text{ in.}) \end{array} \right\}$	$\left\{ \begin{array}{l} 15 \\ (2 \text{ in.}) \\ 8.5 \\ (2 \text{ in.}) \end{array} \right\}$	$\left\{ \begin{array}{l} 55 \\ 27 \end{array} \right\}$						[63]
1095....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1096....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1097....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1098....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1099....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1100....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1101....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1102....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1103....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1104....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1105....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1106....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1107....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1108....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1109....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1110....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1111....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1112....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1113....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1114....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1115....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1116....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1117....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1118....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1119....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1120....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1121....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1122....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1123....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1124....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1125....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1126....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1127....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1128....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1129....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1130....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1131....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1132....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1133....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1134....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1135....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1136....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1137....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1138....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1139....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1140....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1141....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1142....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1143....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1144....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1145....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1146....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1147....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1148....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1149....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1150....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1151....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1152....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1153....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1154....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1155....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1156....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1157....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1158....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1159....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1160....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1161....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1162....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1163....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1164....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1165....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1166....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1167....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1168....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1169....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1170....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1171....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1172....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1173....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1174....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1175....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1176....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1177....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1178....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1179....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1180....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1181....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1182....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1183....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1184....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1185....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1186....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1187....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1188....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1189....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1190....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1191....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1192....	do.....	Rod, 3/4 in., hot-rolled.....	800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[63]	
1193....														

TABLE 13.—Copper and copper alloys, high-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Short-time properties					Creep properties				Reference	
				"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Stress (kips/in. ²) for designated creep rate per 1,000 hours	1.0%	0.1%		0.01%
COPPER-TIN ALLOYS—Continued														
1107....	Percent Sn 12.25, Zn 1.46, Pb 0.01, Fe 0.01.	Cast.....	ϕ_f	$kips/in.^2$ 14.0	$kips/in.^2$ 20.0 (yld pnt)	$kips/in.^2$ 40.4 (2 in.)	Percent 15 (2 in.)	Percent 18 (2 in.)	.....	0.001%	0.01%	0.1%	1.0%	Hours
			70	10.1	18.2 (yld pnt)	32.4 (2 in.)	5.5 (2 in.)	7.8	.....	.....	10.0 (0.08%)	.....	.....	250
			550	.....	.....	.....	.....	.....	.....	.....	.....	3.0	.....	250
			600	7.5	16.5 (yld pnt)	33.6 (2 in.)	9.5 (2 in.)	.....	.....	.....	.....	2.0 (0.06%)	.....	500
			800	6.5	15.1 (yld pnt)	22.5 (2 in.)	3.5 (2 in.)	8.0	.....	.....	.....	.....	.....	.....
COPPER-ZINC ALLOYS (SEE ALSO FIGS. 67 AND 68)														
1108....	Cu 84.79, Fe 0.004, Pb 0.002, Zn rem.	Wire, 0.125 in. diam, ann to 0.050-mm grain size.	$\left\{ \begin{array}{l} \text{Room} \\ 300 \\ 400 \end{array} \right\}$	.....	9.0 (0.5% extn)	41.0 (2 in.)	47 (2 in.)	.....	.....	.....	.....	.....	.....	.....
1109....	...do.....	Wire, 0.125 in. diam, drawn (84% red.).	$\left\{ \begin{array}{l} \text{Room} \\ 300 \\ 400 \end{array} \right\}$	.....	67.0 (0.5% extn)	96.5 (2 in.)	7 (2 in.)	.....	.....	4.9	8.0 6.2	.....	.....	.....
1110....	Zn 4.86, Pb 5.24, Sn 5.10.....	Cast.....	$\left\{ \begin{array}{l} \text{Room} \\ 500 \end{array} \right\}$	.....	14.3 (yld pnt)	30.2 (2 in.)	24 (2 in.)	.....	.....	.....	.....	.....	.....	.....
1111....	Admiralty brass: Cu 71.06, Sn 0.92, Pb 0.015, Fe 0.008, Zn rem.	Wire, 0.125 in. diam, ann to 0.055-mm grain size.	$\left\{ \begin{array}{l} \text{Room} \\ 500 \end{array} \right\}$	.....	15.5 (0.5% extn)	52.0 (2 in.)	60 (2 in.)	.....	.....	.....	.....	.....	.....	.....
1112....	...do.....	Wire, 0.125 in. diam, drawn (60% red.).	$\left\{ \begin{array}{l} \text{Room} \\ 500 \end{array} \right\}$	.....	71.0 (0.5% extn)	109 (2 in.)	6 (2 in.)	.....	.....	.....	2.2	5.0	.....	.....
1113....	Cu 70.45, Pb <0.05, Fe 0.01, Zn rem.	Wire, 0.125 in. diam, ann to 0.200-mm grain size.	$\left\{ \begin{array}{l} \text{Room} \\ 400 \\ 500 \end{array} \right\}$	.....	8.5 (0.5% extn)	42.5 (2 in.)	55 (2 in.)	.....	.....	.....	.....	0.90	.....	.....
1114....	...do.....	Wire, 0.125 in. diam, ann to 0.022-mm grain size.	$\left\{ \begin{array}{l} \text{Room} \\ 400 \\ 500 \end{array} \right\}$	.....	.....	.....	.....	.....	.....	2.4	2.7	3.7	.....	.....
1115....	...do.....	Wire, 0.125 in. diam, drawn (84% red.); coarse grained.	$\left\{ \begin{array}{l} \text{Room} \\ 400 \\ 500 \end{array} \right\}$	.....	19.0 (0.5% extn)	52.0 (2 in.)	49 (2 in.)	.....	.....	.....	.....	8.5 2.2	.....	.....
1116....	Cu 69.43, Pb <0.05, Fe 0.01, Zn rem.	Wire, 0.125 in. diam, ann to 0.085-mm grain size.	$\left\{ \begin{array}{l} \text{Room} \\ 300 \\ 400 \\ 500 \end{array} \right\}$	.....	11.5 (0.5% extn)	48.5 (2 in.)	57 (2 in.)	.....	.....	.....	.....	.....	.....	.....
1117....	...do.....	Wire, 0.125 in. diam, ann to 0.016-mm grain size.	$\left\{ \begin{array}{l} \text{Room} \\ 300 \\ 400 \\ 500 \end{array} \right\}$	.....	22.5 (0.5% extn)	59.5 (2 in.)	42 (2 in.)	.....	.....	.....	.....	.....	.....	.....

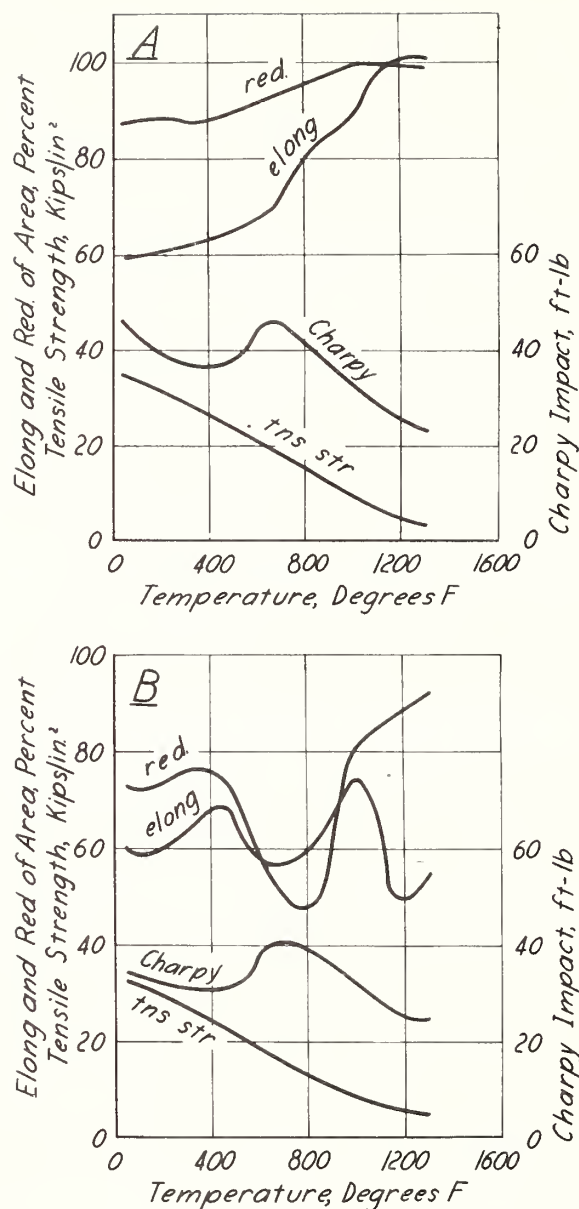


FIGURE 62.—Short-time tensile properties and impact value of hot-rolled oxygen-free and tough-pitch copper at high temperatures (Lorig, Dahle, and Roberts [856]).

(Elongation in 2 in.)

A, Oxygen-free (OFHC); B, electrolytic tough-pitch.

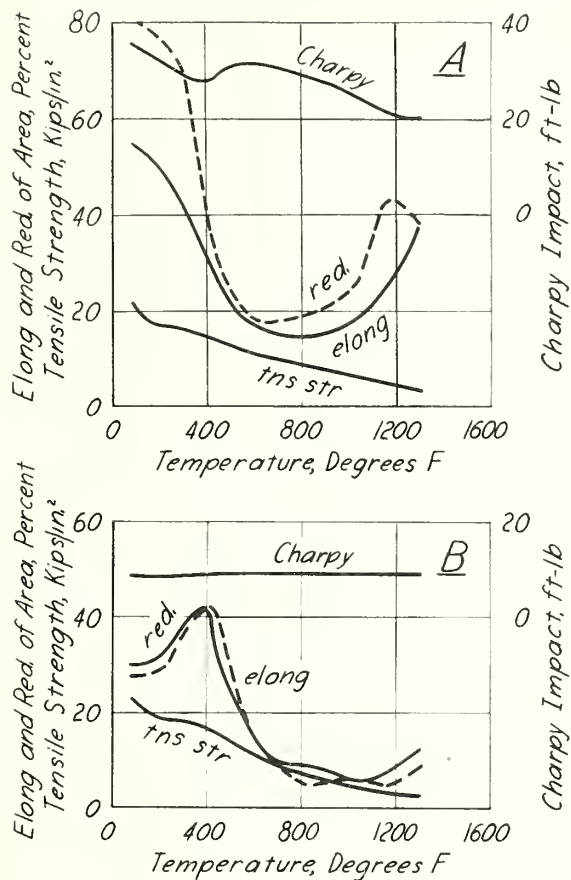


FIGURE 63.—Short-time tensile properties and impact value of cast oxygen-free and tough-pitch copper at high temperatures (Lorig, Dahle, and Roberts [656]).

(Elongation in 2 in.)

A, Oxygen-free (OFHC); B, electrolytic tough-pitch.

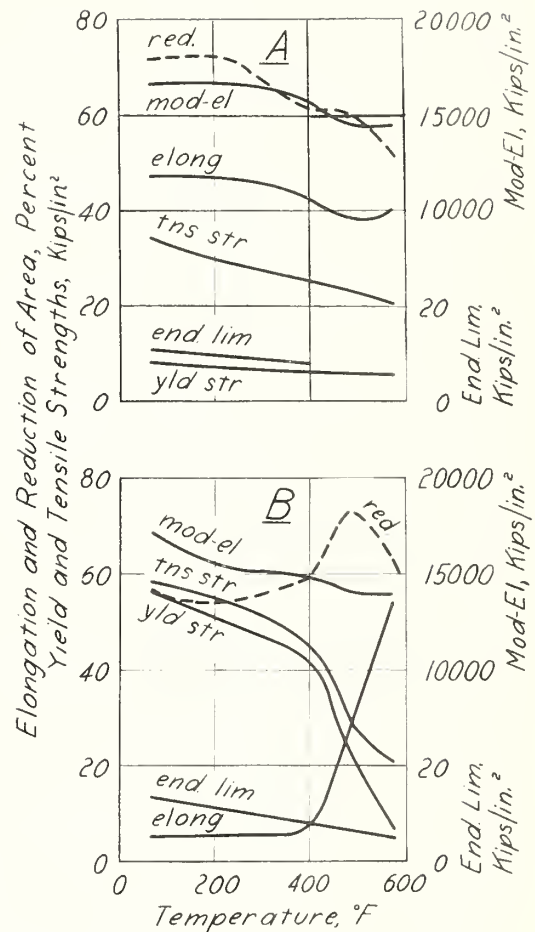


FIGURE 64.—Short-time tensile properties and endurance limit of copper at high temperatures (Schwinning and Strobel [657]).

(Yield strength, 0.2%)

A, Annealed 1/2 hour at 1,200°F; B, hard-rolled.

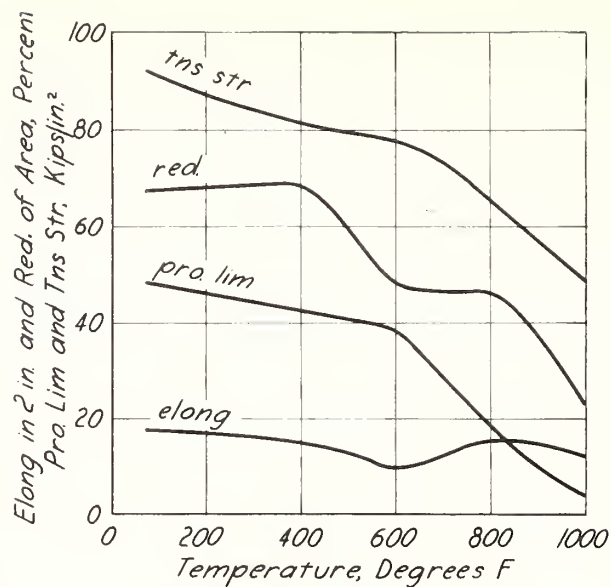


FIGURE 65.—Short-time tensile properties of a copper-nickel-zinc alloy at high temperatures (Clark and White [189]).

Ni 29.38%, Zn 5.67%, Mn 0.42%.

Rod, 3/4 in. diameter, cold-drawn (27% red.).

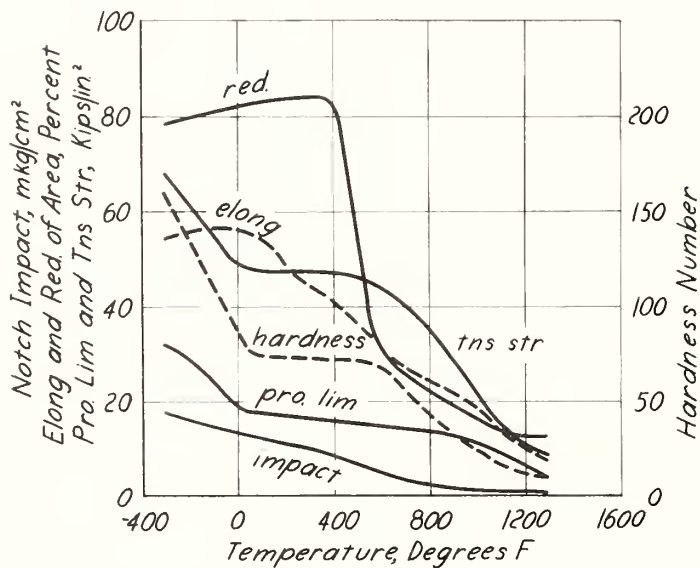


FIGURE 68.—Short-time tensile properties, impact value, and hardness of a copper-tin alloy containing 5 percent of tin at various temperatures (Broniewski and Szreniawski [658]).

(Elongation in 10 diam)

Cold-drawn and annealed 1/2 hour at 1,110°F.

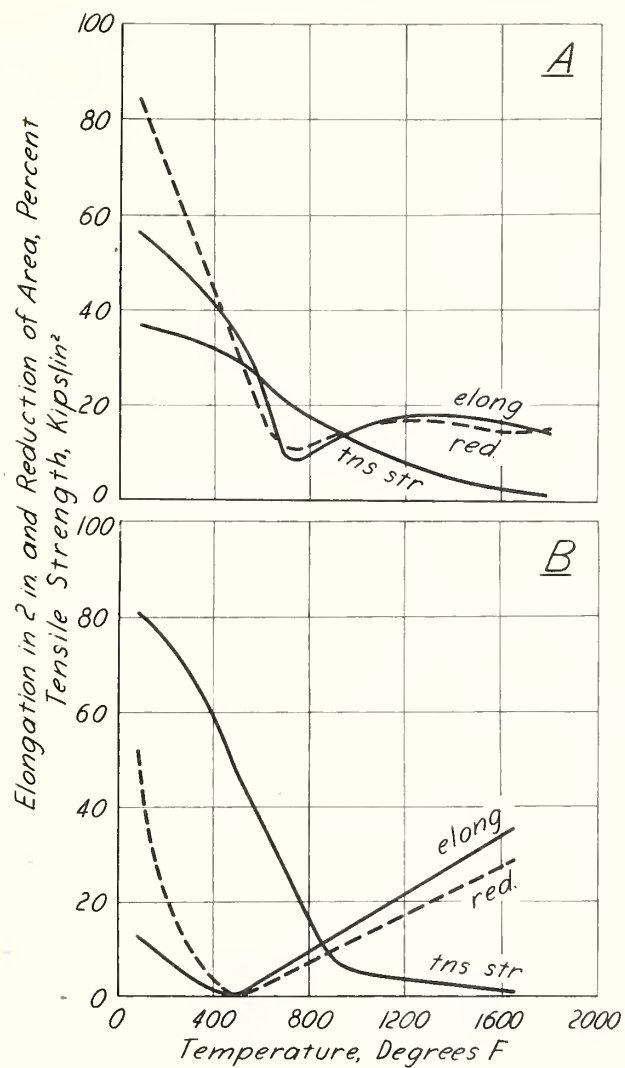


FIGURE 67.—Short-time tensile properties of copper-zinc alloys at high temperatures (Price [173]).

A, Zn 10.05%, Fe 0.02%, Pb 0.001%; annealed; B, Zn 19.85%, Fe 0.02%, Pb 0.01%; cold-drawn (30% red.).

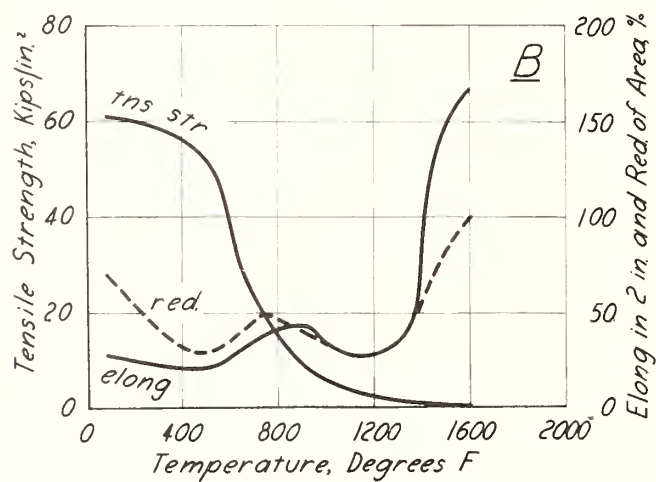
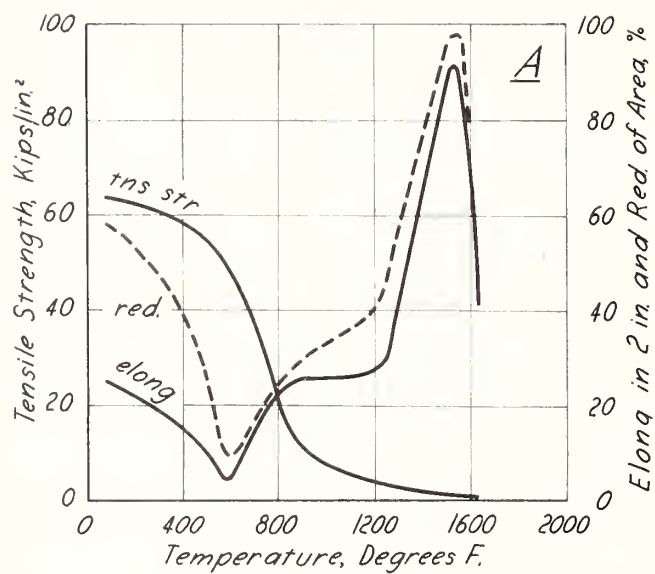


FIGURE 68.—Short-time tensile properties of copper-zinc alloys at high temperatures (Price [173]).

A, Zn 31.98%, Fe 0.02%, Pb 0.001%; cold-rolled (20% red.); B, Zn 37.54%, Pb 0.04%, Fe 0.02%; cold-drawn (20% red.).

TABLE 14.—Copper and copper alloys, low-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Tensile properties					Hardness number	Impact value	Remarks	Reference
				Modulus of elasticity	Yield strength	Tensile strength	Elongation	Reduction of area				
COPPER-BERYLLIUM ALLOYS—Continued												
1132....	Be 2.02, Ni 0.26, Fe 0.03....	Rod, 5/8 in., amn.....	Room -42	Ktols/in. ² 20,000	Ktols/in. ² 111	Ktols/in. ² 113	Percent 11 (2 in.)	Percent 42	225	ft.-lb 12 46	Tensile specimen 0.375 in. diam; square impact specimen.	[25]
1133....	...do.....	Rod, 5/8 in.; 2 hr at 575°F.....	Room -42	20,000	112	118	12 (2 in.)	42	.....	12 51	...do.....	[25]
1134....	Be 2.56, Fe 0.034.....	Rod, 1 in. diam, w-q from 1,470°F.	Room -112 -184 -232	17,000 21,600 21,700	24.9 (0.1% perm) 29.1 (0.1% perm) 50.0 (0.1% perm)	75.2 86.7 112	36 (2 in.) 38 (2 in.) 41 (2 in.)	6 (2 in.) 4 (2 in.) 50	375	12 2 12 4 12 41 12 40 12 40	Tensile specimens 0.25 in. diam.	[64]
1135....	...do.....	Rod, 1 in. diam, w-q from 1,470°F. aged 2 hr at 570°F.	Room -112 -184 -232	21,400 22,700 23,400 20,600	125 (0.1% perm) 147 (0.1% perm) 139 (0.1% perm) 155 (0.1% perm)	187 202 198 214	2.6 (2 in.) 0.4 (2 in.) 0.4 (2 in.) 3.0 (2 in.)	5.0 5.0 4.0 6.0	..... ..... ..... .....	12 2.0 12 3.0 12 2.5 12 3.0	...do.....	[64]
COPPER-NICKEL ALLOYS												
1136....	Ni 5.86, Al 1.73.....	Rod, 1 in. diam, w-q from 1,650°F.	Room -40 -112 -184 -232	..... ..... ..... .....	11.4 (0.1% perm) 16.1 (0.1% perm) 16.4 (0.1% perm) 15.0 (0.1% perm) 22.8 (0.1% perm)	51.5 55.8 57.3 61.6 67.2	42 (2 in.) 42 (2 in.) 42 (2 in.) 44 (2 in.) 49 (2 in.)	80 80 79 82 82	..... ..... ..... ..... .....	12 58 12 67	Tensile specimens 0.25 in. diam.	[64]
1137....	...do.....	Rod, 1 in. diam, w-q from 1,650°F. aged 2 hr at 1,020°F.	Room -40 -112 -184 -232	 22,400 24,300 20,800	 61.6 (0.1% perm) 51.5 (0.1% perm) 63.4 (0.1% perm) 54.9 (0.1% perm)	90.9 104 101 108 107	24 (2 in.) 24 (2 in.) 22 (2 in.) 26 (2 in.) 26 (2 in.)	50 57 57 63 67	..... ..... ..... ..... .....	12 40 12 55	...do.....	[64]
1138....	Ni 19.49, Zn 5.43, Mn 0.80..	Annealed.....	Room -25 -60 -110 -175	..... ..... ..... .....	35.2 (0.5% extn)	54.7	43 (2 in.) ..... ..... .....	..... ..... ..... .....	R _B 49	68 56 56 53	...do.....	[193]

1139....	Ni 20.56, Mn 0.11, Si 0.03..	Rod, 1 in. diam, ann.....	Room (-40 -112 -173 -292)	..... ..... ..... .....	27.7 (0.1% perm) 29.0 (0.1% perm) 28.9 (0.1% perm) 29.2 (0.1% perm) 32.5 (0.1% perm)	51.5 59.6 61.6 66.1 73.7	26 (2 in.) 29 (2 in.) 29 (2 in.) 28 (2 in.) 36 (2 in.)	78 77 76 75 72	..... ..... ..... ..... .....	Iz 77 Iz 81 Iz 79 Iz 84 Iz 85	Tensile specimens 0.25 in. diam.	[64]
1140....	Ni 29.54, Zn 0.62, Mn 0.57..	Annealed.....	Room (-25 -60 -110 -175)	..... ..... ..... .....	34.2 (0.5% extn)	57.6	54 (2 in.) ..... ..... .....	..... ..... ..... ..... .....	R _p 55 59 59 60	66 ..... ..... ..... .....	.....	[193]
1141....	Ni 30.50, Zn 14.30.....	Rod, 1 in. diam, ann.....	Room (-40 -112 -184 -292)	..... ..... ..... .....	27.9 (0.1% perm) 28.6 (0.1% perm) 27.5 (0.1% perm) 28.8 (0.1% perm) 28.4 (0.1% perm)	75.3 78.2 83.1 89.8 104	33 (2 in.) 34 (2 in.) 39 (2 in.) 38 (2 in.) 41 (2 in.)	52 52 52 52 55	..... ..... ..... ..... .....	Iz 80 Iz 87 Iz 83 Iz 80 Iz 87	Tensile specimens 0.25 in. diam.	[64]
1142....	Ni 45.78, Mn 0.39, Co 0.26, Si 0.15, Fe 0.07.	...do.....	Room (-40 -112 -184 -292)	..... ..... ..... .....	19.6 (0.1% perm) 21.0 (0.1% perm) 22.1 (0.1% perm) 24.1 (0.1% perm) 26.3 (0.1% perm)	60.0 67.6 72.2 77.1 89.6	40 (2 in.) 43 (2 in.) 48 (2 in.) 48 (2 in.) 57 (2 in.)	77 78 75 74 76	..... ..... ..... ..... .....	Iz 80 Iz 85 Iz 81 Iz 83 Iz 86	do.....	[64]

COPPER-SILICON ALLOYS

1143....	Si 2.75, Mn 0.97, Fe 0.15...	Rod, 1/2 in. diam, cold-drawn (42% red.)..	77 (-112 -310)	..... ..... .....	..... ..... .....	74.2 82.9 100	40 (2 in.) 32 (2 in.) 36 (2 in.)	75 72 72	..... ..... .....	..... ..... .....	.....	[193]
1144....	Si 3.05, Mn 0.98, Fe 0.17...	Annealed.....	Room (-25 -60 -110 -175)	..... ..... ..... .....	29.9 (0.5% extn)	82.4	66 (2 in.) ..... ..... .....	..... ..... ..... ..... .....	R _p 54	66 75 73 69 64	.....	[193]

COPPER-TIN ALLOYS

1145....	Sn 3.99, P 0.40.....	Rod, 1/2 in., hard-drawn.....	Room (-42)	16,500 16,500	82.5 85.0	87.0 88.0	20 (2 in.) 20 (2 in.)	70 68	178	Iz 46 Iz 44	Tensile specimens 0.375 in. diam; round impact specimens.	[25]
1146....	Sn 5.0, Zn 0.30, Pb 0.10, P 0.02.	Cold-worked.....	Room (-40)	.....	.....	.....	.....	.....	.....	Iz 62 Iz 60	.....	[25]
1147....	Sn 10.0, Zn 1.61.....	Cast.....	Room (-423)	.....	29.3 (yld pnt) 46.4 (yld pnt)	45.5 58.0	30 (10 diam) 18 (10 diam)	36 38	90 .....	..... .....	Tensile specimens 0.12 in. diam.	[66]

TABLE 14.—Copper and copper alloys, low-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Tensile properties					Hardness number	Impact value	Remarks	Reference
				Modulus of elasticity	Yield strength	Tensile strength	Elongation	Reduction of area				
COPPER-ZINC ALLOYS												
1118....	Zn 5, Sn 5, Pb 5.....	Cast.....	t_p Room -50 -75	Ktpsi/in. ²	Ktpsi/in. ²	Ktpsi/in. ²	Percent	Percent ..... ..... .....	..... ..... .....	f_t-lb 5.5 6 6	..... ..... .....	[25]
1119....	Cu 71.6, Zn rem.....	.....	61 -22 -112	..... ..... .....	9.5 (yld pnt) 10.4 (yld pnt) 12.2 (yld pnt)	31.5 43.2 48.6	83 (2 in.) 76 (2 in.) 74 (2 in.)	76 80 80	..... ..... .....	85 90 89	Impact specimens 10-mm square; sharp notch.	[65]
1150....	Admiralty brass: Zn 28.41, Sn 0.95, Fe 0.03, Pb 0.01.	Annealed.....	Room -25 -60 -110 -175	..... ..... ..... .....	13.3 (0.5% extn)	46.5	84 (2 in.) ..... .....	..... ..... ..... .....	..... ..... ..... .....	61 51 59 62 59	..... ..... ..... ..... .....	[193]
1151....	Zn 30.50, Fe 0.10.....	Rod, 1 in. diam, annealed.....	Room -40 -112 -184 -202	..... ..... ..... .....	28.2 (0.1% perm) 26.9 (0.1% perm) 27.3 (0.1% perm) 28.0 (0.1% perm) 29.6 (0.1% perm)	51.1 54.7 57.1 61.2 73.5	49 (2 in.) 58 (2 in.) 60 (2 in.) 55 (2 in.) 75 (2 in.)	77 77 79 78 73	..... ..... ..... ..... .....	12 66 12 66 12 69 12 70 12 78	..... ..... ..... ..... .....	[64]
1152....	Zn 33.....	Annealed 2 hr at 1,020°F.....	Room -108 -297	..... ..... .....	..... ..... .....	56.9 61.2 76.4	50 (10 diam) 50 (10 diam) 51 (10 diam)	72 77 71	^a 77 ^a 86 ^a 100	^b 14.4 ^b 16.9 ^b 14.2	..... ..... .....	[194]
1153....	do.....	Cold-worked.....	Room -108 -297	..... ..... .....	..... ..... .....	85.3 92.4 103	6.3 (10 diam) 7.8 (10 diam) 10 (10 diam)	66 72 66	^a 142 ^a 149 ^a 172	^b 8.1 ^b 9.2 ^b 9.4	..... ..... .....	[194]
1154....	Zn 35, Pb 3.....	Annealed 3/4 hr at 650°F, f-c.....	80 -20 -40	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	Endurance limit ^b.....26.0 kpsi/in. ² .. Endurance limit ^d.....27.5 kpsi/in. ² .. Endurance limit ^b.....27.0 kpsi/in. ²	[195]
1155....	Naval brass: Zn 36.36, Sn 0.31, Pb 0.08.	Rod, 1/2 in., hard-drawn.....	Room -42	15,000 15,000	54.0 58.0	72.0 74.5	24 (2 in.) 26 (2 in.)	65 65	138	12 38 12 37	Testile specimens 0.375 in. diam; square impact specimens.	[25]
1156....	Zn 38.48, Fe 1.21, Sn 0.72, Al 0.10, Pb 0.09.	do.....	Room -42	15,500 15,500	81.0 81.5	88.0 94.5	12 (2 in.) 14 (2 in.)	36 38	178	12 10 12 14	do.....	[25]

1157....	Zn 38.85, Sn 1.43, Pb 1.25, Fe 1.08, Sn 0.90.	Rod, 1 in. diam, ann.....	Room	.....	24.0 (0.1% perm)	72.1	28 (2 in.)	44	.....	Iz 20	Tensile specimens 0.25 in. diam.	[64]
			-40	.....	27.6 (0.1% perm)	75.5	29 (2 in.)	45	.....	Iz 20		
			-112	.....	27.0 (0.1% perm)	75.5	31 (2 in.)	43	.....	Iz 22		
			-184	.....	27.8 (0.1% perm)	80.9	35 (2 in.)	45	.....	Iz 21		
			-292	.....	28.8 (0.1% perm)	94.8	37 (2 in.)	41	.....	Iz 20		
1158....	Zn 38.91, Sn 0.75, Fe 0.08, Pb 0.01.	Annealed.....	Room	.....	35.0 (0.5% extn)	94.6	41 (2 in.)	.....	R _B 61	16	.....	[193]
			-25	.....	.....	.....	.....	.....	.....	18	.....	
			-60	.....	.....	.....	.....	.....	.....	18	.....	
			-110	.....	.....	.....	.....	.....	.....	17	.....	
			-175	.....	.....	.....	.....	.....	.....	.....	.....	
1159....	Zn 40.....	Annealed 2 hr at 1,020°F.....	Room	.....	.....	57.6	51 (10 diam)	76	a 95	b 8.6	.....	[194]
			-108	.....	.....	61.2	53 (10 diam)	75	a 104	b 8.6	.....	
			-297	.....	.....	75.8	.....	71	a 142	b 8.3	.....	
1160 ^a	do.....	Cold-worked.....	Room	.....	.....	79.7	20 (10 diam)	66	a 150	b 5.1	.....	[194]
			-108	.....	.....	82.9	21 (10 diam)	68	a 160	b 5.3	.....	
			-297	.....	.....	98.4	24 (10 diam)	64	a 181	b 5.3	.....	
1161....	Zn 40, Pb 1.3.....	Annealed 2 hr at 1,020°F.....	Room	.....	.....	52.7	50 (10 diam)	62	.....	b 4.4	.....	[194]
			-108	.....	.....	54.6	50 (10 diam)	64	.....	b 4.9	.....	
			-297	.....	.....	69.0	51 (10 diam)	62	.....	b 4.6	.....	
1162....	do.....	Cold-worked (12% red.).....	Room	.....	.....	63.7	28 (10 diam)	57	.....	b 2.2	.....	[194]
			-108	.....	.....	70.4	27 (10 diam)	59	.....	b 2.5	.....	
			-297	.....	.....	86.5	31 (10 diam)	57	.....	b 2.2	.....	

^a Cone number (120° cone, 25 kg, 5 min).

^b Notch impact value, m-kg/cm².

^c Tensile tests on material cold-worked 40% reduction; hardness and impact tests on material cold-worked 12% reduction.

^d Endurance limit at 5 × 10⁷ cycles.

^e Tensile tests on material cold-worked 25% reduction; hardness and impact tests on material cold-worked 17% reduction.

TABLE 15.—Copper and copper alloys, thermal expansion

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade							Reference
			Low temperature miscellaneous	20° to 60°C	20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 500°C		High temperature miscellaneous
PURE AND COMMERCIAL COPPER										
1163 ^a	Electro copper.....	Annealed at 1,020°C.....	 × 10 ⁻⁶	 × 10 ⁻⁶	 × 10 ⁻⁶	 × 10 ⁻⁶	 × 10 ⁻⁶	 × 10 ⁻⁶	 × 10 ⁻⁶	{ 18.6 (0° to 600°C) 19.0 (0° to 700°C) 19.4 (0° to 800°C) 19.8 (0° to 900°C) 20.3 (0° to 1,000°C) } [195]
1164 ^a	Cu 99.979, O ₂ 0.02.....	Fully ann.....	{ 14.2 (-180° to 0°C) 15.5 (-100° to 0°C) 16.2 (-50° to 0°C) }	16.9	17.1	17.2	17.6	18.0	18.3		[68]
1165.....	Cu 99.85.....	Roll.....	.....	.....	16.6	17.1	17.6	18.1	18.6	[69]
COPPER-ALUMINUM ALLOYS										
1166 ^c	Al 7.34, Zn 0.40, Si 0.09.....	Hot-rolled.....	.....	.....	16.6	17.4	18.2	.....	.....	[715]
1167.....	Al 9.29, Fe 0.44, Sn 0.38, Ni 0.18.....	Rod, 3/8 in. diam, hard-drawn (2% red.).....	.....	.....	16.2	16.3	16.8	17.9	18.5	{ 19.0 (20° to 600°C) 18.9 (20° to 700°C) } [716]
1168.....	Al 10.8, Fe 6.0, Mn 3.5.....	Cast.....	.....	.....	17.6	17.9	19.2	.....	.....	[68]
COPPER-ANTIMONY ALLOY										
1169.....	Sb 5.....	.....	.....	.....	19.2	.....	.....	.....	.....	[72]
COPPER-BERYLLIUM ALLOYS										
1170.....	Be 2.14, Fe 0.05, Si 0.02.....	1/2 hr at 800°C, quenched, aged 2 1/2 hr at 300°C.....	.....	16.4	16.6	17.0	17.6	.....	.....	[197]
1171.....	Be 3.03, Fe 0.03, Si 0.02.....	(quenched from 800°C, hard-drawn (20% red.), 1 3/4 hr at 300°C.....	.....	.....	16.3	16.9	17.3	.....	.....	[197]
COPPER-IRON ALLOYS										
1172.....	Fe 22.5, Ni 12.5.....	Cast; ann and h-t.....	.....	.....	.....	22.0	.....	.....	.....	[717]
1173.....	Fe 33.5, Ni 18.5.....	do.....	.....	.....	.....	11.3	.....	.....	.....	[717]
1174.....	Fe 50.....	Forged.....	.....	.....	18.5	.....	.....	16.5	.....	{ 16.7 (20° to 600°C) 16.3 (20° to 800°C) 15.0 (20° to 900°C) } [121]
COPPER-LEAD ALLOYS										
1175.....	Pb 13, Sn 7, Zn 4.....	Cast from 1,100°C.....	.....	18.4	.....	.....	.....	.....	.....	[716]
1176.....	Pb 14, Sn 8.....	Cast.....	.....	.....	18.2	18.6	19.2	.....	.....	[68]
1177.....	Pb 20.50, Sn 9.72, P 0.02.....	Sand-cast from 1,155°C.....	.....	18.6	18.6	18.8	.....	.....	.....	[198]
1178.....	Pb 21.79, Sn 4.45, Ni 0.35, Zn 0.25, Sb 0.15, P 0.05.....	do.....	.....	18.4	18.9	18.8	.....	.....	.....	[199]
1179.....	Pb 26.62, Sn 7.75, Ni 0.25.....	Sand-cast from 1,095°C.....	.....	19.0	19.0	19.0	.....	.....	.....	[199]

COPPER-MANGANESE ALLOYS							
Wm 4.87, Fe 0.03.....	Rolled.....						[69]
wire, 0.02 in. diam, cold-drawn (90% red.), 18 hr at 140°C.....			18.0				[209]
Wm 9.4, Al 5.5, Fe 0.22.....	Rod, 3/16 in. diam.....		18.1	18.5	18.9	19.3	[146]
Manganin: Wm 12, Ni 2.....							

[1183] ^a	Ni 1.03, Fe 0.03.....	Forged; vacuum ann 3 hr at 750°C.	14.1 (-182° to 0°C)	§ 15.9		16.6		16.7		17.2	17.3		[201]
[1184]	Ni 3.14, Si 0.60.....	Quenched from 850°C.											[202]
[1185]	Ni 3.57, Fe 0.09.....	Forged; vacuum ann 3 hr at 750°C.	13.9 (-182° to 0°C)	§ 15.7								17.8	[201]
[1186]	Ni 9.47, Fe 0.11.....	do.	13.6 (-182° to 0°C)	§ 15.4									[201]
[1187]	Ni 13.84, Fe 0.11.....	do.	13.3 (-182° to 0°C)	§ 15.1									[201]
[1188]	Ni 19.72, Fe 0.15.....	do.	13.0 (-182° to 0°C)	§ 14.7									[201]
[1189] ^a	Cu 52.15, Ni 20.22, Mn 0.13, Fe 0.05, C 0.012, Pb 0.005, S 0.003, Si 0.003, Zn rem.	Cast; ann.....				15.1	16.2	16.8	17.4				[203]
[1190] ^a	Cu 61.96, Ni 25.56, Mn 0.10, Fe 0.07, C 0.020, S 0.005, Pb 0.004, Si 0.004, Zn rem.	do.....				15.4	16.2	16.8	17.4				[503]
[1191] ^a	Ni 25.60, Fe 0.49, Mn 0.41, Si 0.06, C 0.03.	Cast.....									17.2		[59]
[1192]	Ni 28.55, Fe 7.00, Si 0.10, C 0.20, Mn 0.11, S 0.023, P 0.012.	do.....				15.5	15.8	16.2	16.5	16.9			[59]
[1193]	Ni 28.70, Sn 0.91.....	Extruded; ann, drawn.....				15.2	15.4	16.3					[718]
[1194] ^a	Ni 29.2, Fe 0.19, Mn 0.02.....	Forged; vacuum ann 3 hr at 750°C.	12.5 (-182° to 0°C)	§ 14.4		16.2	16.6	17.0	17.8				[201]
[1195] ^a	Cu 62.02, Si 29.77, Mn 0.14, Fe 0.06, C 0.019, Si 0.007, Pb 0.003, S 0.002, Zn rem.	Cast; ann.....											[203]
[1196] ^a	Ni 34.90, Cr 4.88, Mn 1.41, Fe 1.28, C 0.21, Si 0.07.	Forged.....				14.6	15.0	15.5	15.9	16.4			[59]
[1197] ^a	Constantan: Ni 45.....	Drawn.....		^b 14.9									[59]
[1198] ^a	Ni 49.73, Fe 0.15, Mn 0.04.....	Forged; vacuum ann 3 hr at 750°C.	11.8 (-182° to 0°C)	§ 13.7								18.8 (0° to 1,000°C)	[201]

1199.....	Si 3.04, Mn 1.03, Fe 0.09.....	Annealed.....			17.4	17.6	18.1	18.2	18.7	$\left\{ \begin{array}{l} 19.1 \text{ (20}^\circ \text{ to 600}^\circ \text{C)} \\ 19.6 \text{ (30}^\circ \text{ to 700}^\circ \text{C)} \\ 20.1 \text{ (20}^\circ \text{ to 800}^\circ \text{C)} \\ 20.8 \text{ (20}^\circ \text{ to 900}^\circ \text{C)} \end{array} \right\}$	[716]
1200 ^b	Si 3.3, Fe 2.6.....	Sand-cast; slowly cooled to r-t.....			15.1	13.7	13.8	14.1	14.8	$\left\{ \begin{array}{l} 15.8 \text{ (15}^\circ \text{ to 600}^\circ \text{C)} \\ 16.6 \text{ (15}^\circ \text{ to 700}^\circ \text{C)} \\ 17.3 \text{ (15}^\circ \text{ to 800}^\circ \text{C)} \\ 18.0 \text{ (15}^\circ \text{ to 900}^\circ \text{C)} \end{array} \right\}$	[714]
1201.....	Si 4.40, Mn 0.96, Fe 0.11.....	Cast.....			17.4	17.5	18.0	18.2	18.9	$\left\{ \begin{array}{l} 19.8 \text{ (20}^\circ \text{ to 600}^\circ \text{C)} \\ 20.6 \text{ (20}^\circ \text{ to 700}^\circ \text{C)} \\ 21.1 \text{ (20}^\circ \text{ to 800}^\circ \text{C)} \\ 21.7 \text{ (20}^\circ \text{ to 900}^\circ \text{C)} \end{array} \right\}$	[716]
1202 ^b	Si 6.17, Fe 3.7.....	Sand-cast; slowly cooled to r-t.....			10.6	11.8	12.8	14.4	15.8	$\left\{ \begin{array}{l} 16.9 \text{ (15}^\circ \text{ to 600}^\circ \text{C)} \\ 17.6 \text{ (15}^\circ \text{ to 700}^\circ \text{C)} \\ 18.0 \text{ (15}^\circ \text{ to 800}^\circ \text{C)} \end{array} \right\}$	[714]
1203 ^b	Si 10.....				11.9	14.6	14.9	15.4	16.2	$\left\{ \begin{array}{l} 16.2 \text{ (15}^\circ \text{ to 600}^\circ \text{C)} \\ 16.1 \text{ (15}^\circ \text{ to 700}^\circ \text{C)} \end{array} \right\}$	[714]

[illegible]^a Base temp.

TABLE 15.—Copper and copper alloys, thermal expansion—Continued

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade							Reference
			Low temperature miscellaneous	20° to 60°C	20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 500°C		High temperature miscellaneous
COPPER-TIN ALLOYS—Continued										
1206.....	Sn 5.16, Zn 2.43, Pb 0.69, P 0.04, Fe 0.03.	Cast.....	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶ 18.1	× 10 ⁻⁶ 18.4	× 10 ⁻⁶ 18.8	× 10 ⁻⁶ 19.1	× 10 ⁻⁶ 19.4	 × 10 ⁻⁶
1207.....	Sn 6.5, Zn 2.0, Pb 1.5.....	do.....	.....	.....	17.4	17.9	18.7	.....	.....	.....
1208.....	Sn 6.70, Pb 7.48, Zn 3.20, Sb 0.15, Ni 0.15, P 0.05.	Sand-cast from 1,165°C.....	.....	17.7	18.1	18.4	.....	.....	.....	.....
1209 ^a	Sn 7.67, P 0.11.....	Cast.....	.....	.....	17.6	17.9	18.2	.....	.....	.....
1210.....	Sn 8.58, Pb 2.08, Zn 0.34, Ni 0.25, Sb 0.15.	Sand-cast from 1,165°C.....	.....	17.2	17.5	17.9	.....	.....	.....	.....
1211.....	Sn 9.16, Pb 8.57, P 0.24.....	Cast.....	.....	.....	19.1	19.2	19.4	19.5	19.6	.....
1212.....	Sn 9.5, Pb 2.5, Zn 2.0.....	do.....	.....	.....	17.7	18.3	19.2	.....	.....	.....
1213.....	Sn 9.58, Pb 9.15, Zn 0.60, Sb 0.15, Ni 0.15, P 0.04.	Sand-cast from 1,165°C.....	.....	18.0	18.4	18.6	.....	.....	.....	.....
1214.....	Sn 9.97, Zn 2.75, Pb 0.53, P 0.03.	do.....	.....	17.6	17.8	.....	.....	.....	.....	.....
1215.....	Sn 10.0, Ni 3.5, Pb 2.5.....	Cast.....	.....	.....	17.1	17.8	19.0	.....	.....	.....
1216.....	Sn 10, Pb 10.....	do.....	.....	.....	17.8	18.4	19.2	.....	.....	.....
1217.....	Sn 10, Zn 2.....	do.....	.....	17.8	18.1	18.5	18.8	.....	.....	.....
1218.....	Sn 10.10, Ni 5.46, P 0.06.....	do.....	.....	.....	17.3	17.7	18.1	18.4	18.8	.....
1219.....	Sn 11.0, Pb 1.5.....	do.....	.....	.....	17.4	18.2	19.1	.....	.....	.....
1220.....	Sn 11.08, Pb 11.90, P 0.02.....	Sand-cast from 1,165°C.....	.....	17.7	18.6	18.6	.....	.....	.....	.....
1221.....	Sn 11.30, Ni 8.04, P 0.12.....	Cast.....	.....	.....	16.3	16.8	17.4	18.0	18.6	.....
1222.....	Sn 11.65, P 0.06.....	do.....	.....	.....	17.2	17.8	18.4	19.0	19.6	.....
1223.....	Sn 11.96, Pb 4.22, P 0.02.....	Sand-cast from 1,165°C.....	.....	17.4	17.9	18.3	.....	.....	.....	.....
1224.....	Sn 12.0, Pb 7.5, P 1.0.....	Cast.....	.....	.....	18.3	18.7	19.4	.....	.....	.....
1225.....	Sn 14.95, Pb 0.21.....	do.....	.....	.....	18.0	18.2	18.6	18.8	19.3	.....
1226.....	Sn 17.60, P 0.08.....	do.....	.....	.....	18.4	18.7	19.0	19.3	19.6	.....
COPPER-ZINC ALLOYS										
1227 ^c	Zn 2.97, Fe 0.02, Pb 0.01.....	Cast.....	.....	.....	17.2	17.5	17.9	.....	.....	.....
1228.....	Zn 5.1, Sn 5.0, Pb 4.9.....	do.....	.....	.....	17.8	18.1	18.5	18.9	19.3	.....
1229 ^d	Zn 9.70, Fe 0.03, Pb 0.01.....	do.....	.....	.....	17.4	17.9	18.3	.....	.....	.....
1230.....	Zn 19.25, Pb 3.33, Sn 3.51, Ni 0.10, Fe 0.09.	do.....	.....	.....	17.9	18.4	19.0	19.6	20.2	.....
1231 ^c	Zn 19.89, Pb 0.05, Fe 0.03.....	do.....	.....	.....	17.8	18.4	19.0	.....	.....	.....
1232 ^a	Cu 62.43, Ni 15.35, Mn 0.10, Fe 0.04, C 0.011, S 0.004, Pb 0.003, Zn rem.	Cast; am.....	.....	.....	15.0	15.6	16.2	16.8	.....	.....
1233.....	Zn 23.0, Al 6.8, Mn 3.8, Fe 2.8, Cu 63.17, Ni 12.33, Mn 0.13, Fe 0.04, C 0.003, Si 0.007, Pb 0.005, S 0.003, Zn rem.	Cast.....	.....	.....	17.8	18.8	20.9	.....	.....	.....
1234 ^a	Cu 62.62, Ni 16.05, Mn 0.13, Fe 0.04, Si 0.009, C 0.007, Pb 0.005, S 0.003, Zn rem.	Cast; am.....	.....	.....	14.8	15.4	16.2	16.8	.....	.....
1235 ^a	Zn 28.....	do.....	.....	.....	15.0	15.8	16.4	17.0	.....	.....
1236.....	Zn 34.....	do.....	.....	.....	17.8	18.5	19.1	19.8	20.5	.....
1237.....	Zn 37.67, Al 1.08, Sn 0.90, Fe 0.69, Mn 0.36.	Rollled; am.....	.....	.....	19.5	20.0	20.5	21.1	21.6	.....
1238.....	Fe 0.69, Mn 0.36.	Cast.....	.....	.....	20.0	20.4	20.8	21.6	22.7	.....
1239 ^a	Zn 38.86, Sn 0.71, Pb 0.20, Fe 0.02.	Hot-rolled.....	.....	.....	20.7	21.3	21.9	22.7	26.6	.....
1240.....	Cu 56.46, Pb 0.73, Fe 0.105, Sn 0.043, P 0.038, S 0.027, Zn rem.	Slowly cooled from 580°C.....	.....	.....	20.2	21.4	22.3	24.0	25.6	.....

^aBase temperature 0°C instead of 20°C. ^bBase temperature 25°C instead of 20°C. ^c0° to 40°C. ^dBase temperature 30°C instead of 20°C.

TABLE 16.—Copper and copper alloys, electrical and thermal properties

Serial number	Composition	Condition	Electrical properties			Thermal properties		Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity	Conductivity	Temperature coefficient of conductivity	
PURE AND COMMERCIAL COPPER (SEE ALSO FIGS. 69, 70 AND 71)								
	Percent		Percent IACS	Microhm cm	per °C × 10 ⁻⁴	Watts cm ⁻¹ °C ⁻¹		
1241....	Cu 99.999.....	Annealed at 500°C and rapidly quenched	103.06 (20°C)	1.6700 (20°C)	.....	.....	per °C × 10 ⁻⁴	[81]
1242....	O ₂ 0.022, Fe 0.0016, S 0.0015.....	1 hr at 550°C, a-c.....	{ 101.66 (20°C) 58.90 (200°C)	{ 1.666 (20°C) 2.927 (200°C)	{ 39.2 (20°-200°C)	{ 3.94 (20°C) 3.91 (200°C)	{ -0.40 (20°-200°C)	[205]
1243....	Cu 99.94, P 0.042, Fe 0.004.....	Rod, 7/8 in. diam, cold-rolled; 1 hr at 650°C, a-c.....	74.72 (20°C)	2.307 (20°C)	.....	{ 3.04 (20°C) 3.31 (200°C)	{ 4.9 (20°-200°C)	[206]
1244....	do.....	.....	48.93 (200°C)	3.524 (200°C)	22.0 (20°-200°C)	.....	.....	[205]
1245....	Oxygen-free copper: Co 0.05.....	Wire, 0.081 in. diam; annealed at 500°C in hydrogen, quenched.....	85.0	2.028	.....	.....	.....	[207]
1246....	Oxygen-free copper: Fe 0.05.....	do.....	78.2	2.203	.....	.....	.....	[207]
1247....	Oxygen-free copper: Ni 0.05.....	do.....	98.2	1.756	.....	.....	.....	[207]
COPPER-ALUMINUM ALLOYS								
1248....	Al 0.47, Fe 0.02.....	Rolled, annealed 2 hr at 750°C.....	{ 55.3 (20°C) 39.5 (200°C)	{ 3.12 (20°C) 4.36 (200°C)	{ 22.2 (20°-200°C)	{ 2.35 (20°C) 2.61 (200°C)	{ 6.1 (20°-200°C)	[205]
1249....	Al 1.....	.....	37 (20°C)	4.7 (20°C)	.....	.....	.....	[208]
1250....	Al 1.89, Fe 0.03.....	Rolled, annealed at 700°C.....	{ 27.4 (20°C) 22.4 (200°C)	{ 6.28 (20°C) 7.69 (200°C)	{ 12.4 (20°-200°C)	{ 1.23 (20°C) 1.54 (200°C)	{ 14.4 (20°-200°C)	[205]
1251....	Al 2.....	.....	24 (20°C)	7.2 (20°C)	.....	.....	.....	[208]
1252....	Al 2, Sn 1.8.....	.....	18 (20°C)	9.6 (20°C)	.....	.....	.....	[208]
1253....	Al 3.....	.....	19 (20°C)	9.1 (20°C)	.....	.....	.....	[208]
1254....	Al 3, Sn 1.8.....	.....	15 (20°C)	11.5 (20°C)	.....	.....	.....	[208]
1255....	Al 5.10.....	Chill-cast.....	.....	.....	.....	1.07 (60°-270°C)	.....	[76]
1256....	Al 5.11, Ni 4.98, Si 0.74, Fe 0.08.....	Rod, 7/8 in. diam, cold-drawn; 4 hr at 850°C, quenched.....	{ 8.8 (20°C) 8.2 (200°C)	{ 19.5 (20°C) 21.0 (200°C)	{ 4.42 (20°-200°C)	{ 0.45 (20°C) 0.66 (200°C)	{ 26.5 (20°-200°C)	[205]
1257....	do.....	Rod, 7/8 in. diam, cold-drawn; 4 hr at 850°C, quenched, 2 hr at 500°C, a-c.....	{ 12.2 (20°C) 11.0 (200°C)	{ 14.1 (20°C) 15.7 (200°C)	{ 6.17 (20°-200°C)	{ .57 (20°C) .79 (200°C)	{ 22.2 (20°-200°C)	[205]
1258....	Al 6, Mn 6.....	Wire, 0.02 in. diam, cold-drawn (75% red.).....	5.1 (25°C)	34 (25°C)	.....	.....	.....	[209]
1259....	do.....	Wire, 0.02 in. diam, cold-drawn (75% red.); 18 hr at 140°C.....	.....	.....	^a 0.57 (20°-30°C)	.....	.....	[209]
1260....	Al 7.72, Fe 0.13.....	Rolled; 3 1/2 hr at 750°C, f-c.....	{ 15.2 (20°C) 13.2 (200°C)	{ 11.3 (20°C) 13.1 (200°C)	{ 8.55 (20°-200°C)	{ .72 (20°C) .94 (200°C)	{ 16.4 (20°-200°C)	[205]
1261....	Al 8, Mn 4.....	Wire, 0.02 in. diam, cold-drawn (75% red.).....	6.0 (25°C)	29 (25°C)	.....	.....	.....	[209]
1262....	do.....	Wire, 0.02 in. diam, cold-drawn (75% red.); 18 hr at 140°C.....	.....	.....	^a 1.51 (20°-30°C)	.....	.....	[209]
1263....	Al 9.41, Fe 0.52, Sn 0.38, Ni 0.31.....	Rod, 7/8 in. diam, cold-drawn; 3 1/2 hr at 750°C, very slowly cooled.....	{ 12.6 (20°C) 11.0 (200°C)	{ 13.7 (20°C) 15.7 (200°C)	{ 8.29 (20°-200°C)	{ .60 (20°C) .80 (200°C)	{ 18.5 (20°-200°C)	[205]
1264....	Al 9.77, Ni 3.71, Fe 2.96, Mn 1.95.....	Cast.....	.....	.....	.....	{ .34 (100°C) .53 (400°C)	{	[210]
1265....	Al 9.97, Mn 2.77.....	do.....	.....	.....	.....	{ .59 (100°C) .80 (400°C)	{	[210]
1266....	Al 10.....	do.....	12.5 (20°C)	13.8 (20°C)	.....	.....	.....	[97]

^aThis value is alpha of the general equation, $P_t = P_{2\theta} [1 + \alpha (t - 25)]$.

^aThis value is alpha of the general equation, $R_t = R_{25} [1 + \alpha (t - 25)]$.

TABLE 16.—Copper and copper alloys. *Electrical and thermal properties—Continued*

Serial number	Composition	Condition	Electrical properties			Thermal properties		Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity	Conductivity	Temperature coefficient of conductivity	
COPPER-ALUMINUM ALLOYS—Continued								
1267....	Al 12.15, Fe 0.08..... Percent	Rollled; 2 hr at 750°C, very slowly cooled.	$\frac{10^9 \text{ ohm}^{-1} \text{ cm}^{-1}}{11.9 (20^\circ\text{C})}$ { 14.9 (200°C)	$\frac{10^9 \text{ ohm cm}}{14.4 (20^\circ\text{C})}$ 17.4 (200°C)	$\frac{10^{-4}}{11.5 (20^\circ\text{C})}$ { 11.5 (20°-200°C)	$\frac{10^{12} \text{ ohm}^{-1} \text{ cm}^{-1}}{14.0 (20^\circ\text{C})}$ { 14.0 (20°-200°C)	[205]	
1268....	Al 12.78.....	Chill-cast.....	.....	.....	.....	.71 (50°-270°C)	[78]	
COPPER-ARSENIC ALLOYS								
1269....	As 0.114.....	Chill-cast.....	.....	.....	.....	2.11 (60°-270°C)	[78]	
1270....	As 0.185.....	do.....	.....	.....	.....	1.22 (60°-270°C)	[78]	
COPPER-BERYLLIUM ALLOYS								
1271....	Be 1.52.....	Cast; quenched from 845°C, 18 hr at 315°C.	36.1	1.78	.....	.....	[211]	
1272....	Be 1.92, Zr 1.36, Fe 0.109.....	Cast.....	18.1	9.33	.....	.....	[211]	
1273....	do.....	Cast; quenched from 815°C.....	15.8	10.9	.....	.....	[211]	
1274....	do.....	Cast; quenched from 815°C, 48 hr at 345°C.	30.5	5.05	.....	.....	[211]	
1275....	Be 2.00-2.25, Ni 0.25-0.50.....	Quenched from 840°C.....	17	10.1	.....	.....	[212]	
1276....	do.....	Quenched from 840°C; tempered at 250°-300°C.	18-25	6.9-9.6	.....	.....	[212]	
1277....	do.....	Quenched from 840°C, rolled (37% red.).	17	10.1	.....	.....	[212]	
1278....	do.....	Quenched from 840°C, rolled (57% red.), tempered at 250°-300°C.	30	5.8	.....	.....	[212]	
1279....	Be 2.04.....	Cast.....	22.0	7.84	.....	.....	[211]	
1280....	do.....	Cast; quenched from 800°C.....	11.5	8.84	.....	.....	[211]	
1281....	do.....	Cast; quenched from 800°C, 5 hr at 370°C.	32.8	5.29	.....	.....	[211]	
1282....	Be 2.24, Ni 0.27, Fe 0.06.....	Rod, 7/8 in. diam, cold-drawn; 1/2 hr at 815°C, quenched.	{ 19.2 (20°C) 14.5 (200°C)	{ 8.96 (20°C) 11.6 (200°C)	{ 10.6 (20°-200°C) 12.7 (20°-200°C)	{ 0.46 (20°C) 1.04 (200°C)	{ 11.9 (20°-200°C) 8.0 (20°-200°C)	{ [205] [205]
1283....	do.....	Rod, 7/8 in. diam, cold-drawn; 1/2 hr at 815°C, quenched, 2 hr at 300°C, a-c.	{ 22.0 (20°C) 11.4 (200°C)	{ 7.84 (20°C) 9.61 (200°C)	{ 12.7 (20°-200°C) 9.34 (20°-200°C)	{ 1.03 (20°C) 1.17 (200°C)	{ 12.5 (20°-200°C) 13.4 (20°-200°C)	{ [205] [205]
1284....	do.....	Rod, 1/2 in. at 815°C, quenched, cold-drawn.	{ 15.7 (20°C) 11.1 (200°C)	{ 10.3 (20°C) 12.2 (200°C)	{ 9.75 (20°-200°C) 9.34 (20°-200°C)	{ 0.71 (20°C) 1.83 (200°C)	{ 13.4 (20°-200°C) 12.5 (20°-200°C)	{ [205] [205]
1285....	do.....	Rod, 1/2 in. at 815°C, quenched, cold-drawn; 2 hr at 275°C, a-c.	{ 18.0 (20°C) 15.4 (200°C)	{ 9.58 (20°C) 11.2 (200°C)	{ 9.34 (20°-200°C) 9.34 (20°-200°C)	{ 1.82 (20°C) 1.06 (200°C)	{ 12.5 (20°-200°C) 13.4 (20°-200°C)	{ [205] [205]
1286....	Be 2.5.....	Quenched from 750°C.....	17	10.1	.....	.....	[212]	
1287....	do.....	Quenched from 750°C, b-c.....	42	5.4	.....	.....	[212]	
COPPER-CADMIUM ALLOYS								
1288....	Cd 0.61, Cu 0.02.....	Wire, 0.050 in. diam, hard-drawn.....	90.1	1.91	.....	.....	[213]	
1289....	do.....	Wire, 0.050 in. diam, 2 hr at 500°C.....	98.2	1.76	.....	.....	[213]	
1290....	Cd 0.85, Si 0.009, Fe 0.007.....	Rod, 7/8 in. diam, cold-drawn; 2 hr at 700°C, a-c.	{ 87.2 (20°C) 81.8 (200°C)	{ 1.98 (20°C) 3.21 (200°C)	{ 94.5 (20°-200°C) 94.5 (20°-200°C)	{ 3.45 (20°C) 1.52 (200°C)	{ 1.2 (20°-200°C) 7.2 (20°-200°C)	{ [205] [205]
1291....	Cd 0.80, Fe 0.07.....	Rod, 7/8 in. diam, cold-drawn; 1 1/2 hr at 750°C, a-c.	{ 67.0 (20°C) 45.8 (200°C)	{ 2.57 (20°C) 3.76 (200°C)	{ 25.7 (20°-200°C) 25.7 (20°-200°C)	{ 2.76 (20°C) 3.11 (200°C)	{ 7.2 (20°-200°C) 7.2 (20°-200°C)	{ [205] [205]

1292....	Cd 1.07, Sn 0.59, Fe 0.02, Si 0.02.....	do.....	{ 56.4 (20°C) 40.2 (200°C)	3.05 (20°C) 1.29 (200°C)	{ 22.4 (20°-200°C)	{ 2.33 (20°C) 2.69 (200°C)	} 8.7 (20°-200°C)	[205]
1293....	Cd 1.30, O ₂ 0.025, Mn 0.003.....	Wire, 0.064 in. diam, hard-drawn.....	81.5	2.01	.....	.....	.....	[213]
1294....	do.....	Wire, 0.064 in. diam, 2 hr at 300°C.....	91.0	1.83	.....	.....	.....	[213]
COPPER-CHROMIUM ALLOYS								
1295....	Cr 0.31, Ag 0.103.....	Heat-treated.....	96	1.80	.....	.....	.....	[211]
1296....	Cr 0.38, Be 0.08.....	Rod, 1 1/4 in. diam, cast; 1 hr at 900°C, w-q.	47.4	3.61	.....	.....	.....	[119]
1297....	do.....	Rod, 1 1/4 in. diam, cast; 1 hr at 900°C, w-q.	69.0	2.50	.....	.....	.....	[115]
1298....	Cr 0.49, Ag 0.401.....	do.....	91	1.89	.....	.....	.....	[211]
COPPER-COBALT ALLOY								
1299....	Co 2.6, Be 0.1.....	Rod, 1 in. diam, cast; 1 hr at 900°C, w-q.	19.6	8.80	.....	.....	.....	[116]
1300....	do.....	Rod, 1 in. diam, cast; 1 hr at 900°C, w-q, 3 hr at 300°C.	48	3.6	.....	.....	.....	[119]
COPPER-IRON ALLOYS								
1301....	Fe 0.20.....	Quenched from 650°C.....	.....	.....	.....	.....	.....	[78]
1302....	do.....	Quenched from 1,000°C.....	.....	.....	.....	2.98 (60°-270°C)	.....	[78]
1303....	Fe 1.07.....	Quenched from 650°C.....	.....	.....	.....	2.94 (60°-270°C)	.....	[78]
1304....	do.....	Quenched from 1,000°C.....	.....	.....	.....	2.89 (60°-270°C)	.....	[78]
1305....	Fe 18.69, Mn 0.471, Si 0.047, C 0.023....	Rod, 7/8 in. diam, cold-drawn; 1 1/2 hr at 800°C, very slowly cooled.	{ 21.2 (20°C) 15.5 (200°C)	8.11 (20°C) 11.1 (200°C)	{ 20.7 (20°-200°C)	{ 0.99 (20°C) 1.13 (200°C)	} 9.1 (20°-200°C)	[205]
COPPER-LEAD ALLOY								
1306....	Pb 13.32, Sn 8.04, Ni 0.20, P 0.10.....	Sand-cast.....	{ 9.8 (20°C) 8.5 (200°C)	17.5 (20°C) 20.3 (200°C)	{ 8.86 (20°-200°C)	{ 0.12 (20°C) 0.61 (200°C)	} 21.7 (20°-200°C)	[205]
COPPER-MANGANESE ALLOYS								
1307....	Mn 0.43, Fe 0.01, Mg 0.01.....	Hot-rolled; 2 hr at 700°C.....	{ 51.0 (20°C) 37.9 (200°C)	3.38 (20°C) 4.34 (200°C)	{ 19.0 (20°-200°C)	{ 2.26 (20°C) 2.56 (200°C)	} 7.4 (20°-200°C)	[205]
1308....	Mn 4.55, Fe 0.06, Mg 0.02.....	do.....	{ 9.6 (20°C) 8.4 (200°C)	17.9 (20°C) 18.4 (200°C)	{ 1.40 (20°-200°C)	{ 0.49 (20°C) 0.69 (200°C)	} 22.4 (20°-200°C)	[205]
1309....	Mn 6, Al 3.....	Wire, 0.02 in. diam, cold-drawn (75% red.).....	6.0 (25°C)	29 (25°C)	.....	.....	.....	[209]
1310....	do.....	Wire, 0.02 in. diam, cold-drawn (75% red.); 18 hr at 140°C.	.....	.....	.....	.....	.....	[205]
1311....	w, 10.....	Wire, 0.02 in. diam, cold-drawn (75% red.).....	.....	.....	.....	.....	.....	[209]
1312....	do.....	Wire, 0.02 in. diam, cold-drawn (75% red.); 18 hr at 140°C.	.....	.....	.....	.....	.....	[209]
1313....	Mn 14, Al 2.....	Wire, 0.02 in. diam, cold-drawn (75% red.).....	.....	.....	.....	.....	.....	[209]
1314....	do.....	Wire, 0.02 in. diam, cold-drawn (75% red.); 18 hr at 140°C.	.....	.....	.....	.....	.....	[209]
1315....	Mn 15.....	Wire, 0.02 in. diam, cold-drawn (75% red.).....	.....	.....	.....	.....	.....	[209]
1316....	do.....	Wire, 0.02 in. diam, cold-drawn (75% red.); 18 hr at 140°C.	.....	.....	.....	.....	.....	[209]
1317....	Mn 19.82, Fe 0.09, C 0.035, Mg 0.02.....	Hot-rolled; 2 hr at 700°C.....	{ 2.5 (20°C) 2.5 (200°C)	68.8 (20°C) 67.8 (200°C)	{ -0.80 (20°-200°C)	{ 0.15 (20°C) 0.22 (200°C)	} 24.7 (20°-200°C)	[205]
1318....	Mn 32.....	Quenched.....	1.6	105	.....	.....	.....	[215]

^a This value is alpha of the general equation, $R_t = R_{25} [1 + \alpha (t - 25)]$.

TABLE 16.—Copper and copper alloys, electrical and thermal properties—Continued

Serial number	Composition	Condition	Electrical properties			Thermal properties			Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity	Conductivity	Temperature coefficient of conductivity		
COPPER-NICKEL ALLOYS									
1319....	Ni 1.97, Mg 0.04, Fe 0.02.....	Cold-rolled; 1 hr at 800°C.....	Percent IACS { 34.2 (20°C) 30.3 (200°C)	Microhm cm 1.40 (20°C) 5.69 (200°C)	per °C x 10 ⁻⁴ { 16.1 (20°-200°C) 3.84 (20°-200°C)	watts cm ⁻¹ °C ⁻¹ { 1.72 (20°C) 2.01 (200°C)	per °C x 10 ⁻⁴ { 9.6 (20°-200°C) 23.0 (20°-200°C)	[205]	
1320....	Ni 3.01, Si 0.88, Fe 0.01.....	Rod, 7/8 in. diam, cold rolled; 3 hr at 870°C, quenched.	{ 16.8 (20°C) 15.8 (200°C)	10.2 (20°C) 10.9 (200°C)	3.84 (20°-200°C)	{ 0.76 (20°C) 1.07 (200°C)	{ 23.0 (20°-200°C) 11.6 (20°-200°C)	[205]	
1321....	...do.....	Rod, 7/8 in. diam, cold-rolled; 3 hr at 870°C, f-c.	{ 19.0 (20°C) 29.9 (200°C)	4.42 (20°C) 5.77 (200°C)	16.8 (20°-200°C)	{ 1.69 (20°C) 2.04 (200°C)	{ 11.6 (20°-200°C) 13.8 (20°-200°C)	[205]	
1322....	Ni 5.09, Mg 0.03, Fe 0.01.....	Rod, cold-rolled; 1 hr at 800°C.....	{ 21.4 (20°C) 18.3 (200°C)	8.07 (20°C) 9.40 (200°C)	9.12 (20°-200°C)	{ 1.00 (20°C) 1.21 (200°C)	{ 13.8 (20°-200°C) 16.1 (20°-200°C)	[205]	
1323....	Ni 5.14, Sn 1.96, Zn 1.65.....	Cast.....	.....	.....	.....	{ 0.46 (100°C) 0.62 (100°C)	.....	[210]	
1324....	Ni 15.....	.....	8.8 (20°C)	19.6 (20°C)	3.44 (20°C)	{ 0.17 (20°C) 0.60 (200°C)	{ 16.1 (20°-200°C)	[216]	
1325....	Ni 16.06, Sn 9.67, Zn 0.99.....	Cast.....	.....	.....	.....	{ 0.36 (100°C) 0.50 (100°C)	.....	[210]	
1326....	Ni 18.38, Zn 17.06, Mn 0.30, Fe 0.19, C 0.023.	Rod, 7/8 in. diam, cold-drawn; 1/2 hr at 750°C, a-c.	{ 5.8 (20°C) 5.6 (200°C)	29.1 (20°C) 30.8 (200°C)	2.57 (20°-200°C)	{ 0.33 (20°C) 0.42 (200°C)	{ 14.2 (20°-200°C) 16.3 (20°-200°C)	[205]	
1327....	Ni 19.79, Mn 0.30, Fe 0.23.....	Rod, cold-rolled; annealed at 800°C.....	{ 6.5 (20°C) 6.2 (200°C)	26.6 (20°C) 27.8 (200°C)	2.37 (20°-200°C)	{ 0.36 (20°C) 0.47 (200°C)	{ 16.3 (20°-200°C) 18.1 (20°-200°C)	[205]	
1328....	Ni 19.89, Zn 8.22, Pb 5.40, Sn 3.31, Mn 0.23, Fe 0.14.	Semi-cast.....	{ 5.0 (20°C) 4.7 (200°C)	34.3 (20°C) 36.5 (200°C)	3.50 (20°-200°C)	{ 0.28 (20°C) 0.37 (200°C)	{ 18.1 (20°-200°C) 14.3 (20°-200°C)	[205]	
1329....	Ni 29.44, Zn 5.69, Mn 0.52, Fe 0.07.....	Rod, 7/8 in. diam, cold-drawn; annealed at 750°C.	{ 4.6 (20°C) 4.4 (200°C)	37.8 (20°C) 38.7 (200°C)	1.28 (20°-200°C)	{ 0.28 (20°C) 0.36 (200°C)	{ 14.3 (20°-200°C) 15.6 (20°-200°C)	[205]	
1330....	Ni 30.23, Mn 0.13, Fe 0.05, Mg 0.05.....	Rod, cold-rolled; 1 hr at 800°C.....	{ 4.8 (20°C) 4.7 (200°C)	36.3 (20°C) 36.6 (200°C)	0.48 (20°-200°C)	{ 0.29 (20°C) 0.37 (200°C)	{ 15.6 (20°-200°C)	[205]	
1331....	Ni 4.....	.....	3.6	48	.....	{ 0.23 (85°C) 0.23 (129°C) 0.26 (437°C)	.....	[217]	
1332....	Constantan; Ni 45.....	.....	3.5 (20°-100°C)	19 (20°-100°C)	.....	0.23 (20°-100°C)	.....	[218]	
CUPPER-PHOSPHORUS ALLOYS									
1333....	P 0.135.....	Chill-cast.....	.....	.....	.....	2.11 (60°-270°C)	.....	[78]	
1334....	P 0.406.....	...do.....	.....	.....	.....	1.22 (60°-270°C)	.....	[78]	
1335....	P 0.480, Fe 0.05.....	Rod, 7/8 in. diam, cold-rolled; 1 hr at 650°C, a-c.	20.4 (20°C)	8.44 (20°C)	.....	{ 0.90 (20°C) 1.25 (200°C)	{ 21.4 (20°-200°C)	[206]	
1336....	...do.....	...do.....	17.7 (200°C)	9.73 (200°C)	8.43 (20°-200°C)	.....	.....	[205]	
1337....	P 0.800, Fe 0.06.....	...do.....	11.3 (20°C)	15.3 (20°C)	.....	{ 0.54 (20°C) 0.74 (200°C)	{ 21.1 (20°-200°C)	[206]	
1338....	...do.....	...do.....	10.4 (200°C)	16.7 (200°C)	5.03 (20°-200°C)	.....	.....	[205]	

COPPER-SILICON ALLOYS

1339...	Si 0.19, Fe 0.02.....	Red, 7/8 in. diam, cold-drawn; 2 hr at 700°C.	51.0 (20°C) 36.7 (200°C)	3.38 (20°C) 1.70 (200°C)	21.5 (20°-200°C)	2.13 (20°C) 2.18 (200°C)	8.9 (20°-200°C)	[205]
1340...	Si 1.50, Mn 0.30, Fe 0.06.....	..do.....	11.4 (20°C) 10.1 (200°C)	15.1 (20°C) 16.6 (200°C)	5.30 (20°-200°C)	0.51 (20°C) 0.73 (200°C)	30.0 (20°-200°C)	[205]
1341...	Si 2, Sn 1.8.....	..do.....	8 (20°C)	21.6 (20°C)	.....	.....	.....	[205]
1342...	Si 3.11, Zn 1.12, Fe 0.02.....	Red, 7/8 in. diam, cold-drawn; 2 hr at 700°C, a.c.	7.9 (20°C) 7.3 (200°C)	21.8 (20°C) 23.6 (200°C)	1.69 (20°-200°C)	0.37 (20°C) 0.52 (200°C)	22.0 (20°-200°C)	[205]
1343...	Si 3.91, Fe 0.02.....	Red, 7/8 in. diam, cold-drawn; ann at 700°C.	6.8 (20°C) 6.3 (200°C)	25.3 (20°C) 27.4 (200°C)	4.38 (20°-200°C)	0.34 (20°C) 0.47 (200°C)	30.6 (20°-200°C)	[205]
1344...	Si 4.68, Mn 1.03, Fe 0.08.....	Sand-cast.....	4.9 (20°C) 4.6 (200°C)	35.1 (20°C) 37.1 (200°C)	3.07 (20°-200°C)	0.25 (20°C) 0.56 (200°C)	33.9 (20°-200°C)	[205]

COPPER-SILVER ALLOYS

1345...	Ag 1.52, Cr 0.75.....		80	2.16				[211]
---------	-----------------------	-------	----	------	-------	-------	-------	-------

COPPER-TIN ALLOYS

1346...	Sn 0.99, Fe 0.01, P 0.002.....	Red, 7/8 in. diam, cold-rolled; 1/2 hr at 650°C, slowly cooled.	54.1 (20°C)	3.19 (20°C)	.....	2.27 (20°C) 2.36 (200°C)	7.5 (20°-200°C)	[206]
1347...	..do.....	..do.....	38.8 (200°C)	4.44 (200°C)	21.8 (20°-200°C)	.....	.....	[205]
1348...	Sn 1.....	..do.....	51 (20°C)	3.4 (20°C)	.....	.....	.....	[208]
1349...	Sn 1.60, Si 0.90.....	Wrought.....	13 (20°C)	13.3 (20°C)	.....	.....	.....	[219]
1350...	Sn 1.8, Al 1.....	..do.....	24 (20°C)	7.2 (20°C)	.....	.....	.....	[205]
1351...	Sn 1.92, Fe 0.01, P 0.01.....	Red, 7/8 in. diam, cold-rolled; 1/2 hr at 650°C, slowly cooled.	36.5 (20°C)	4.73 (20°C)	.....	1.65 (20°C) 2.01 (200°C)	12.1 (20°-200°C)	[206]
1352...	..do.....	..do.....	28.7 (200°C)	6.00 (200°C)	14.9 (20°-200°C)	.....	.....	[205]
1353...	Sn 2.....	..do.....	35 (20°C)	4.9 (20°C)	.....	.....	.....	[208]
1354...	Sn 3.....	..do.....	21 (20°C)	8.2 (20°C)	.....	.....	.....	[206]
1355...	Sn 4.18, P 0.33, Pb 0.04, Fe 0.01.....	Wrought.....	12.6 (20°C)	13.7 (20°C)	.....	0.63 (20°C) 0.82 (200°C)	17.1 (20°-200°C)	[206]
1356...	..do.....	..do.....	11.4 (200°C)	15.1 (200°C)	5.40 (20°-200°C)	.....	.....	[205]
1357...	Sn 1.92, F 0.06, Fe 0.05, Pb 0.01.....	..do.....	18.4 (20°C)	9.3 (20°C)	.....	0.82 (20°C) 1.10 (200°C)	19.7 (20°-200°C)	[206]
1358...	..do.....	..do.....	16.0 (200°C)	10.8 (200°C)	8.22 (20°-200°C)	.....	.....	[205]
1359...	Sn 7.48, P 0.04, Fe 0.02, Pb 0.01.....	..do.....	13.6 (20°C)	12.7 (20°C)	.....	0.64 (20°C) 0.87 (200°C)	20.1 (20°-200°C)	[206]
1360...	..do.....	..do.....	12.2 (200°C)	14.1 (200°C)	6.37 (20°-200°C)	.....	.....	[205]
1361...	Sn 8.87, Zn 3.05, Fe 0.03.....	Sand-cast.....	11.6 (20°C) 10.3 (200°C)	14.8 (20°C) 16.7 (200°C)	7.11 (20°-200°C)	0.54 (20°C) 0.72 (200°C)	18.1 (20°-200°C)	[205]
1362...	Sn 10.40, Fe 0.05, P 0.03, Pb 0.01.....	Wrought.....	11.1 (20°C)	15.5 (20°C)	.....	0.51 (20°C) 0.72 (200°C)	23.0 (20°-200°C)	[206]
1363...	..do.....	..do.....	10.0 (200°C)	17.2 (200°C)	5.81 (20°-200°C)	.....	.....	[205]
1364...	Sn 14.35.....	Cast, fully am.....	9.0 (0°C)	19.1 (0°C)	5.11 (0°-100°C)	.....	.....	[220]
1365...	Sn 20.49.....	..do.....	7.0 (0°C)	21.6 (0°C)	6.20 (0°-100°C)	.....	.....	[220]
1366...	Sn 32.36.....	..do.....	3.8 (0°C)	15.9 (0°C)	5.93 (0°-100°C)	.....	.....	[220]
1367...	Sn 38.77.....	..do.....	20.0 (0°C)	8.60 (0°C)	35.8 (0°-100°C)	.....	.....	[220]
1368...	Sn 46.60.....	..do.....	17.7 (0°C)	9.73 (0°C)	33.9 (0°-100°C)	.....	.....	[220]

TABLE 16.—Copper and copper alloys, electrical and thermal properties—Continued

Serial number	Composition	Condition	Electrical properties			Thermal properties			Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity	Conductivity	Temperature coefficient of conductivity		
COPPER-ZINC ALLOYS									
1369....	Zn 0.35, Fe 0.02, Pb 0.01.....	Wrought; 1 hr at 700°C, a-c.....	Percent IACS 95.3 (20°C)	Microhm cm 1.81 (20°C)	per °C. × 10 ⁻⁴	katts cm ⁻¹ °C ⁻¹ { 3.70 (20°C) 3.72 (200°C)	per °C. × 10 ⁻⁴ { 0.38 (20°-200°C)	[221]	
1370....	do.....	do.....	57.0 (200°C)	3.02 (200°C)	37.2 (20°-200°C)	.....	.....	[205]	
1371....	Zn 0.95, Fe 0.02.....	Wrought; 1 hr at 700°C, a-c.....	82.2 (20°C)	2.10 (20°C)	.....	{ 3.31 (20°C) 3.44 (200°C)	{ 2.10 (20°-200°C)	[221]	
1372....	do.....	do.....	52.0 (200°C)	3.32 (200°C)	32.4 (20°-200°C)	.....	.....	[205]	
1373....	Zn 3.04, Fe 0.02.....	Rod, 7/8 in. diam, cold-drawn; 3/4 hr at 700°C, a-c.....	{ 33.1 (20°C) 33.5 (200°C)	{ 2.73 (20°C) 3.37 (200°C)	{ 25.0 (20°-200°C)	{ 2.65 (20°C) 2.89 (200°C)	{ 4.3 (20°-200°C)	[205]	
1374....	Zn 1.09, Pb 3.80, Sn 3.76, P 0.25, Fe 0.02.....	Rod, 7/8 in. diam, cold-drawn; 2 hr at 700°C, a-c.....	{ 12.2 (20°C) 10.9 (200°C)	{ 11.1 (20°C) 15.9 (200°C)	{ 6.82 (20°-200°C)	{ 0.56 (20°C) 0.76 (200°C)	{ 20.6 (20°-200°C)	[205]	
1375....	Zn 1.77, Fe 0.02.....	Rod, 7/8 in. diam, cold-drawn; 3/4 hr at 700°C, a-c.....	{ 57.0 (20°C) 40.2 (200°C)	{ 3.02 (20°C) 4.29 (200°C)	{ 23.1 (20°-200°C)	{ 2.42 (20°C) 2.72 (200°C)	{ 6.8 (20°-200°C)	[205]	
1376....	Zn 5, Sn 5, Pb 5.....	Sand-cast from 1,150°C.....	16.7	10.3	.....	.....	.....	[222]	
1377....	Zn 5, Sn 5, Pb 5, Al 0.10.....	do.....	13.2	13.1	.....	.....	.....	[222]	
1378....	Zn 5, Sn 5, Pb 5, Sb 0.25.....	do.....	16.0	10.8	.....	.....	.....	[222]	
1379....	Zn 9.51, Pb 1.32, Fe 0.02.....	Wrought; 1/2 hr at 575°C, a-c.....	42.3 (20°C)	4.08 (20°C)	.....	{ 1.81 (20°C) 2.14 (200°C)	{ 10.2 (20°-200°C)	[221]	
1380....	do.....	do.....	31.7 (200°C)	5.43 (200°C)	18.4 (20°-200°C)	.....	.....	[205]	
1381....	Zn 12.97, Pb 1.88, Fe 0.05.....	Rod, 7/8 in. diam, cold-drawn; 2 hr at 700°C, a-c.....	{ 35.6 (20°C) 27.2 (200°C)	{ 4.84 (20°C) 6.33 (200°C)	{ 17.0 (20°-200°C)	{ 1.60 (20°C) 1.86 (200°C)	{ 8.8 (20°-200°C)	[205]	
1382....	Zn 14.21, Si 1.00, Mn 0.20, Fe 0.04.....	Chill-cast.....	{ 6.1 (20°C) 5.6 (200°C)	{ 28.4 (20°C) 30.7 (200°C)	{ 4.33 (20°-200°C)	{ 0.28 (20°C) 0.40 (200°C)	{ 22.8 (20°-200°C)	[205]	
1383....	Zn 17.65, Ni 13.24, Pb 10.14, Sn 2.23, Fe 0.10.....	Sand-cast.....	{ 5.9 (20°C) 5.3 (200°C)	{ 29.4 (20°C) 32.4 (200°C)	{ 5.53 (20°-200°C)	{ .31 (20°C) .43 (200°C)	{ 21.8 (20°-200°C)	[205]	
1384....	Zn 17.76, Al 1.44, Mn 3.31, Fe 1.78.....	Rod, 7/8 in. diam, cold-drawn; 3 hr at 650°C, very slowly cooled.....	{ 10.0 (20°C) 9.2 (200°C)	{ 17.2 (20°C) 18.8 (200°C)	{ 5.21 (20°-200°C)	{ .50 (20°C) .68 (200°C)	{ 19.5 (20°-200°C)	[205]	
1385....	Zn 22.22, Al 1.98, Fe 0.01.....	Rod, 7/8 in. diam, cold-drawn; 2 hr at 700°C, a-c.....	{ 22.6 (20°C) 18.2 (200°C)	{ 7.64 (20°C) 9.45 (200°C)	{ 13.1 (20°-200°C)	{ 1.00 (20°C) 1.25 (200°C)	{ 13.3 (20°-200°C)	[205]	
1386....	Zn 23.86, Ni 10.36, Mn 0.18, Fe 0.08, C 0.01.....	Rod, 7/8 in. diam, cold-drawn; 1/2 hr at 750°C, a-c.....	{ 8.5 (20°C) 7.9 (200°C)	{ 20.2 (20°C) 21.8 (200°C)	{ 4.30 (20°-200°C)	{ 0.46 (20°C) .61 (200°C)	{ 18.2 (20°-200°C)	[205]	
1387....	Zn 25.93, Ni 17.95, Mn 0.18, Fe 0.08, C 0.02.....	do.....	{ 5.6 (20°C) 5.3 (200°C)	{ 30.8 (20°C) 32.5 (200°C)	{ 3.06 (20°-200°C)	{ .30 (20°C) .41 (200°C)	{ 21.7 (20°-200°C)	[205]	
1388....	Zn 27.77, Sn 1.02, Fe 0.02.....	Wrought; 3/4 hr at 700°C, a-c.....	24.6 (20°C)	6.99 (20°C)	.....	{ 1.10 (20°C) 1.36 (200°C)	{ 13.3 (20°-200°C)	[221]	
1389....	do.....	do.....	19.8 (200°C)	8.70 (200°C)	13.4 (20°-200°C)	.....	.....	[205]	
1390....	Zn 29.88, Ni 10.13, Mn 0.15, Fe 0.04, Mg 0.04.....	Rod, 7/8 in. diam, cold-drawn; 4 hr at 750°C, a-c.....	{ 8.5 (20°C) 7.8 (200°C)	{ 20.2 (20°C) 22.1 (200°C)	{ 4.95 (20°-200°C)	{ 0.42 (20°C) .57 (200°C)	{ 19.1 (20°-200°C)	[205]	
1391....	Zn 30.50, Ni 5.41, Fe 0.05.....	do.....	{ 12.6 (20°C) 11.1 (200°C)	{ 13.7 (20°C) 15.5 (200°C)	{ 7.21 (20°-200°C)	{ .59 (20°C) .77 (200°C)	{ 17.8 (20°-200°C)	[205]	
1392....	Zn 33.72, Pb 0.03, Fe 0.01.....	Rod, 7/8 in. diam, cold-drawn; 3/4 hr at 650°C, a-c.....	{ 26.9 (20°C) 21.1 (200°C)	{ 6.40 (20°C) 8.17 (200°C)	{ 15.9 (20°-200°C)	{ 1.20 (20°C) 1.46 (200°C)	{ 12.0 (20°-200°C)	[205]	

1393....	Zn 34.53, Pb 0.03, Fe 0.01.....	Wrought; 3/4 hr at 650°C, a-c.....	26.4 (20°C)	6.52 (20°C)	.....	{ 1.20 (20°C) 1.12 (200°C)	{ 10.5 (20°-200°C)	[221]
1394....	...do.....	...do.....	20.7 (200°C)	8.33 (200°C)	15.4 (20°-200°C)	.....	.....	[205]
1395....	Zn 34.79, Pb 3.29, Fe 0.07.....	Rod, 7/8 in. diam, cold-drawn.....	{ 23.8 (20°C) 18.8 (200°C)	7.24 (20°C) 9.15 (200°C)	{ 11.7 (20°-200°C)	{ 1.08 (20°C) 1.33 (200°C)	{ 12.7 (20°-200°C)	[205]
1396....	Zn 37.09, Pb 1.12, Sn 1.03, Al 0.18, Si 0.15, Fe 0.02.....	Chill-cast.....	{ 23.4 (20°C) 17.6 (200°C)	7.38 (20°C) 9.78 (200°C)	{ 18.1 (20°-200°C)	{ 1.00 (20°C) 1.20 (200°C)	{ 10.7 (20°-200°C)	[205]
1397....	Zn 38.36, Fe 1.06, Sn 0.98, Pb 0.13, Mn 0.12.....	Rod, 7/8 in. diam, cold-drawn; 3 hr at 650°C, very slowly cooled.....	{ 23.7 (20°C) 18.2 (200°C)	7.28 (20°C) 9.45 (200°C)	{ 16.5 (20°-200°C)	{ 1.01 (20°C) 1.23 (200°C)	{ 12.4 (20°-200°C)	[205]
1398....	Zn 42.34, Ni 1.02, Fe 0.49.....	Rod, 7/8 in. diam, cold-drawn.....	{ 24.8 (20°C) 18.6 (200°C)	6.94 (20°C) 9.28 (200°C)	{ 18.7 (20°-200°C)	{ 1.14 (20°C) 1.30 (200°C)	{ 7.8 (20°-200°C)	[205]
1399....	Zn 45.02, Fe 0.02.....	Wrought; 2 hr at 650°C, very slowly cooled.....	35.3 (20°C)	1.89 (20°C)	.....	{ 1.49 (20°C) 1.60 (200°C)	{ 3.89 (20°-200°C)	[221]
1400....	...do.....	...do.....	23.3 (200°C)	7.41 (200°C)	28.7 (20°-200°C)	.....	.....	[205]

COPPER-ZIRCONIUM ALLOYS

1401....	Zr 1.45.....	Cast.....	61.1	2.82	.....	.....	.....	[211]
1402....	...do.....	Cast; 2 hr at 900°C, w-q.....	56.7	3.04	.....	.....	.....	[211]
1403....	...do.....	Cast; 2 hr at 900°C, w-q, 24 hr at 455°C.....	75.5	2.28	.....	.....	.....	[211]
1404....	Zr 2.98, Be 1.49, Fe 0.07.....	Cast.....	20.6	8.37	.....	.....	.....	[211]
1405....	...do.....	Cast; quenched from 815°C, 18 hr at 345°C.....	29.1	5.92	.....	.....	.....	[211]
1406....	Zr 3.24.....	Cast.....	44.0	3.92	.....	.....	.....	[211]
1407....	...do.....	Cast; 2 hr at 900°C, w-q.....	41.2	4.18	.....	.....	.....	[211]
1408....	...do.....	Cast; 2 hr at 900°C, w-q, 24 hr at 455°C.....	55.0	3.13	.....	.....	.....	[211]

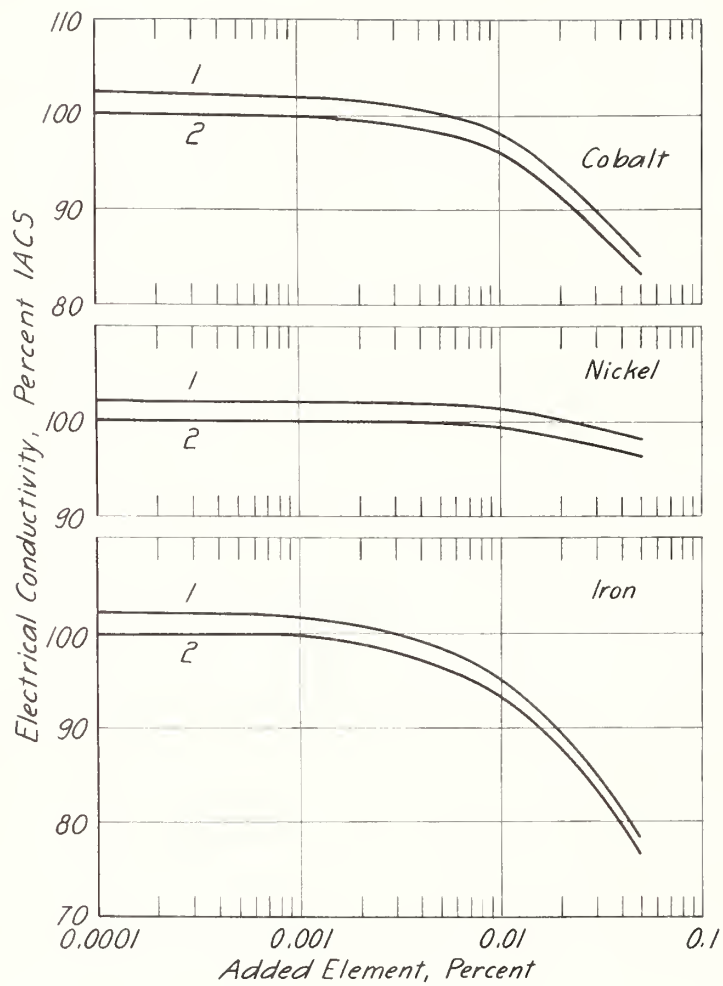


FIGURE 89.—Effect of iron, nickel, and cobalt on the electrical conductivity of high-purity oxygen-free copper (Smart and Smith [207]).

Curves: 1, annealed at 930°F; 2, annealed at 1,110°F and cold-drawn (75% red).

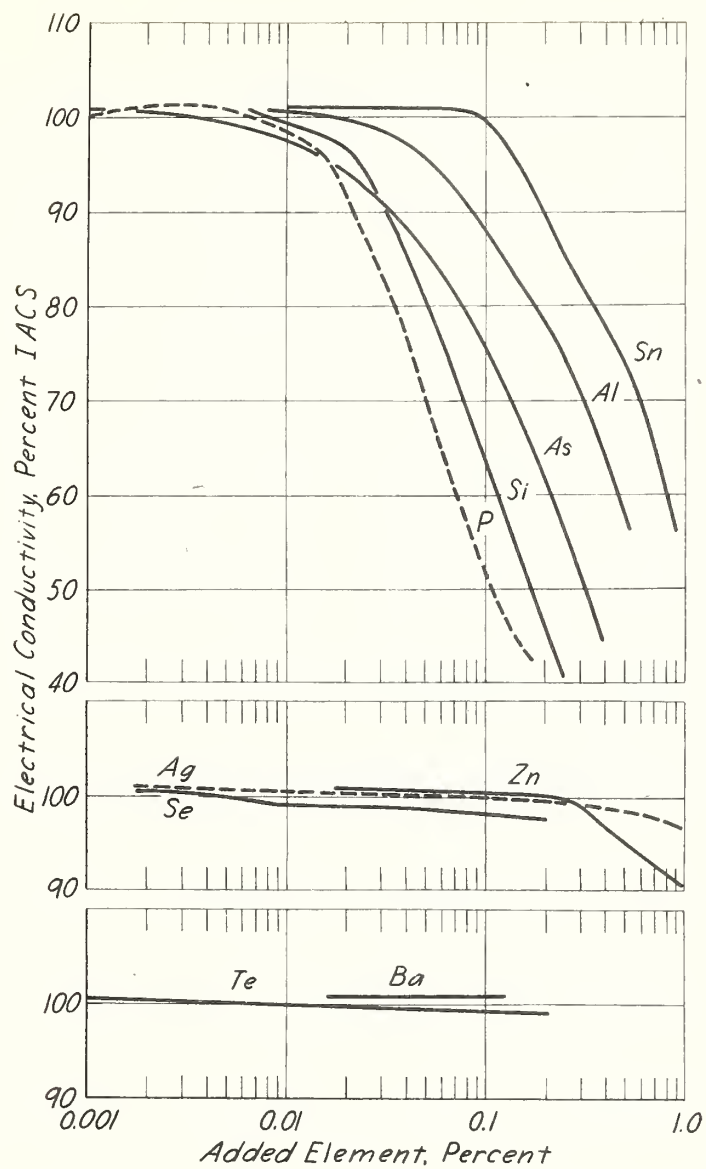


FIGURE 70.—Effect of various elements on the electrical conductivity of annealed oxygen-bearing copper (Skowronski and Wyman [659]).

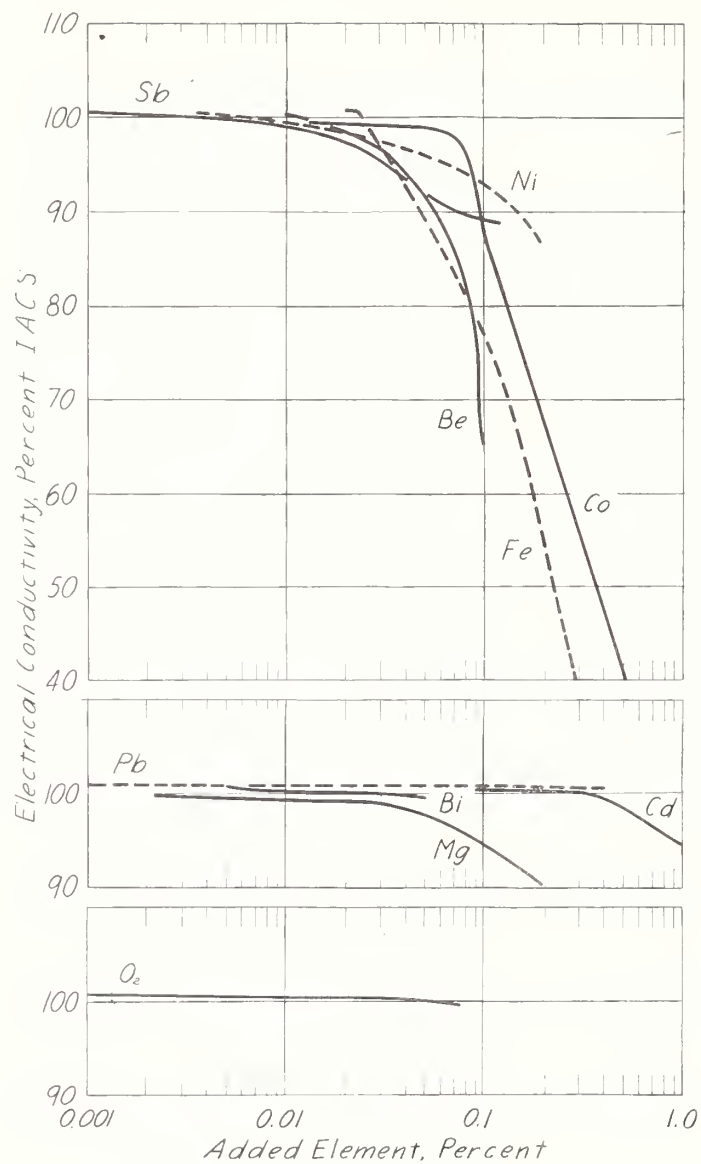


FIGURE 71.—Effect of various elements on the electrical conductivity of annealed oxygen-bearing copper (Skowronski and Wyman [659]).

VII. IRON AND STEEL

(181)

1. SOCIETY OF AUTOMOTIVE ENGINEERS'
STEEL NUMBERING SYSTEM [411]

A numerical index system is used to identify the composition of these steels, which makes it possible to use numerals on shop drawings and blueprints that are partially descriptive of the material covered by such numbers. The first digit indicates the type to which the steel belongs; thus "1" indicates a carbon steel, etc. In the case of simple alloy steels, the second digit generally indicates the approximate percentage of the predominant alloying element. Usually the last two or three digits indicate the approximate average carbon content in "points," or hundredths of 1 percent. Thus "2340" indicates a nickel steel of approximately 3 percent of nickel (3.25-3.75) and 0.40 percent of carbon (0.38-0.43).

In some instances, to avoid confusion, it has been found necessary to depart from this system of identifying the approximate alloy composition by varying the second and third digits of the number. An instance of such departure is the steel numbers selected for several corrosion and heat-resisting alloys.

The basic numerals are:

<i>Type of steel</i>	<i>Numerals (and digits)</i>
Carbon steels.....	1xxx
Plain carbon.....	10xx
Free cutting (screw stock).....	11xx
Manganese steels.....	13xx
Nickel steels.....	2xxx
3.50% Ni.....	23xx
5.00% Ni.....	25xx
Nickel-chromium steels.....	3xxx
1.25% Ni, 0.60% Cr.....	31xx
1.75% Ni, 1.00% Cr.....	32xx
3.50% Ni, 1.50% Cr.....	33xx
Corrosion and heat-resisting.....	30xxx
Molybdenum steels.....	4xxx
Carbon-molybdenum.....	40xx
Chromium-molybdenum.....	41xx
Chromium-nickel-molybdenum.....	43xx
Nickel-molybdenum (1.75% Ni).....	46xx
Nickel-molybdenum (3.50% Ni).....	48xx
Chromium steels.....	5xxx
Low chromium.....	51xx
Medium chromium.....	52xxx
Corrosion and heat-resisting.....	51xxx
Chromium-vanadium steels.....	6xxx
1% Cr.....	61xx
Silicon-manganese steels.....	9xxx
2% Si.....	92xx

TABLE 17.—Combined standard steel lists of American Iron and Steel Institute and Society of Automotive Engineers, 1942 [223]

1. Specifications are changing frequently; the sponsoring organization should be consulted for the latest revision.
2. A single value indicates maximum unless otherwise qualified.
3. AISI code: A is basic open-hearth alloy steel; B is acid bessemer carbon steel; C is basic open-hearth carbon steel; D is acid open-hearth carbon steel; E is electric furnace steel.
4. AISI lowest standard maximum phosphorus or sulfur content is 0.05 percent each and the lowest standard minimum silicon content is 0.15 percent for acid open-hearth or acid electric furnace alloy steel.
5. AISI 52000 series may be specified to either 0.30 to 0.45 percent or 0.35 to 0.50 percent manganese, but it is recommended that the full range be allowed wherever possible.
6. SAE compositions may apply to either open-hearth or electric furnace steels. Where they apply to electric furnace steels, the maximum phosphorus and sulfur shall be 0.025 percent.
7. NE denotes National Emergency Steels; designation promulgated by the Office of Production Management.

AISI number	SAE number	Chemical composition limits, percent								Serial numbers of corresponding steels in the tables	
		C	Mn	P	S	Si	Ni	Cr	Mo			Other
CARBON STEELS (CONDENSED)											
1008.....	1008.....	0.10	0.30-0.50	0.040	0.050	.....	.....	.....	.....	1439, 1440, 1441, 2431, 2532.	.....
1010.....	1010.....	0.08-0.13	0.30-0.50	0.040	0.050	.....	.....	.....	.....	1445, 1448, 2302, 2303.	.....
1015.....	1015.....	0.13-0.18	0.30-0.50	0.040	0.050	.....	.....	.....	.....	1449, 1453, 2210, 2211; figure 88.	.....
1016.....	1016.....	0.13-0.18	0.60-0.90	0.040	0.050	.....	.....	.....	.....	.....	.....
1020.....	1020.....	0.18-0.23	0.30-0.50	0.040	0.050	.....	.....	.....	.....	1454, 1455, 1456, 1458, 1461, 2213.	.....
1022.....	1022.....	0.18-0.23	0.70-1.00	0.040	0.050	.....	.....	.....	.....	1460, 2304, 2305.	.....
1024.....	1024.....	0.20-0.26	1.35-1.65	0.040	0.050	.....	.....	.....	.....	2257. ^a	.....
1025.....	1025.....	0.22-0.28	0.30-0.50	0.040	0.050	.....	.....	.....	.....	1462. ^a 1465, 1466, 2308. ^a	.....
1030.....	1030.....	0.28-0.34	0.60-0.90	0.040	0.050	.....	.....	.....	.....	1470, 1471, 1472, 2215, 2309.	.....
1035.....	1035.....	0.32-0.38	1.00-1.50	0.040	0.050	.....	.....	.....	.....	1473, 1474, 1475, 1476, 1477, 1478, 2216; ^a figure 88.	.....
1036.....	1036.....	0.32-0.39	0.60-0.90	0.040	0.050	.....	.....	.....	.....	.....	.....
1040.....	1040.....	0.37-0.44	0.60-0.90	0.040	0.050	.....	.....	.....	.....	1479, 1480, 1481, 1482, 1483, 2217, 2310, 2311.	.....
1045.....	1045.....	0.43-0.50	0.60-0.90	0.040	0.050	.....	.....	.....	.....	1485, 1486, 1487, 2218, 2312, 2313, 2314, 2432, 2533.	.....
1050.....	1050.....	0.48-0.55	0.60-0.90	0.040	0.050	.....	.....	.....	.....	1488, 1489, 1490, 1491.	.....
1052.....	1052.....	0.47-0.55	1.20-1.50	0.040	0.050	.....	.....	.....	.....	.....	.....
1055.....	1055.....	0.50-0.60	0.60-0.90	0.040	0.050	.....	.....	.....	.....	1492, 2219; figures 88 and 120.	.....
1060.....	1060.....	0.55-0.65	0.60-0.90	0.040	0.050	.....	.....	.....	.....	1493, 1494, 1495.	.....
1066.....	1066.....	0.60-0.71	0.80-1.10	0.040	0.050	.....	.....	.....	.....	Figure 89. ^a	.....
1070.....	1070.....	0.65-0.75	0.70-1.00	0.040	0.050	.....	.....	.....	.....	1496, 2315.	.....
1080.....	1080.....	0.75-0.88	0.60-0.90	0.040	0.050	.....	.....	.....	.....	1501. ^a 1502. ^a	.....
1085.....	1085.....	0.80-0.93	0.70-1.00	0.040	0.050	.....	.....	.....	.....	.....	.....
1095.....	1095.....	0.90-1.05	0.30-0.50	0.040	0.050	.....	.....	.....	.....	1506, 1507, 1508, 1510, 2318; figure 88.	.....
FREE CUTTING STEELS (CONDENSED)											
1111.....	1111.....	0.08-0.13	0.60-0.90	0.09-0.13	0.10-0.15	.....	.....	.....	.....	1447.	.....
1112.....	1112.....	0.08-0.13	0.60-0.90	0.09-0.13	0.10-0.15	.....	.....	.....	.....	.....	.....
1113.....	1113.....	0.08-0.13	0.60-0.90	0.09-0.13	0.10-0.15	.....	.....	.....	.....	.....	.....
1115.....	1115.....	0.13-0.18	0.70-1.00	0.045	0.08-0.13	.....	.....	.....	.....	1451, 1459. ^a	.....
1117.....	1117.....	0.14-0.20	1.00-1.30	0.045	0.08-0.13	.....	.....	.....	.....	.....	.....
1118.....	1118.....	0.14-0.20	1.30-1.60	0.045	0.08-0.13	.....	.....	.....	.....	.....	.....
1132.....	1132.....	0.27-0.34	1.35-1.65	0.045	0.08-0.13	.....	.....	.....	.....	.....	.....
1137.....	1137.....	0.32-0.39	1.35-1.65	0.045	0.08-0.13	.....	.....	.....	.....	.....	.....
1141.....	1141.....	0.37-0.45	1.35-1.65	0.045	0.08-0.13	.....	.....	.....	.....	.....	.....
1145.....	1145.....	0.42-0.49	0.70-1.00	0.045	0.04-0.07	.....	.....	.....	.....	.....	.....
MANGANESE STEELS											
1320.....	1320.....	0.18-0.23	1.60-1.90	0.040	0.040	0.20-0.35	.....	.....	.....	2562. ^a	.....
1330.....	1330.....	0.28-0.33	1.60-1.90	0.040	0.040	0.20-0.35	.....	.....	.....	1887, 1888, 1890.	.....
1335.....	1335.....	0.33-0.38	1.60-1.90	0.040	0.040	0.20-0.35	.....	.....	.....	1889, 1893, 1894.	.....
1340.....	1340.....	0.38-0.43	1.60-1.90	0.040	0.040	0.20-0.35	.....	.....	.....	.....	.....
1345.....	1345.....	0.43-0.48	1.60-1.90	0.040	0.040	0.20-0.35	.....	.....	.....	.....	.....
1350.....	1350.....	0.48-0.53	1.60-1.90	0.040	0.040	0.20-0.35	.....	.....	.....	2583.....	.....

^a Indicates a composition approximately the standard.

TABLE 17.—Combined standard steel lists of American Iron and Steel Institute and Society of Automotive Engineers, 1942 [223]—Continued

AISI number	SAE number	Chemical composition limits, percent							Serial numbers of corresponding steels in the tables	
		C	Mn	P	S	Si	Ni	Cr	Mo	Other

NICKEL STEELS										
A 2317.....	2317.....	0.15-.20	0.40-.60	0.040	0.040	0.20-.35	3.25-3.75	.....	.....	1965, 2471, 2330, 2386, 2387, 2590, 1970, 1971, 2279, figure 121, 1966, 1967, 2385.
A 2330.....	2330.....	0.28-.33	0.60-.80	0.040	0.040	0.20-.35	3.25-3.75	.....	.....	.....
A 2335.....	3120.....	0.33-.38	0.60-.80	0.040	0.040	0.20-.35	3.25-3.75	.....	.....	.....
A 2340.....	2340.....	0.38-.43	0.70-.90	0.040	0.040	0.20-.35	3.25-3.75	.....	.....	.....
A 2345.....	2345.....	0.43-.48	0.70-.90	0.040	0.040	0.20-.35	3.25-3.75	.....	.....	.....
E 2512.....	.....	0.09-.11	0.45-.60	0.025	0.025	0.20-.35	4.75-5.25	.....	.....	.....
A 2515.....	2515.....	0.12-.17	0.40-.60	0.040	0.040	0.20-.35	4.75-5.25	.....	.....	.....
E 2517.....	.....	0.15-.20	0.45-.60	0.025	0.025	0.20-.35	4.75-5.25	.....	.....	.....

NICKEL-CHROMIUM STEELS										
A 3045.....	.....	0.43-.48	0.75-.95	0.040	0.040	0.20-.35	0.60-.80	.....	.....	.....
A 3115.....	3115.....	0.13-.18	0.40-.60	0.040	0.040	0.20-.35	1.10-1.40	.....	.....	.....
A 3120.....	3120.....	0.17-.22	0.60-.80	0.040	0.040	0.20-.35	1.10-1.40	.....	.....	.....
A 3130.....	3130.....	0.28-.33	0.60-.80	0.040	0.040	0.20-.35	1.10-1.40	.....	.....	.....
A 3135.....	3135.....	0.33-.38	0.60-.80	0.040	0.040	0.20-.35	1.10-1.40	.....	.....	.....
A 3140.....	3140.....	0.38-.43	0.70-.90	0.040	0.040	0.20-.35	1.10-1.40	.....	.....	.....
A 3145.....	3145.....	0.43-.48	0.70-.90	0.040	0.040	0.20-.35	1.10-1.40	.....	.....	.....
A 3150.....	3150.....	0.48-.53	0.70-.90	0.040	0.040	0.20-.35	1.10-1.40	.....	.....	.....
E 3240.....	3240.....	0.38-.45	0.40-.60	0.040	0.040	0.20-.35	1.65-2.00	.....	.....	.....
E 3240.....	3240.....	0.08-.13	0.15-.60	0.025	0.025	0.20-.35	3.25-3.75	.....	.....	.....
E 3310.....	3310.....	0.14-.19	0.45-.60	0.025	0.025	0.20-.35	3.25-3.75	.....	.....	.....

MOLYBDENUM STEELS (CONDENSED)										
A 4023.....	4023.....	0.20-.25	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	1914, 1915.
A 4027.....	4027.....	0.25-.30	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4032.....	4032.....	0.30-.35	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4037.....	4037.....	0.35-.40	0.75-1.00	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4042.....	4042.....	0.40-.45	0.75-1.00	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4047.....	4047.....	0.45-.50	0.75-1.00	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4063.....	4063.....	0.60-.67	0.75-1.00	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4068.....	4068.....	0.64-.72	0.75-1.00	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
NE 8020.....	8020.....	0.18-.23	1.00-1.30	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
NE 8022.....	8022.....	0.20-.25	1.00-1.30	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
NE 8038.....	8038.....	0.35-.42	1.30-1.60	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4119.....	4119.....	0.17-.22	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4120.....	4120.....	0.23-.28	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4125.....	4125.....	0.28-.33	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4130.....	4130.....	0.33-.38	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4134.....	4134.....	0.38-.43	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
E 4135.....	4135.....	0.43-.48	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4137.....	4137.....	0.48-.53	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4140.....	4140.....	0.53-.58	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4145.....	4145.....	0.58-.63	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
A 4150.....	4150.....	0.63-.68	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
NE 8613.....	8613.....	0.12-.17	0.75-1.00	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
NE 8615.....	8615.....	0.13-.18	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
NE 8617.....	8617.....	0.18-.23	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
NE 8620.....	8620.....	0.23-.28	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
NE 8715.....	8715.....	0.13-.18	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
NE 8720.....	8720.....	0.18-.23	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....
NE 8722.....	8722.....	0.20-.25	0.70-.90	0.040	0.040	0.20-.35	.....	.....	0.20-.30	.....

TABLE 17.—Combined standard steel lists of American Iron and Steel Institute and Society of Automotive Engineers, 1942 [223]—Continued

AISI number	SAE number	Chemical composition limits, percent							Serial numbers of corresponding steels in the tables	
		C	Mn	P	S	Si	Ni	Cr	Mo	Other

OTHER NATIONAL EMERGENCY STEELS—Continued										
NE 9542.....	.....	0.40-.45	1.20-1.50	0.040	0.040	0.40-.60	0.40-.60	0.40-.60	0.15-.25	.....
NE 9550.....	.....	.48-.53	1.20-1.50	.040	.040	.40-.60	.40-.60	.40-.60	.15-.25	.....
NE 9550.....	.....	.28-.33	1.20-1.50	.040	.040	.40-.60	.40-.60	.40-.60	.....	.....
NE 9555.....	.....	.32-.38	1.20-1.50	.040	.040	.40-.60	.40-.60	.40-.60	.....	.....
NE 9557.....	.....	.35-.40	1.20-1.50	.040	.040	.40-.60	.40-.60	.40-.60	.....	.....
NE 9560.....	.....	.38-.43	1.20-1.50	.040	.040	.40-.60	.40-.60	.40-.60	.....	.....
NE 9562.....	.....	.40-.45	1.30-1.60	.040	.040	.40-.60	.40-.60	.40-.60	.....	.....
NE 9565.....	.....	.43-.48	1.30-1.60	.040	.040	.40-.60	.40-.60	.40-.60	.....	.....
NE 9550.....	.....	.48-.53	1.30-1.60	.040	.040	.40-.60	.40-.60	.40-.60	.....	.....

STAINLESS STEELS										
301.....	.....	0.08-.20	2.00	.....	.....	.....	6.00-8.00	16.00-18.00	.....	.....
302.....	.....	.08-.20	2.00	.....	.....	.....	8.00-10.00	17.00-19.00	.....	.....
302B.....	.....	.08-.20	2.00	.....	.....	.....	8.00-10.00	17.00-19.00	.....	.....
303.....	.....	.20	2.00	.....	.07	.....	8.00-10.00	17.00-19.00	0.60	.....
304.....	.....	.08	2.00	.....	.....	.....	8.00-10.00	18.00-20.00	.....	.....
308.....	.....	.08	2.00	.....	.....	.....	10.00-12.00	19.00-22.00	.....	.....
308S.....	.....	.08	2.00	.....	.....	.....	12.00-15.00	22.00-24.00	.....	.....
310.....	.....	.25	2.00	.....	.....	.....	12.00-15.00	22.00-24.00	.....	.....
310S.....	.....	.25	2.00	.....	.....	.....	19.00-22.00	24.00-26.00	.....	.....
316.....	.....	.10	2.00	.....	.....	.....	24.00-26.00	18.00-20.00	.....	.....
317.....	.....	.10	2.00	.....	.....	.....	10.00-14.00	16.00-18.00	.....	.....
321.....	.....	.10	2.00	.....	.....	.....	10.00-14.00	17.00-20.00	.....	.....
325.....	.....	.50	.....	.....	.....	.....	8.00-12.00	7.00-10.00	.....	.....
329.....	.....	.20	.....	.....	.....	.....	19.50-23.50	.....	.....	.....
330.....	.....	.25	.....	.....	.....	.....	2.50-5.00	23.00-28.00	1.00-2.00	.....
330S.....	.....	.25	.....	.....	.....	.....	33.00-36.00	14.00-16.00	.....	.....
347.....	.....	.10	2.00	.....	.....	.....	8.00-12.00	17.00-19.00	.....	.....
403.....	.....	.15	.....	.....	.....	.....	.....	11.50-13.50	.....	.....
405.....	.....	.08	.....	.....	.....	.....	.....	11.50-13.50	.....	.....
406.....	.....	.15	.....	.....	.....	.....	.....	12.00-14.00	.....	.....
410.....	.....	.15	.....	.....	.....	.....	.....	10.00-14.00	.....	.....
414.....	.....	.15	.....	.....	.....	.....	.....	10.00-14.00	.....	.....
416.....	.....	.15	.....	.....	.....	.....	2.50	12.00-14.00	.....	.....
420.....	.....	.15 minimum	.....	.....	.07	.....	.....	12.00-14.00	0.60	.....
430F.....	.....	.15 minimum	.....	.....	.07	.....	.....	12.00-14.00	.....	.....
430.....	.....	.12	.....	.....	.....	.....	.....	14.00-16.00	.60	.....
430F.....	.....	.12	.....	.....	.....	.....	.....	14.00-16.00	.....	.....
431.....	.....	.20	.....	.....	.07	.....	.....	14.00-16.00	.....	.....
440.....	.....	.12 minimum	.....	.....	.....	.....	.....	14.00-18.00	.....	.....
441.....	.....	.20 minimum	.....	.....	.....	.....	.....	14.00-18.00	.....	.....
442.....	.....	.35	.....	.....	.....	.....	.....	18.00-23.00	.....	.....
446.....	.....	.35	.....	.....	.....	.....	.....	23.00-30.00	.....	.....
501.....	.....	.10 minimum	.....	.....	.....	.....	.....	4.00-6.00	.....	.....
502.....	.....	.10	.....	.....	.....	.....	.....	4.00-6.00	.....	.....

* Indicates a composition approximately the standard.

S or Se 0.07 minimum.

Minimum 4 times carbon.

TABLE 16.—Substitutes for constructional steels [224]
[This table is based on average hardenability values]

Standard steels		Recommended substitutes	Standard steels		Recommended substitutes
AISI numbers	SAE numbers		AISI numbers	SAE numbers	
A 2317.....	2317.....	NE 8020, NE 8022, NE 9420	A 4615.....	4615.....	NE 8715, NE 9420.
A 2320.....	.....	NE 8020, NE 8022, NE 9420	A 4620.....	4620.....	NE 8715, NE 9420.
A 2330.....	2330.....	NE 1330, NE 9430, NE 9630	A 4640.....	4640.....	NE 1340, NE 9437, NE 9637.
A 2335.....	.....	NE 1340, NE 9435, NE 9635	A 4645.....	.....	NE 1345, NE 9440, NE 9640.
A 2340.....	2340.....	NE 1345, NE 9442, NE 9642	A 4815.....	4815.....	NE 8715, NE 9420.
A 2345.....	2345.....	NE 1350, NE 9445, NE 9645	A 4820.....	4820.....	NE 8720, NE 9422.
A 2350.....	.....	NE 9450, NE 9650	A 5120.....	5120.....	NE 8715, NE 9420.
A 2512.....	.....	NE 8715, NE 9415	A 5130.....	.....	NE 1330, NE 9430, NE 9630.
A 2515.....	2515.....	NE 8720, NE 9422	A 5135.....	.....	NE 1335, NE 9435, NE 9635.
A 3045.....	.....	NE 1345, NE 9440, NE 9640	A 5140.....	5140.....	NE 1340, NE 9435, NE 9635.
A 3115.....	.....	NE 8020, NE 9420	A 5145.....	.....	NE 1345, NE 9440, NE 9640.
A 3120.....	3120.....	NE 8020, NE 9420	A 5150.....	5150.....	NE 1350, NE 9445, NE 9645.
A 3130.....	3130.....	NE 1330, NE 9430, NE 9630	E 52065.....	.....	NE 52100C.
A 3135.....	3135.....	NE 1335, NE 9435, NE 9635	E 52068.....	.....	NE 52100B.
A 3140.....	3140.....	NE 1345, NE 9440, NE 9640	E 52069.....	.....	NE 52100A.
A 3141.....	3141.....	NE 1345, NE 9442, NE 9642	E 52100.....	52100.....	NE 52100A.
A 3145.....	3145.....	NE 1350, NE 9445, NE 9645	E 52101.....	.....	NE 52100A.
A 3150.....	3150.....	NE 9450, NE 9650	E 52107.....	.....	NE 52100A.
A 3240.....	3240.....	NE 1345, NE 9442, NE 9642	A 6120.....	.....	NE 8715, NE 9420.
A 3250.....	.....	NE 9450, NE 9650	A 6130.....	.....	NE 1330, NE 9430, NE 9630.
A 4023.....	.....	NE 8020, NE 8022, NE 9420	A 6135.....	.....	NE 1335, NE 9435, NE 9635.
A 4024.....	.....	NE 8020, NE 8022, NE 9420	A 6140.....	.....	NE 1340, NE 9435, NE 9635.
A 4027.....	4027.....	NE 8022, NE 9422	A 6145.....	.....	NE 1345, NE 9440, NE 9640.
A 4032.....	4032.....	NE 8022, NE 9422	.....	6150.....	NE 1350, NE 9445, NE 9645.
A 4037.....	4037.....	NE 1330, NE 9430, NE 9630	NE 8124.....	.....	NE 8020, NE 8022, NE 9420,
A 4042.....	.....	NE 1330, NE 9430, NE 9630	.....	NE 9422.	NE 9422.
A 4047.....	4047.....	NE 1335, NE 9435, NE 9635	NE 8233.....	.....	NE 1330, NE 9430, NE 9630.
A 4063.....	4063.....	NE 9255	NE 8238.....	.....	NE 1335, NE 9430, NE 9630.
A 4065.....	.....	NE 9260	NE 8442.....	.....	NE 1345, NE 9442, NE 9642.
A 4068.....	.....	NE 9262	NE 8547 ^a.....	.....	NE 9540.
A 4119.....	4119.....	NE 8715, NE 9420	NE 8620.....	.....	NE 8715, NE 8420.
A 4120.....	.....	NE 8022, NE 9422	NE 8630.....	.....	NE 1330, NE 9430, NE 9630.
A 4130.....	4130.....	NE 1330, NE 9430, NE 9630	NE 8635.....	.....	NE 1340, NE 9435, NE 9635.
A 4137.....	4137.....	NE 1340, NE 9437, NE 9637	NE 8720.....	.....	NE 9420.
A 4140.....	4140.....	NE 1345, NE 9440, NE 9640	NE 8735.....	.....	NE 1340, NE 9435, NE 9635.
A 4142.....	.....	NE 1345, NE 9442, NE 9642	NE 8739.....	.....	NE 1340, NE 9437, NE 9637.
A 4145.....	4145.....	NE 1350, NE 9445, NE 9645	NE 8744.....	.....	NE 1345, NE 9442, NE 9642.
A 4150.....	4150.....	NE 9450, NE 9650	.....	.....	NE 1350, NE 9445, NE 9645.
A 4320.....	4320.....	NE 8720, NE 9422	NE 8749.....	.....	NE 9450, NE 9650.
A 4337 ^a.....	.....	NE 9537	NE 8817.....	.....	NE 8720, NE 9422.
A 4340 ^a	4340.....	NE 9540	NE 8949 ^a.....	.....	NE 8720, NE 9422.
					NE 9450, NE 9650.

^aRecommended for large sections only.

TABLE 19.—Approximate hardness conversion table for SAE carbon and alloy constructional steels^a [225]

Brinell number 3,000-kg load 10-mm ball	Vickers number	Rockwell number		Shore Scleroscope number	Approximate tensile strength kips/in. ²	Brinell number 3,000-kg load 10-mm ball	Vickers number	Rockwell number		Shore Scleroscope number	Approximate tensile strength kips/in. ²
		C scale 150-kg load 120° diamond cone	B scale 100-kg load 1/16-in. ball					C scale 150-kg load 120° diamond cone	B scale 100-kg load 1/16-in. ball		
.....	.....	.....	.....	.....	.....	223	223	20	97	32	110
.....	.....	.....	.....	.....	.....	217	217	18	96	31	107
.....	.....	.....	.....	.....	.....	212	212	17	96	31	104
780	1150	70	.....	106	384	207	207	16	95	30	101
745	1050	68	.....	100	368	202	202	15	94	30	99
712	960	66	.....	.....	.....	197	197	13	93	29	97
682	885	64	.....	91	337	192	192	12	92	28	95
653	820	62	.....	87	324	187	187	10	91	28	93
627	765	60	.....	81	311	183	183	9	90	27	91
601	717	58	.....	78	298	179	179	8	89	27	89
575	675	57	.....	75	276	174	174	7	88	26	87
555	633	55	.....	72	266	170	170	6	87	26	85
534	598	53	.....	70	256	166	166	4	86	25	83
514	567	52	.....	67	247	163	163	3	85	25	82
495	540	50	.....	63	229	159	159	2	84	24	80
477	515	49	.....	61	220	156	156	1	83	24	78
461	494	47	.....	59	212	153	153	.....	82	23	76
444	472	46	.....	57	204	149	149	.....	81	23	75
429	454	45	.....	55	196	146	146	.....	80	22	74
415	437	44	.....	54	189	143	143	.....	79	22	72
401	420	42	.....	51	176	140	140	.....	78	21	71
388	404	41	.....	51	170	137	137	.....	77	21	70
375	380	40	.....	49	165	134	134	.....	76	21	68
363	375	38	.....	48	160	131	131	.....	74	20	66
352	363	37	.....	46	155	128	128	.....	73	20	65
341	350	36	.....	45	150	126	126	.....	72	.....	64
331	339	35	.....	44	146	124	124	.....	71	.....	63
321	327	34	.....	43	142	121	121	.....	70	.....	62
311	316	33	.....	42	138	118	118	.....	69	.....	61
302	305	32	.....	40	135	116	116	.....	68	.....	60
293	296	31	.....	40	131	114	114	.....	67	.....	59
285	287	30	105	39	128	112	112	.....	66	.....	58
277	279	29	104	38	125	109	109	.....	65	.....	56
269	270	28	104	37	122	107	107	.....	64	.....	55
262	263	26	103	36	120	105	105	.....	62	.....	54
255	256	25	102	35	119	103	103	.....	61	.....	53
248	248	24	102	34	116	101	101	.....	60	.....	52
241	241	23	100	33	113	99	99	.....	59	.....	51
235	235	22	99	33	113	97	97	.....	57	.....	50
229	229	21	98	33	113	95	95	.....	56	.....	49

^aThis table applies only to steel of uniform chemical composition and uniform heat treatment, and it is not recommended for nonferrous metals or for case-hardened steels.

5. SOCIETY OF AUTOMOTIVE ENGINEERS'
SUMMARY CHARTS [411]

The information contained in the conventional mechanical property charts has been reorganized to present a clearer picture to the engineer of the relation of hardness to yield strength, tensile strength, and reduction of area.

Figures 72 and 73 illustrate the principle that regardless of composition, steels of the same hardness produced by tempering after hardening, will have approximately the same tensile strengths. Figure 74 shows that the reduction of area varies inversely with the hardness and that, for a given hardness, the reduction of area is higher for alloy steels than it is for plain carbon steels.

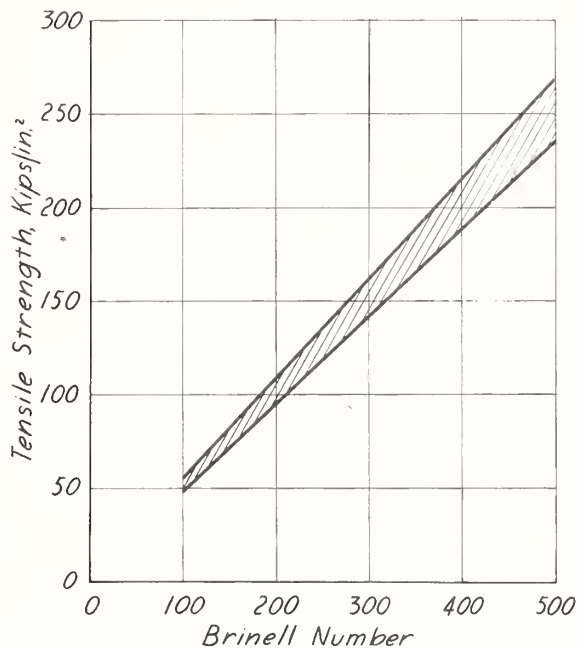


FIGURE 72.—Relation between hardness and tensile strength for steels [411].

Applicable to carbon and alloy steels with carbon contents of 0.3 to 0.5 percent in the hardened and tempered, as rolled, annealed, and normalized conditions.

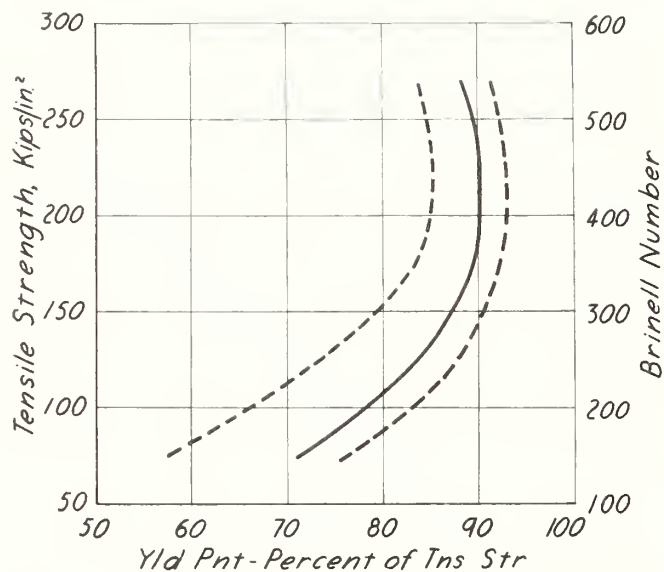


FIGURE 73.—Relation between tensile strength and yield point for steels [411].

Applicable to carbon and alloy steels with carbon contents of 0.3 to 0.5 percent in the quenched and tempered condition. The solid curve should be used as the normal expectancy curve; the broken lines represent variations which may occur. The low ratio of yield point to tensile strength represented by the left side of the zone is an indication of incomplete response to hardening.

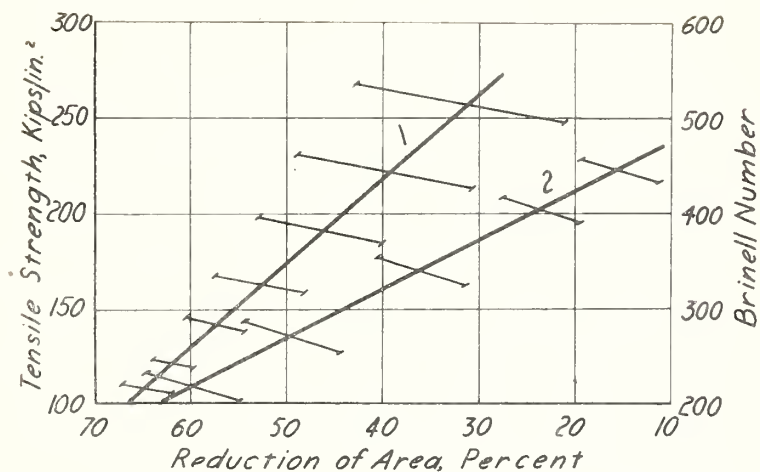


FIGURE 74.—Relation between tensile strength and reduction of area for steels [411].

Curves: 1, alloy steels SAE 1800, 2300, 3100, 3200, 4100, 4300, 5100, 6100; 2, carbon steels SAE 1000 series.

The two diagonal lines may be taken as the normal expectancy curves in estimating the normal reduction of area from tensile strength or hardness. Cross lines indicate variations from the mean which may be caused by quality differences and by the magnitude of the parasitic stresses induced by quenching.

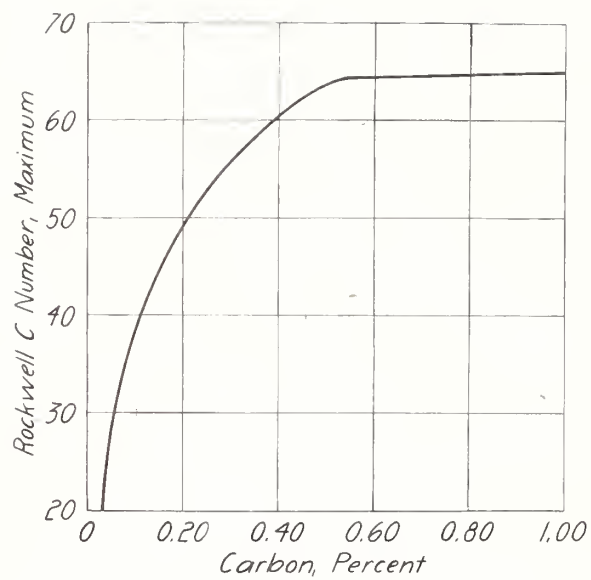


FIGURE 75.—Maximum hardness obtainable in quenched carbon and alloy steels (Burns, Moore, and Archer [58]).

6. JOMINY END-QUENCH TEST, DEFINITION

The curves in figure 76 illustrate the method of comparing the hardenability of steels by means of the Jominy end-quench tests, which is recommended as the standard method of determining hardenability by the

Society of Automotive Engineers. The test consists in quenching one end of a 1-in.-diameter sample of the steel and measuring the distance to which it hardens from the quenched end. The method may also be used to predict the hardness obtainable with any steel in a new application.

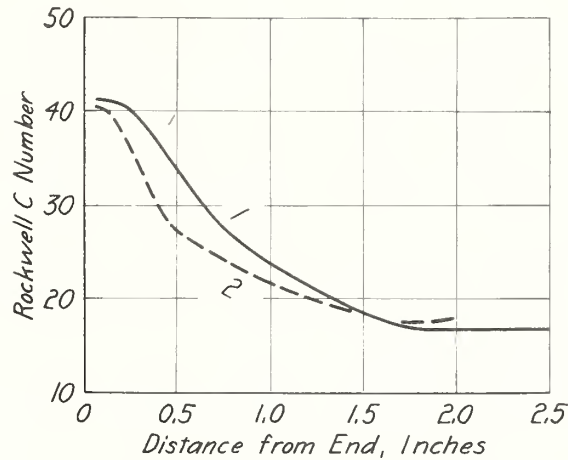


FIGURE 76.— Comparison of the hardenability of a standard steel and an alternate emergency steel [607].

Curves: 1, C 0.14%, Ni 4.98%, Mn 0.50%, Si 0.26% (standard electric furnace steel A 2515), normalized at 1,700°F, quenched from 1,475°F; 2, C 0.18%, Ni 0.63%, Cr 0.47%, Mo 0.33%, Mn 0.86%, Si 0.30% (NE 8817), normalized at 1,600°F, quenched from 1,550°F.

TABLE 20.—Iron and steel, normal-temperature properties

[For a discussion of the definiteness of values reported for yield strength and particularly for "proportional limit" see pages 5 and 6. Hardness numbers are Brinell numbers unless prefixed R_B , R_C , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed Iz (Izod method).]

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
PURE AND INGOT IRON (SEE ALSO FIGS. 77, 78, AND 79)												
1409..	Percent Fe 99.99.....	Rod, 1/4 in., swaged, ann 4 hr at 1,600°F.	Klps/in. ² 28,500	Klps/in. ²	Klps/in. ² 8.1-8.6 (0.2% offset)	Klps/in. ² 28.5-29.7	Percent 36-46 (2 in.)	Percent 85-94	.....	60	ft-lb	[226]
1410..	Fe 99.989.....	Rod, 1/4 in. diam.	28,000- 29,700	4.6-5.4	.....	20.4-26.7	36-49 (4 Area)	100	.....	.....	.....	[227]
1411..	Armco iron: Fe 99.819..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[228]
1412..	Electro iron: C 0.006, Si 0.005, P 0.005, S 0.004.	As deposited.....	.....	.....	.....	55-114	3-25 (2 in.)	.....	.....	140-350	.....	[229]
1413..	do.....	Pused, ann.....	.....	.....	10-20	35-40	40-60 (1.5 in.)	70-80	.....	45-80	21	[229]
1414..	Carbonyl iron: C 0.015, Ni 0.011, Mn 0.005, N ₂ 0.003, Cu 0.002, O ₂ 0.002, Si 0.002, P 0.0006, S 0.0005.	Plate, 5/16 in., rolled.	.....	.....	27-37 (yld pnt)	38.4	21 (1 in.)	96	.....	80	.....	[230]
1415..	Armco iron: C 0.015, S 0.050, Mn 0.03, Si 0.01, P 0.007.	Hot-rolled.....	.....	21.3	22.7 (yld pnt)	44.3	47 (2 in.)	75	26.2	83	.....	[231]
1416..	Armco iron: C 0.02, S 0.042, Mn 0.03, Si 0.02, P 0.005.	Rod, 1 in. diam, ann.	.....	16.1	19.0 (yld pnt)	42.4	48 (2 in.)	76	26.0	69	19	[38]
1417..	do.....	Rod, 1 in. diam, 1/4 hr at 1,500°F, w-q.	.....	35.0	36.3 (yld pnt)	50.0	36 (2 in.)	76	33.0	109	54	[38]
1418..	C 0.032, Mn 0.025, Si 0.003.	1/2 hr at 1,750°F, f-c.	.....	14.0	16.0 (0.01% perm)	42.5	46 (2 in.)	72	21.0	.....	.....	[17]
1419..	do.....	3/4 hr at 1,750°F, w-d, tempered 2 hr at 700°F.	.....	20.0	22.5 (0.01% perm)	44.0	46 (2 in.)	75	24.0	.....	.....	[17]
1420..	Swedish iron: C 0.034, O ₂ 0.030, P 0.056, Si 0.024, Cu 0.005, Cr 0.004, Ni 0.004, N ₂ 0.004, S 0.003.	Rod, 7/8 in. diam, hot-rolled.	.....	.....	37.5 (yld pnt)	45.7	54 (1 in.)	78	.....	75	.....	[230]
1421..	Armco iron: C 0.04, S 0.032, Si 0.03, Mn 0.02, P 0.005.	Cold-drawn.....	.....	.....	69.2 (yld pnt)	73.1	12 (2 in.)	63	33.3	142	.....	[231]
1422..	C 0.044, Mn 0.025, S 0.025, Si 0.003, P 0.002.	Rod, rolled.....	.....	28.5	42.5	60.9	16 (2 in.)	67	.....	.....	Shear str.....41.2 klps/in. ² .	[86]
1423..	Ingot iron.....	Rod, ann.....	.....	.....	.....	.....	.....	.....	.....	.....	Comp yld str.....20.6 klps/in. ² .	[229]

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Ref-er-ence
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
CARBON STEELS—Continued												
1439..	Percent C 0.08, Mn 0.41, S 0.033, P 0.024 (open-hearth rimming).	Strip, 0.104 in., rolled.	.....	.....	Kt _{ps} /in. ² 38.4 (yld pnt)	Kt _{ps} /in. ² 52.6	Percent 35 (2 in.)	Percent	R ₅₅	ft-lb .....	.....	[235]
1440..	C 0.09, Mn 0.42, S 0.038, P 0.016.	Sheet, ann.....	.....	.....	29.1	48.6	40 ^a (2 in.)	.....	V 91	.....	Erichsen.....11.7 mm.....	[236]
1441..	C 0.09, Mn 0.31.....	Cast; ann 2 hr at 1,650°F.	30,000	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....12,000 klps/in. ²	[237]
1442..	C 0.10, Mn 0.72, Si 0.06.	Normalized at 1,650°F.	.....	.....	36.3 (0.1%)	63.8	37 (2 in.)	64	26.9	Iz 65	.....	[238]
1443..	C 0.11, Mn 0.60, Si 0.40, S 0.035, P 0.030.	Cast.....	.....	.....	26.0 (yld pnt)	59.0	13 (10 diam)	30	.....	126 ^b 3.7	.....	[239]
1444..	do.....	Cast; 6 hr at 1,650°F, f-c.	.....	.....	35.0 (yld pnt)	60.0	30 (10 diam)	60	.....	116 ^b 15	.....	[239]
1445..	C 0.11, Mn 0.45, S 0.044, P 0.008, Si 0.01.	Bar, 1 in. diam, hot-rolled.	.....	34.0	35.5 (yld pnt)	49.5	46 (2 in.)	73	.....	94	57	[239]
1446..	C 0.11, Mn 0.53, P 0.051, Si 0.05, S 0.037.	Bar, 15/32 in. diam, cold-drawn (57% red.).	.....	15.1	87.2 (yld pnt)	90.0	14 (4 /area)	49	.....	Iz 33	.....	[239]
1447..	C 0.12, Mn 0.84, S 0.12, P 0.099, Si 0.01.	Bar, 1 1/8 in. diam, cold-rolled.	30,400	.....	76.0 (0.001% offset)	83.3	18 (2 in.)	52	.....	V 205	.....	[240]
1448..	C 0.13.....	Bar, 3/16 in., cold- rolled.	.....	.....	60.0 (0.002% perm)	94.0	.....	.....	46.0	.....	.....	[241]
1449..	C 0.10-0.20, Mn 0.30-0.60.	Bar, 1 in. diam, cold-drawn.	.....	.....	55.0	68.0	25	55	.....	140	.....	[242]
1450..	C 0.10-0.20, Mn 0.30-0.60, Pb 0.20-0.30.	do.....	.....	.....	55.0	67.0	27	56	.....	137	.....	[242]
1451..	C 0.10-0.20, Mn 0.70-1.00, S 0.075-0.15.	Bar, 7/8 in. diam, cold-drawn.	.....	.....	66.0	67.0	18	51	.....	137	31	[242]
1452..	C 0.10-0.20, Mn 0.70-1.00, S 0.70-1.00, Pb 0.20-0.30.	do.....	.....	.....	69.0	71.0	18	51	.....	143	27	[242]
1453..	C 0.16, Mn 0.44, S 0.024, P 0.012, Si 0.01.	Plate, 3/4 in., rolled.	29,500	.....	26.8 (0.001% offset) 29.5 (yld pnt)	56.0	45 (2 in.)	64	.....	98	Comp yld str (0.001%)...30.4 klps/in. ² Compressive str.....55.8 klps/in. ²	[243]
1454..	C 0.18, Mn 0.40, Si 0.25.	Cast.....	.....	.....	27.9	54.5	16	20	^a 14.2	115 ^b 1.3	.....	[249]

1455..	...do.....	Cast; ann at 1,650°F	.....	.....	.....	61.2	23	42	^a 19.9	117	^b 4.7	.....	[239]
1456..	C 0.18, Mn 0.37, Si 0.06, S 0.039, P 0.013	Bar, 1/2 in., hot- rolled.	.....	.....	36.2	61.5	41 (2 in.)	67	28.0	.....	.....	.....	[38]
1457..	C 0.18, Mn 0.32, P 0.115, S 0.12, Si 0.12	Cold-rolled.....	29,800	.....	.....	98.2	15 (2 in.)	46	.....	.....	.....	.....	[240]
1458..	C 0.15-0.25, Mn 0.30-0.50	Rod, 1/8 in., cold- drawn.	30,000	.....	108	116	11 (10 in.)	39	53.0	.....	.....	.....	[167]
1459..	C 0.20, Mn 0.67, S 0.060, Si 0.03, P 0.025	Bar, 7/16 in., cold- drawn.	.....	.....	.....	86.8	14 (2 in.)	49	41.0	.....	.....	.....	[38]
1460..	C 0.20, Mn 0.78, Ni 0.20, Si 0.18, P 0.032, S 0.022	Normalized at 1,650°F.	.....	.....	34.1	70.8	29	52	^a 19.7	140	.....	Shear str.....54.4 kips/in. ²	[244]
1461..	C 0.20, Mn 0.50, Si 0.16, S 0.034, P 0.012	Wrought.....	.....	.....	.....	63.7	41 (2 in.)	57	32.0	R _s 75	.....	.....	[245]
1462..	C 0.24, Mn 0.54, Si 0.24, Ni 0.028, P 0.019, S 0.011	Bar, 1 in. diam, hot-rolled; nor- malized.	.....	.....	30.5	72.0	40 (4 /ATeR)	61	.....	140	Iz 35	.....	[63]
1463..	C 0.24, Mn 0.57, Si 0.06	1 br at 1,650°F, w-q, tempered 2 hr at 800°F.	.....	.....	50.0	79.0	28 (2 in.)	68	37.0	.....	.....	.....	[17]
1464..	C 0.15-0.30, Mn 0.40-0.70, Si 0.15-0.30, P <0.11, S <0.06 (acid bessemer).	Seamless pipe, rolled.	.....	.....	.....	74	35 (2 in.)	.....	45	.....	.....	.....	[246]
1465..	C 0.25, Mn 0.45, S 0.040, Si 0.03, P 0.012	Plate, 3/4 in., rolled.	29,600	.....	.....	63.1	40 (2 in.)	60	.....	122	.....	Com yld str (0.001%).....30.0 kips/in. ² Compressive str.....66.2 kips/in. ² Poisson's ratio.....0.306.	[243]
1466..	C 0.25, Mn 0.38, S 0.035, P 0.010 (rimming).	Wrought.....	.....	.....	.....	64.6	43 (2 in.)	56	24.0	R _s 68	.....	.....	[245]
1467..	C 0.15-0.35.....	.....	29,500	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....11,400 kips/in. ² Poisson's ratio.....0.297.	[243]
1468..	C 0.26, Mn 0.75, Si 0.30, Ni 0.15, P 0.060, S 0.044, Cr 0.04	Water-quenched from 1,650°F, tempered at 750°F.	.....	.....	.....	121	15 (2 in.)	44	.....	.....	Iz 26	.....	[239]
1469..	...do.....	Oil-quenched from 1,650°F, tempered at 750°F.	.....	.....	.....	98.6	26 (2 in.)	59	.....	207	Iz 51	.....	[239]
1470..	C 0.27, Mn 0.72, Si 0.21, S 0.024, P 0.014	Wrought; ann at 1,450°F, f-c.	27,500	.....	.....	67.4	46 (2 in.)	64	.....	153	.....	Shear str.....75.9 kips/in. ² Mod-el (shear).....11,800 kips/in. ² Poisson's ratio.....0.316.	[247]
1471..	...do.....	Wrought; w-q from 1,600°F, tempered at 1,100°F.	29,600	.....	.....	91.1	42 (2 in.)	70	.....	191	.....	Shear str.....90.6 kips/in. ² Mod-el (shear).....12,000 kips/in. ² Poisson's ratio.....0.310.	[247]
1472..	C 0.30, Mn 0.67, Ni 0.21, Si 0.14	Normalized at 1,560°F.	.....	.....	.....	78.4	30 (2 in.)	55	29.1	.....	Iz 32	.....	[238]

^a Reversed torsion.

^b Notch impact value, m-kg/cm.²

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
			Kt./in. ²	Kt./in. ²	Kt./in. ²	Kt./in. ²	Percent	Percent	Kt./in. ²	ft.-lb		
1473..	C 0.33, Mn 0.77, Si 0.32, P 0.04, S 0.036.	Cast.....	.....	19.9	33.5	76.2	26 (2 in.)	34	.....	141	Torsion yld str.....34.6 kips/in. ² Torsion str.....60.5 kips/in. ²	[239]
1474..	...do.....	Cast; ann at 1,700°F.	.....	37.1	41.2	79.8	27 (2 in.)	40	.....	143	Torsion yld str.....25.8 kips/in. ² Torsion str.....59.5 kips/in. ²	[239]
1475..	C 0.34, Mn 0.88, Si 0.35, S 0.035, P 0.019.	Plate, 3/4 in., rolled.	29,800	.....	34.9 (0.001% offset) 42.8 (yld pnt)	86.3	33 (2 in.)	58	.....	169	Comp yld str (0.001%) 35.7 kips/in. ² Compressive str.....36.8 kips/in. ² Poisson's ratio.....0.291.	[243]
1476..	C 0.35, Mn 0.55, Si 0.19, S 0.030, P 0.016.	Annealed at 1,280°F.	.....	.....	42.7	68.0	39 (2 in.)	66	35.5	30	.....	[233]
1477..	C 0.35, Mn 0.64, Si 0.06, S 0.024, P 0.012.	Bar, 3/4 in. diam, normalized at 1,750°F.	.....	37.0	40.0 (yld pnt)	78.2	32 (2 in.)	57	.....	.....	.....	[63]
1478..	C 0.36, Mn 0.55, Si 0.30, Mn 0.06, Cr 0.014.	1 hr at 1,550°F, w-q, tempered 2 hr at 1,000°F.	.....	70.0	71.5 (0.01% perm)	97.5	26 (2 in.)	60	42.0	.....	.....	[17]
1479..	C 0.38, Mn 0.65, Si 0.22, S 0.029, P 0.015.	Wrought; ann at 1,450°F, f-c.	28,800	.....	41.5	75.7	44 (2 in.)	56	.....	146	Shear str.....79.8 kips/in. ² Mod-el (shear).....11,700 kips/in. ² Poisson's ratio.....0.287.	[247]
1480..	...do.....	Wrought; w-q from 1,600°F, tempered at 1,100°F.	30,000	.....	57.8	99.5	40 (2 in.)	65	.....	204	Shear str.....96.7 kips/in. ² Mod-el (shear).....12,400 kips/in. ² Poisson's ratio.....0.296.	[247]
1481..	C 0.41, Mn 0.64, Si 0.23, S 0.028, P 0.027.	Bar, 3 in. diam, cold-finished.	.....	.....	89.8 (yld pnt)	92.8	19	43	.....	R _B 94	.....	[248]
1482..	C 0.42, Mn 0.83.....	Oxy-acetylene flame-hardened.	.....	75.0	.....	105	.....	.....	.....	Iz 27	.....	[249]
1483..	C 0.43, Mn 0.68, Si 0.20, P 0.035, S 0.033.	Bar, 1 in. diam, ann 1 hr at 1,550°F.	.....	32.5	44.6 (0.2% perm)	88.8	26 (2 in.)	42	.....	167	.....	[63]
1484..	C 0.44, Mn 0.75, Pb 0.20, S 0.027, P 0.023.	Cold-drawn.....	.....	.....	74.0 (0.2% offset)	115	12 (2 in.)	30	48.0	211	Mod rupture.....95.0 kips/in. ²	[250]
1485..	C 0.44, Mn 0.69, P < 0.045, S < 0.045.	Wire, 0.250 in. diam, quenched, tempered, coiled, tempered at 850°F.	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....11,300 kips/in. ² .	[153]

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation					Reduction of area
CARBON STEELS—Continued											
1504..	Percent C 0.85, Mn 0.48, Si 0.24, Ni 0.14, S 0.029, Cr 0.026, P 0.013.	Bar, 3/4 in. diam, drawn.	.....	Kips/in. ² 56.0	Kips/in. ² 69.4 (0.2% perm)	Kips/in. ² 139	Percent 15 (2 in.)	Percent 22	Kips/in. ²	ft-lb	[253]
1505..	C 0.89, Mn 0.22, Si 0.19, S 0.019, P 0.013.	Annealed.....	.....	.....	41.0 (yld pnt)	76.2	35 (2 in.)	56	.....	12 1.6	[141]
1506..	C 0.91, Mn 0.38, Si 0.16, S 0.037, P 0.036 (acid open- hearth).	Oil-quenched from 1,575°F, tempered at 940°F.	30,200	.....	$\left\{ \begin{array}{l} 114 \\ (0.01\%) \\ 179 \\ (0.2\%) \end{array} \right\}$	225	7 (2 in.)	.....	$\left\{ \begin{array}{l} 80.0 \\ 85.0 \\ 91.0 \end{array} \right\}$	.....	[254]
1507..	C 0.93, Mn 0.38, S 0.045, Si 0.03, P 0.017.	Bar, 2 in. x 7/8 in., hot-rolled.	.....	51.1	.....	133	7.2 (2 in.)	12	.....	2.2	[38]
1508..	...do.....	Bar, 2 in. x 7/8 in., 1/4 hr at 1,600°F, a-c, 1/4 hr at 1,450°F, f-c.	.....	28.0	33.4 (yld pnt)	84.1	25 (2 in.)	37	30.5	2.2	[38]
1509..	C 0.97, Mn 0.06, Si 0.03, S 0.025, P 0.018.	Cast.....	.....	.....	49.9	72.6	2.0 (2 in.)	1.8	.....	.....	[239]
1510..	C 1.04, Mn 0.96, Si 0.16, S 0.018, P 0.015.	1/3 hr at 1,550°F, quenched in oil at 120°F, tempered 1/4 hr at 800°F.	29,800	.....	$\left\{ \begin{array}{l} 144 \\ (0.01\%) \\ 194 \\ (0.2\%) \end{array} \right\}$	237	5 (2 in.)	.....	$\left\{ \begin{array}{l} 98.0 \\ 123 \end{array} \right\}$	.....	[254]
1511..	C 1.09, Mn 0.33, Si 0.28.	1 hr at 1,475°F, f-c.	.....	53.0	63.5 (0.01% perm)	106	28 (2 in.)	52	42.5	.....	[17]
1512..	C 1.20, Mn 0.25, Si 0.19, P 0.021, S 0.021.	Bar, 2 in. x 1 in., 1/4 hr at 1,580°F, f-c.	.....	58.6	60.7 (yld pnt)	117	7.9 (2 in.)	12	50.0	1.9	[38]
1513..	...do.....	Bar, 2 in. x 1 in., 1/4 hr at 1,580°F, f-c, 1/2 hr at 1,420°F, o-q, tem- pered 1/2 hr at 800°F.	.....	108	113 (yld pnt)	180	9.2 (2 in.)	22	85.0	3.1	[38]
1514..	C 1.38, Mn 0.22, Cr 0.03.	Wire, 0.039 in. diam, quenched from 1,445°F, tempered at 750°F.	.....	.....	.....	.....	.....	.....	.....	.....	[16]
ALUMINUM STEELS											
1515..	C 0.20-0.30, Al 0.90- 1.40, Cr 0.90-1.40, Mn 0.40-0.60, Mo 0.15- 0.25, Si <0.030.	Quenched from 1,750°F, tempered at 1,100°F.	.....	.....	117	132	18 (2 in.)	.....	.....	280	[255]

1516..	...do.....	Quenched from 1,750°F, tempered at 1,300°F.	.....	85	102	26 (2 in.)	70	.....	225	.....	[255]
1517..	C 0.30-0.40, Al 0.90-1.40, Cr 0.90-1.40, Mn 0.40-0.60, Mo 0.15-0.25, Si <0.030.	Quenched from 1,750°F, tempered at 1,100°F.	.....	137	155	15 (2 in.)	52	.....	310	.....	[255]
1518..	...do.....	Quenched from 1,750°F, tempered at 1,100°F, nitrided 90 hr at 900°F.	.....	129	159	5 (2 in.)	16	.....	.....	.....	[255]
1519..	...do.....	Quenched from 1,750°F, tempered at 1,300°F.	.....	103	121	23 (2 in.)	62	.....	230	.....	[255]
1520..	...do.....	Quenched from 1,750°F, tempered at 1,300°F, nitrided 90 hr at 900°F.	.....	98	123	8 (2 in.)	20	.....	.....	.....	[255]
1521..	C 0.55, Al 1.14, Cr 1.10, Mn 0.55, Mo 0.20, Si 0.15, S 0.019, P 0.014.	Bar, 1 in. diam, o-q from 1,550°F, tempered at 1,000°F.	.....	183	206	11 (2 in.)	36	.....	451	18	[256]
1522..	...do.....	Bar, 1 in. diam, o-q from 1,550°F, tempered at 1,300°F.	.....	107	130	21 (2 in.)	56	.....	278	1z 59	[256]
1523..	C 0.36, Al 2.03, Cr 1.62, Mn 0.57, Si 0.31, S 0.10, P 0.019, S 0.010.	1 hr at 1,750°F, o-q, tempered 4 hr at 1,200°F, f-c.	.....	115 (0.01% perm)	148	18 (2 in.)	54	.....	.....	27	[257]
1524..	...do.....	1 hr at 1,750°F, o-q, tempered 4 hr at 1,200°F, f-c, nitrided.	.....	81.4 (0.01% perm)	147	7.3 (2 in.)	14	.....	.....	.....	[257]

CHROMIUM STEELS (SEE ALSO FIGS. 91, 92, AND 93)

1525..	C 0.11, Cr 0.38, Mn 1.17, Si 0.68.	Bar.....	.....	59.0	77.0	37 (2 in.)	77	.....	151	.....	Shear str.....78.1 kips/in. ²	[258]
1526..	C 0.30, Cr 0.38, Mn 0.89.	Normalized at 1,580°F.	.....	.....	81.3	35 (2 in.)	65	.....	159	1z 57	.....	[259]
1527..	C 0.30, Cr 0.45, Mn 1.19, Si 0.67, P 0.033, S 0.019.	Rolled.....	30,400	.....	85.6	30 (2 in.)	.....	.....	156	.....	Shear str.....84.2 kips/in. ² Mod-el (shear).....11,900 kips/in. ² Poisson's ratio.....0.276.	[247]
1528..	C 0.86, Cr 0.48, Mn 1.19, Si 0.23, P 0.020, S 0.011.	Wrought.....	.....	.....	103 (yld pnt)	22 (2 in.)	37	.....	192	1z 4	.....	[141]
1529..	C 0.37, Cr 0.50, Mn 1.14, Si 0.84, S 0.033, P 0.021.	Bar, 3/4 in. diam, hot-rolled.	30,000	.....	125 (0.005% perm)	23 (2 in.)	58	63.5	255	13	Mod-el (shear).....12,200 kips/in. ²	[260]
1530..	C 0.60, Cr 0.56, Mn 0.62, Si 0.26.	Oil-quenched from 1,470°F, tempered at 750°F.	30,600	170	238	2.5 (8 in.)	2.0	107-116	469	1z 2.0	Mod rupture.....199 kips/in. ² Mod-el (shear).....12,000 kips/in. ²	[259]
1531..	...do.....	Oil-quenched from 1,470°F, tempered at 1,110°F.	30,500	101	164	6.6 (8 in.)	30	85.1	339	1z 22	Mod rupture.....135 kips/in. ² Mod-el (shear).....12,100 kips/in. ²	[259]

*Reversed torsion.

*Zero to maximum torsion.

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
CHROMIUM STEELS—Continued													
1532..	Percent C 0.20, Cr 0.75, Mn 0.57, Si 0.21, S 0.024, P 0.010.	Bar, 3/4 in., normalized at 1,700°F.	.....	.....	56.0	ktps/in. ² 76.0	Percent 35	Percent 68	.....	131	ft-lb 48	.....	[242]
1533..	C 0.20, Cr 0.75, Mn 0.57, Si 0.21, Pb 0.12, S 0.024, P 0.010.	...do....	.....	.....	54.0	75.5	35	66	.....	137	51	.....	[242]
1534..	C 0.59, Cr 0.82, Mn 0.83, Si 0.35.	Forged....	.....	.....	85.0	114	7.0 (2 in.)	47	.....	286	1z 3.0	.....	[259]
1535..	C 0.42, Cr 0.83, Mn 0.56.	Oxy-acetylene flame-hardened.	.....	135	.....	150	.....	.....	.....	{ 325 495	1z 48	.....	[249]
1536..	C 0.29, Cr 0.87, Mn 0.43.	Annealed....	.....	.....	40.3	74.4	34 (2 in.)	57	.....	112	1z 44	.....	[259]
1537..	C 0.42, Cr 0.94, Mn 0.74, Si 0.40.	Cast; air-cooled from 1,650°F, tempered at 1,245°F.	.....	.....	51.0	91.0	18 (2 in.)	26	.....	212	.....	.....	[259]
1538..	C 0.52, Cr 0.94, Mn 0.86, Si 0.22, Pb 0.17, S 0.030, P 0.012.	Annealed at 1,550°F.	.....	.....	46.0	106	22	36	.....	179	10	.....	[242]
1539..	...do....	Oil-quenched from 1,550°F, tempered at 1,200°F.	.....	.....	127	150	18	57	.....	280	28	.....	[242]
1540..	C 0.10, Cr 0.99, Mn 0.39, Si 0.17.	Normalized at 1,650°F.	.....	.....	41.4 (0.5% extn)	60.0	42 (2 in.)	75	.....	.....	1z 88	.....	[259]
1541..	C 0.45, Cr 1.14, Mn 0.69, Si 0.12.	Normalized at 1,525°F.	30,300	.....	89.6	121	12 (8 in.)	50	.....	250	.....	.....	[259]
1542..	...do....	Oil-quenched from 1,525°F, tempered at 795°F.	29,800	.....	213	225	4.3 (8 in.)	17	101	450	1z 12	Mod rupture.....186 ktps/in. ² Mod-el (shear).....11,400 ktps/in. ²	[259]
1543..	...do....	Oil-quenched from 1,525°F, tempered at 1,065°F.	30,100	.....	157	167	8.6 (8 in.)	36	85.1	354	1z 50	Mod rupture.....144 ktps/in. ² Mod-el (shear).....11,500 ktps/in. ²	[259]
1544..	C 0.30, Cr 1.23, Mn 0.49.	Normalized at 1,525°F.	.....	.....	51.5	84.0	33 (2 in.)	64	.....	169	1z 55	.....	[259]
1545..	C 0.30, Cr 1.25, Mn 0.19, Si 0.05.	Oil-quenched from 1,695°F, tempered 1 hr at 990°F.	.....	.....	91.4	112	20 (2 in.)	63	.....	.....	1z 53	.....	[259]
1546..	C 0.33, Cr 1.60, Mn 0.28, Si 0.05.	Annealed at 1,700°F.	.....	.....	35.6	79.7	29 (2 in.)	47	.....	.....	.....	.....	[259]
1547..	...do....	Oil-quenched from 1,560°F, tempered 1 hr at 1,110°F.	.....	.....	86.7	111	22 (2 in.)	63	.....	211	1z 46	.....	[259]
1548..	C 0.35, Cr 1.75, Mn 0.60, Si 0.35.	Bar, 7/8 in. diam, forged; normalized at 1,830°F.	.....	.....	105	159	17 (2 in.)	36	.....	318	1z 7	.....	[259]

1549..	...do.....	Bar, 7/8 in. diam, forged; o-q from 1,600°F, tempered 2 hr at 1,200°F.	.....	.....	104	126	24 (2 in.)	64	.....	257	Iz 69	.....	[259]
1550..	C 0.39, Cr 2.04, Mn 0.48, Si 0.19.	Normalized at 1,650°F, tempered at 1,150°F.	.....	.....	78.0	109	23 (2 in.)	64	.....	196	Iz 21	.....	[259]
1551..	...do.....	011-quenched from 1,650°F, tempered 1 hr at 980°F.	.....	.....	155	172	14 (2 in.)	49	.....	330	Iz 22	.....	[259]
1552..	C 0.39, Cr 2.54, Mn 0.25, Si 0.14.	Forged.....	.....	.....	66.1	121	27 (2 in.)	52	.....	.....	.....	.....	[259]
1553..	C 0.06, Cr 2.65.....	Bar, 3/4 in. diam, a-c.	.....	.....	43.5 (yld pnt)	60.0	42 (2 in.)	79	.....	121	Iz 85	.....	[261]
1554..	C 0.37, Cr 2.80, Mn 0.47, Si 0.20.	Normalized at 1,650°F, tempered at 1,000°F.	.....	.....	137	159	14 (2 in.)	47	.....	311	Iz 8	.....	[259]
1555..	C 0.36, Cr 2.37, Mn 0.78.	Cast; w-q from 1,650°F, tempered at 1,150°F.	.....	.....	127	151	14 (2 in.)	29	.....	.....	.....	.....	[259]
1556..	C 0.11, Cr 3.15, Mn 0.42, Si 0.30.	Normalized at 1,650°F.	.....	.....	69.5 (0.5% extn)	102	19 (2 in.)	49	.....	.....	Iz 30	.....	[259]
1557..	C 0.27, Cr 3.57, Mn 0.30, Si 0.26.	Normalized at 1,650°F, tempered at 1,150°F.	.....	.....	78.0	102	23 (2 in.)	71	.....	198	Iz 73	.....	[259]
1558..	...do.....	011-quenched from 1,650°F, tempered 1 hr at 980°F.	.....	.....	132	167	14 (2 in.)	51	.....	364	Iz 18	.....	[259]
1559..	...do.....	Water-quenched from 1,650°F, tempered 1 hr at 1,110°F.	.....	.....	105	125	20 (2 in.)	65	.....	261	Iz 45	.....	[259]
1560..	C 0.10, Cr 5.21, Mn 0.50, Si 0.34, S 0.039, P 0.008	Forged to 11/16 in.; a-c from 1,600°F.	.....	.....	109 (0.5% extn)	181	16 (2 in.)	53	.....	.....	18	.....	[262]
1561..	...do.....	Forged to 11/16 in.; a-c from 1,600°F.	.....	.....	67.3 (0.5% extn)	84.8	28 (2 in.)	78	.....	.....	60	.....	[262]
1562..	...do.....	Forged to 11/16 in.; f-c from 1,600°F.	.....	.....	27.3 (0.5% extn)	68.0	38 (2 in.)	76	.....	.....	47	.....	[262]
1563..	C 0.30, Cr 5.27, Mn 0.30, Si 0.28, S 0.042, P 0.008.	Forged to 11/16 in.; a-c from 1,600°F.	.....	.....	117 (0.5% extn)	222	14 (2 in.)	32	.....	.....	15	.....	[262]
1564..	...do.....	Forged to 11/16 in.; f-c from 1,600°F.	.....	.....	33.4 (0.5% extn)	79.0	34 (2 in.)	76	.....	.....	79	.....	[262]
1565..	C 0.10, Cr 5.44.....	Bar, 1 in. diam, rolled.	.....	.....	150	181	5 (2 in.)	12	.....	375	Iz 22	.....	[259]
1566..	C 0.08, Cr 6.03.....	Bar, 3/4 in. diam, a-c from 1,380°F.	.....	.....	54.0 (yld pnt)	83.5	31 (2 in.)	74	.....	153	Iz 91	.....	[261]
1567..	...do.....	Bar, 3/4 in. diam, a-c from 1,650°F.	.....	.....	163 (yld pnt)	197	6 (2 in.)	20	.....	351	Iz 19	.....	[261]
1568..	C 0.30, Cr 7.26, Mn 0.51, Si 0.33, S 0.042, P 0.008.	Forged to 11/16 in.; a-c from 1,600°F.	.....	.....	123 (0.5% extn)	233	12 (2 in.)	35	.....	.....	9.6	.....	[262]

^c Surface hardness.

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Ref-er-ence
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
CHROMIUM STEELS—Continued												
1569..	Percent C 0.30, Cr 7.26, Mn 0.54, Si 0.33, S 0.042, P 0.008.	Forged to 11.16 in.; a-c from 1,600°F, tempered at 1,380°F.	Kips/in. ²	Kips/in. ²	Kips/in. ² 76.3 (0.5% extn)	Kips/in. ² 104	Percent 28 (2 in.)	Percent 71	Kips/in. ²	<i>f_t</i> -lb 65	.....	[262]
1570..	...do.....	Forged to 11.16 in.; f-c from 1,600°F.	.....	.....	37.9 (0.5% extn)	84.7	34 (2 in.)	75	.....	80	.....	[262]
1571..	C 0.12, Cr 8.94, Mn 0.49, Si 0.17.	Bar, 1 in. diam, forged; a-m at 1,600°F.	.....	.....	26.0 (yld pnt)	69.3	34 (2 in.)	69	.....	135	58	[263]
1572..	C 0.08, Cr 11.10.....	Oil-quenched from 1,800°F.	.....	71.5	30.0	105	21 (2 in.)	68	.....	235	1z 59	[264]
1573..	C 2.40, Cr 11.5, Mn 0.35, Si 0.30.	Oil-quenched from 1,700°F, tempered at 400°F.	.....	.....	.....	.....	.....	.....	.....	R _c 61	1z 8.0	[265]
1574..	...do.....	Oil-quenched from 1,700°F, tempered at 600°F.	.....	.....	.....	.....	.....	.....	.....	R _c 60	1z 5.5	[265]
1575..	C 0.10, Cr 12, Mn 0.5, Si 0.3, P 0.02, S 0.02.	Annealed.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[266]
1576..	C 0.08, Cr 12.20, Si 0.23, Mn 0.18, Ni 0.18, Cu 0.13.	2 hr at 1,800°F, f-c	.....	15.0	25.0 (0.01% perm)	61.5	40 (2 in.)	70	.....	.....	.....	[17]
1577..	...do.....	1 hr at 1,800°F, w-q, tempered 2 hr at 1,200°F.	.....	45.0	60.0 (0.01% perm)	92.5	24 (2 in.)	72	.....	.....	.....	[17]
1578..	C 0.42, Cr 12.26, Si 0.56, Mn 0.27, Ni 0.20, S 0.058, Cu 0.04, P 0.016.	Bar, 1 in. diam, 1 hr at 1,650°F, w-q, tempered 1 hr at 1,000°F.	.....	27.5	.....	172	11 (2 in.)	41	.....	.....	Torsion str.....110 kips/in. ²	[267]
1579..	...do.....	Bar, 1 in. diam, 1 hr at 1,650°F, w-q, tempered 1 hr at 1,200°F.	.....	56.0	.....	122	15 (2 in.)	52	.....	.....	Torsion str.....83.3 kips/in. ²	[267]
1580..	C 0.43, Cr 12.37, Si 0.13.	Oil-quenched from 1,740°F, tempered at 1,110°F.	32,600	82.5	111	140	17 (2 in.)	51	.....	302	1z 10	[264]
1581..	...do.....	Oil-quenched from 1,740°F, tempered at 1,240°F.	31,900	58.0	80.5	101	26 (2 in.)	59	.....	238	1z 26	[264]
1582..	C 0.15, Cr 13.50, Si 0.11.	Oil-quenched from 1,740°F, tempered at 1,110°F.	31,300	82.2	110	132	21 (2 in.)	63	.....	285	1z 27	[264]
1583..	...do.....	Oil-quenched from 1,740°F, tempered at 1,200°F.	31,600	60.2	72.1	97.5	28 (2 in.)	69	.....	206	1z 107	[264]

1584..	C 0.38, Cr 14.07, Mn 0.27, Ni 0.22, Si 0.21.	Oil-quenched from 1,800°F, tempered at 900°F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....11,700 kips/in. ² ..	[264]
1585..	C 0.85, Cr 14.99, Mn 0.39, Ni 0.26, Si 0.16, Cu 0.03, P 0.020, S 0.005.	Bar, 1 in. diam, 1 hr at 1,650°F, w-q, tempered 1 hr at 900°F.	.....	70.0	.....	230	5.0 (2 in.)	8.6	104 85.0	.....	.....	.....	.....	.....	.....	.....	.....	Torsion str.....150 kips /in. ²	[267]
1586..	...do.....	Bar, 1 in. diam, 1 hr at 1,650°F, w-q, tempered 1 hr at 1,200°F.	.....	51.0	.....	132	12 (2 in.)	30	72.5 37.0	.....	.....	.....	.....	.....	.....	.....	.....	Torsion str.....87.2 kips/in. ²	[267]
1587..	C 0.40, Cr 15.21, Si 0.59, Mn 0.28, Ni 0.18, S 0.058, P 0.017.	Bar, 1 in. diam, 1 hr at 1,650°F, w-q, tempered 1 hr at 900°F.	.....	72.5	.....	164	12 (2 in.)	38	84.5 40.0	.....	.....	.....	.....	.....	.....	.....	.....	Torsion str.....110 kips/in. ²	[267]
1588..	...do.....	Bar, 1 in. diam, 1 hr at 1,650°F, w-q, tempered 1 hr at 1,200°F.	.....	51.8	.....	116	20 (2 in.)	54	59.5 30.0	.....	.....	.....	.....	.....	.....	.....	.....	Torsion str.....73.4 kips/in. ²	[267]
1589..	C 0.20, Cr 16.17, Mn 1.06, Si 0.30.	Oil-quenched from 1,740°F, tempered 3 hr at 940°F.	32,800	50.6	88.8	189	10 (2 in.)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[264]
1590..	C 0.09, Cr 16.53.....	Sheet, 0.18 in., hot-rolled.	.....	.....	104	133	4.5 (8 in.)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[264]
1591..	...do.....	Sheet, 0.18 in., ann.	.....	.....	49	70	20 (8 in.)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[264]
1592..	C 0.10, Cr 17, Mn 0.5, Si 0.3, P 0.02, S 0.02.	Annealed.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Specific gravity..7.57..... Melting range.....2,710°-2,750°F.	[266]
1593..	C 0.12, Cr 18.24.....	Hot-rolled.....	.....	52.5	67.5	90.0	28 (2 in.)	59	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[264]
1594..	...do.....	Cold-drawn.....	.....	79.0	88.5	102	22 (2 in.)	67	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[264]
1596..	C 0.07, Cr 18.56, Si 0.73, Mn 0.43, P 0.087, S 0.020.	Bar, 5/8 in. diam, rolled.	.....	.....	51.2 (yld pnt)	76.5	31 (2 in.)	72	45.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	[266]
1596..	C 0.75, Cr 23.12, Si 0.75.	Forged; f-c from 1,500°F in 5 days.	.....	.....	.....	95.8	11 (2 in.)	12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[264]
1597..	C 0.35, Cr 25.08.....	Cast.....	.....	.....	51.0	59.0	1.0 (2 in.)	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[264]
1598..	C 0.14, Cr 26.28, Mn 0.50, Si 0.36.	Forged.....	.....	.....	62.0	89.0	9.0 (2 in.)	11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[264]
1599..	C 0.15, Cr 27, Mn 0.7, Si 0.3, P 0.02, S 0.02.	Annealed.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Specific gravity..7.49..... Melting range.....2,710°-2,750°F.	[266]
1600..	C 0.20, Cr 27.37, Mn 0.32, Si 0.28, Ni 0.19, Cu 0.04.	...do.....	.....	26.3	44.5	81.0	28 (2 in.)	57	44.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	[264]

CHROMIUM-ALUMINUM STEELS

1601..	C 0.32, Cr 1.24, Al 0.83, Mn 0.72, Ni 0.34, Si 0.22.	Water-quenched from 1,545°F, tempered at 1,110°F.			106	130	15 (5 diam)	55	69										[269]
--------	--	---	-------	-------	-----	-----	----------------	----	----	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

^aReversed torsion.

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	Proportional limit ^a	Yield strength	Tensile strength	Elongation					Reduction of area
CHROMIUM-ALUMINUM STEELS—Continued											
1602..	Percent C 0.32, Cr 1.24, Al 0.80, Mn 0.72, Mo 0.34, Si 0.22.	Water-quenched from 1,545°F, tempered at 1,110°F, ni- trided 48 hr at 900°F.	Ktbs/in. ²	Ktbs/in. ²	Ktbs/in. ² 114	Ktbs/in. ² 144	Percent 7.2 (5 diam)	Percent 11	Ktbs/in. ² 88	ft-lb	[269]
1603..	C 0.34, Cr 1.29, Al 1.06, Mn 0.48, Si 0.25, Mo 0.16, Cu 0.14, Ni 0.13, N ₂ 0.009, V 0.008.	.....	.....	.....	.....	.....	.....	.....	.....	Melting point.....2,745°F..	[228]
1604..	C 0.30, Cr 1.43, Al 1.12, Si 0.43, Mn 0.41.	Oil-quenched from 1,630°F, tempered at 1,200°F.	.....	.....	92.4	115	22 (5 diam)	68	59.7	.....	[268]
1605..	...do.....	Oil-quenched from 1,630°F, tempered at 1,200°F, ni- trided 48 hr at 900°F.	.....	.....	95.3	118	.....	25	78.2	.....	[268]
1606..	C 0.35, Cr 1.50, Al 1.25, Mn 0.50, Mo 0.20.	Oil-quenched from 1,750°F, tempered 1 hr at 1,200°F.	.....	.....	.....	149	16 (4 diam)	.....	61.0	V 288-295	[270]
1607..	...do.....	Oil-quenched from 1,750°F, tempered 1 hr at 1,200°F, ni- trided 48 hr at 950°F.	.....	.....	.....	141	.....	.....	82.0	V 974-1,000	[270]
1608..	...do.....	Oil-quenched from 1,750°F, tempered 1 hr at 950°F, ni- trided 48 hr at 950°F.	.....	.....	140 (0.2%)	155	4 (4 diam)	.....	87.0	V 1,002- 1,064	[270]
1609..	C 0.35, Cr 1.67, Al 0.91, Mn 0.54, Si 0.22, Mo 0.20, Ni 0.20, P 0.014, S 0.012.	Bar, 1 1/16 in. diam, o-q from 1,750°F, 1 hr at 1,100°F, f-c, 3 hr at 1,000°F.	.....	71.6	149 (yld pnt)	162	16 (2 in.)	49	76.0	340 1z 20-32	[271]
1610..	...do.....	Bar, 1 1/16 in. diam, o-q from 1,750°F, 1 hr at 1,100°F, f-c, 3 hr at 1,000°F, nitrided 90 hr at 950°F.	.....	.....	140 (yld pnt)	162	6.0 (2 in.)	8.2	84.0	V 974-1,064 1z 8-13	[271]
1611..	C 0.44, Cr 1.71, Al 1.33, Mn 0.34.	Bar, 1 in. diam, o-q from 1,560°F, tem- pered at 1,165°F.	29,800	66.0	119 (0.5%)	139	19 (2 in.)	.....	{ 71.5 d 51.3 }	V 292	[272]
1612..	...do.....	Bar, 1 in. diam, o-q from 1,560°F, tem- pered at 1,165°F, nitrided 90 hr at 930°F.	29,300	60.5	113 (0.5%)	144	.....	.....	{ 86.0 d 52.4 }	V 1,080	[272]

1613..	C 0.37, Cr 8.29, Al 4.60, Si 1.06, Mn 0.33.	Bar, 1 1/16 in. diam, rolled.	.....	70.0	.....	90.0	5.6 (2 in.)	5.1	.....	R _c 15	f _{1z} 40	.....	[273]
1614..	C 0.67, Cr 8.56, Al 6.30, Si 1.10, Mn 0.41.	...do.....	.....	105	.....	125	3.1 (2 in.)	3.5	.....	R _c 31	f _{1z} 23	.....	[273]

CHROMIUM-COBALT STEELS

1615..	C 1.30, Cr 14.0, Co 5.24, Mo 0.85, Mn 0.19, Si 0.19.	Oil-quenched from 1,650°F, tempered at 1,470°F.	.....	80.6	.....	132	8.4 (4 in.)	8.2	.....	300	b ¹ 1.5	.....	[274]
1616..	C 0.13, Cr 18.0, Co 17.6, Mo 3.10, Mn 0.52, Si 0.33.	.....	.....	.....	.....	167	.....	3	.....	.....	.....	.....	[275]

CHROMIUM-COLUMBIUM STEELS

1617..	C 0.09, Cr 2.53, Cb 0.56.	Bar, 3/4 in. diam, 2 hr at 1,380°F, a-c.	.....	.....	.....	66.8	35 (2 in.)	78	.....	131	1z 98	.....	[261]
1618..	C 0.06, Cr 3.76, Cb 0.56.	...do.....	.....	.....	.....	73.5	31 (2 in.)	79	.....	131	1z 95	.....	[261]
1619..	C 0.09, Cr 5.62, Cb 1.04.	Bar, 1 in. diam, rolled.	.....	.....	.....	111	16 (2 in.)	62	.....	192	1z 59	.....	[259]
1620..	...do.....	Bar, 1 in. diam, 4 hr at 1,380°F, a-c.	.....	.....	.....	62.0	29 (2 in.)	78	.....	112	1z 108	.....	[259]
1621..	...do.....	Bar, 1 in. diam, 1/6 hr at 1,650°F, a-c.	.....	.....	.....	61.0	27 (2 in.)	70	.....	143	1z 105	.....	[259]
1622..	C 0.08, Cr 6.04, Cb 0.56, Mo 0.51.	Bar, 3/4 in. diam, 4 hr at 1,380°F, a-c.	.....	.....	.....	75.0	35 (2 in.)	78	.....	143	1z 95	.....	[261]
1623..	C 0.10, Cr 12.42, Cb 1.18.	Bar, 1 in. diam, rolled.	.....	.....	.....	63.3	30 (2 in.)	53	.....	121	1z 15	.....	[276]
1624..	C 0.07, Cr 19.20, Cb 1.00.	...do.....	.....	.....	.....	72.0	22 (2 in.)	41	.....	149	.....	.....	[276]

CHROMIUM-COPPER STEELS

1625..	C 0.11, Cr 0.53, Cu 0.37, Si 0.82, P 0.068.	Bar, 1 in. diam, normalized.	.....	.....	.....	56.6 (yld pnt)	29 (2 in.)	51	.....	.....	1z 38	.....	[277]
1626..	C 0.10, Cr 0.55, Cu 0.34, Mn 0.96, Si 0.80, Cb 0.12, P 0.066.	...do.....	.....	.....	.....	63.5 (yld pnt)	27 (2 in.)	56	.....	.....	1z 57	.....	[277]
1627..	C 0.32, Cr 0.56, Cu 0.28, Mn 0.55, Si 0.32.	Oil-quenched from 1,565°F, tempered at 800°F.	.....	.....	.....	84.5	19 (2 in.)	37	.....	255	1z 10	.....	[259]
1628..	...do.....	Furnace-cooled from 1,600°F.	.....	.....	.....	49.3	28 (2 in.)	60	.....	146	1z 57	.....	[259]
1629..	C 0.08, Cr 0.99, Cu 0.35, Mn 0.45, Si 0.23, Cb 0.11, P 0.064.	Bar, 1 in. diam, normalized.	.....	.....	.....	56.5 (yld pnt)	27 (2 in.)	56	.....	.....	1z 72	.....	[277]
1630..	C 0.12, Cr 1.00, Cu 0.33, Mn 0.46, Si 0.25, P 0.090.	...do.....	.....	.....	.....	62.0 (yld pnt)	30 (2 in.)	70	.....	.....	1z 57	.....	[277]

^bNotch impact value, m-kg/cm.²

^dAxial.

^eUnnotched.

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area			
			Kt./sq. in.	Kt./sq. in.	Kt./sq. in.	Kt./sq. in.	Percent	Percent			
1631..	C 0.08, Cr 1.01, Cu 0.41, Si 0.80, Mn 0.27, P 0.145, S 0.020.	Bar, 3/4 in., hot-rolled.	30,400	.....	60.0 (0.005% perm)	78.4	40 (2 in.)	72	156	ft-lb	[260]
1632..	C 0.50, Cr 1.53, Cu 0.32, Si 0.55.	Furnace-cooled from 1,600°F.	.....	.....	102	103	16 (2 in.)	31	.....	.....	[259]
1633..	C 0.13, Cr 1.66, Cu 0.45, Si 0.12.	Oil-quenched from 1,565°F, tempered at 800°F.	.....	.....	52.5	70.0	23 (2 in.)	52	223	12 21	[259]
1634..	C 0.25, Cr 1.73, Cu 0.27, Mn 0.48, Si 0.09.	Oil-quenched from 1,575°F, tempered at 1,000°F.	.....	.....	144	156	14 (2 in.)	45	302	12 2	[259]
1635..	C 0.15, Cr 2.88, Cu 0.57, Si 0.20.	Oil-quenched from 1,565°F, tempered at 800°F.	.....	.....	58.5	67.0	23 (2 in.)	52	255	12 24	[259]
1636..	...do.....	Furnace-cooled from 1,740°F.	.....	.....	61.5	67.5	24 (2 in.)	61	126	12 43	[259]
1637..	C 0.24, Cr 3.12, Cu 0.23, Si 0.31.	Oil-quenched from 1,575°F, tempered at 1,000°F.	.....	.....	153	165	1.0 (2 in.)	3.5	352	.....	[259]
1638..	...do.....	Furnace-cooled from 1,475°F.	.....	.....	42.5	86.0	18 (2 in.)	.....	.....	.....	[259]
1639..	C 0.33, Cr 11.54, Cu 0.84, Si 0.09, Mn 0.08, Ni 0.08.	2 hr at 1,700°F, f-c.	.....	35.0	42.0 (0.01% perm)	96.8	28 (2 in.)	61	52.0	.....	[17]
1640..	C 0.11, Cr 11.84, Cu 0.94, Si 0.10, Ni 0.07, Mn 0.04.	2 hr at 1,600°F, f-c.	.....	35.0	42.0 (0.01% perm)	79.8	32 (2 in.)	66	39.0	.....	[17]
1641..	C 0.61, Cr 15.61, Cu 1.10, Mn 0.35, Ni 0.24, S 0.035, Si 0.03, P 0.018.	Bar, 1 in. diam, ann.	.....	25.0	.....	99.8	28 (2 in.)	48	54.5 { 22.0	Torsion str...76.1 kips/in. ²	[267]
1642..	...do.....	Bar, 1 in. diam, 1 hr at 1,650°F, w-q, tempered 1 hr at 900°F.	.....	119	.....	200	9.0 (2 in.)	13	114 { 47.0	Torsion str...119 kips/in. ²	[267]
1643..	C 0.08, Cr 16.76, Cu 0.94, Si 0.73.	Hot-rolled; a-c from 1,500°F.	.....	45.9	.....	78.2	44 (2 in.)	68	163	.....	[264]
1644..	C low, Cr 18, Cu 8-10.	Forged; a-c, tempered.	.....	.....	72	95-105	29 (2 in.)	57	250-260	12 66	[264]
1645..	C 0.10, Cr 22.52, Cu 1.04, N ₂ 0.26.	Bar, 1 in. diam, 6 hr at 1,650°F, w-q.	.....	.....	54.0 (yld pt)	97.8	27 (2 in.)	57	174	12 25	[278]

CHROMIUM-MANGANESE STEELS

1646..	C 0.06, Cr 12.05, Mn 3.91.	Wrought; o-q from 1,635°F., tempered at 1,200°F.	.....	.....	70.0	102	20 (2 in.)	56	.....	159	Iz 52	.....	[264]
1647..	C 0.05, Cr 12.08, Mn 7.16.	...do.....	.....	.....	106	145	10 (2 in.)	38	.....	262	Iz 15	.....	[264]
1648..	C 0.08, Cr 13.60, Mn 13.42.	Air-cooled from 1,920°F.	.....	.....	56.1	192	9 (2 in.)	25	.....	292	Iz 55	.....	[264]
1649..	C 0.20, Cr 15.74, Mn 2.49, Si 0.30.	Oil-quenched from 1,740°F., tempered 3 hr at 840°F.	33,000	61.0	94.5	208	7 (2 in.)	.....	.....	418	.....	.....	[264]
1650..	C 0.18, Cr 17.04, Mn 1.98, Si 0.30.	...do.....	29,400	50.3	81.1	152	.....	.....	.....	321	.....	.....	[264]
1651..	C 0.09, Cr 17.36, Mn 8.60, Co 2.45, Si 0.24.	Quenched.....	.....	.....	43.0	245	18 (2 in.)	22	.....	269	Iz 52	.....	[264]
1652..	C 0.07, Cr 17.67, Mn 8.89, Mo 0.52, Si 0.19.	...do.....	.....	.....	52.0	102	40 (2 in.)	44	.....	179	Iz 117	.....	[264]
1653..	C 0.07, Cr 17.75, Mn 8.83, Si 2.89.	Water-quenched from 1,920°F.	.....	.....	56.0	128	36 (2 in.)	37	.....	187	Iz 120	.....	[264]
1654..	C 0.07, Cr 17.89, Mn 8.26, Si 0.20.	...do.....	.....	.....	48.0	122	27 (2 in.)	28	.....	163	Iz 112	.....	[264]
1655..	C 0.09, Cr 18.15, Mn 8.44, Ni 1.09.	Water-quenched from 1,965°F.	.....	.....	56.0	120	50 (2 in.)	59	.....	187	Iz 120	.....	[264]
1656..	C 0.09, Cr 18.19, Mn 8.89, Si 0.36, P 0.23.	Water-quenched from 1,920°F.	.....	.....	81.0	100	27 (2 in.)	36	.....	217	Iz 1	.....	[264]
1657..	C 0.06, Cr 18.25, Mn 8.65, Cu 1.10.	...do.....	.....	.....	47.0	117	41 (2 in.)	41	.....	170	Iz 120	.....	[264]
1658..	C 0.18, Cr 18.34, Mn 11.75, Si 0.32.	...do.....	.....	.....	47.8	135	51 (2 in.)	65	.....	217	Iz 85	.....	[264]
1659..	C 0.10, Cr 18.45, Mn 8.83, Si 0.52, Ni 0.14.	...do.....	.....	.....	59.0	117	50 (2 in.)	57	.....	192	Iz 119	.....	[264]
1660..	C 0.17, Cr 19.00, Mn 5.26, Ni 5.11, Si 0.67.	Cast.....	.....	.....	40.0	94.0	47 (2 in.)	48	.....	163	Iz 49	.....	[264]
1661..	C 0.15, Cr 19.05, Mn 8.67, Cu 1.10, Si 0.66.	...do.....	.....	.....	53.0	98.0	18 (2 in.)	25	.....	207	Iz 6	.....	[264]
1662..	C 0.10, Cr 22.17, Mn 6.15, Ni 5.73, Cu 1.09.	Water-quenched from 1,920°F.	.....	.....	41.0	96.0	56 (2 in.)	69	.....	153	Iz 115	.....	[264]
1663..	C 0.35, Cr 22.36, Mn 6.19, Ni 6.16, Cu 2.00, Si 0.38.	Cast.....	.....	.....	11.0	73.0	15 (2 in.)	.....	.....	170	Iz 24	.....	[264]
1664..	C 0.10, Cr 22.82, Mn 10.86, Si 0.30.	1.4 hr at 1,830°F, w-q.	.....	.....	65.0	86.3	20 (2 in.)	48	.....	159	Iz 37	.....	[264]
1665..	C 0.20, Cr 25.05, Mn 8.00, Si 0.45.	6 hr at 1,650°F, w-q.	.....	.....	61.0	86.5	32 (2 in.)	45	.....	156	Iz 5	.....	[264]
1666..	C 0.21, Cr 25.10, Mn 11.90, Si 0.37.	...do.....	.....	.....	70.6	90.0	20 (2 in.)	40	.....	156	Iz 10	.....	[264]

^a Reversed torsion.

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
CHROMIUM-MOLYBDENUM STEELS													
1667..	Percent C 0.31, Cr 0.57, Mn 0.22.	Cast; normalized at 1,650°F, tempered at 1,100°F.	Ktpsi/in. ²	Ktpsi/in. ²	Ktpsi/in. ² 71.0	Ktpsi/in. ² 104	Percent 20 (2 in.)	Percent 35	Ktpsi/in. ²	207	ft-lb Iz 22	.....	[279]
1668..	C 0.30, Cr 0.66, Mn 0.20, Mn 0.75, Si 0.19, Pb 0.12, S 0.028, P 0.012.	Annealed at 1,600°F.	.....	.....	55.0	86.0	28	50	.....	143	27	.....	[242]
1669..	...do.....	Oil-quenched from 1,600°F, tempered at 1,125°F.	.....	.....	99.0	119	20	62	.....	217	44	.....	[242]
1670..	C 0.26, Cr 0.66, Mn 0.56, Mn 0.58, V 0.30, Si 0.14, Ni 0.11, S 0.035, P 0.025.	Bar, 1 1/8 in., cast; 1/2 hr at 1,650°F, a-c.	.....	26.9	78.4 (0.2% perm)	120	23 (2 in.)	55	.....	.....	Iz 6.5	.....	[280]
1671..	...do.....	Bar, 1 1/8 in., cast; 1/2 hr at 1,650°F, w-q.	.....	33.6	151 (0.2% perm)	221	14 (2 in.)	43	.....	.....	Iz 15	.....	[280]
1672..	...do.....	Bar, 1 1/8 in., cast; 1/2 hr at 1,650°F, w-q, tempered 6 hr at 750°F.	.....	139	172 (0.2% perm)	192	14 (2 in.)	52	.....	.....	Iz 18	.....	[280]
1673..	C 0.36, Cr 0.70, Mn 0.18, Mn 0.61, Si 0.23, Ni 0.16, P 0.017, S 0.014.	1 hr at 1,600°F, o-q, tempered 1 hr at 1,000°F.	.....	.....	99.4	125	16 (2 in.)	62	65.0	.....	16	.....	[233]
1674..	C 0.31, Cr 0.71, Mn 0.17, Mn 0.65.	Bar, 5/8 in. diam, normalized.	.....	.....	45.0 (0.2% perm)	76.2	32 (2 in.)	66	42.0	145	.....	.....	[47]
1675..	...do.....	Bar, 5/8 in. diam, o-q from 1,625°F, tempered 1/2 hr at 1,100°F.	.....	.....	120 (0.2% perm)	140	18 (2 in.)	63	86.0	290	.....	.....	[47]
1676..	...do.....	Bar, 5/8 in. diam, o-q from 1,625°F, tempered 1/2 hr at 650°F.	.....	.....	168 (0.2% perm)	199	10 (2 in.)	45	114	432	.....	.....	[47]
1677..	C 0.33, Cr 0.78, Mn 0.24, Mn 0.54, Si 0.21, S 0.023, P 0.026.	Wrought; f-c from 1,450°F.	28,600	.....	42.5	76.7	48 (2 in.)	66	.....	170	.....	Shear str.....87.4 kips/in. ² , Mod-el (shear).....12,000 kips/in. ² , Poisson's ratio.....0.288.	[247]
1678..	...do.....	Wrought; o-q from 1,600°F, tempered at 1,100°F.	28,800	.....	90.5	126	28 (2 in.)	60	.....	223	.....	Shear str.....114 kips/in. ² , Mod-el (shear).....11,800 kips/in. ² , Poisson's ratio.....0.272.	[247]
1679..	C 0.39, Cr 0.86, Mn 0.17, Mn 0.86.	Oil-quenched from 1,625°F, tempered at 500°F.	.....	.....	166	211	6.5 (2 in.)	32	.....	388	.....	.....	[259]

1680..	C 0.33, Cr 0.95, Mn 0.15, Mn 0.71, SI 0.13.	1 hr at 1,575°F, 0-n, tempered 1 hr at 1,000°F.	.....	78.0	95.0 (0.01% perm)	124	18 (2 in.)	64	58.5	.....	.....	[17]
1681..	C 0.43, Cr 0.95, Mn 0.33, Mn 0.59, Mn 0.30, SI 0.27, S 0.015, P 0.012.	Bar, 3 5/32 in. diam, rolled.	.....	.....	{ 110 (0.02%) 114 (0.2%) }	110	12 (10 diam)	57	66.9	274	^b 8.2	[281]
1682..	C 0.42, Cr 0.97, Mn 0.18, Mn 0.60.	Oxy-acetylene flame- hardened.	.....	130	.....	147	.....	.....	.....	{ 350 514 }	Iz 40	[249]
1683..	C 0.50, Cr 1.03, Mn 0.19, Mn 0.48, SI 0.24.	Furnace-cooled from 1,600°F.	.....	.....	50.8	111	21 (2 in.)	41	44.5	.....	4.8	[259]
1684..	do.....	Water-quenched from 1,600°F, tempered at 900°F.	.....	.....	128	172	12 (2 in.)	42	88.0	.....	12	[259]
1685..	C 0.99, Cr 1.05, Mn 0.25, Mn 0.73, SI 0.60.	Cast; a-c from 1,525°F, tempered at 1,100°F.	.....	.....	89.0	158	7.0 (2 in.)	9.0	.....	.....	.....	[259]
1686..	C 0.26, Cr 1.58, Mn 0.64, Mn 0.41, SI 0.06.	Oil-quenched from 1,650°F, tempered 2 hr at 1,110°F.	.....	96.3	113	132	21 (2 in.)	62	.....	287	Iz 25	[259]
1687..	C 0.12, Cr 1.98, Mn 0.53, SI 0.55, Mn 0.44.	Bar, 1 in. diam, ann.	25,900	30.5	40.5 (0.1% perm)	71.5	35 (2 in.)	68	.....	131	39	[282]
1688..	C 0.33, Cr 2.03, Mn 0.54, Mn 0.17, SI 0.06.	Oil-quenched from 1,650°F, tempered 2 hr at 1,020°F.	.....	148	174	190	16 (2 in.)	50	.....	412	Iz 19	[259]
1689..	do.....	Oil-quenched from 1,650°F, tempered 2 hr at 1,290°F.	.....	82.9	98.6	117	25 (2 in.)	66	.....	250	Iz 63	[259]
1690..	C 0.28, Cr 2.78, Mn 0.23, Mn 0.84, SI 0.33, SI 0.13, P 0.017, S 0.001.	Bar, 3 5/32 in. diam, rolled.	.....	.....	{ 101 (0.02%) 113 (0.2%) }	133	14 (10 diam)	69	62.6	270	^b 11	[281]
1691..	C 0.29, Cr 3.22, Mn 0.58, Mn 0.51.	Bar, 1 1/8 in., 0-q from 1,650°F, tem- pered at 1,260°F.	.....	.....	118 (yld pnt)	142	23 (2 in.)	68	.....	.....	Iz 87	[283]
1692..	C 0.07, Cr 3.68, Mn 0.50.	Bar, 3/4 in. diam, 2 hr at 1,380°F, a-c.	.....	.....	52.0 (yld pnt)	77.0	31 (2 in.)	76	.....	143	Iz 90	[261]
1693..	do.....	Bar, 3/4 in. diam. a-c from 1,650°F.	.....	.....	82.0 (yld pnt)	112	12 (2 in.)	28	.....	290	Iz 27	[261]
1694..	C 0.16, Cr 5.13, Mn 0.58, SI 0.37, Mn 0.36.	Bar, 1 in. diam, ann.	.....	26.5	31.4 (0.1% perm)	76.0	34 (2 in.)	69	.....	143	55	[282]
1695..	C 0.08, Cr 5.81, Mn 0.45.	Bar, 3/4 in. diam, 4 hr at 1,380°F, a-c.	.....	.....	56.0 (yld pnt)	86.0	29 (2 in.)	72	.....	149	Iz 101	[261]
1696..	do.....	Bar, 3/4 in. diam, a-c from 1,650°F.	.....	.....	113 (yld pnt)	173	4 (2 in.)	16	.....	340	Iz 12	[261]
1697..	C 0.13, Cr 8.72, Mn 0.53, V 0.26, Mn 0.38, SI 0.07.	Bar, 1 in. diam, forged; ann at 1,660°F.	.....	.....	40.4 (yld pnt)	70.2	36 (2 in.)	75	.....	140	48	[263]
1698..	C 0.16, Cr 9.30, Mn 1.36.	Cast; normalized at 1,550°F, tempered . 3 hr at 1,100°F.	.....	.....	67.0 (yld pnt)	99.0	20 (2 in.)	54	.....	212	.....	[264]

^cSurface hardness.

^bNotch impact value, ft-lb/cm.²

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	*Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
CHROMIUM-MOLYBDENUM STEELS—Continued												
1699..	Percent C 0.12, Cr 9.42, Mn 1.41, Mn 0.38, Si 0.09.	Bar, 1 in. diam, forged; ann at 1,600°F.	Ktpsi/in. ²	Ktpsi/in. ²	Ktpsi/in. ² 41.8 (yld pnt)	Ktpsi/in. ² 81.5	Percent 34 (2 in.)	Percent 77	Ktpsi/in. ²	143	ft-lb 63	[263]
1700..	C 1.55, Cr 12.00, Mo 0.80, Mn 0.30, Si 0.30, V 0.25.	Air-cooled from 1,850°F, tempered at 400°F.	.....	.....	.....	.....	.....	.....	.....	R _c 62	12 56	[265]
1701..	C 0.10, Cr 12.75, Mo 0.35, Mn 0.40, Si 0.40, S 0.30, Ni 0.25, P 0.020.	Annealed.....	.....	.....	45.5 (0.2% perm)	75.0	30 (2 in.)	62	43.1	152	12 85	[285]
1702..	do.....	Heat-treated.....	.....	.....	82.5 (0.2% perm)	105	20 (2 in.)	57	55.6	217	12 70	[285]
1703..	C 1.20, Cr 13.50, Mo 1.15, Co 1.15, Mn 0.40, Si 0.65.	Oil-quenched from 1,650°F, tempered at 1,200°F.	.....	.....	.....	120	12 (4 in.)	16	.....	265	b 0.8	[274]
1704..	C 0.35, Cr 16.3, Mo 1.49, Ni 0.64, Si 0.43, Mn 0.34.	.....	.....	.....	70.3 (0.2%)	125	14 (10 diam)	38	.....	.....	.....	[275]
CHROMIUM-NICKEL STEELS (SEE ALSO FIGS. 89, 94 TO 100, INCLUSIVE)												
1705..	C 0.32, Cr 0.46, Ni 0.40, Co 0.25, Si 0.14.	Forged.....	.....	.....	44.8	63.3	4.0 (2 in.)	7.5	.....	.....	.....	[259]
1706..	do.....	Oil-quenched from 1,565°F, tempered at 800°F.	.....	.....	106	111	10 (2 in.)	24	.....	340	12 5	[259]
1707..	do.....	Furnace-cooled from 1,600°F.	.....	.....	52.3	66.0	24 (2 in.)	52	.....	.....	.....	[256]
1708..	C 0.30, Cr 0.72, Ni 0.50, Mn 0.50, Mo 0.30.	Cast; f-c from 1,650°F.	.....	.....	45.0 (yld pnt)	82.6	14 (2 in.)	20	.....	.....	6	[286]
1709..	do.....	Cast; o-q from 1,650°F, tempered at 1,250°F.	.....	.....	82.8 (yld pnt)	105	12 (2 in.)	25	.....	.....	16	[286]
1710..	C 0.45, Cr 0.93, Ni 0.23, Mn 0.66, Si 0.27.	Oil-quenched from 1,560°F, tempered at 1,110°F.	.....	.....	116 (0.1%)	149	20 (2 in.)	52	62.7	.....	12 40	[236]
1711..	C 0.34, Cr 1.01, Ni 0.49, Mn 0.56, Mo 0.22, Si 0.20, P 0.013, S 0.006.	Bar, 3 5/32 in. diam, rolled.	.....	.....	99.1 (0.02%) 112 (0.2%)	134	13 (10 diam)	65	66.9	267	b 14	[261]
1712..	C 0.44, Cr 1.52, Ni 0.39, Mn 0.79, Mo 0.32, V 0.25, Si 0.24, S 0.025, P 0.024.	do.....	.....	.....	117 (0.02%) 128 (0.2%)	148	11 (10 diam)	55	74.0	278	b 11	[281]

1713..	C 0.27, Cr 2.47, Ni 1.22, Mn 0.54, Si 0.41, Mo 0.34, V 0.20, P 0.07.	...	...	...	...	136	14 (10 diam)	71	68.3	262	b 18	.....	[281]
1714..	C 0.30, Cr 2.51, Ni 1.22, Mn 0.53, Si 0.38, Mo 0.23, V 0.22, P 0.011, S 0.001.	...	...	...	...	168	11 (10 diam)	52	75.4	301	b 5.0	.....	[281]
1715..	Oil-quenched from 1,535°F, tempered at 1,110°F.	...	103	.....	127	17	53	a 45.0	290	.....	.....	Shear str. 78.8 kips/in. ² .	[244]
1716..	Forged. ....	...	.....	83 (yld pnt)	134	37	42	.....	260	Iz 50	.....	.....	[287]
1717..	Hot-rolled.	...	29.0	45.5	90.7	45 (2 in.)	62	.....	.....	Iz 79	.....	.....	[274]
1718..	Plate, 1.4 in., o-q from 1,785°F, tem- pered 3 hr at 840°F.	30,600	134	178	202	9 (2 in.)	.....	.....	387	.....	.....	.....	[264]
1719..	Air-cooled from 1,740°F, tempered at 1,200°F.	.....	.....	86.8	110	24 (2 in.)	62	.....	248	Iz 68	.....	.....	[264]
1720..	.....	.....	.....	138	151	17 (2 in.)	47	.....	302	Iz 20	.....	.....	[264]
1721..	.....	.....	.....	.....	88.0	70 (2 in.)	77	33.0	.....	77	.....	.....	[233]
1722..	Water-quenched from 2,010°F.	.....	.....	31.9	66.5	66 (2 in.)	78	.....	126	Iz 100	.....	.....	[264]
1723..	Cast; w-q from 2,010°F.	.....	.....	32.0	72.0	61 (2 in.)	63	.....	131	Iz 85	.....	.....	[264]
1724..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Specific gravity .7.92 Melting range 2,550°-2,590°F.	[266]
1725..	Water-quenched from 2,100°F.	.....	30.0	.....	93.0	68 (2 in.)	75	38.0	170	.....	.....	.....	[288]
1726..	Mixed powders; compacted at 30 tons/in. ² , sintered 32 hr at 2,500°F in hydrogen.	.....	.....	.....	79.2	20	30	.....	R _B 67	.....	.....	Density 7.64 gm/cm ³ Shrinkage 25%.	[289]
1727..	Alloy powder; compacted at 30 tons/in. ² , sintered 24 hr at 2,500°F in hydrogen.	.....	.....	.....	58.3	44	56	.....	R _B 64	.....	.....	Density 7.89 gm/cm ³ Shrinkage 10.2%	[289]
1728..	Sheet, ann. ....	.....	.....	28.0 (0.1% perm)	89.0	65 (2 in.)	.....	32-34	R _B 76	.....	.....	.....	[290]

^aReversed torsion.^bNotch impact value, m-kg/cm.²^cCompression specimen o-q from 1,825°F, tempered at 400°F.

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	Proportional limit ^a	Yield strength	Tensile strength	Elongation	Reduction of area				
CHROMIUM-NICKEL STEELS—Continued												
7729..	Percent C 0.10, Cr 18.07, Ni 15.09, Mn 0.41, Si 0.06.	Water-quenched from 2,010°F.	Ktpsi/in. ²	Ktpsi/in. ² 21.8	Ktpsi/in. ² 34.8 (0.5%)	Ktpsi/in. ² 79.7	Percent 55 (2 in.)	Percent 77	Ktpsi/in. ²	ft-lb Iz 105	.....	[291]
7730..	C 0.07, Cr 18.2, Ni 9.42, Co 0.51.	Water-quenched from 2,100°F.	.....	.....	36.0	89.5	60 (2 in.)	72	.....	Iz 120	.....	[264]
7731..	C 0.15, Cr 18.32, Ni 9.82, W 3.09, Si 2.57.	.....	.....	.....	57.0	116	51 (2 in.)	63	.....	.....	.....	[264]
7732..	C 0.08, Cr 18.50, Ni 8.50, Mn 0.60, Si 0.40, Mo 0.35, S 0.30, P 0.020.	Annealed.....	.....	.....	32.5 (0.2% perm)	85.0	55 (2 in.)	60	35.0	Iz 73	.....	[285]
7733..	C 0.08, Cr 18.50, Ni 8.50, Mn 0.60, Si 0.50, Se 0.30, P 0.120, S 0.020.	...do.....	.....	.....	34.5 (0.2% perm)	87.2	60 (2 in.)	65	31.5	Iz 100	.....	[285]
7734..	C 0.08, Cr 18.58, Ni 9.68, Ti 0.42.	Air-cooled from 1,920°F.	.....	.....	38.1	86.5	59 (2 in.)	64	.....	Iz 111	.....	[264]
7735..	C 0.12, Cr 18.9, Ni 8.0.	Hard-drawn.....	27,700	.....	.....	.....	.....	.....	.....	.....	.....	[237]
7736..	C 0.07, Cr 18.95, Ni 7.69.	Bar, 3.8 in. diam, cold-rolled.	25,000	13.0	.....	143	21 (1.5 in.)	.....	85.0	Iz 34	.....	[292]
7737..	Cr 19, Ni 9, Bi 0.26...	Cast; w-q from 2,075°F.	.....	19.5	30.4 (0.2% extn)	69.3	58	74	.....	.....	.....	[283]
7738..	C 0.06, Cr 19.30, Ni 10.57, Mn 0.70, Si 0.50, S 0.016, P 0.010.	Weld, deposit only..	.....	.....	51.1	79.0	45 (2 in.)	.....	.....	Iz 65	.....	[294]
7739..	...do.....	Weld, deposit only; ann 1/4 hr at 1,950°F, w-q.	.....	.....	40.1	74.0	45 (2 in.)	.....	.....	Iz 81	.....	[294]
7740..	C 0.27, Cr 19.52, Ni 7.28, W 4.70, Si 2.12, Mn 0.51.	Air-cooled from 1,650°F.	.....	74.2	.....	132	28 (4 in.)	39	.....	b 5.8	.....	[274]
7741..	C 0.06, Cr 19.88, Ni 10.57, Mn 0.62, Si 0.42, S 0.015, P 0.008.	Cast.....	.....	.....	29.5	66.2	58 (2 in.)	.....	.....	Iz 106	.....	[294]
7742..	...do.....	Cast; ann 1/4 hr at 1,950°F, w-q.	.....	.....	33.0	66.5	63 (2 in.)	.....	.....	Iz 111	.....	[294]
7743..	C 0.25, Cr 20, Ni 7, Si 1.5.	Forged.....	.....	.....	67 (yld pnt)	125	42	46	.....	Iz 50	.....	[287]
7744..	C 0.30, Cr 20, Ni 7, W 4, Si 1.5.	...do.....	.....	.....	85 (yld pnt)	137	34	41	.....	Iz 35	.....	[287]

1745..	C 0.11, Cr 20.71, Ni 10.76, Al 1.24, Si 1.14, Ti 0.80, Mn 0.55, P 0.030, S 0.010.	Cast; w-q from 2,000°F.	.....	.....	52.5 .01% peral	08	20 (2 in.)	30	30-40	.....	1z 12	.....	[295]
1746..	C 0.34, Cr 21.39, Ni 10.95, W 3.16, Si 1.39, Mn 0.46.	Air-cooled from 1,740°F.	29,100	.....	44.8 (0.1%)	1'8	25	35	47.0	269	1z 40	.....	[238]
1747..	C 0.25, Cr 22, Ni 7....	Wrought.	.....	.....	45.5	111	48 (5 diam)	.....	.....	.....	b 20	.....	[296]
1748..	C Low, Cr 23, Ni 4, N ₂ 0.29.	...do.	.....	.....	81.1	117	50 (5 diam)	.....	.....	.....	b 22	.....	[296]
1749..	C 0.20, Cr 22-25, Ni 10-13.	Sheet, ann.	.....	.....	35.5 (y1d pnt)	78.4	44 (8 in.)	.....	.....	R _B 72	.....	.....	[298]
1750..	C 0.20, Cr 23-27, Ni 17-21.	...do.	.....	.....	45.2 (y1d pnt)	91.0	32 (9 in.)	.....	.....	R _B 82	.....	.....	[298]
1751..	C 0.42, Cr 23.5, Ni 20.7, W 2.8, Si 1.42, Mn 0.12.	Air-cooled from 1,740°F.	29,000	.....	45 (0.1%)	121	26	34	46	255	1z 42	.....	[297]
1752..	C 0.22, Cr 24.0, Ni 20.0, Si 1.07.	Bar, 1 in. diam, rolled.	.....	.....	37.0 (y1d pnt)	83.0	53 (2 in.)	71	.....	R _B 86	.....	.....	[410]
1753..	C 0.13, Cr 24.5, Ni 20.3, Si 0.85.	...do.	.....	.....	40.0 (y1d pnt)	88.0	40 (2 in.)	53	.....	R _B 92	.....	.....	[410]
1754..	C 0.15, Cr 25, Ni 12, Mn 1.0, Si 0.7, P 0.02, S 0.02.	Annealed.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[266]
1755..	C 0.25, Cr 25, Ni 18, Si 2.	Forged.	.....	.....	74 (y1d pnt)	112	29	46	.....	195	1z 50	.....	[287]
1756..	C 0.15, Cr 25, Ni 20, Mn 1.0, Si 0.7, P 0.02, S 0.02.	Annealed.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[266]
1757..	C 0.10, Cr 25.03, Ni 11.53, Si 0.81, Mn 0.78.	Cast.	.....	.....	40.5	80.5	43 (2 in.)	56	.....	170	1z 29	.....	[264]
1758..	...do.	Cast; air-cooled from 2,010°F.	.....	.....	46.5	85.0	49 (2 in.)	65	.....	146	1z 94	.....	[264]
1759..	C 0.10, Cr 25.09, Ni 1.56, N ₂ 0.29.	Bar, 1 in. diam, 6 hr at 1,650°F, w-q.	.....	.....	62.0 (y1d pnt)	94.0	2 (2 in.)	50	.....	183	1z 37	.....	[278]
1760..	C 0.08, Cr 25.5, Ni 19.8, W 3.35, Si 0.69.	Bar, 1 in. diam, rolled.	.....	.....	57.0 (y1d pnt)	93.0	32 (2 in.)	65	.....	R _B 86	.....	.....	[410]
1761..	C 0.10, Cr 25-30, Ni 3-5, Mo 1-1.5.	Hot-rolled.	.....	.....	88.0	127	23 (2 in.)	48	.....	.....	1z 13	.....	[298]
1762..	...do.	Wrought; 1/2 hr at 1,925°F, w-q.	.....	.....	80.0	107	33 (2 in.)	55	.....	229	1z 56	.....	[296]

CHROMIUM-NITROGEN STEELS

1763..	C 0.07, Cr 13.44 N ₂ 0.025.	Bar, 1 in. diam, o-q from 1,740°F.	.....	.....	139 (y1d pnt)	151	10 (2 in.)	15	.....	293	1z 5	.....	[276]
1764..	...do.	Bar, 1 in. diam, o-q from 1,740°F, tem- pered 2 hr at 1,110°F.	.....	.....	66.0 (y1d pnt)	95.5	23 (2 in.)	60	.....	187	1z 58	.....	[278]

^b Notch impact value, m-kg/cm.²

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
CHROMIUM-NITROGEN STEELS—Continued												
1765..	Percent C 0.07, Cr 16.39, N ₂ 0.12.	Bar, 1 in. diam, 3 hr at 1,380°F, a-c.	.....	.....	Ktpsi/in. ² (yld pnt)	Ktpsi/in. ² 92.0	Percent 27 (2 in.)	Percent 66	Ktpsi/in. ²	183	ft-lb 12 86	[278]
1766..	C 0.08, Cr 18.46, N ₂ 0.17.	...do.....	.....	.....	68.0 (yld pnt)	103	25 (2 in.)	57	.....	174	12 61	[278]
1767..	C 0.10, Cr 22.30, N ₂ 0.21.	Bar, 1 in. diam; 6 hr at 1,650°F, w-q.	.....	.....	54.0 (yld pnt)	85.0	29 (2 in.)	66	.....	166	12 24	[278]
1768..	C 0.12, Cr 25.66, N ₂ 0.30.	...do.....	.....	.....	54.0 (yld pnt)	85.5	30 (2 in.)	60	.....	179	12 13	[278]
CHROMIUM-SILICON STEELS												
1769.	C 0.37, Cr 1.65, Si 1.05, Mn 0.33.	Bar, 3/4 in. x 1 3/4 in., forged; a-c from 1,650°F.	.....	.....	77.7	128	22 (2 in.)	57	.....	.....	12 22	[259]
1770..	...do.....	Bar, 3/4 in. x 1 3/4 in., forged; o-q from 1,600°F, tem- pered at 1,020°F.	.....	.....	154	174	12 (2 in.)	45	.....	358	12 10	[259]
1771..	C 0.43, Cr 1.80, Si 1.40, Mn 0.74.	Bar, 7/8 in. diam, forged; o-q from 1,600°F, tempered 2 hr at 1,200°F.	.....	.....	122	148	21 (2 in.)	52	.....	302	12 29	[259]
1772..	C 0.13, Cr 1.94, Si 1.93, Mo 0.59, Mn 0.52.	Bar, 1 in. diam, ann.	29,800	42.5	58.4 (0.1% perm)	90.4	31 (2 in.)	66	.....	179	33	[282]
1773..	C 0.11, Cr 5.39, Si 1.60, Mo 0.61, Mn 0.60.	...do.....	.....	46.5	56.0 (0.1% perm)	87.5	34 (2 in.)	73	.....	170	36	[282]
1774..	C 0.14, Cr 5.57, Si 1.48, Mo 0.68, Mn 0.62.	...do.....	.....	33.0	43.1 (0.1% perm)	88.4	32 (2 in.)	65	.....	197	10	[282]
1775..	C 0.44, Cr 8.1, Si 3.5, Mn 0.52, N 0.15.	Oil-quenched from 1,740°F, tempered at 1,290°F.	28,000	.....	101 (0.1%)	148	16	32	53.8	270	.....	[238]
1776..	C 0.12, Cr 12.50, Si 1.18, Cu 1.15.	Air-cooled from 1,750°F, tempered at 860°F.	.....	140	.....	207	16 (2 in.)	58	.....	.....	.....	[264]
1777..	C 0.17, Cr 13.90, Si 1.35.	Oil-quenched from 1,740°F, tempered at 1,110°F.	29,300	51.2	67.4	103	27 (2 in.)	62	.....	229	12 9	[264]
1778..	C 0.50, Cr 30, Si 1.5..	Forged.....	.....	.....	56 (yld pnt)	101	18	30	.....	215	12 5	[287]

CHROMIUM-TITANIUM STEELS

1779..	C 0.14, Cr 0.77, Ti 0.18, Mn 0.72, Si 0.29.	Rolled.....	.....	.....	57.5	77.0	26 (5 diam)	68	.....	.....	.....	[259]
1780..	C 0.11, Cr 5.41, Ti 0.75.	Bar, 1 in. diam, rolled.	.....	.....	84.0	100	18 (2 in.)	68	.....	Iz 24	.....	[259]
1781..	do.....	Bar, 1 in. diam, rolled; 4 hr at 1,380°F, a-c.	.....	.....	28.0	61.0	37 (2 in.)	78	.....	Iz 63	.....	[259]
1782..	do.....	Bar, 1 in. diam, rolled; 1/6 hr at 1,650°F, a-c.	.....	.....	29.0	62.0	44 (2 in.)	79	.....	Iz 112	.....	[259]
1783..	C 0.11, Cr 13.35, Ti 0.85.	Hot-rolled.....	.....	.....	36.0	63.4	25 (2 in.)	70	.....	.....	.....	[264]
1784..	C 0.07, Cr 19.20, Ti 1.00.	do.....	.....	.....	52.0	72.0	22 (2 in.)	41	.....	.....	.....	[264]
1785..	C 0.18, Cr 26.90, Ti 1.20.	Bar, 1 in. diam, rolled.	.....	.....	66.0 (yld pnt)	86.5	29 (2 in.)	64	.....	.....	.....	[276]

CHROMIUM-TUNGSTEN STEELS

1786..	C 0.88, Cr 0.50, W 0.40, Mn 1.13, Si 0.26, P 0.010, S 0.007.	.....	.....	.....	.....	85.0	.....	.....	.....	Iz 13	.....	[141]
1787..	C 0.45, Cr 0.95, W 0.49, Mn 0.63.	Cast; f-c from 1,600°F.	.....	.....	65.0	110	10 (2 in.)	.....	.....	S 30	.....	[259]
1788..	do.....	Cast; o-q from 1,550°F, tempered at 1,000°F.	.....	.....	125	137	4.0 (2 in.)	8.0	.....	S 49	.....	[259]
1789..	C 0.42, Cr 1.23, W 1.20, Mn 0.32, V 0.29, Si 0.07.	Oil-quenched from 1,600°F, reheated to 1,460°F, o-q, tempered 1/2 hr at 1,200°F.	.....	115	.....	139	18 (2 in.)	58	.....	.....	.....	[299]
1790..	C 0.55, Cr 2.07, W 1.49, Mn 0.36, Si 0.16.	Bar, 3/4 in. diam, ann.	.....	66.0	.....	112	21 (2 in.)	52	.....	.....	.....	[259]
1791..	C 0.36, Cr 2.47, W 2.00, Mn 0.62, V 0.23, Si 0.19.	Billet, oil-quenched, tempered at 1,030°F.	.....	152	.....	201	15 (2 in.)	53	.....	.....	.....	[259]
1792..	C 0.22, Cr 5.14, W 0.76, Mn 0.38, Ni 0.26, Si 0.23, P 0.014, S 0.002.	Bar, 3/4 in., nor- malized at 1,550°F, tempered at 1,100°F.	.....	104	119 (yld pnt)	137	24 (2 in.)	68	.....	285	.....	[63]
1793..	C 0.40, Cr 7.93, W 7.70, Si 0.76, Mn 0.59, Ni 0.26.	Annealed.....	.....	.....	51.5	110	24 (2 in.)	56	.....	.....	.....	[259]
1794..	C 0.12, Cr 8.64, W 1.00, Mn 0.45, Si 0.12.	Bar, 1 in. diam, forged; ann at 1,600°F.	.....	.....	28.3 (yld pnt)	69.1	38 (2 in.)	75	.....	126	41	[263]
1795..	C 0.08, Cr 9.10, W 0.97, Mn 0.42, V 0.25, Si 0.17.	do.....	.....	.....	47.9 (yld pnt)	77.9	35 (2 in.)	71	.....	174	49	[263]

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
CHROMIUM-TUNGSTEN STEELS—Continued												
1796..	Percent C 0.46, Cr 11.94, W 4.80, Si 2.69, Mn 0.49.	Oil-quenched from 1,675°F, tempered at 1,470°F.	Ktpsi/in. ²	Ktpsi/in. ² 101	Ktpsi/in. ²	Ktpsi/in. ² 129	Percent 5.0 (4 in.)	Percent	300	ft-lb 50.3	.....	[274]
CHROMIUM-VANADIUM STEELS												
1797..	C 0.29, Cr 0.51, V 0.28, Mn 0.63.	Annealed at 1,500°F..	.....	.....	49.5	72.8	34 (2 in.)	62	136	28	.....	[259]
1798..	...do.....	Water-quenched from 1,650°F, tempered at 1,050°F.	.....	.....	95.9	114	24 (2 in.)	62	239	.....	.....	[259]
1799..	C 0.25, Cr 0.52, V 0.17, Mn 1.20, Si 0.47.	Cast.....	.....	.....	78.0	109	5.0 (2 in.)	4.0	.....	.....	.....	[259]
1800..	C 0.30, Cr 0.65, V 0.39, Mn 0.19.	Oil-quenched from 1,650°F, tempered at 1,110°F.	.....	.....	107	131	22 (2 in.)	54	.....	Iz 12	.....	[259]
1801..	C 0.58, Cr 0.73, V 0.18, Mn 0.68.	Annealed at 1,500°F..	.....	49.5	.....	92.4	28 (2 in.)	44	163	28	.....	[259]
1802..	...do.....	Water-quenched from 1,650°F, tempered at 1,050°F.	.....	.....	140	181	14 (2 in.)	38	351	.....	.....	[259]
1803..	C 0.46, Cr 0.88, V 0.14, Mn 0.69, Si 0.21.	1 hr at 1,700°F, a-c, 1 hr at 1,575°F, f-c.	.....	40.0	55.0 (0.01% perm)	98.8	26 (2 in.)	51	.....	.....	.....	[17]
1804..	...do.....	1 hr at 1,575°F, o-q, tempered 1 hr at 1,000°F.	.....	90.0	125 (0.01% perm)	151	16 (2 in.)	54	.....	.....	.....	[17]
1805..	C 0.52, Cr 0.88, V 0.21, Mn 0.66.	2/3 hr at 1,600°F, quenched in oil at 130°F, tempered 1 hr at 810°F.	30,200	.....	140 (0.01%) 229 (0.1%)	237	11 (2 in.)	.....	477-488	.....	Mod rupture.....183 kips/in. ² Mod-el (shear).....11,200 kips/in. ²	[254]
1806..	C 0.15, Cr 0.91, V 0.18, Mn 0.58, Si 0.21, S 0.026, P 0.010.	Bar, 3/4 in., nor- malized at 1,700°F.	.....	.....	59.5	75.0	35	73	131	58	.....	[242]
1807..	...do.....	Bar, 3/4 in., cold- drawn.	.....	.....	.....	82.0	24	70	149	55	.....	[242]
1808..	C 0.15, Cr 0.91, V 0.18, Mn 0.58, Si 0.21, Pb 0.16, S 0.026, P 0.010.	Bar, 3/4 in., nor- malized at 1,700°F.	.....	.....	58.0	75.0	36	70	126	53	.....	[242]
1809..	C 0.46, Cr 0.93, V 0.60, Mn 0.73, Si 0.19, S 0.043, P 0.032.	Oil-quenched from 1,650°F, tempered at 1,130°F.	.....	146	.....	164	12	42	355	.....	Shear str.....78.0 kips/in. ²	[244]

1810..	C 0.54, Cr 0.95, V 0.15, Mn 0.82, Si 0.26, S 0.025, P 0.016.	Bar, 1 in. diam, o-q from 1,600°F, tem- pered 1 hr at 450°F.	.....	.....	.....	247 (0.2% offset)	319	5	10	127	R _c 56	10	.....	[25]
1811..	...do.....	Bar, 1 in. diam, austempered 1/6 hr at 1,600°F, to salt at 460°F, held 4 hr.	.....	.....	.....	264 (0.2% offset)	318	6	26	129	R _c 56	9	.....	[25]
1812..	C 0.60, Cr 0.97, V 0.18, Mn 0.64, S 0.03, P 0.02.	Wire, 0.040 in. diam, quenched from 1,690°F, tem- pered at 212°F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....11,200 kips/in. ² ..	[16]
1813..	C 0.49, Cr 0.98, V 0.24, Mn 0.71, Si 0.24, Cu 0.10, Ni 0.08.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Welding point.....2,721°F.	[228]
1814..	C 0.55, Cr 0.99, V 0.19.	Furnace-cooled from 1,850°F.	.....	.....	.....	.....	102	26 (2 in.)	48	44.5	.....	16	Torsion str.....77.0 kips/in. ²	[259]
1815..	...do.....	Water-quenched from 1,850°F, tempered at 1,100°F.	.....	.....	.....	130	164	16 (2 in.)	50	92.0	.....	14	Torsion str.....110 kips/in. ²	[259]
1816..	C 0.59, Cr 1.04, V 0.22, Mn 0.68, Si 0.16, S 0.038, P 0.033.	Oil-quenched from 1,850°F, tempered at 860°F.	.....	179	.....	.....	202	9.5	31	82.7	480	.....	Shear str.....132 kips/in. ²	[244]
1817..	C 0.54, Cr 1.16, V 0.27, Mn 0.68, Si 0.29.	Normalized at 1,560°F.	30,300	103	.....	.....	156	11 (8 in.)	47	.....	300	.....	.....	[259]
1818..	...do.....	Oil-quenched from 1,860°F, tempered at 750°F.	30,300	.....	.....	237	250	5.6 (8 in.)	12	105	500	12 9	Mod rupture.....205 kips/in. ² Mod-el (shear).....11,800 kips/in. ² ..	[259]
1819..	...do.....	Oil-quenched from 1,860°F, tempered at 1,110°F.	30,700	.....	.....	169	178	7.4 (8 in.)	31	95.2	356	12 30	Mod rupture.....148 kips/in. ² Mod-el (shear).....11,800 kips/in. ² ..	[259]
1820..	C 0.37, Cr 1.18, V 0.16, Mn 0.71, Si 0.33, S 0.037, P 0.024.	Wrought; f-c from 1,430°F.	29,400	.....	.....	49.2	88.7	42 (2 in.)	62	.....	179	.....	Shear str.....89.5 kips/in. ² Mod-el (shear).....11,800 kips/in. ² .. Poisson's ratio...0.289.	[247]
1821..	...do.....	Wrought; o-q from 1,600°F, tempered at 1,100°F.	30,000	.....	.....	124	151	24 (2 in.)	48	.....	285	.....	Shear str.....132 kips/in. ² Mod-el (shear).....12,900 kips/in. ² .. Poisson's ratio...0.279.	[247]
1822..	C 0.46, Cr 1.40, V 0.18, Mn 0.57, Si 0.17, Ni 0.15.	Oil-quenched from 1,860°F, tempered at 915°F.	.....	.....	.....	161 (0.1%)	195	16 (2 in.)	48	94.1	.....	12 24	.....	[238]
1823..	...do.....	Oil-quenched from 1,860°F, tempered at 1,200°F.	.....	.....	.....	71.7 (0.1%)	125	22 (2 in.)	60	56.0	.....	12 55	.....	[238]
1824..	C 0.12, Cr 1.53, V 0.11, Mn 0.30, Si 0.17.	Forged; o-q from 1,700°F, tempered at 300°F.	.....	.....	.....	71.0 (yld pnt)	113	23 (2 in.)	51	.....	.....	12 42	.....	[300]
1825..	C 0.33, Cr 7.70, V 0.18, Mn 0.37, Si 0.26, P 0.028, S 0.013.	.....	.....	.....	.....	45 (yld pnt)	84	76 (2 in.)	34	.....	.....	44	.....	[301]

^a Reversed torsion.

^b Notch impact value, m-kj/cm.²

^c Zero to maximum torsion.

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation					Reduction of area
CHROMIUM-VANADIUM STEELS—Continued											
1826..	Percent C 0.17, Cr 8.40, V 0.21, Mn 0.47, Si 0.05.	Bar, 1 in. diam, forged; ann at 1,600°F.	Ktpsi/in. ²	Ktpsi/in. ²	Ktpsi/in. ² 28.8 (yld pnt)	Ktpsi/in. ² 68.9	Percent 38 (2 in.)	Percent 75	Ktpsi/in. ²	ft-lb 54	[263]
1827..	C 2.10, Cr 12.00, V 1.00, Mn 0.30, Si 0.25.	Oil-quenched from 1,800°F, tempered at 400°F.	.....	.....	.....	.....	.....	.....	.....	Iz 20	[265]
1828..	...do.	Oil-quenched from 1,800°F, tempered at 600°F.	.....	.....	.....	.....	.....	.....	.....	Iz 21	[265]
1829..	C 0.03, Cr 13.47, V 0.27, P 0.04, S 0.01.	Bar, 3 in. diam, hot-rolled.	26,500	18.1	.....	82.4	16 (8 in.)	26	40.0	7	[96]
CHROMIUM-ZIRCONIUM STEEL											
1830..	C 0.12, Cr 0.53, Zr 0.10, Si 0.76, Mn 0.59, P 0.021, S 0.018.	Bar, 7/8 in. diam, rolled.	.....	.....	55.5 (yld pnt)	76.0	51 (2 in.)	73	.....	.....	[302]
1831..	...do.	Bar, 7/8 in. diam, normalized at 1,630°F.	.....	.....	49.5 (yld pnt)	73.0	52 (2 in.)	74	.....	.....	[302]
COBALT STEELS											
1832..	C 0.16, Co 0.53, Mn 1.04, Si 0.61, S 0.10, P 0.07.	Bar, annealed.....	.....	49.2	.....	69.4	34 (2 in.)	47	.....	.....	[303]
1833..	C 0.25, Co 1.80, Mn 1.04, Si 0.61, S 0.11, P 0.07.	...do.....	.....	51.5	.....	78.4	29 (2 in.)	39	.....	.....	[303]
1834..	C 0.55, Co 4.50, Mn 0.79, Si 0.69, S 0.11, P 0.06.	...do.....	.....	56.0	.....	103	19 (2 in.)	22	.....	.....	[303]
1835..	C 0.62, Co 5.50.....	Forged.....	.....	.....	73.9 (yld pnt)	109	22 (2 in.)	42	.....	.....	[303]
1836..	C 0.84, Co 11.8.....	...do.....	.....	.....	73.0 (yld pnt)	146	12 (2 in.)	22	.....	.....	[303]
1837..	C 0.93, Co 16.37.....	...do.....	.....	.....	85.1 (yld pnt)	169	9.5 (2 in.)	13	.....	.....	[303]
1838..	Co 19.05, Ni 5.07, Ti 2.51.	Forged; w-q from 1,740°F, 72 hr at 1,200°F.	.....	95.0	120 (0.2%)	151	.....	3.1	.....	.....	[304]
1839..	C 0.16, Co 29.2, Cr 10.65, Mo 4.08, W 2.00, Mn 1.67, Si 1.33.	.....	.....	.....	85.5 (0.2%)	171	6.1 (10 diam)	14	.....	.....	[275]

1840..	C 0.09, Co 30.6, Cr 12.22, Mo 4.25, W 1.70, Si 1.61, Mn 0.85.	.....	.....	46.9 (0.5%)	142	66 (5 diam)	55	.....	.....	.....	[275]
COPPER STEELS (SEE ALSO FIGS. 101 TO 104, INCLUSIVE)											
1841..	C 0.08, Cu 0.25, Mn 0.38, S 0.026, P 0.008.	Sheet, 0.062 in., rolled.	.....	42.4	51.2	31 (8 in.)	.....	.....	R _B 60	30	.....
1842..	C 0.10, Cu 0.30, Mn 0.50, Si 0.24, P 0.068.	Bar, 1 in. diam, normalized.	.....	45.5 (yld pnt)	67.5	33 (2 in.)	60	.....	.....	1z 53	.....
1843..	C 0.11, Cu 0.34, Mn 0.55, Si 0.28, Mo 0.12, P 0.080.	...do.....	.....	40.0 (yld pnt)	74.5	32 (2 in.)	59	.....	.....	1z 38	.....
1844..	C 0.13, Cu 0.40, Mn 0.55, P 0.09.	Plate, 1/2 to 3/4 in., rolled.	.....	58 (yld pnt)	70	23 (2 in.)	59	.....	.....	.....	.....
1845..	C 0.08, Cu 0.47, Mn 1.21, Ti 0.43, Si 0.21, P 0.101.	Bar, 7/8 in. diam, rolled; a-c from 1,650°F.	.....	54.5 (yld pnt)	70.9	34 (2 in.)	73	.....	137	1z 127	.....
1846..	...do.....	Bar, 7/8 in. diam, rolled; w-q from 2,600°F.	.....	96.5	112	18 (2 in.)	62	.....	255	1z 42	.....
1847..	C 0.12, Cu 0.53, Mn 1.15, Ti 0.31, Si 0.22, P 0.118, S 0.011.	Plate, 5/8 in., rolled.	.....	69.9	90.7	26 (2 in.)	71	.....	.....	49	.....
1848..	C 0.09, Cu 0.60, Mn 0.70, Si 0.40, Ni 0.33, Cr 0.25, P 0.10.	Plate, 1/2 to 3/4 in., rolled.	.....	50 (yld pnt)	75	25 (8 in.)	.....	49	.....	1z 75	.....
1849..	C 0.07, Cu 0.80, Cr 0.69, Ni 0.45, Mn 0.42, Si 0.22, S 0.023, P 0.010.	Sheet, 0.062 in., rolled.	.....	65.0	75.0	24 (8 in.)	.....	.....	R _B 84	34	.....
1850..	C 0.27, Cu 0.82, Mn 0.17, S 0.029, P 0.010, Si 0.01.	Bar, 1 in. diam, 1 hr at 1,600°F, w-q, 2 hr at 900°F, f-c.	62.0	71.6 (0.01% perm)	90.1	26 (2 in.)	62	49.5	.....	40	.....
1851..	C 0.19, Cu 1.00, Al 0.85.	Normalized at 1,500°F.	.....	61.5 (0.5% extn)	77.3	34 (2 in.)	64	.....	149	.....	.....
1852..	...do.....	Normalized at 1,500°F, reheated 4 hr at 930°F.	.....	77.2 (0.5% extn)	95.0	26 (2 in.)	59	.....	191	.....	.....
1853..	C 0.28, Cu 1.00, Cr 0.90, Mn 0.64, Si 0.24, P 0.042, S 0.036.	Cast.....	29.1	49.1 (0.2% perm)	87.4	20 (2 in.)	38	.....	.....	1z 10	.....
1854..	...do.....	Cast; a-c from 1,650 F, tempered 4 hr at 930°F.	65.0	85.1 (0.2% perm)	117	15 (2 in.)	26	.....	.....	1z 5	.....
1855..	C 0.27, Cu 1.06, Mn 0.60, Si 0.24, P 0.040, S 0.035.	Cast.....	31.4	48.4 (0.2% perm)	81.5	11 (2 in.)	13	.....	.....	1z 8	.....
1856..	...do.....	Cast; a-c from 1,650°F, tempered 4 hr at 930°F.	60.5	72.1 (0.2% perm)	99.5	15 (2 in.)	24	.....	.....	1z 10	.....

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area			
			Kt./sq. in.	Kt./sq. in.	Kt./sq. in.	Kt./sq. in.	Percent	Percent			
COPPER STEELS—Continued											
1857..	C 0.24, Cu 1.0, Mn 0.98.	Normalized at 1,550°F.	.....	.....	85.4 (0.5% extn)	122	19 (2 in.)	51	243	.....	[310]
1858..	...do.....	Normalized at 1,650°F, reheated 4 hr at 930°F.	.....	.....	108 (0.5% extn)	134	20 (2 in.)	54	282	.....	[310]
1859..	C 0.18, Cu 1.0, Ti 0.93.	Normalized at 1,550°F.	.....	.....	66.8 (0.5% extn)	78.0	33 (2 in.)	75	155	.....	[310]
1860..	...do.....	Normalized at 1,590°F, reheated 4 hr at 930°F.	.....	.....	88.6 (0.5% extn)	96.9	29 (2 in.)	68	190	.....	[310]
1861..	C 0.22, Cu 1.0, V 0.23.	Normalized at 1,590°F.	.....	.....	67.4 (0.5% extn)	83.6	30 (2 in.)	63	163	.....	[310]
1862..	...do.....	Normalized at 1,590°F, reheated 4 hr at 930°F.	.....	.....	89.2 (0.5% extn)	102	26 (2 in.)	59	210	.....	[310]
1863..	C 0.08, Cu 1.05, Mn 0.48, Ni 0.47, Si 0.13, P 0.120, S 0.024.	Sheet, 0.062 in., rolled.	.....	.....	73.0	80.0	23 (8 in.)	.....	R _B 89	.....	[306]
1864..	C 0.08, Cu 1.07, Ni 0.54, Mn 0.43, Si 0.16, P 0.104, S 0.022.	Bar, 3/4 in., hot- rolled.	29,700	.....	56.1 (0.005% perm)	70.8	38 (2 in.)	69	145	Mod-el (shear) ..11,500 kips/in. ²	[260]
1865..	C 0.10, Cu 1.10, Mn 0.60, Ni 0.55, P 0.10, Si <0.30.	Plate, 1/2 to 3/4 in., rolled.	.....	.....	50 (yld pnt)	75	25 (8 in.)	60	.....	.....	[306]
1866..	C 0.23, Cu 1.20, Mn 0.61, Si 0.38, P 0.044, S 0.031.	Cast; 1 hr at 1,650 F, a-c.	.....	.....	57.5	88.1	30 (2 in.)	51	.....	.....	[233]
1867..	...do.....	Cast; 1 hr at 1,650°F, tempered 3 hr at 930°F.	.....	.....	79.4	106	24 (2 in.)	48	.....	.....	[233]
1868..	C 0.09, Cu 1.40, Ni 0.80, Mn 0.70, Mo 0.10.	Plate, 1/2 to 3/4 in., rolled.	.....	.....	55 (yld pnt)	70	25 (8 in.)	50	.....	.....	[306]
1869..	C 0.20, Cu 1.75, Mn 1.16, Si 0.70.	Cast; ann at 1,650°F.	.....	.....	80.6 (yld pnt)	94.1	23 (2 in.)	42	.....	.....	[312]
1870..	C 0.09, Cu 2.0, Mn 1.91.	Normalized at 1,550°F.	.....	.....	73.6 (0.5% extn)	122	20 (2 in.)	46	233	.....	[310]
1871..	...do.....	Normalized at 1,590°F, tempered 4 hr at 930°F.	.....	.....	.....	114	24 (2 in.)	61	216	.....	[310]
1872..	C 0.08, Cu 2.0, V 0.22.	Normalized at 1,650°F.	.....	.....	79.8 (0.5% extn)	84.5	30 (2 in.)	68	176	.....	[310]

1873..	...do.....	Normalized at 1,650°F, reheated 4 hr at 930°F.	.....	.....	98.0 (0.5% extn)	104	26 (2 in.)	63	.....	222	.....	.....	[310]
1874..	C 0.21, Cu 4.0, Mn 1.31.	Normalized at 1,540°F.	.....	.....	109 (0.5% extn)	139	12 (2 in.)	23	.....	369	.....	.....	[310]
1875..	...do.....	Normalized at 1,590°F, tempered 4 hr at 930°F.	.....	.....	.....	158	15 (2 in.)	47	.....	285	.....	.....	[310]
MANGANESE STEELS (SEE ALSO FIG. 105)													
1876..	C 0.27, Mn 1.48, Cu 1.05, Si 0.21, P 0.040, S 0.037.	Cast.....	.....	35.8	63.6 (0.2% perm)	88.0	4 (2 in.)	5	.....	.....	Iz 3	.....	[311]
1877..	...do.....	Cast; a-c from 1,650°F	.....	51.5	67.4 (0.2% perm)	97.2	17 (2 in.)	30	.....	.....	Iz 14	.....	[311]
1878..	...do.....	Cast; a-c from 1,650°F, tempered 4 hr at 930°F.	.....	82.9	86.9 (0.2% perm)	110	10 (2 in.)	20	.....	.....	Iz 9	.....	[311]
1879..	C 0.31, Mn 1.5, Cr 0.65, Mo 0.35.	Cast; a-c from 1,650°F, tempered at 1,000°F.	.....	.....	114 (yld pnt)	154	15 (2 in.)	36	.....	340	7	.....	[286]
1880..	...do.....	Cast; o-q from 1,575°F, tempered at 1,000°F.	.....	.....	165 (yld pnt)	180	13 (2 in.)	32	.....	402	10	.....	[286]
1881..	C 0.41, Mn 1.5, Ni 0.30, Si 0.19.	Water-quenched from 1,650°F, tempered at 1,150°F.	.....	.....	60.5 (0.1%)	105	25 (2 in.)	58	44.8	.....	Iz 20	.....	[238]
1882..	C 0.28, Mn 1.51, V 0.11, Si 0.42.	Cast; a-c from 1,650°F, reheated to 1,500°F, a-c, tempered at 1,150°F.	.....	.....	67.5 (yld pnt)	95.4	30 (2 in.)	63	46.0	.....	Iz 69	.....	[313]
1883..	C 0.34, Mn 1.56, Ni 1.22, Cr 0.71, Mo 0.32.	Cast; a-c from 1,650°F, tempered at 1,000°F.	.....	.....	142 (yld pnt)	176	14 (2 in.)	37	.....	387	.....	.....	[313]
1884..	...do.....	Cast; a-c from 1,650°F, tempered at 1,250°F.	.....	.....	92.0 (yld pnt)	124	23 (2 in.)	51	.....	269	.....	.....	[313]
1885..	C 0.33, Mn 1.60, Mo 0.35.	Cast; a-c from 1,650°F, tempered at 1,000°F.	.....	.....	92.7 (yld pnt)	120	18 (2 in.)	45	.....	280	Iz 9	.....	[313]
1886..	C 0.19, Mn 1.62, Cu 0.45, Si 0.41, Cr 0.06.	Forged, finished at 2,010°F.	.....	.....	52.6 (yld pnt)	97.2	23 (5 diam)	54	.....	.....	^b 8.8	.....	[314]
1887..	C 0.31, Mn 1.66, Si 0.25, S 0.024, P 0.015.	Wrought; f-c from 1,450°F.	27,800	.....	43.2	84.9	42 (2 in.)	54	.....	169	.....	Shear str.....84.3 kips/in. ² .. Mod-el (shear)..12,000 kips/in. ² .. Poisson's ratio..0.295.	[247]
1888..	...do.....	Wrought; o-q from 1,325°F, tempered at 1,100°F.	28,600	.....	78.5	112	33 (2 in.)	57	.....	204	.....	Shear str.....101 kips/in. ² .. Mod-el (shear)..12,100 kips/in. ² .. Poisson's ratio..0.296.	[247]
1889..	C 0.36, Mn 1.68, Cr 0.10, Ni 0.04.	Oil-quenched from 1,550°F, tempered at 450°F.	.....	.....	218 (yld pnt)	233	7 (2 in.)	28	.....	.....	Iz 12	.....	[315]

^b Notch impact value, m-kg/cm.²

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	Proportional limit	Yield strength	Tensile strength	Elongation				
			$\text{Kt}/\text{sq. in.}$	$\text{Kt}/\text{sq. in.}$	$\text{Kt}/\text{sq. in.}$	$\text{Kt}/\text{sq. in.}$	Percent				
	Percent				($\text{Kt}/\text{sq. in.}$)						
1890..	C 0.30, Mn 1.68, P 0.042.	Cast; a-c from 1,600°F, tempered at 1,050°F.	.....	.....	74.0 (yld pt)	106	28 (2 in.)	Percent 59	.....	ft-lb Iz 40	[313]
1891..	C 0.09, Mn 1.70, Cr 1.05, Si 0.17.	Bar, 1 in. diam, rolled.....	.....	.....	50.0	89.0	23 (2 in.)	44	.....	.....	[259]
1892..	...do.....	Bar, 1 in. diam, rolled; normalized at 1,650°F.	.....	.....	52.0	90.0	26 (2 in.)	52	171	Iz 37	[259]
1893..	C 0.35, Mn 1.71, Si 0.30, S 0.030, P 0.021.	Cast.....	.....	39.0	.....	80.8	2.1 (2 in.)	4	32.0	3	[316]
1894..	...do.....	1 hr at 1,650°F, a-c, 1 hr at 1,525°F, a-c, tempered 1 hr at 600°F.	.....	46.8	.....	104	25 (2 in.)	56	45.0	28	[316]
1895..	C 0.27, Mn 1.71, Mo 0.25.	Rolled.....	.....	.....	78.0 (yld pt)	120	19 (2 in.)	37	.....	.....	[286]
1896..	...do.....	Rolled; normalized at 1,600°F.	.....	.....	88.0 (yld pt)	127	20 (2 in.)	32	.....	Iz 28	[286]
1897..	...do.....	Rolled; w-q from 1,550°F, tempered at 1,100°F.	.....	.....	119 (yld pt)	136	20 (2 in.)	43	.....	Iz 52	[286]
1898..	C 0.43, Mn 1.75, Cr 0.40, Si 0.34.	Bar, 1 in. diam, rolled.	.....	.....	82.0	123	13 (2 in.)	35	.....	.....	[259]
1899..	C 0.31, Mn 1.77, Si 0.23, Pb 0.15, S 0.031, P 0.015.	Annealed at 1,525°F.	.....	.....	66.5	95.5	28 (2 in.)	56	159	17	[242]
1900..	...do.....	Water-quenched from 1,525°F, tempered at 1,125°F.	.....	.....	113	121	20	55	.....	20	[242]
1901..	C 0.42, Mn 1.78, Si 0.24, V 0.046.	Oil-quenched from 1,500°F, tempered at 450°F.	.....	.....	232 (yld pt)	270	12 (2 in.)	50	.....	Iz 48	[317]
1902..	C 0.36, Mn 2.24.....	Oil-quenched from 1,650°F, tempered at 1,110°F.	.....	82.9	96.8 (yld pt)	117	25 (2 in.)	61	249	Iz 21	[286]
1903..	C 0.30, Mn 2.30, Mo 0.52.	...do.....	.....	116	138 (yld pt)	152	17 (2 in.)	55	330	Iz 41	[286]
1904..	C 1.0-1.4, Mn 10-14, Si 0.3-1.0, P <0.10, S <0.05.	Rolled or hammered..	.....	40-60	.....	130-160	60-70 (2 in.)	40-60	.....	.....	[318]
1905..	...do.....	Cast, h-t.....	.....	.....	.....	80-100	15-35 (2 in.)	15-35	.....	.....	[316]
1906..	...do.....	Cast and ground, h-t.	.....	42.9	.....	118	44 (2 in.)	39	39.0	.....	[316]

1907..	C 0.15, Mn 16.58, Cr 7.49, Si 4.00, Ti 0.55.	Air-cooled from 1,920°F.	.....	.....	60.3 (0.2%)	141	28 (5 diam)	28	.....	.....	.....	[276]
1908..	C 0.30, Mn 17.30, Cr 5.32, Si 0.62.	Water-quenched from 1,920°F.	.....	.....	36.3	117	34 (10 diam)	34	.....	.....	.....	[319]
1909..	C 0.36, Mn 17.72, Cr 5.52, Si 0.49, N ₂ 0.12.	...do.....	.....	.....	69.0	138	43 (10 diam)	46	.....	.....	.....	[319]
1910..	C 0.25, Mn 17.96, Si 0.40.	...do.....	.....	.....	41.5	131	14 (10 diam)	.....	.....	.....	.....	[319]
1911..	C 0.26, Mn 17.96, Si 2.33.	...do.....	.....	.....	44.8	133	17 (10 diam)	.....	.....	.....	.....	[319]
1912..	C 0.26, Mn 16.41, Ni 1.56, Si 0.47.	...do.....	.....	.....	39.8	120	44 (10 diam)	54	.....	.....	.....	[319]
1913..	C 0.26, Mn 20.25, Cr 18.06, Si 0.25.	Water-quenched from 2,400°F.	.....	.....	46.0 (yld pnt)	91.5	50 (2 in.)	53	.....	170	Iz 120	[320]

MOLYBDENUM STEELS (SEE ALSO FIG. 106)

1914..	C 0.23, Mo 0.17, Mn 0.67, Si 0.52, Cu 0.10.	Annealed at 1,650°F.	.....	.....	54.0	82.2	31 (5 diam)	63	.....	.....	.....	[321]
1915..	C 0.24, Mo 0.22, Mn 0.85, Si 0.19, S 0.037, P 0.02.	Plate, 5/8 in., rolled.	.....	.....	60.4 (yld pnt)	88.2	30 (2 in.)	15	.....	194	.....	[322]
1916..	C 0.29, Mo 0.30, Mn 1.29, Si 0.46.	Cast.....	.....	.....	72.6 (yld pnt)	97.0	6.0 (2 in.)	12	.....	223	16	[313]
1917..	...do.....	Cast; a-c from 1,700°F, w-q from 1,500°F, tempered at 1,050°F.	.....	.....	117 (yld pnt)	134	18 (2 in.)	48	.....	302	36	[313]
1918..	C 0.44, Mo 0.31, Mn 1.29.	Oil-quenched from 1,600°F, tempered at 700°F.	.....	.....	185 (yld pnt)	220	11 (2 in.)	37	.....	430	Iz 9	[288]
1919..	...do.....	Oil-quenched from 1,600°F, tempered at 840°F.	.....	.....	170 (yld pnt)	195	12 (2 in.)	37	.....	400	Iz 15	[286]
1920..	C 0.23, Mo 0.49, Mn 0.81, Si 0.40, V 0.09.	Cast; a-c from 1,650°F, a-c from 1,550°F, tempered at 1,250°F.	.....	.....	57.0 (yld pnt)	83.0	25 (2 in.)	60	.....	39.8	.....	[313]
1921..	C 0.30, Mo 0.52, V 0.215.	Rollled.....	.....	.....	102	135	18 (2 in.)	46	.....	282	.....	[286]
1922..	...do.....	Rollled; w-q from 1,560°F, tempered at 1,110°F.	.....	.....	113	141	19 (2 in.)	60	.....	320	.....	[286]
1923..	C 0.11, Mo 0.51, Mn 0.47, Si 0.17, S 0.014, P 0.010.	Normalized 1/2 hr at 1,650°F.	.....	.....	.....	63.0	37 (2 in.)	74	.....	P _B 69	50	[323]
1924..	C 0.20, Mo 0.60, Mn 0.55, V 0.30, Si 0.21, Ni 0.06, Cr 0.05, S 0.030, P 0.023.	Bar, 1 1/8 in., cast; normalized 1/2 hr at 1,650°F.	.....	47.0	65.0 (0.05% perm)	86.7	29 (2 in.)	62	.....	.....	Iz 9	[280]
1925..	...do.....	8ar, 1 1/8 in., cast; 1/2 hr at 1,650°F, w-q, tempered 6 hr at 1,110°F.	.....	125	134 (0.2% perm)	147	.....	64	.....	.....	Iz 16	[280]

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Import value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
MOLYBDENUM STEELS—Continued													
1926..	Percent C 0.35, Mo 0.61, Mn 0.79, Cr 0.41, Si 0.22, P 0.033, S 0.019.	Bar, 3 5/32 in. diam, rolled.	Kt/ps/in. ²	Kt/ps/in. ²	Kt/ps/in. ² { 88.5 (0.02%) 96.1 (0.2%)	Kt/ps/in. ² { 125 (10 diam)	Percent 14 (10 diam)	Percent 64	Kt/ps/in. ² 61.2	281	ft-lb 15	.....	[281]
1927..	C 0.34, Mo 0.64, Mn 0.79, Cr 0.40, Si 0.21, P 0.029, S 0.018.	...do.....	.....	.....	Kt/ps/in. ² { 113 (0.02%) 151 (0.2%)	Kt/ps/in. ² { 172 (10 diam)	5.4 (10 diam)	44	61.2	373	b 3.1	.....	[281]
1928..	C 0.33, Mo 0.96.....	Rollad; o-q from 1,650°F, tempered at 1,020°F.	.....	.....	111	133	18	55	.....	281	.....	.....	[286]
1929..	C 0.84, Mo 1.02.....	Rollad.....	.....	.....	116	179	14 (2 in.)	34	.....	.....	.....	.....	[286]
1930..	C 0.87, Mo 1.02.....	Rollad; ann at 1,750°F.	.....	.....	58.2	121	17 (2 in.)	22	.....	228	.....	.....	[286]
1931..	...do.....	Rollad; normalized at 1,650°F.	.....	.....	103	152	13 (2 in.)	28	.....	302	.....	.....	[286]
1932..	...do.....	Rollad; o-q from 1,560°F, tempered at 1,025°F.	.....	.....	194	240	9.1 (2 in.)	25	.....	418	.....	.....	[286]
1933..	C 0.19, Mo 1.03.....	Rollad.....	.....	.....	50.2	75.1	33 (2 in.)	64	.....	.....	.....	.....	[286]
1934..	C 0.44, Mo 1.05.....	...do.....	.....	.....	77.0	122	20 (2 in.)	49	.....	.....	.....	.....	[286]
1935..	C 0.22, Mo 1.06, Mn 0.50, Si 0.13.	Cast; ann at 1,650°F.	.....	.....	40.2 (yld pnt)	70.2	28 (2 in.)	50	.....	146	.....	.....	[313]
1936..	C 1.21, Mo 1.09.....	Rollad; ann at 1,750°F.	.....	.....	58.4	95.5	5.6 (2 in.)	7.5	.....	207	.....	.....	[286]
1937..	...do.....	Rollad; normalized at 1,650°F.	.....	.....	117	159	11 (2 in.)	18	.....	321	.....	.....	[286]
1938..	C 0.50, Mo 1.15.....	Oil-quenched from 1,560°F, tempered at 975°F.	.....	.....	195 (yld pnt)	226	13 (2 in.)	35	.....	435	Iz 19	.....	[286]
1939..	C 0.25, Mo 1.38, Cr 1.10, Mn 0.32, Si 0.07.	Oil-quenched from 1,650°F, tempered at 1,110°F.	.....	110	138	156	19 (2 in.)	57	.....	341	Iz 15	.....	[259]
1940..	...do.....	Oil-quenched from 1,650°F, tempered at 1,280°F.	.....	87.3	95.2	112	25 (2 in.)	66	.....	236	Iz 66	.....	[259]
1941..	C 0.11, Mo 3.0.....	Forged.....	.....	.....	38.1	76.2	34 (2 in.)	67	.....	133	.....	.....	[286]
1942..	Mo 5, Cu 1 (-200 mesh powder).	Mixed powders; com- pacted at 12 1/2 tons/in. ² , sintered 1 hr at 2,200°F in hydrogen.	.....	.....	.....	.....	.....	.....	.....	R _B 50	.....	Density.....7.49 gm/cm ³ . Porosity.....6.6%.	[52]

1943..	...do.....	Wire, 0.050 in. diam, drawn from above compact.	.....	.....	.....	62.9	14	.....	.....	.....	Density.....8.34 gm/cm ³ ..	[52]
1944..	C 0.07, Mo 7.14.....	Forged.....	.....	.....	.....	82.9	30 (2 in.)	57	.....	160	.....	[286]
1945..	C 0.55, Mo 7.94, Co 5.41, Cr 3.9, V 0.99, W 0.36, Mn 0.12.	.....	.....	.....	.....	109	15 (2 in.)	23	.....	.....	.....	[286]
1946..	Mo 10, Cu 1 (-200 mesh powder).	Mixed powders; compacted at 12 1/2 tons/in ² , sintered 1 hr at 2,200°F in hydrogen.	.....	.....	.....	.....	.....	.....	.....	R _B 81	Density.....6.96 gm/cm ³ .. Porosity.....13.3%.	[52]
1947..	...do.....	Wire, 0.016 in. diam, drawn from above compact.	.....	.....	.....	.....	14	.....	.....	.....	Density.....8.42 gm/cm ³ ..	[52]
1948..	C 0.09, Mo 12.5.....	Forged.....	.....	.....	.....	62.7	14 (2 in.)	38	.....	174	.....	[286]
1949..	Mo 15, Cu 1 (-200 mesh powder).	Mixed powders; compacted at 12 1/2 tons/in ² , sintered 1 hr at 2,200°F in hydrogen.	.....	.....	.....	.....	.....	.....	.....	R _B 84	Density.....7.42 gm/cm ³ .. Porosity.....7.5%.	[52]
1950..	...do.....	Wire, 0.016 in. diam, drawn from above compact.	.....	.....	.....	.....	15	.....	.....	.....	Density.....8.77 gm/cm ³ ..	[52]
1951..	C 0.08, Mo 19.70.....	Forged.....	.....	.....	85.1	130	2 (2 in.)	2	.....	275	.....	[286]

NICKEL STEELS (SEE ALSO FIGS. 107 AND 108)

1952..	C 0.76, Ni 0.30, Mn 0.55, Si 0.19.	Normalized at 1,510°F.	.....	.....	62.7 (0.1%)	141	16 (2 in.)	25	43.7	.....	1 1/2 3	.....	[238]
1953..	C 0.34, Ni 0.45, Mn 1.04.	Wrought, 1 3/4 in. x 3/4 in., normalized at 1,470°F.	.....	60.5	62.7 (0.2% perm)	93.2	31	62	.....	190	1 1/2 40	.....	[324]
1954..	...do.....	Wrought, 1 3/4 in. x 3/4 in., w-q from 1,960°F, tempered at 1,110°F.	.....	82.9	89.2 (0.2% perm)	112	22	61	.....	247	1 1/2 57	.....	[324]
1955..	C 0.33, Ni 1.45, Mn 1.04.	Wrought, 1 3/4 in. x 3/4 in., normalized at 1,470°F.	.....	65.0	68.5 (0.2% perm)	98.6	31	64	.....	202	1 1/2 3	.....	[324]
1956..	...do.....	Wrought, 1 3/4 in. x 3/4 in., w-q from 1,960°F, tempered at 1,110°F.	.....	96.3	103 (0.2% perm)	119	23	61	.....	256	1 1/2 53	.....	[324]
1957..	C 0.26, Ni 1.40, Mn 0.62, Si 0.23, P 0.039, S 0.034.	Cast; tempered 4 hr at 930°F.	.....	20.2	40.3 (0.2% perm)	75.0	15 (2 in.)	28	.....	.....	1 1/2 9	.....	[311]
1958..	C 0.08, Ni 1.99, Mn 0.48.	Normalized, tempered at 1,200°F.	.....	.....	47.0 (yld pt)	61.5	40	70	.....	.....	63	.....	[325]

^b Notch impact value, in-kg/cm.²

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	Proportional limit ^a	Yield strength	Tensile strength	Elongation	Reduction of area				
			Kips/in. ²	Kips/in. ²	Kips/in. ²	Kips/in. ²	Percent	Percent		Kips/in. ²		
NICKEL STEELS—Continued												
1959..	Percent C 0.05, Ni 2.11, Mn 0.17, Si 0.01.	Bar, 1 1/8 in. diam, a-c from 1,625°F., tempered at 1,200°F.	.....	.....	39.0 (0.5% extn)	83.7	41 (2 in.)	73	106	ft-lb 58	.....	[326]
1960..	C 0.12, Ni 2.2, Mn 0.4, Si 0.1.	Annealed at 1,600°F, w-q from 1,400°F.	.....	.....	35.8	85.1	32 (2 in.)	65	.....	Iz 80	.....	[238]
1961..	C 0.05, Ni 2.69, Mn 0.44, Si 0.20.	Bar, 3 in. diam, a-c from 1,575°F, tem- pered at 1,200°F.	.....	.....	53.0 (0.5% extn)	71.2	36 (2 in.)	73	144	60	.....	[326]
1962..	C 0.24, Ni 2.7, Mn 0.94.	Bar, 6 in. diam, forged; a-c from 1,475°F, f-c from 1,100°F.	.....	.....	63.0 (yld pnt)	86.3	.....	.....	183	Iz 105	.....	[327]
1963..	C 0.39, Ni 2.96, Mn 0.55, Si 0.11.	oil-quenched from 1,560°F, tempered at 1,150°F.	.....	.....	78.4 (0.1%)	111	24 (2 in.)	64	.....	Iz 70	.....	[238]
1964..	C 0.35, Ni 3.19, Mn 0.58, Si 0.25, S 0.045, P 0.033.	oil-quenched from 1,510°F, tempered at 1,200°F.	.....	86.2	.....	109	21	62	295	.....	Shear str.....82.2 kips/in. ² .	[244]
1965..	C 0.29, Ni 3.37, Mn 0.52.	Bar, 5/8 in. diam, o-q from 1,500°F, tempered 1/2 hr at 1,100°F.	.....	.....	127 (0.2% perm)	129	20 (2 in.)	67	257	.....	.....	[47]
1966..	C 0.47, Ni 3.46, Mn 0.92, Si 0.30, S 0.026, P 0.013.	Bar, 3/4 in. diam, ann at 1,475°F.	.....	.....	71.5	117	22	16	217	14	.....	[242]
1967..	...do.....	Bar, 3/4 in. diam, o-q from 1,475°F, tempered at 1,150°F.	.....	.....	85.5	126	20	42	220	24	.....	[242]
1968..	C 0.47, Ni 3.46, Mn 0.92, Si 0.30, Pb 0.20, S 0.026, P 0.013.	Bar, 3/4 in. diam, ann at 1,475°F.	.....	.....	74.5	118	23	48	217	14	.....	[242]
1969..	...do.....	Bar, 3/4 in. diam, o-q from 1,475°F, tempered at 1,150°F.	.....	.....	94.0	124	20	46	223	23	.....	[242]
1970..	C 0.43, Ni 3.47, Mn 0.64, Si 0.20, S 0.023, P 0.015.	Wrought; f-c from 1,450°F.	30,000	.....	53.0	94.4	33 (2 in.)	45	187	.....	Shear str.....90.0 kips/in. ² . Mod-el (shear)...12,100 kips/in. ² . Poisson's ratio...0.308.	[247]
1971..	...do.....	Wrought; o-q from 1,450°F, tempered at 1,100°F.	28,200	.....	82.2	117	34 (2 in.)	58	226	.....	Shear str.....107 kips/in. ² . Mod-el (shear)...11,700 kips/in. ² . Poisson's ratio...0.298.	[247]
1972..	C 0.43, Ni 3.60, Mn 0.57.	Oxy-acetylene flame- hardened.	.....	125	.....	135	.....	.....	578	Iz 69	.....	[249]
1973..	C 0.14, Ni 4.9, Mn 0.28, Si 0.16.	Normalized at 1,845°F, w-q from 1,400°F.	.....	.....	60.5 (0.1%)	136	18 (2 in.)	47	.....	Iz 24	.....	[238]

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
NICKEL-CHROMIUM STEELS—Continued													
1997..	Percent C 0.45, Ni 1.25, Cr 0.66, Mn 0.83, Si 0.29, Pb 0.18, S 0.027, P 0.012.	Oil-quenched from 1,475°F, tempered at 1,200°F.	Ktpsi/in. ²	Ktpsi/in. ²	Ktpsi/in. ² 140	Ktpsi/in. ² 151	Percent 19	Percent 58	Ktpsi/in. ²	290	ft-lb 30	.....	[242]
1998..	C 0.37, Ni 1.28, Cr 0.52, Mn 0.55.	Bar, 1 1/8 in. diam, h-t.	28,500	.....	25.0 (0.001% offset)	131	18 (2 in.)	59	.....	.....	.....	.....	[240]
1999..	C 0.37, Ni 1.33, Cr 0.65, Mn 0.75, Si 0.18, S 0.030, P 0.017.	Hot-rolled.....	.....	.....	74.0 (yld pnt)	115	25 (2 in.)	67	a 44.0	.....	.....	.....	[331]
2000..	...do.....	Quenched from 1,510°F, tempered at 930°F.	.....	.....	153 (yld pnt)	162	16 (2 in.)	60	a 56.0	.....	.....	.....	[331]
2001..	C 0.27, Ni 1.54, Cr 0.61, Mn 0.66, Si 0.23, P 0.039, S 0.036.	Cast.....	.....	38.1	62.7 (0.2% perm)	89.3	4 (2 in.)	5	.....	.....	Iz 3	.....	[311]
2002..	...do.....	Air-cooled from 1,650°F.	.....	29.1	60.7 (0.2% perm)	101	21 (2 in.)	42	.....	.....	Iz 22	.....	[311]
2003..	C 0.28, Ni 1.51, Cr 0.73, Mn 0.69, Si 0.24, S 0.016, P 0.014.	Bar, 1 in. diam, 1 hr at 1,550°F, w-q, 2 hr at 1,000°F, f-c.	.....	102	123 (0.01% perm)	138	19 (2 in.)	53	68.0	.....	31	.....	[309]
2004..	C 0.33, Ni 1.52, Cr 0.64, Mn 0.62.	Oxy-acetylene flame- hardened.	.....	110	.....	130	.....	.....	.....	c 534	Iz 75	.....	[249]
2005..	C 0.40, Ni 1.65, Cr 0.99, Mn 0.51, Si 0.20, S 0.025, P 0.019.	Wrought; i-c from 1,450°F.	28,800	.....	43.8	89.9	40 (2 in.)	54	.....	170	.....	Shear str.....90.6 kpsi/in. ² , Mod-el (shear).....11,300 kpsi/in. ² Poisson's ratio..0.299.	[247]
2006..	...do.....	Wrought; o-q from 1,530°F, tempered at 1,100°F.	29,000	.....	91.0	129	34 (2 in.)	59	.....	224	.....	Shear str.....115 kpsi/in. ² , Mod-el (shear).....12,100 kpsi/in. ² Poisson's ratio..0.290.	[247]
2007..	C 0.32, Ni 2.04, Cr 0.97, Mn 0.20.	Bar, 1 1/2 in. x 3/4 in., forged; o-q from 1,650°F, tem- pered 1 hr at 1,110°F.	.....	78.4	89.2 (0.2% perm)	111	22	65	.....	.....	Iz 75	.....	[332]
2008..	...do.....	Bar, 1 1/2 in. x 3/4 in., forged; a-c from 1,650°F.	.....	47.0	63.2 (0.2% perm)	101	27	61	.....	.....	Iz 67	.....	[332]
2009..	C 0.43, Ni 2.16, Cr 0.95, Mn 0.60, Si 0.21, P 0.023, S 0.016.	Bar, 1 in. diam, 1 hr at 1,550°F, w-q, 2 hr at 1,000°F, f-c.	.....	106	143 (0.01% perm)	158	17 (2 in.)	50	76.0	.....	16	.....	[309]

2010..	C 0.31, Ni 3.20, Cr 0.75, Mn 0.70, Si 0.11.	Oil-quenched from 1,510°F, tempered at 1,110°F.	.....	.....	112 (0.1%)	134	22 (2 in.)	61	58.2	.....	Iz 68	[238]
2011..	C 0.26, Ni 3.52, Cr 0.53, Mn 0.37, Si 0.09, S 0.032, P 0.026.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[238]
2012..	C 0.28, Ni 3.70, Cr 0.26, Mn 0.50, Si 0.19, S 0.036, P 0.015.	Bar, 1 in. diam, 1 hr at 1,675°F, a-c, 1 hr at 1,450°F, w-q, 2 hr at 1,000°F, f-c.	.....	94.3	115 (0.01% perm)	128	21 (2 in.)	62	64.0	.....	29	[309]
2013..	...do.....	Bar, 1 in. diam, 1 hr at 1,450°F, f-c.	.....	53.8	59.5 (0.01% perm)	90.2	30 (2 in.)	59	49.0	.....	31	[309]
2014..	C 0.28, Ni 4.20, Cr 1.50, Mn 0.50, Si 0.15.	Air-cooled from 1,510°F, tempered at 480°F.	.....	.....	146 (0.1%)	237	12 (2 in.)	45	101	.....	Iz 12	[238]
2015..	C 0.14, Ni 4.49, Cr 1.30, Mn 0.40, Si 0.21.	Oil-quenched from 1,400°F.	.....	.....	108 (0.1%)	189	18 (2 in.)	64	87.4	.....	Iz 30	[238]
2016..	Ni 12.2, Cr 1.0.....	.....	27,000	.....	.....	.....	.....	.....	.....	.....	.....	[329]
2017..	C 0.23, Ni 15.46, Cr 15.04, Mn 0.81, Si 0.19, Cu 0.09.	Hot-rolled.....	.....	28.0	44.5	94.6	53 (2 in.)	66	.....	R _c 3	Iz 96	[274]
2018..	...do.....	Water-quenched from 1,800°F.	.....	26.5	45.0	92.9	51 (2 in.)	68	.....	.....	Iz 101	[274]
2019..	Ni 16.2, Cr 2.5.....	.....	27,900	.....	.....	.....	.....	.....	.....	.....	.....	[329]
2020..	C 0.18, Ni 29.29, Cr 19.01.	Cast.....	.....	20.0	29.0 (y1d prt)	67.2	20 (2 in.)	22	.....	131	.....	[407]
2021..	...do.....	Forged.....	.....	13.5	53.5 (y1d prt)	93.5	22 (2 in.)	18	.....	207	.....	[407]
2022..	C 0.29, Ni 33.19, Cr 11.60, Mn 1.30.	Air-cooled from 1,650°F.	.....	.....	.....	94.6	19 (4 in.)	55	.....	190	b 12	[274]
2023..	C 0.39, Ni 34.70, Cr 10.89, Mn 1.10, Si 0.15.	.....	.....	.....	67.2	112	29 (2 in.)	47	57.0	.....	.....	[274]
2024..	Ni 35.7, Cr 1.7.....	.....	22,300	.....	.....	.....	.....	.....	.....	.....	.....	[329]
2025..	C 0.43, Ni 37, Cr 10, Si 0.25.	Forged.....	.....	.....	63 (y1d prt)	108	30	50	.....	200	Iz 50	[287]
2026..	C 0.40, Ni 40.0, Cr 17.0, Mn 1.0, Si 1.0.	Cast.....	.....	.....	50.0	65.0	1.5 (2 in.)	1.5	.....	241	.....	[271]

NICKEL-CHROMIUM-ALUMINUM STEEL

2027..	C 0.42, Ni 2.65, Cr 1.68, Al 1.33, Mn 0.38, Si 0.19.	Oil-quenched from 1,600°F, tempered at 1,220°F.	.....	.....	136	155	16 (5 diam)	54	78.2	.....	.....	[269]
2028..	...do.....	Oil-quenched from 1,600°F, tempered at 1,220°F, ni- trided 48 hr at 930°F.	.....	.....	.....	169	0 (5 diam)	2	96.7	.....	.....	[269]

^a Reversed torsion.

^b Notch impact value, m-kj/cm.²

^c Surface hardness.

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area			
			Kips/in. ²	Kips/in. ²	Kips/in. ²	Kips/in. ²	Percent (2 in.)	Percent	Kips/in. ²		
2029..	C 0.38, Ni 1.59, Cr 0.59, Mo 0.21, Mn 0.63.	Forged; f-c from 1,280°F.	.....	.....	81.3 (yld pt)	112	22 (2 in.)	52	.....	.....	[327]
2030..	C 0.41, Ni 1.74, Cr 0.65, Mo 0.34, Mn 0.75, Si 0.22, Pb 0.17, S 0.022, P 0.012.	Annealed at 1,525°F.	.....	.....	134	142	18	46	.....	.....	[242]
2031..	C 0.39, Ni 1.74, Cr 0.72, Mo 0.32, Mn 0.65, Si 0.27.	Bar, o-q from 1,525°F, tempered at 1,125°F.	.....	128	135	145	20 (2 in.)	58	.....	.....	[333]
2032..	C 0.30, Ni 1.75, Cr 0.65, Mo 0.33, Mn 0.53, Si 0.14, Pb 0.11, S 0.023, P 0.013.	Bar, 3.4 in. diam, normalized at 1,600°F.	.....	.....	77.5	115	21	66	.....	.....	[242]
2033..	C 0.32, Ni 1.92, Cr 0.86, Mo 0.30, Mn 0.60, Si 0.16, S 0.019, P 0.014.	Wrought; f-c from 1,450°F.	28,700	.....	49.6	96.2	37 (2 in.)	58	.....	.....	[247]
2034..	do.....	Wrought; o-q from 1,550°F, tempered at 1,100°F.	28,500	.....	105	140	32 (2 in.)	64	.....	.....	[247]
2035..	C 0.31, Ni 2.07, Cr 2.05, Mo 0.39, Mn 0.48, Si 0.29, P 0.007, S 0.006.	Bar, 3 5/32 in. diam, rolled.	.....	.....	113 (0.02%) 124 (0.2%)	145	14 (10 diam)	69	74.0	.....	[281]
2036..	C 0.34, Ni 2.20, Cr 2.17, Mo 0.36, Mn 0.45, Si 0.28, P 0.012, S 0.009.	do.....	.....	.....	143 (0.02%) 169 (0.2%)	188	10 (10 diam)	52	89.6	.....	[281]
2037..	C 0.32, Ni 2.12, Cr 0.49, Mo 0.38, Mn 0.99, Si 0.23, Cu 0.13, S 0.04, P 0.03.	Bar, 6 in., cast; ann at 1,575°F, o-q from 1,550°F, tem- pered at 1,200°F.	29,300	70.0	98.0	118	10 (4 /area)	16	60.0 { 40.0	.....	[334]
2038..	C 0.27, Ni 2.55, Cr 0.65, Mo 0.61, Mn 0.68, V 0.20.	Bar, 1 1/2 in. x 3/4 in., forged; o-q from 1,550°F, tempered 1 hr at 1,110°F.	.....	150	179 (0.2% perm)	193	17	55	.....	.....	[332]
2039..	C 0.31, Ni 2.60, Cr 0.75, Mo 0.60, Mn 0.48.	Forged; o-q from 1,650°F, tempered 1 hr at 1,110°F.	.....	125	159 (0.2% perm)	173	16	53	.....	.....	[332]

2040..	C 0.28, Ni 2.77, Cr 1.24, Mo 0.41, Mn 0.46, Si 0.25, S 0.031, P 0.010.	Bar, 3 5/32 in. diam, rolled.	.....	.....	83.3 (0.02%) 105 (0.2%)	126	16 (10 diam)	65	65.4	248	^b 12	.....	[281]
2041..	C 0.27, Ni 2.98, Cr 1.31, Mo 0.41, Mn 0.42, Si 0.20, P 0.023, S 0.015.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[326]
2042..	C 0.21, Ni 3.07, Cr 1.5, Mo 0.56, Mn 0.51, Si 0.20, V 0.18.	Oil-quenched from 1,560°F, tempered at 1,185°F.	.....	.....	150 (0.1%)	167	21 (2 in.)	67	71.7	.....	Iz 48	.....	[238]
2043..	C 0.28, Ni 3.72, Cr 0.64, Mo 0.35.	Oil-quenched from 1,650°F, tempered at 1,110°F.	.....	123	142 (yld pnt)	152	18 (2 in.)	57	.....	324	Iz 29	.....	[286]

NICKEL-CHROMIUM-SILICON STEELS

2044..	C 0.43, Ni 20.71, Cr 7.32, Si 1.13, Mn 0.19.	Hot-rolled.....	.....	44.0	55.0	111	48 (2 in.)	60	.....	R _c 7	Iz 98	.....	[274]
2045..	do.....	Water-quenched from 1,830°F.	.....	32.0	46.6	107	43 (2 in.)	56	.....	R _c 5	Iz 75	.....	[274]
2046..	C 0.24, Ni 22.90, Cr 5.42, Si 1.65, Mn 0.80, Cu 0.78, S 0.027, P 0.010.	Bar, 1 in. diam. ann.	.....	25.0	.....	96.0	33 (2 in.)	60	{ 50.0 } 21.0	.....	.....	Torsion str. ....69.3 kips/in. ² ..	[267]
2047..	C 0.39, Ni 25.27, Cr 17.71, Si 1.44, Mn 0.66, Cu 0.12, S 0.030, P 0.018.	do.....	.....	30.0	.....	118	22 (2 in.)	33	54.0	.....	.....	Torsion str. ....74.3 kips/in. ² ..	[267]
2048..	C 0.45, Ni 28.20, Cr 8.38, Si 1.39, Cu 0.67, Mn 0.49, S 0.022, P 0.012.	do.....	.....	22.8	.....	111	24 (2 in.)	49	{ 58.5 } 22.0	.....	.....	Torsion str. ....72.8 kips/in. ² ..	[267]
2049..	C 0.28, Ni 36.80, Cr 8.44, Si 3.00, Mn 0.20.	Hot-rolled.....	.....	28.5	49.0	⁴ 112	40 (2 in.)	52	.....	R _c 2	Iz 56	.....	[274]
2050..	do.....	Water-quenched from 1,830°F.	.....	31.0	47.0	101	41 (2 in.)	54	.....	R _c 5	Iz 59	.....	[274]

NICKEL-CHROMIUM-TITANIUM STEELS

2051..	C 0.13, Ni 3.47, Cr 0.78, Ti 0.26, Mn 0.52, Si 0.31, P 0.022, S 0.004.	Annealed at 1,470°F..	.....	66.9	.....	92.6	24 (5 diam)	54	.....	.....	.....	.....	[335]
2052..	do.....	Water-quenched from 1,590°F.	.....	124	.....	145	14 (5 diam)	59	.....	.....	.....	.....	[335]
2053..	C 0.13, Ni 15.12, Cr 12.64, Ti 2.37.	Water-quenched from 1,830°F.	.....	23.0	40.0	87.2	48 (2 in.)	68	.....	.....	Iz 102	.....	[274]
2054..	do.....	Water-quenched from 1,850°F, tempered 3 hr at 1,290°F.	.....	60.0	75.0	130	37 (2 in.)	61	.....	.....	Iz 84	.....	[274]

^aReversed torsion.

^bNotch impact value, m-kJ/cm.²

TABLE 20. — Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference	
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
NICKEL-CHROMIUM-TUNGSTEN STEELS													
2055..	Percent C 0.16, Ni 3.77, Cr 1.43, W 0.72, Mn 0.38, Si 0.19, Mo 0.08, P 0.015, S 0.005.	Bar, 3 5/32 in. diam, rolled.	Ktpsi/in. ²	Ktpsi/in. ²	Ktpsi/in. ² { 77.4 (0.02%) 128 (0.2%)	Ktpsi/in. ² { 145 (10 diam)	Percent 8.9 (10 diam)	Percent 60	Ktpsi/in. ² 95.3	348	<i>f</i> _{t-lb} b 14	.....	[281]
2056..	C 0.20, Ni 4.21, Cr 1.55, W 0.84, Mn 0.38, Si 0.19, P 0.009, S 0.003.	...do.....	.....	.....	Ktpsi/in. ² { 106 (0.02%) 115 (0.2%)	Ktpsi/in. ² { 129 (10 diam)	Percent 15 (10 diam)	Percent 75	66.9	253	b 20	.....	[281]
2057..	C 0.41, Ni 28.5, Cr 14.4, W 3.2, Si 1.75, Mn 0.92.	Water-quenched from 1,830°F.	29,100	.....	82.7 (yld pnt)	109	38	46	.....	235	1z 49	.....	[298]
2058..	C 0.32, Ni 31.11, Cr 12.25, W 3.72, Mn 1.27, Si 1.13.	Air-cooled from 1,650°F.	.....	49.1	.....	104	30 (4 in.)	46	.....	195	b 8.6	.....	[274]
NICKEL-CHROMIUM-VANADIUM STEELS													
2059..	C 0.27, Ni 2.07, Cr 1.04, V 0.46, Mn 0.10.	Forged; o-q from 1,650°F, tempered at 1,110°F.	.....	116	129 (0.2% perm)	145	20	57	.....	.....	1z 24	.....	[322]
2060..	C 0.27, Ni 2.09, Cr 1.05, V 0.13, Mn 0.21.	...do.....	.....	98.6	118 (0.2% perm)	136	20	62	.....	.....	1z 39	.....	[332]
2061..	C 0.27, Ni 2.93, Cr 1.38, V 0.18, Mn 0.55, Si 0.21, P 0.012, S 0.009.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Melting point...2,743°F.	[328]
NICKEL-COPPER STEELS													
2062..	C 0.08, Ni 0.75, Cu 0.65, Mn 0.38, Mo 0.10, P 0.11, Si 0.05.	Plate, 1/2 to 3/4 in., rolled.	.....	.....	50 (yld pnt)	70	27 (8 in.)	60	48	.....	1z 130	.....	[306]
2063..	C 0.26, Ni 1.49, Cu 1.00, Mn 0.72, Si 0.22, P 0.040, S 0.036.	Cast.....	.....	26.9	52.2 (0.2% perm)	82.9	13 (2 in.)	15	.....	.....	1z 5	.....	[311]
2064..	...do.....	Cast; a-c from 1,650°F, tempered at 1,110°F.	.....	47.0	71.7 (0.2% perm)	97.7	21 (2 in.)	31	.....	.....	1z 26	.....	[311]
2065..	C 0.31, Ni 1.36, Cu 1.02, Mn 0.70, Cr 0.48, Si 0.22, P 0.038, S 0.037.	Cast.....	.....	49.3	75.5 (0.2% perm)	86.9	2 (2 in.)	3	.....	.....	1z 3	.....	[311]
2066..	...do.....	Cast; a-c from 1,650°F, tempered at 1,110°F.	.....	62.7	84.2 (0.2% perm)	116	13 (2 in.)	19	.....	.....	1z 14	.....	[311]

2067..	C 0.22, Ni 1.98, Cu 0.92, Mn 0.69, Si 0.25, P 0.045, S 0.019.	Bar, 3/4 in. diam, hot-rolled.	29, 100	.....	54.1 (0.005% perm)	91.3	30 (2 in.)	54	54.5	194	24	Mod-el (shear) ... 11,600 lbf/in. ² .	[260]
2068..	C 0.08, Ni 2.00, Cu 1.00, Mn 0.55, Si 0.3.	Plate, 1/2 to 3/4 in., rolled.	.....	.....	55 (yld pnt)	75	25 (8 in.)	60	40	.....	40	.....	[306]
2069..	C 0.53, Ni 17.3, Cu 6.25, Cr 3.0, Si 2.84.	Cast.....	.....	.....	46.2	92.4	28 (2 in.)	32	.....	.....	.....	.....	[274]
2070..	C 0.17, Ni 28.88, Cu 7.01, Mn 0.84, Si 0.02.	Hot-rolled.....	.....	16.0	49.5	83.4	44 (2 in.)	71	.....	.....	Iz 111	.....	[274]
2071..	...do.....	Water-quenched from 1,470°F.	.....	31.0	48.5	82.0	42 (2 in.)	69	.....	.....	Iz 109	.....	[274]

NICKEL-MANGANESE STEELS

2072..	C 0.30, Ni 1.50, Mn 1.50.	Cast.....	.....	.....	64.5	96.2	27	52	.....	.....	28	.....	[336]
2073..	C 0.37, Ni 15.0, Mn 1.50.	Rolled.....	.....	40.0	.....	107	40 (2 in.)	51	.....	.....	.....	.....	[337]
2074..	...do.....	Rolled; quenched above 1,400°F.	.....	19.5	.....	73.0	38 (2 in.)	46	.....	.....	.....	.....	[337]

NICKEL-MOLYBDENUM STEELS

2075..	C 0.39, Ni 1.60, Mo 0.40, Mn 0.45, Si 0.20.	Rolled.....	.....	.....	88.0 (yld pnt)	119	18 (2 in.)	39	.....	262	10	.....	[286]
2076..	...do.....	Rolled; o-q from 1,500°F, tempered at 1,100°F.	.....	.....	138 (yld pnt)	150	16 (2 in.)	50	.....	321	19	.....	[286]
2077..	C 0.18, Ni 1.64, Mo 0.24, Mn 0.47.	Oxy-acetylene flame- hardened.	.....	105	.....	120	.....	.....	.....	{ 250 c 177	Iz 62	.....	[249]
2078..	C 0.41, Ni 1.96, Mo 0.31.	Oil-quenched from 1,525°F, tempered at 1,200°F.	.....	96.3	121 (yld pnt)	130	23	63	67.2	252	Iz 83	.....	[338]
2079..	...do.....	Quenched from 1,525°F into lead at 840°F (austempered).	.....	60.9	105 (yld pnt)	128	19	46	.....	.....	Iz 11	.....	[338]
2080..	C 0.28, Ni 2.50, Mo 0.31, Mn 0.88.	Bar, 10 in. diam, forged; a-c from 1,500°F, tempered at 1,200°F.	.....	.....	73.3 (yld pnt)	96.9	25 (2 in.)	60	.....	.....	.....	.....	[327]
2081..	C 0.20, Ni 3.48, Mo 0.51, Mn 0.40.	Forged.....	.....	94.0	.....	110	13 (2 in.)	24	.....	210	.....	.....	[286]
2082..	...do.....	Forged; o-q from 1,550°F, tempered at 1,100°F.	.....	123	.....	132	21 (2 in.)	62	.....	360	.....	.....	[286]
2083..	C 0.05, Ni 3.72, Mo 0.21, Si 0.15, Mn 0.13.	Bar, 1 1/4 in. diam, a-c from 1,600°F, tempered at 1,200°F.	.....	.....	43.2 (0.5% extn)	63.5	40 (2 in.)	78	.....	130	70	.....	[326]

^b Notch impact value, m-kg/cm.²

^c Surface hardness.

TABLE 20.—Iron and steel, normal temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
NICKEL-MOLYBDENUM STEELS—Continued												
2084..	Percent C 0.26, Ni 4.54, Mo 0.51.	Oil-quenched from 1,650°F, tempered at 1,110°F.	Kt/psi/in. ² 121	Kt/psi/in. ² 121	Kt/psi/in. ² (yld pnt) 139	Kt/psi/in. ² 145	Percent 19 (2 in.)	Percent 57	Kt/psi/in. ² 312	ft.-lb Iz 29	.....	[286]
2085..	C 0.09, Ni 5.35, Mo 0.34, Mn 0.86, Si 0.22.	Bar, 2 1/2 in. diam. a-c from 1,575°F, tempered at 1,200°F.	.....	.....	51.0 (0.5% extn)	108	26 (2 in.)	66	 217	61	.....	[326]
NICKEL-SILICON STEELS												
2086..	C 0.37, Ni 2.95, Si 2.50, Mo 0.70, Mn 0.52.	Plate, o-q from 1,575°F, tempered at 1,100°F.	.....	164	.....	.....	186 7 (2 in.)	29	92.0	385	Iz 18	[286]
2087..	C 0.11, Ni 3.00, Si 2.47, Mn 0.70.	...do.....	.....	146	.....	.....	170 14 (2 in.)	26	85.0	360	Iz 12	[286]
2088..	C 0.16, Ni 3.02, Si 1.42, Mn 0.80.	Plate, o-q from 1,575°F, tempered at 650°F.	.....	247	.....	.....	281 2 (2 in.)	5	.....	555	Iz 19	[340]
2089..	C 0.17, Ni 3.11, Si 1.58, Mn 0.87, Cr 0.32.	1 hr at 1,475°F, f-c.	.....	40.0	77.0 (0.01% perm)	140	22 (2 in.)	43	65.0	.....	.....	[17]
2090..	...do.....	1 hr at 1,500°F, o-q, tempered 1 hr at 1,000°F.	.....	90.0	115 (0.01% perm)	162	18 (2 in.)	46	89.0	.....	.....	[17]
NICKEL-VANADIUM STEELS												
2091..	C 0.30, Ni 1.52, V 0.11, Mn 0.81.	Normalized at 1,700°-1,850°F, normalized at 1,500°F, tempered at 1,000°-1,200°F.	.....	.....	66.2	96.0	28	55	.....	.....	Iz 56	[339]
2092..	C 0.19, Ni 1.62, V 0.10, Mn 0.64.	...do.....	.....	.....	57.0	83.5	27	52	.....	.....	.....	[339]
SILICON STEELS												
2093..	C 0.30, Si 0.99, Mn 1.00.	Rolled.....	.....	.....	61.0 (yld pnt)	95.0	25 (2 in.)	48	.....	.....	Iz 33	[340]
2094..	...do.....	Normalized at 1,650°F.	.....	.....	67.0 (yld pnt)	94.0	30 (2 in.)	62	.....	.....	Iz 40	[340]
2095..	...do.....	Water-quenched from 1,650°F, tempered at 890°F.	.....	.....	141 (yld pnt)	155	11 (2 in.)	42	.....	.....	Iz 53	[340]
2096..	C 0.13, Si 1.04, Mn 0.71.	Cast.....	.....	.....	34.7 (yld pnt)	65.0	25 (2 in.)	48	.....	.....	.....	[313]
2097..	...do.....	Cast; normalized at 1,830°F.	.....	.....	48.0 (yld pnt)	67.5	26 (2 in.)	58	.....	.....	.....	[313]

2098..	C 0.07, Si 1.17, Mn 0.32, S 0.034, P 0.013.	Roll-d.....	.....	.....	.....	47.5	67.5	30 (3 in.)	72	.....	130	^b 3.1	.....	[340]
2099..	C 0.15, Si 1.2, Mn 0.8, Cr 0.6.	Oil-quenched from 1,550°F, tempered at 600°F.	.....	.....	.....	75.0	115	21 (2 in.)	67	.....	207	.....	.....	[259]
2100..	C 0.30, Si 1.2, Mn 0.8, Cr 0.6.	Oil-quenched from 1,550°F, tempered at 800°F.	.....	.....	.....	160	184	14 (2 in.)	51	.....	375	.....	.....	[259]
2101..	...do.....	Oil-quenched from 1,550°F, tempered at 1,200°F.	.....	.....	.....	100	112	25 (2 in.)	68	.....	219	.....	.....	[258]
2102..	C 0.45, Si 1.2, Mn 0.8, Cr 0.6.	Oil-quenched from 1,550°F, tempered at 800°F.	.....	.....	.....	199	224	13 (2 in.)	46	.....	434	.....	.....	[258]
2103..	...do.....	Oil-quenched from 1,550°F, tempered at 1,200°F.	.....	.....	.....	115	130	23 (2 in.)	63	.....	250	.....	.....	[259]
2104..	C 0.18, Si 1.30, Mn 1.22, Cu 0.13, P 0.046, S 0.040.	Cast.....	.....	.....	.....	.....	75.0	26	45	.....	.....	^b 0.9	.....	[340]
2105..	...do.....	Cast; normalized at 1,795°F.	.....	.....	.....	.....	84.0	26	38	.....	.....	^b 5.9	.....	[340]
2106..	C 0.24, Si 1.44, Mn 0.49, P 0.030, S 0.022.	Roll-d.....	.....	.....	.....	.....	88.0	25 (8 in.)	50	.....	.....	12 30	.....	[340]
2107..	C 0.08, Si 1.46, Mn 1.02.	...do.....	30,300	.....	.....	68.3	92.5	16	.....	52.6	.....	.....	.....	[340]
2108..	C 0.37, Si 1.60, Mn 1.04.	Water-quenched from 1,650°F, tempered at 750°F.	.....	.....	.....	190 (yld pnt)	210	10 (2 in.)	41	.....	.....	12 23	.....	[340]
2109..	...do.....	Normalized at 1,650°F.	.....	.....	.....	80.0 (yld pnt)	111	25 (2 in.)	50	.....	.....	12 28	.....	[340]
2110..	C 0.53, Si 1.74, Mn 0.50.	Oil-quenched, tem- pered at 930°F.	31,100	.....	.....	187	213	5.8	.....	91.0	.....	.....	.....	[340]
2111..	C 0.52, Si 1.95, Mn 1.05, Cr 0.05.	Oil-quenched from 1,600°F, tempered at 970°F.	.....	.....	.....	146 (0.1%)	198	15 (2 in.)	36	96.3	.....	12 13	.....	[238]
2112..	C 0.53, Si 1.96, Mn 0.83.	2/3 hr at 1,640°F, quenched in oil at 130°F, tempered 1 hr at 860°F.	29,100	.....	.....	132 (0.01%) 210 (0.1%)	236	12 (2 in.)	.....	{ 112 e 138 }	438-457	.....	Mod rupture.....190 kips/in. ² .. Mod-el (shear).....10,700 kips/in. ² ..	[254]
2113..	C 0.53, Si 2.0, Mn 0.94, S 0.021, P 0.020.	Water-quenched from 1,740°F.	.....	.....	80.7	105	137	15 (8 in.)	35	.....	275	.....	.....	[340]
2114..	...do.....	Oil-quenched from 1,740°F, tempered at 840°F.	.....	149	.....	230	242	4.2 (8 in.)	20	107	457	.....	.....	[340]
2115..	...do.....	Oil-quenched from 1,740°F, tempered at 1,110°F.	.....	108	.....	142	162	12 (8 in.)	30	79.4	332	.....	.....	[340]
2116..	C 0.58, Si 3.11, Mn 0.86.	Roll-d.....	31,400	.....	.....	101	152	11	.....	76.8	.....	.....	.....	[340]

^a Zero to maximum torsion.

^b Notch impact value, m-kgs/cm.²

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
TITANIUM STEEL													
2117..	Percent C 0.29, Ti 0.20, Mn 0.67, Si 0.27.	Cast; f-c from 1,650°F.	Ktpsi/in. ²	Ktpsi/in. ²	Ktpsi/in. ² 50.0 (yld pnt)	Ktpsi/in. ² 80.0	Percent 25 (2 in.)	Percent 42	Ktpsi/in. ²	163	ft-lb 1z 21	.....	[313]
2118..	.. do.....	Cast; a-c from 1,650°F, a-c from 1,525°F, tempered at 1,100°F.	.....	.....	59.0 (yld pnt)	84.8	25 (2 in.)	40	.....	156	1z 22	.....	[313]
TUNGSTEN STEELS													
2119..	C 0.15, W 0.40.....	Forged.....	.....	53.8	.....	69.4	33 (2 in.)	60	.....	.....	.....	.....	[299]
2120..	C 0.28, W 0.64.....	Oil-quenched from 1,650°F, tempered 2 hr at 1,020°F.	.....	44.8	55.1	80.0	33 (2 in.)	68	.....	165	1z 85	.....	[299]
2121..	C 0.11, W 0.94.....	Forged.....	.....	.....	45.0	60.0	18 (8 in.)	64	.....	97	.....	.....	[299]
2122..	C 0.85, W 0.95.....	.. do.....	.....	.....	89.3	161	5.5 (8 in.)	7.5	.....	241	.....	.....	[299]
2123..	C 0.34, W 1.20, Mn 0.32, Cr 0.51, Si 0.20, S 0.003, P 0.032.	Wrought; f-c from 1,450°F.	28,500	.....	48.0	82.5	40 (2 in.)	56	.....	185	.....	Shear str.....34.8 kips/in. ² , Mod-el (shear)...12,700 kips/in. ² Poisson's ratio..0.320.	[247]
2124..	.. do.....	Wrought; o-q from 1,600°F, tempered at 1,100°F.	29,400	.....	.....	158	27 (2 in.)	53	.....	285	.....	Shear str.....135 kips/in. ² , Mod-el (shear)...12,200 kips/in. ² Poisson's ratio..0.281.	[247]
2125..	C 0.21, W 1.49.....	Forged.....	.....	44.8	.....	77.3	26 (2 in.)	47	.....	.....	.....	.....	[299]
2126..	C 0.30, W 1.72.....	Oil-quenched from 1,650°F, tempered 2 hr at 1,020°F.	.....	62.7	73.7	96.3	27 (2 in.)	65	.....	204	1z 76	.....	[299]
2127..	C 0.80, W 2.75.....	Forged.....	.....	.....	107	177	5.5 (8 in.)	18	.....	302	.....	.....	[299]
2128..	C 0.89, W 3.08.....	Normalized.....	.....	.....	109	139	14 (2 in.)	30	.....	.....	.....	.....	[299]
2129..	C 0.33, W 3.82, Mn 0.26, Si 0.05.	Water-quenched from 1,550°F, tempered at 1,100°F.	.....	70.0	.....	94.5	28 (2 in.)	61	.....	241	.....	.....	[299]
2130..	C 0.83, W 4.68.....	Forged.....	.....	.....	122	180	5 (8 in.)	16	.....	302	.....	.....	[299]
2131..	C 0.66, W 6.18, Mn 0.31, Si 0.23, Ni 0.13, Cr 0.10, P 0.021, S 0.005.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Melting point...2,722°F.....	[328]
2132..	C 0.38, W 7.47.....	Annealed.....	.....	53.8	.....	89.6	26 (2 in.)	1/8	.....	.....	.....	.....	[299]

2133..	C 0.81, W 9.89.....	Forged.....	.....	.....	145	182	3.5 (8 in.)	3	.....	293	.....	[299]
2134..	C 0.17, W 11.89.....	...do.....	.....	.....	113	123	5 (8 in.)	48	.....	223	.....	[299]
2135..	...do.....	Forged; w-q from 1,560°F.	.....	.....	64.4	95.6	12 (8 in.)	58	.....	187	.....	[299]
2136..	C 0.61, W 14.5, Cr 3.8, V 0.7, Mn 0.30, Si 0.25.	Annealed.....	32,500	.....	46.6 (0.1%)	116	17	28	40.3	241	.....	[297]
2137..	C 0.08, W 16.40, Cr 3.08, V 0.97, Mo 0.73, Si 0.21, S 0.010, P 0.007.	Normalized at 1,740°F. Normalized at 1,470°F.	.....	.....	63.8 (yld pnt)	111	15 (2 in.)	26	.....	223	.....	[296]
2138..	C 0.71, W 17.30, Cr 3.86, V 0.75.	...do.....	.....	.....	88.2 (yld pnt)	131	19 (2 in.)	19	.....	.....	.....	[299]
2139..	C 1.5, W 17.86, Cr 4.02, V 0.10.	Annealed at 1,650°F.	.....	.....	65.5	123	14	23	.....	250	.....	[299]
2140..	C 0.66, W 18.25, Cr 3.52, V 0.97, Si 0.48, Mn 0.29, Cu 0.05, Ni 0.05.	.....	.....	.....	.....	.....	.....	.....	.....	.....	Melting point...2,660°F.....	[228]
2141..	C 0.66, W 18.68, Cr 2.80.	Annealed at 1,650°F.	.....	.....	108	127	17	30	.....	270	.....	[299]
2142..	C 0.40, W 19.0, Cr 2.90, V 0.16.	...do.....	.....	.....	93.9	118	10	13	.....	270	.....	[299]
2143..	C 0.74, W 19.25.....	Forged.....	.....	.....	102	150	3.5 (8 in.)	4.5	.....	277	.....	[299]
2144..	C 0.39, W 20.54, Ni 10.43, Cr 4.23, Mn 0.22, Mo 0.12, Si 0.04.	Oil-quenched from 2,150°F, tempered at 1,560°F.	.....	17.5	.....	208	6.0 (4 in.)	14	.....	390	b 1.6	[274]
2145..	C 0.74, W 25.28.....	Forged.....	.....	.....	134	161	0.5 (8 in.)	0	.....	351	.....	[299]

VANADIUM STEELS

2146..	C 0.22, V 0.20, Mn 0.82, Si 0.37.	Cast; a-c from 1,700°F, a-c from 1,550°F, tempered at 1,300°F.	.....	.....	47.5 (yld pnt)	79.8	31 (2 in.)	59	.....	.....	1z 52	[313]
2147..	C 0.32, V 0.18, Mn 0.83, Si 0.38.	Cast; normalized at 1,650°F, tempered at 1,240°F.	.....	.....	60.0 (yld pnt)	90.0	24 (2 in.)	45	.....	.....	.....	[313]
2148..	C 0.40, V 0.20, Mn 0.85, Si 0.31.	...do.....	.....	.....	58.6 (yld pnt)	92.4	24 (2 in.)	42	.....	.....	.....	[313]

GRAPHITIC STEELS

2149..	TC 1.50, Si 1.0, Mo 0.25.	Annealed.....	.....	.....	49.5 (yld pnt)	84.5	25 (2 in.)	40	.....	197	.....	[342]
2150..	...do.....	Oil-quenched from 1,475°F, tempered at 1,100°F.	.....	.....	136 (yld pnt)	164	13 (2 in.)	23	.....	302	.....	[342]
2151..	...do.....	Oil-quenched from 1,475°F, tempered at 900°F.	.....	.....	177 (yld pnt)	218	8.5 (2 in.)	14	.....	388	.....	[342]

^bNotch impact value, m-kg/cm.²

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
GRAPHITIC STEELS—Continued												
2152..	Percent TC 1.51, CC 0.55, Si 0.96, Mn 0.40, P 0.015, S 0.014.	Furnace-cooled from 1,500°F.	ktps/in. ²	ktps/in. ²	ktps/in. ² 47.7 (yld pnt)	ktps/in. ² 99.0	Percent 20 (2 in.)	Percent 30	ktps/in. ²	ft-lb Iz 15	.....	[341]
2153..	TC 1.51, CC 0.69, Si 0.96, Mn 0.40, P 0.015, S 0.014.	Normalized at 1,500°F.	.....	.....	65.5 (yld pnt)	138	14 (2 in.)	20	.....	Iz 7.0	.....	[341]
2154..	TC 1.51, CC 0.79, Si 0.96, Mn 0.40, P 0.015, S 0.014.	Water-quenched from 1,450°F, tempered at 1,100°F.	.....	.....	116 (yld pnt)	154	14 (2 in.)	30	.....	.....	.....	[341]
2155..	TC 1.51, CC 0.86, Si 0.96, Mn 0.40, P 0.015, S 0.014.	Water-quenched from 1,450°F, tempered at 900°F.	.....	.....	158 (yld pnt)	202	8.5 (2 in.)	18	.....	.....	.....	[341]
2156..	TC 1.56, Cu 1.75, Si 1.16, Cr 0.46, Mn 0.44, P 0.07, S 0.05.	Cast; 1/3 hr at 1,650°F, a-c to 1,200°F, reheated 1 hr at 1,400°F, f-c to 1,000°F, a-c.	26,800	35.0	.....	72.5	0.2 (4 /area)	0	{ 40.5 a 32.0 }	Iz 1	Shear str.....86.5 kpsi/in. ² , Mod-el (shear).....11,400 kpsi/in. ²	[394]
PLAIN CAST IRONS (SEE ALSO FIGS. 90 AND 109 TO 111, INCLUSIVE)												
2157..	TC 2.50, 4C 1.50, CC 1.00, Si 0.78, Mn 0.74, S 0.09, P 0.04.	Cast.....	^b 20,000	.....	.....	47.7	.....	.....	25.2	Iz 4.1	Compressive str.....159 kpsi/in. ² , Shear str.....60.8 kpsi/in. ² , Mod rupture.....92.0 kpsi/in. ² , Deflection (18-in. span).....0.230 in.	[343]
2158..	TC 2.68, 6C 2.25, CC 0.63, Si 1.99, Mn 0.51, P 0.43, S 0.098, Ti 0.05, Cu 0.04, As 0.01, Cr 0.01, Ni 0.01, Sn 0.01, V 0.01.	do.....	^b 14,800	.....	.....	40.9	.....	.....	19.6	3	Compressive str.....119 kpsi/in. ² , Shear str.....47.3 kpsi/in. ² , Mod rupture.....84.2 kpsi/in. ² , Deflection (18-in. span).....0.439 in., Welding point.....2,142°F.	[344]
2159..	TC 2.90, Si 1.66, Mn 0.76, P 0.13, S 0.107.	Cast (processed iron)	18,900	14.0	46.0 (0.2% perm)	51.0	0.5 (2 in.)	.....	.....	241	.....	[345]
2160..	do.....	Cast; h-t (processed iron).	26,000	21.0	81.3 (0.2% perm)	116	2.0 (2 in.)	1.5	.....	302	.....	[345]
2161..	TC 3.03, CC 0.58, Si 1.93, Mn 0.64, P 0.076, S 0.023.	Cast.....	.....	.....	.....	44.7	0 (2 in.)	0	20.0	1	.....	[233]
2162..	TC 3.12, 6C 2.44, CC 0.68, Si 2.18, P 0.63, Mn 0.44, S 0.10.	do.....	^b 13,600	.....	.....	32.5	.....	.....	16.5	Iz 4.2	Compressive str.....121 kpsi/in. ² , Shear str.....41.6 kpsi/in. ² , Mod rupture.....73.2 kpsi/in. ² , Deflection (18-in. span).....0.301 in.	[343]

2181..	TC 3.49, GC 2.76, CC 0.71, Si 2.08, Ni 1.17, Cr 0.65, Mn 0.55, P 0.19, S 0.08.	...do.....	b 10,700	.....	.....	.....	.....	.....	30.0	.....	.....	.....	13.5	181	Iz 4.2	Compressive str.....109 kips/in. ² Shear str.....42.3 kips/in. ² Mod rupture.....70.3 kips/in. ² Deflection (18-in. span) 0.331 in.	[343]
2182..	TC 2.65, Si 2.48, Ni 1.21, Mn 1.18, Mo 1.15, Cr 0.17.	Bar, 2 1/2 in. diam, cast.	19,000	.....	.....	.....	.....	.....	73-80	.....	.....	.....	.....	288	.....	Compressive str.....188-203 kips/in. ² Shear str.....86.0 kips/in. ² Mod-el (shear).....6,500 kips/in. ²	[177]
2183..	TC 3.24, Si 1.41, Ni 1.30, Mn 0.43, Cr 0.21.	Cast.....	.....	.....	.....	.....	.....	.....	36.9	.....	.....	.....	.....	212	.....	Shear str.....48.7 kips/in. ² Mod-el (shear).....5,100 kips/in. ²	[351]
2184..	TC 3.19, GC 2.20, CC 0.89, Ni 1.43, Si 1.36, Mn 0.85, P 0.32, Cr 0.09, S 0.079.	...do.....	17,000	.....	.....	.....	.....	.....	50.2	.....	.....	.....	.....	256	Iz 13	Mod rupture.....76.2 kips/in. ² Deflection (18-in. span) 0.23 in.	[349]
2185..	TC 3.11, GC 2.30, Si 2.23, Ni 1.49, Mo 0.79, Mn 0.66, Cu 0.18, S 0.104, P 0.10, Cr 0.09, Ti 0.025, As 0.021, V 0.010.	Bar, 1 3/16 in. diam, cast.	.....	.....	.....	.....	.....	.....	53.4	.....	.....	.....	{ 21.0 22.0	.....	.....	Compressive str.....236 kips/in. ² Torsion str.....84.1 kips/in. ²	[346]
2186..	TC 2.76, Si 2.07, Ni 1.57, Mn 0.75, Mo 0.69.	Cast.....	.....	.....	.....	.....	.....	.....	54.1	.....	.....	.....	.....	255	.....	Shear str.....79.2 kips/in. ² Mod-el (shear).....7,100 kips/in. ²	[351]
2187..	TC 3.06, Si 2.17, Ni 1.70, Mn 0.62, Mo 0.62.	...do.....	18,400	.....	.....	.....	.....	.....	52.9	.....	.....	.....	27.5	241	.....	.....	[351]
2188..	TC 3.36, GC 2.39, Ni 1.87, Si 1.25, Mn 0.92, Cr 0.47, P 0.12, S 0.11.	...do.....	18,700	5.0	.....	.....	.....	.....	42.0	0.8 (4 $\sqrt{\text{area}}$)	0	{ 23.7 20.0	.....	285	Iz 0.4	Shear str.....47.0 kips/in. ² Mod-el (shear).....7,100 kips/in. ²	[334]
2189..	TC 2.5-3.25, Ni 3.5- 4.5, Si 0.50-1.5, Mn 0.50-1.25, B 0.70- 1.10, P <0.05, S <0.05.	Cast (white iron)...	.....	.....	.....	.....	.....	.....	30-45	.....	.....	.....	.....	R _c 64-70	.....	Compressive str.....225 kips/in. ² Specific gravity.....7.58. Melting point.....1,975°F.	[352]
2190..	TC 2.46, GC 1.65, CC 0.81, Ni 11.20, Mn 4.09, Si 1.50, P 0.74, S 0.020.	Cast.....	14,500	.....	.....	.....	.....	.....	29.8	.....	.....	.....	.....	157	Iz 22	Mod rupture.....56.0 kips/in. ² Deflection (18-in. span) 0.29 in.	[348]
2191..	TC 3, Ni 14, Cu 7, Cr 2, Si 1.5, Mn 1.0, P 0.2, S 0.1.	...do.....	.....	.....	.....	.....	.....	.....	20-35	.....	.....	.....	.....	120-170	.....	Transverse str.....44-71 kips/in. ² Deflection (18-in. span) 0.2-0.7 in.	[353]
2192..	TC 2.63, GC 1.96, Ni 14.90, Cu 6.94, Si 2.14, Cr 2.09, Mn 1.23, P 0.16, S 0.065, Ti 0.022, As 0.012, V 0.005.	Plate, 1 3/4 in., cast.	.....	.....	.....	.....	.....	.....	31.6	.....	.....	{ 12.0 12.0	.....	.....	.....	Compressive str.....182 kips/in. ² Torsion str.....43.8 kips/in. ²	[346]
2193..	TC 2, Ni 18, Si 5, Cr 2, Mn 1, P 0.1, S 0.1.	Cast.....	.....	.....	.....	.....	.....	.....	18.4	1-4 (2 in.)	.....	.....	.....	110-170	.....	Transverse str.....50.2 kips/in. ² Deflection (18-in. span) 0.7-1.4 in.	[353]

^b At 1/2 load.^f Unnotched.^b Notch impact value, m-kj/cm.²^a Reversed torsion.

TABLE 20.—Iron and steel, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area			
			Kips/in. ² in 10,000	Kips/in. ²	Kips/in. ²	Kips/in. ²	Percent	Percent	Kips/in. ²	ft-lb	
ALLOY CAST IRONS—Continued											
2194..	Percent TC 3.25, GC 2.66, CC 0.59, Si 2.06, P 1.99, Mn 0.53, S 0.16, As 0.05, Ti 0.05, Ni 0.03, V 0.03, Cu 0.02, Sn 0.02.	Cast.....	Kips/in. ² in 10,000	Kips/in. ²	Kips/in. ²	Kips/in. ²	Percent	Percent	Kips/in. ²	ft-lb	[344]
2195..	TC 3.18, Si 1.12, P 0.58, V 0.41, Mn 0.34, S 0.07.	Bar, 2 in. diam, cast.	.....	.....	.....	38.5	.....	.....	.....	.....	[350]
MALLEABLE CAST IRONS (SEE ALSO FIGS. 113 TO 116, INCLUSIVE)											
2196..	TC 1.75-2.30, Si 0.85-1.20, Mn 0.40, P <0.20, S <0.12.	Cast; ann.....	25,000	.....	37.5 (yld pnt)	57.0	22 (2 in.)	.....	25-25.5	110-145	[354]
2197..	TC 2.25-2.70, Si 0.80-1.10.	.....	25,000	.....	32.5 (yld pnt)	50.0	14 (2 in.)	.....	.....	.....	[354]
2198..	TC 2.40, Si 0.80, Mn 0.30, P 0.20, S 0.044.	Cast; ann (European white-heart).	.....	.....	.....	45-58	5-8 (2 in.)	.....	.....	.....	[355]
2199..	TC 2.44, Si 1.00, Mn 0.31, P 0.168, S 0.072.	Cast; ann.....	.....	.....	35.5 (yld pnt)	55.3	18 (2 in.)	.....	30	.....	[356]
2200..	TC 2.45, Si 1.46..	Cast; 15 hr at 1,700°F, cooled to 1,525°F in 2 hr, o-q, tempered 2 hr at 1,325°F (pearlitic).	25,500	39.0	60.3 (yld pnt)	76.2	6.5 (2 in.)	.....	30.5	231	[357]
2201..	...do.....	Cast; 15 hr at 1,700°F, cooled to 1,525°F in 2 hr, o-q, tempered 4 hr at 1,325°F (pearlitic).	25,400	30.2	50.0 (yld pnt)	64.5	8.4 (2 in.)	.....	26.8	183	[357]
2202..	...do.....	Cast; 15 hr at 1,700°F, f-c to 1,325°F in 3 hr, held 20 hr.	25,100	18.0	37.3 (yld pnt)	52.1	15 (2 in.)	.....	22.1	133	[357]
2203..	TC 2.76, Cu 1.25, Si 1.01, Mn 0.26, P 0.128, S 0.028.	Cast; ann.....	.....	.....	45.0	56.0	9.5 (2 in.)	.....	.....	128	[358]

2204..	...do.....	Cast; 1 hr at 1,350°F, 3 hr at 930°F.	.....	.....	57.0	65.0	7.2 (2 in.)	.....	.....	159	.....	[358]
2205..	TC 2.51, S1 1.4, Mo 0.49.	Cast; 15 hr at 1,700°F, cooled to 1,525°F in 2 hr, o-q, tempered 2 hr at 1,325°F (pearlitic).	.....	.....	70.6 (yld pnt)	77.8	3.5 (2 in.)	.....	31.4	245	4.0	[357]
2206..	...do.....	Cast; 15 hr at 1,700°F, cooled to 1,525°F in 2 hr, o-q, tempered 4 hr at 1,325°F (pearlitic).	.....	.....	65.0 (yld pnt)	74.0	7.9 (2 in.)	.....	28.1	223	5.0	[357]
2207..	...do.....	Cast; 15 hr at 1,700°F, f-c to 1,325°F in 3 hr, held 30 hr.	.....	.....	37.2 (yld pnt)	54.5	15 (2 in.)	.....	23.0	130	10	[357]

^a At 1/2 load.

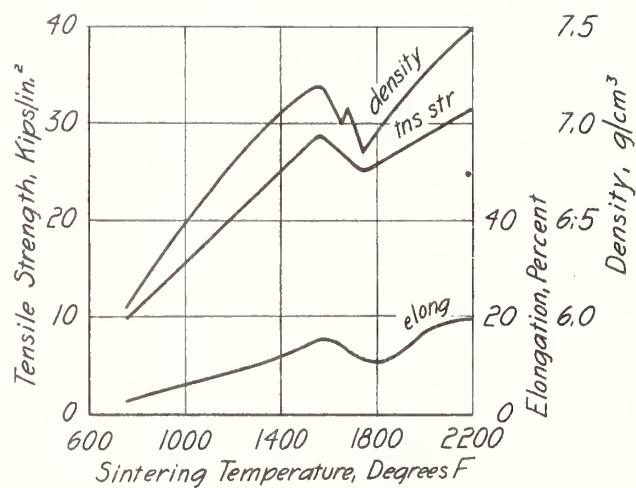


FIGURE 77.—Effect of sintering temperature on the tensile properties and density of electrolytic iron powder compacts [Libsch, Volterra, and Wulff [52]].

Compressed and sintered in hydrogen.

Screen analysis: -100 +200 mesh, 66%; -200 +325 mesh, 17%; 325 mesh, 17%.

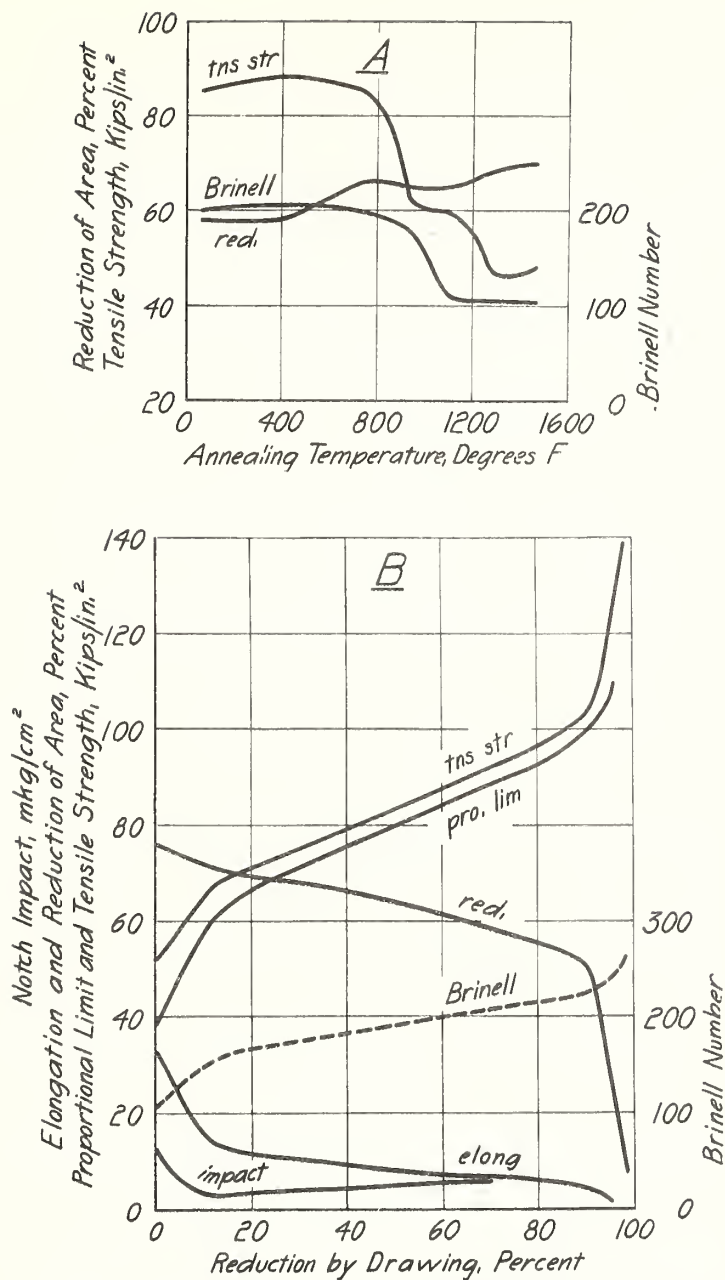


FIGURE 78.—Effect of annealing and cold-drawing on the tensile properties, impact value, and hardness of ingot iron (Broniewski and Rodowski [660])

C 0.080%, P 0.024%, S 0.019%, Si 0.007%.

A, Effect of annealing; material cold-worked (60% red.), annealed 1/2 hour; B, effect of cold-drawing.

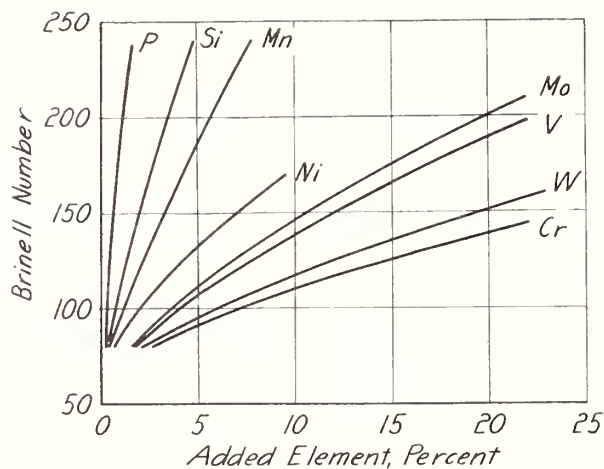


FIGURE 79.—Probable hardening effect of various elements in pure iron (Bain [661]).

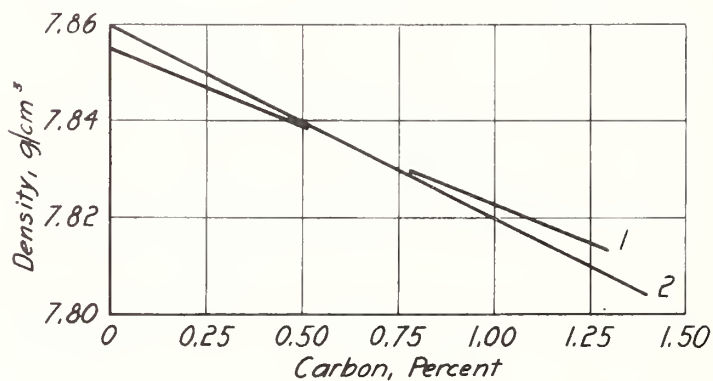


FIGURE 80.—Densities of hot-rolled and annealed carbon steels (Cross and Hill [662]).

Curves: 1, hot-rolled; 2, annealed.

The densities are given approximately by the following formulas:

Hot-rolled....density= $7.855 - 0.032 C$

Annealed.....density= $7.860 - 0.04 C$

(C=carbon content in percent)

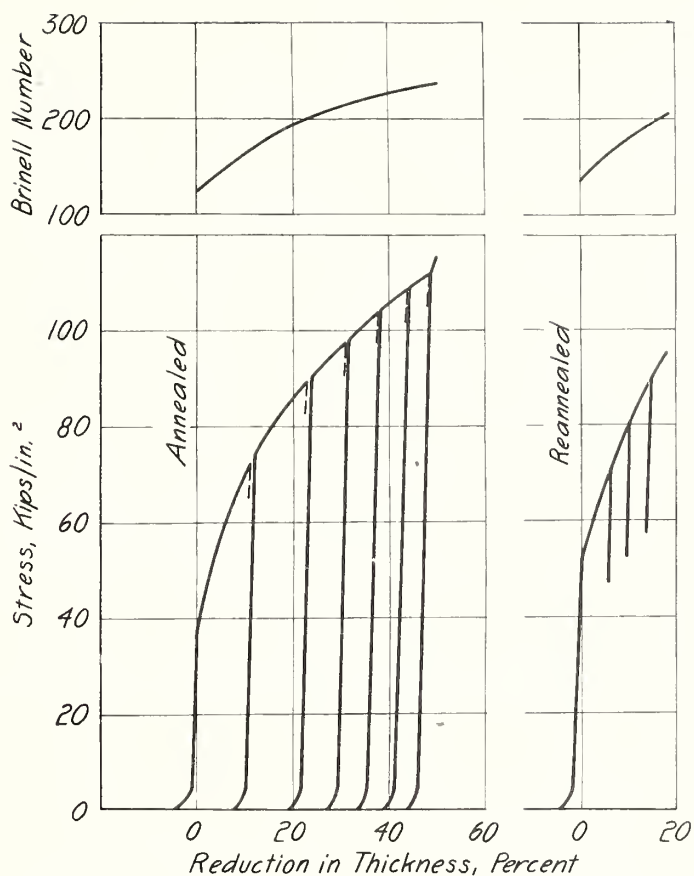


FIGURE 81.—Compressive strength of a 0.15 percent carbon steel (Crane [642])

The sample tested was 3/4 in. in diameter and 1/2 in. in height and had been annealed and furnace cooled. The test was interrupted periodically and the sample removed for hardness and dimension measurements. After compressing the sample to 50 percent of its original height, it was reannealed and the test continued as shown in the section of the curve to the right. The stress values plotted were calculated on the true rather than the original area of the sample.

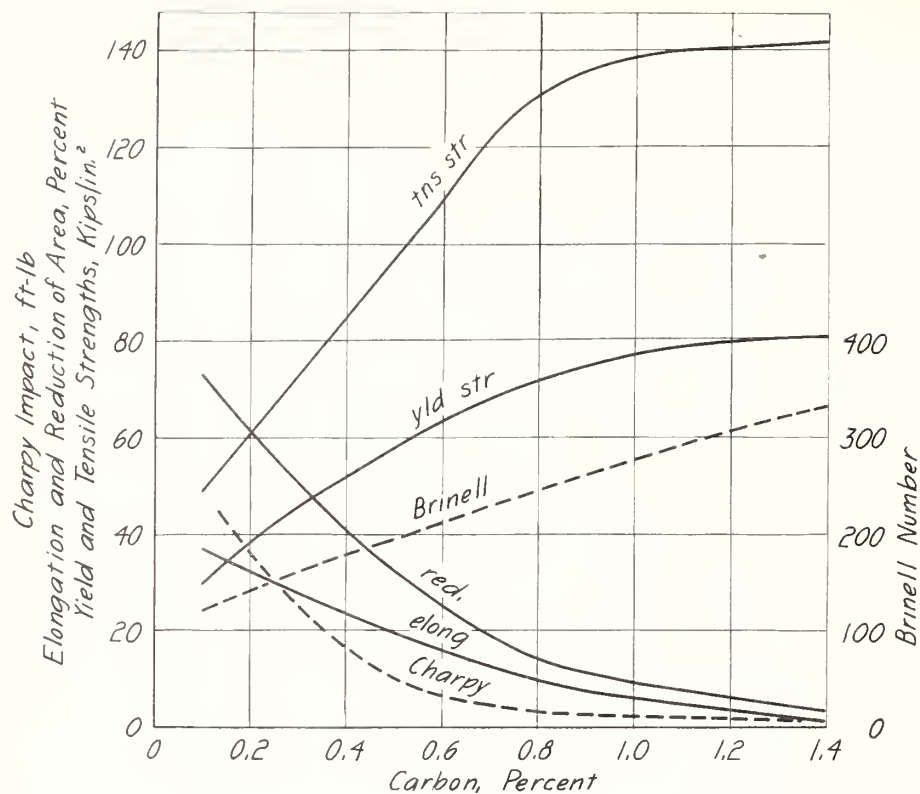


FIGURE 82.—Average tensile properties, impact value, and hardness of hot-worked carbon steels (Sisco [239]).

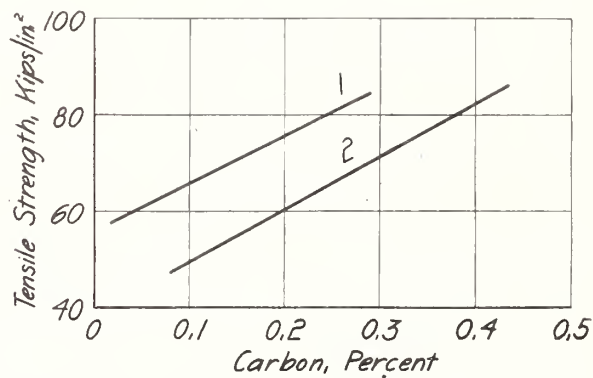


FIGURE 83.—Comparative tensile strengths of hot-rolled Bessemer and open-hearth steels of similar carbon contents (McGinley and Woodworth [663]).

Curves: 1, Bessemer, average P content 0.090%; 2, open hearth, average P content 0.013%.

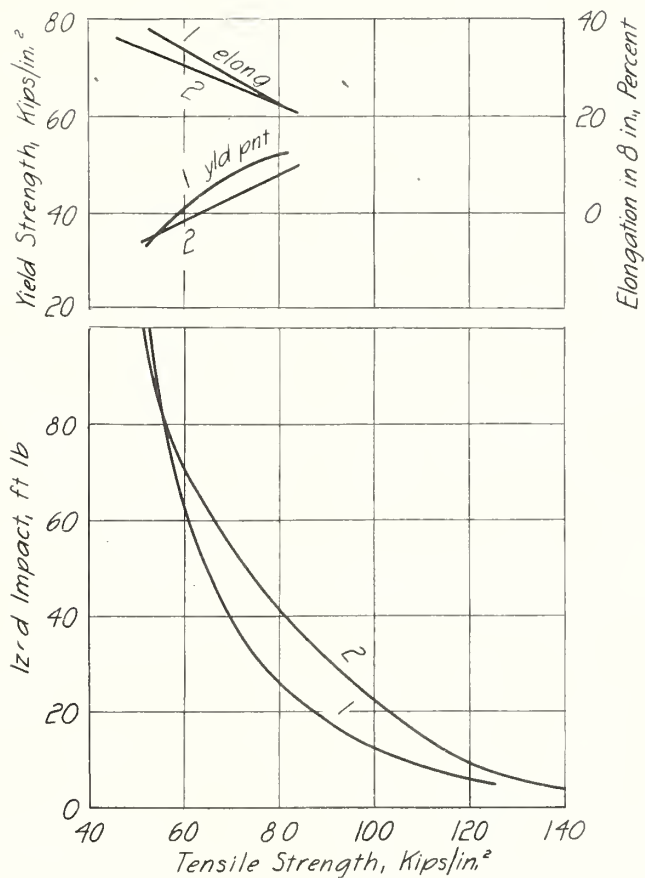


FIGURE 84.—Comparison between yield point, elongation, and impact value for Bessemer and open-hearth steels of equivalent tensile strengths (McGinley and Woodworth [663]).

Curves: 1, Bessemer, average P content 0.090%; 2, open hearth, average P content 0.013%.

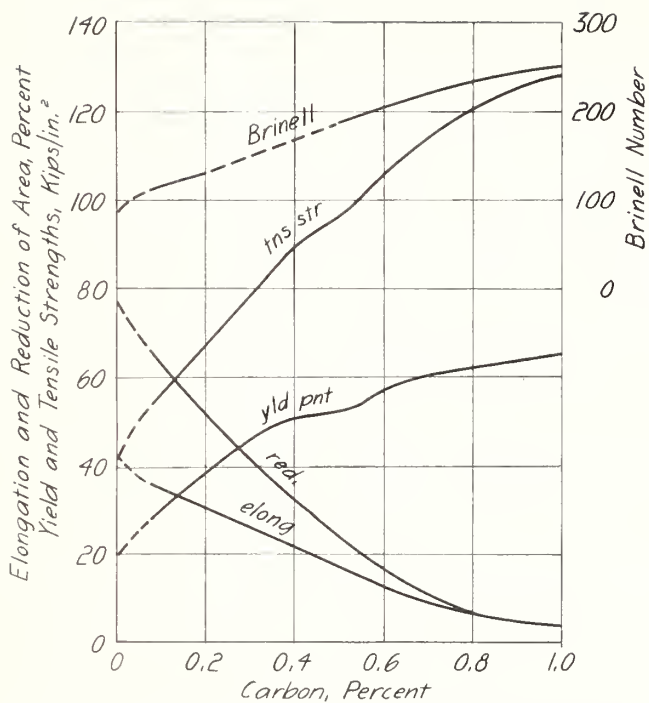


FIGURE 85.—Average tensile properties and hardness of fully annealed cast carbon steels [313].

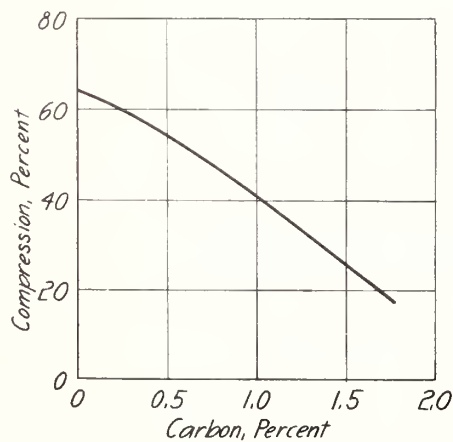


FIGURE 86.—Compression of cast carbon steels under load of 224 kips/in.² (Sisco [239]).

Average of cast and annealed samples.
Samples containing more than 0.70% of carbon fractured before the full load was applied.

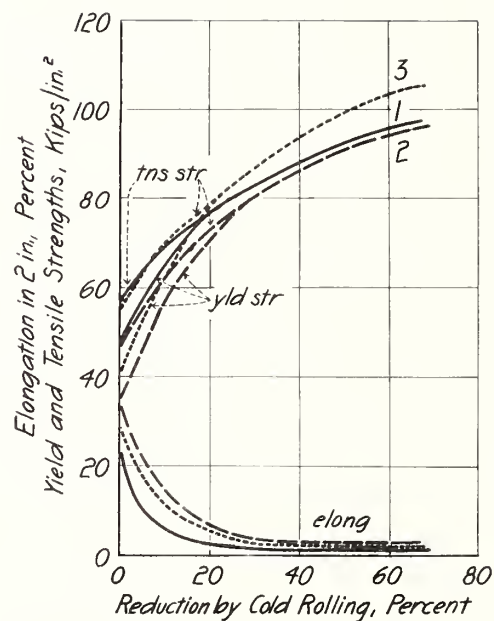


FIGURE 87.—Effect of cold-rolling on the tensile properties of hot-rolled carbon steel (Sisco [239]).

C 0.045%, Mn 0.37%, S 0.023%, P 0.008%.

Strip, 0.08 in. Finishing temperature in hot-rolling: curve 1, 1345°F; curve 2, 1450°F; curve 3, 1615°F.

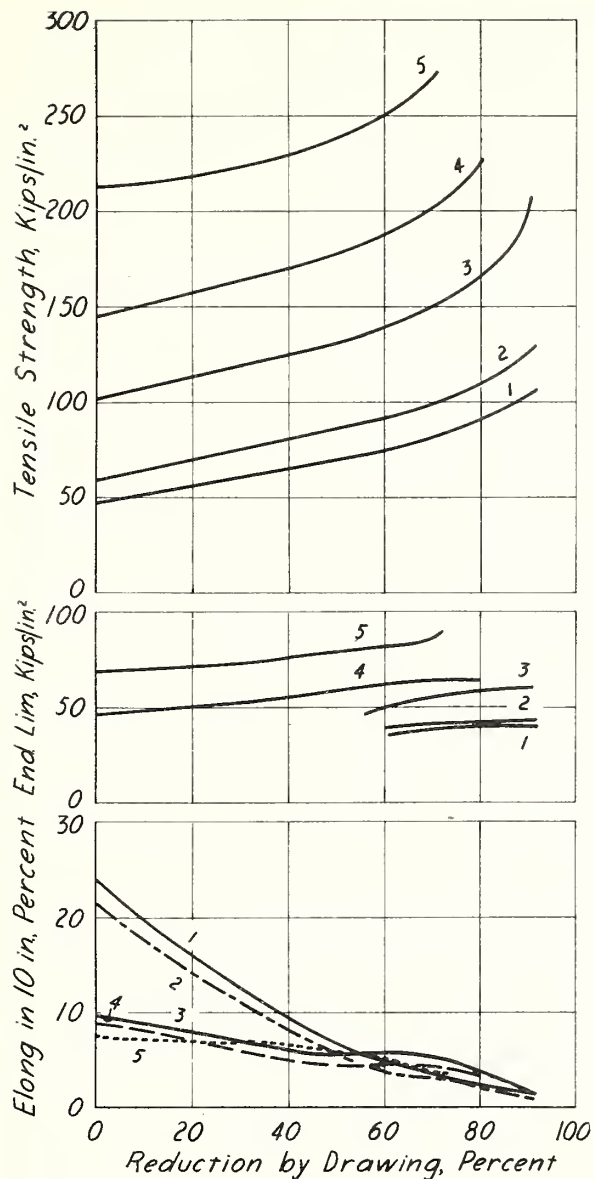


FIGURE 88.—Tensile properties and endurance limit of cold-drawn steel wire (Godfrey [664]).

Curves: 1, C 0.05%, Mn 0.11% (drawn from a hot-rolled green rod); 2, C 0.16%, Mn 0.49% (drawn from a hot-rolled green rod); 3, C 0.39%, Mn 0.75% (drawn from a lead-patented rod); 4, C 0.58%, Mn 0.60% (drawn from wire given an intermittent patenting); 5, C 0.90%, Mn 0.35% (drawn from wire given an intermittent patenting).

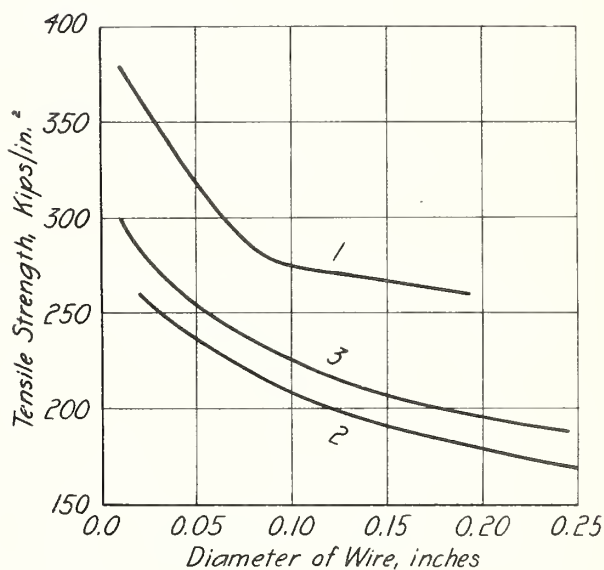


FIGURE 89.—Tensile strength of steel wire (Eakin [665]).

Curves: 1, music wire, C 0.70-1.00%, Mn 0.25-0.50%, Si 0.10-0.30%, P 0.025% (max), S 0.025% (max); 2, hard-drawn steel wire, C 0.50-0.70%, Mn 0.70-1.10%, Si 0.10-0.20%, P 0.04% (max), S 0.04% (max); 3, oil-tempered or stainless-steel wire. The oil-tempered wire had a composition similar to that of the hard-drawn wire (2). The stainless-steel wire contained 18% of chromium and 8% of nickel.

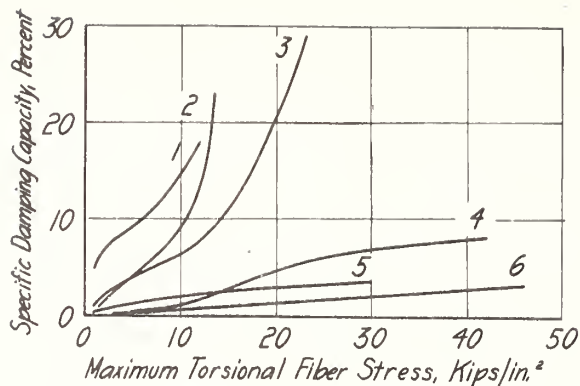


FIGURE 90.—Damping characteristics of steels and cast iron (von Heydekampf [886]).

CHEMICAL COMPOSITION

Curve	Material	C	Mn	Si	Cr	Ni	W	Mo	P	S
1.....	Cast iron ¹.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2.....	C steel.....	0.22	0.04	0.07	.....	.....	.....	.....	0.01	0.014
3.....	C steel.....	.93	.10	.11	.....	.....	.....	.....	.01	.015
4.....	Ni-Cr-Mo steel.....	.16	.40	.15	1.90	4.90	.....	0.70	.....	.....
5.....	Ni-Cr steel.....	.8	.....	.....	0.95	4.2	.....	.....	.....	.....
6.....	Ni-Cr-Mo-W steel.....	.4	.45	.3	1.15	2.5	0.9	.25	.....	.....

¹Pearlitic

MECHANICAL PROPERTIES

Curve	Yield point	Tensile strength	Elongation	Reduction of area	Endurance limit
	Kips/in. ²	Kips/in. ²	Percent	Percent	Kips/in. ²
1.....	.....	.....	.....	.....	.....
2.....	.....	.....	.....	.....	.....
3.....	.....	.....	.....	.....	37.0
4.....	.....	190	11 (10 diam)	.....	77.0
5.....	120-142	142-164	12-16	50-65	.....
6.....	.....	175	12 (10 diam)	.....	78.0

According to von Heydekampf, damping capacity is defined by Föppl as "the amount of work dissipated into heat by a unit volume of the material during a completely reversed cycle of unit stress." It is measured in inch-pounds per cubic inch (or centimeter-kilograms per cubic centimeter) per cycle. In comparing materials, damping capacity should be applied only to those having the same modulus of elasticity. For materials having different moduli, the specific damping capacity should be used. This value is the damping capacity divided by the potential energy at maximum stress. By plotting the specific damping capacity in percent against the maximum torsional stress for various materials, a series of curves is obtained, from which the ability of a material to damp out vibrations may be determined.

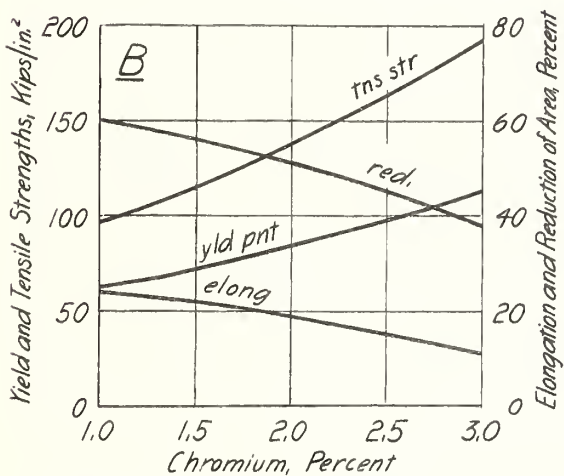
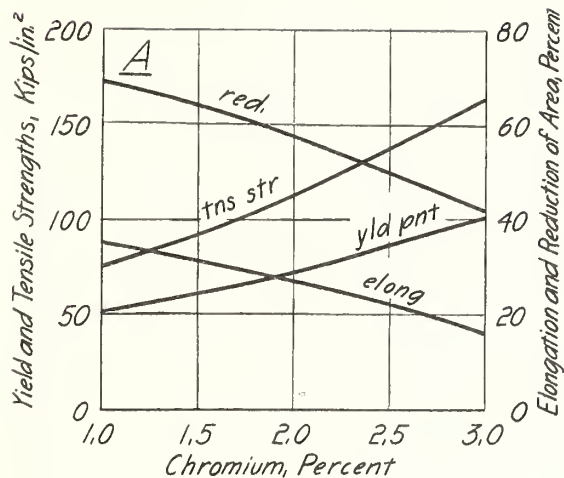


FIGURE 91.—Tensile properties of normalized chromium steels (French [327]).

A, C 0.2%; B, C 0.3%.

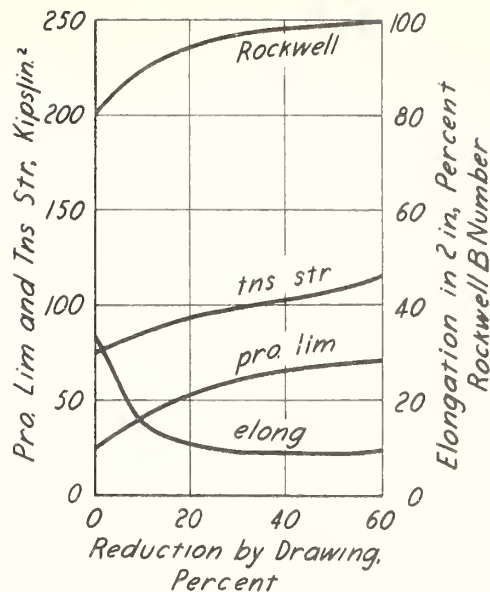


FIGURE 92.—Effect of cold-drawing on the tensile properties and hardness of annealed stainless-steel wire containing 12 percent of chromium (Watkins [887]).

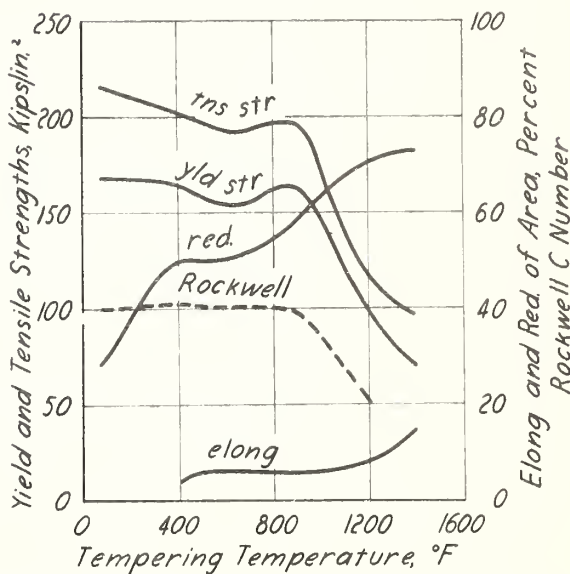


FIGURE 93.—Effect of tempering on the tensile properties and hardness of stainless-steel wire containing 12 percent of chromium (Watkins [887]).

(Elongation in 2 in.)

Oil-quenched from 1,800°F and tempered 1 hour.

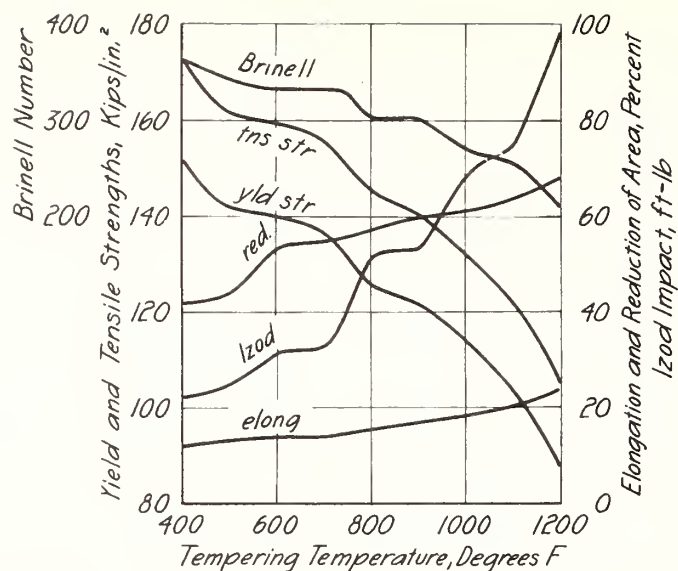


FIGURE 94.—Tensile properties, impact value, and hardness of NE 8630 steel (Jones [668]).

C 0.304%, Cr 0.49%, Ni 0.42%, Mo 0.22%, Mn 0.80%, Si 0.25%,
P 0.014%, S 0.015%.

Bar, 1 in. diameter, normalized at 1,650°F, oil-quenched from 1,550°F, and tempered approximately 1 hour.

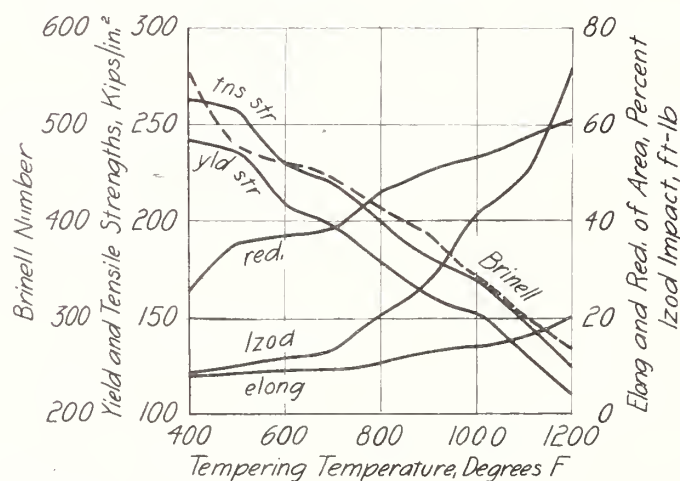


FIGURE 95.—Tensile properties, impact value, and hardness of NE 8739 steel (Jones [668]).

C 0.41%, Cr 0.47%, Ni 0.46%, Mo 0.26%, Mn 0.86%, Si 0.31%,
P 0.015%, S 0.019%.

Bar, 1 in. diameter, normalized at 1,650°F, oil-quenched from 1,525°F, and tempered approximately 1 hour.

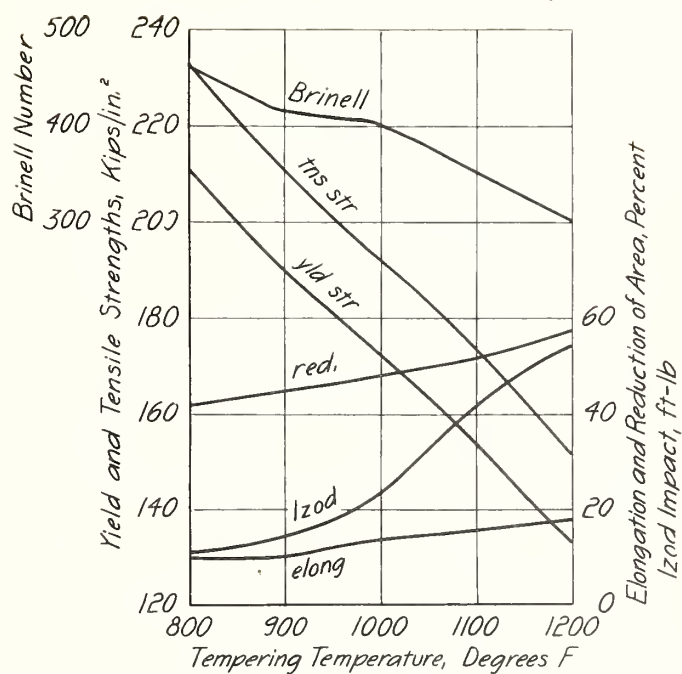


FIGURE 96.—Tensile properties, impact value, and hardness of NE 8949 steel (Jones [668]).

C 0.49%, Cr 0.51%, Ni 0.52%, Mo 0.38%, Mn 1.10%, Si 0.27%,
P 0.018%, S 0.015%.

Bar, 1 in. diameter, normalized at 1,650°F, oil-quenched from 1,500°F, and tempered approximately 1 hour.

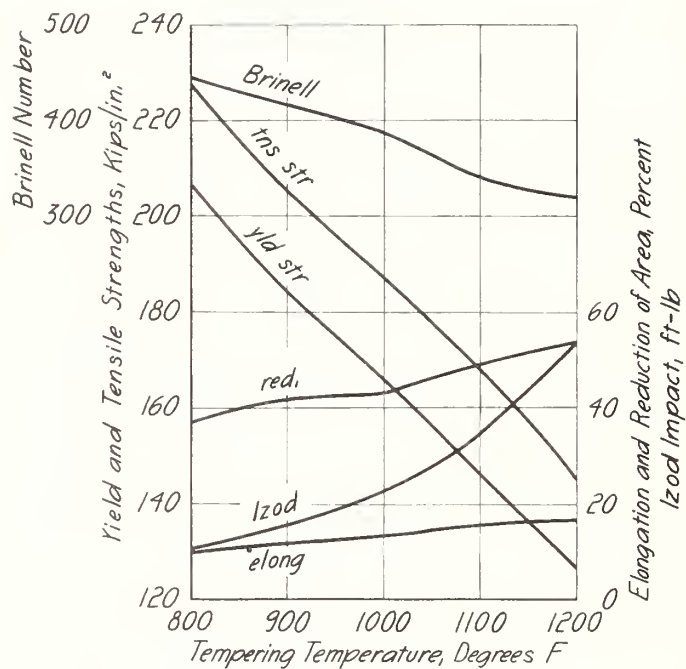


FIGURE 97. Tensile properties, impact value, and hardness of NE 8749 steel (Jones|668|).

C 0.546%, Cr 0.52%, Ni 0.46%, Mo 0.27%, Mn 0.83%, Si 0.23%,
P 0.015%, S 0.015%.

Bar, 1 in. diameter, normalized at 1,650°F, oil-quenched from 1,500°F, and tempered approximately 1 hour.

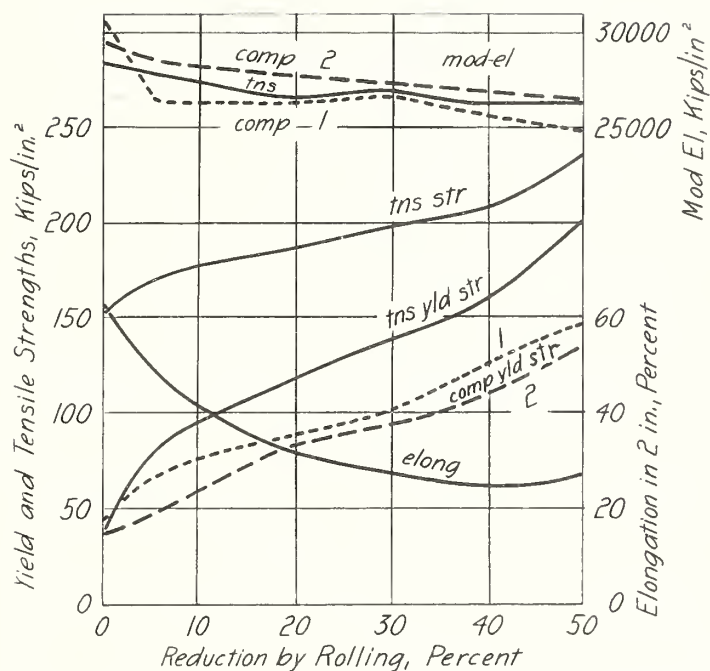


FIGURE 98.—Effect of cold-rolling on the tensile and compressive properties of stainless-steel sheet (Aitchison, Tuckerman, Ramberg, and Whittemore [669]).

(Yield strengths, 0.2% offset)

C 0.11%, Cr 17.90%, Ni 6.72%, Mn 0.56%, Si 0.272%,
P 0.014%, S 0.015%

Sheet, 0.020 in. tested parallel to rolling direction.
Curves: 1, cylinder compression; 2, pack compression.

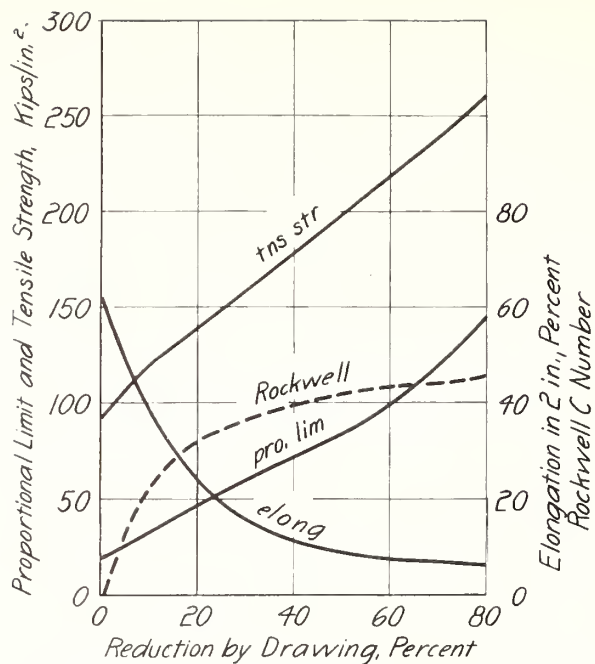


FIGURE 99.—Effect of cold-drawing on the tensile properties and hardness of annealed stainless steel wire (Watkins [667]).

Cr 18%, Ni 8%.

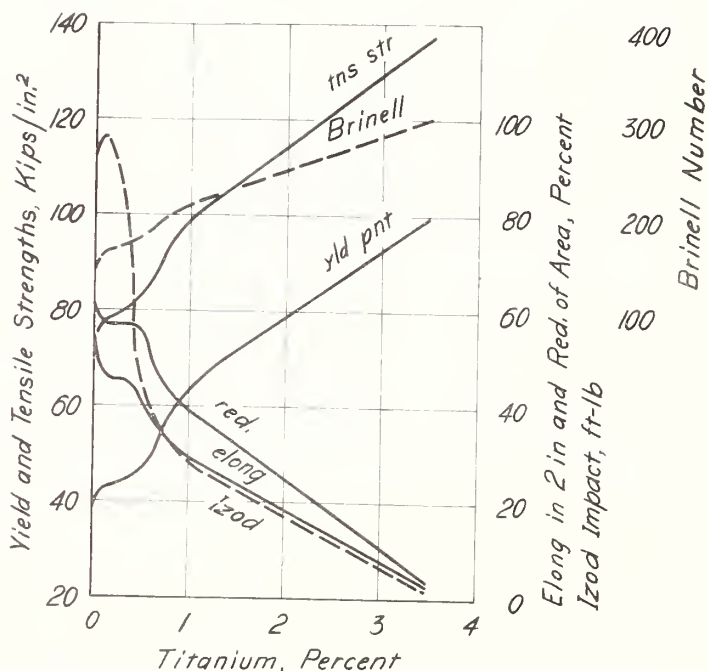


FIGURE 100.—Effect of titanium on the tensile properties, impact value, and hardness of cast chromium-nickel steels (Duma [144]).

Cr 20-24%, Ni 10-13%, Mn 0.60-0.75%, Si 0.4-0.9%, C 0.10-0.13%, P 0.015-0.023%, S 0.006-0.017%. Quenched in water from 2,000°F.

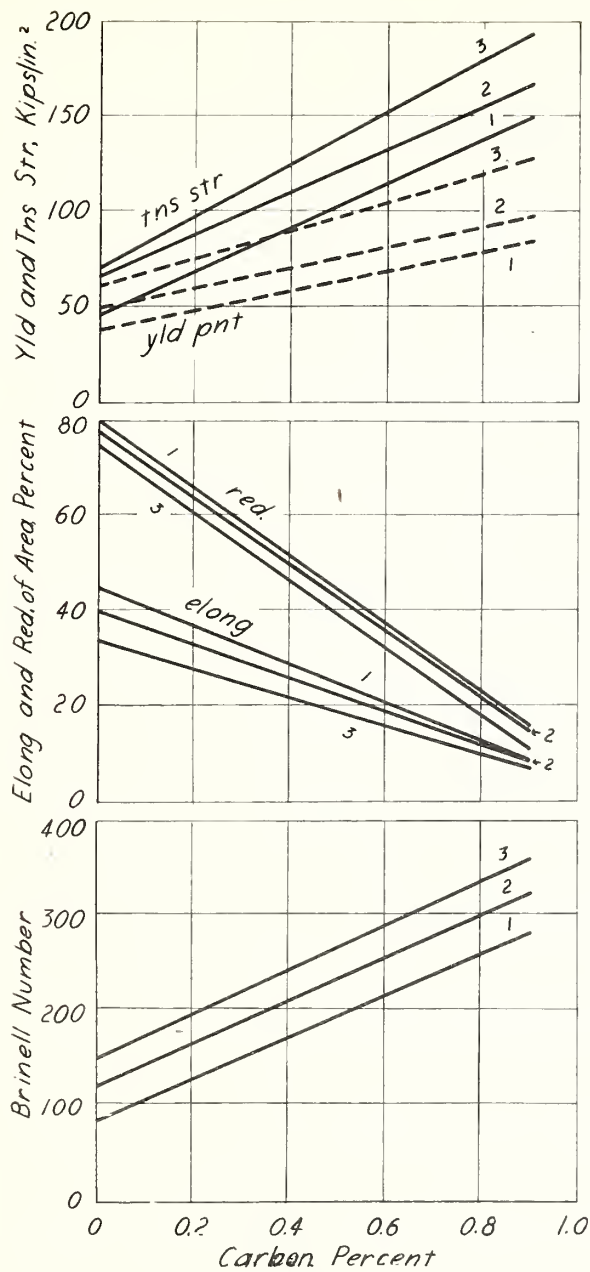


FIGURE 101.—Tensile properties and hardness of normalized copper steels (Lorig [670]).

Curves: 1, Cu 0%; 2, Cu 1%; 3, Cu 2%. Normalized at 1,650°F.

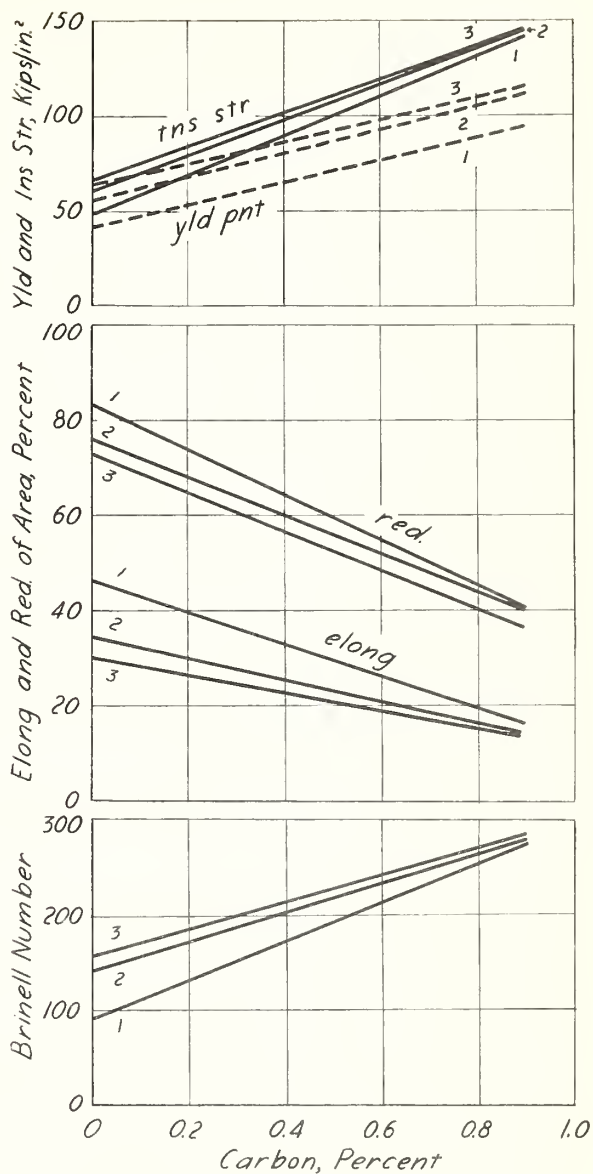


FIGURE 102.—Tensile properties and hardness of quenched and tempered copper steels (Lorig [670]).

Curves: 1, Cu 0%; 2, Cu 1%; 3, Cu 2%. Water-quenched from 1,650°F and tempered at 1,250°F.

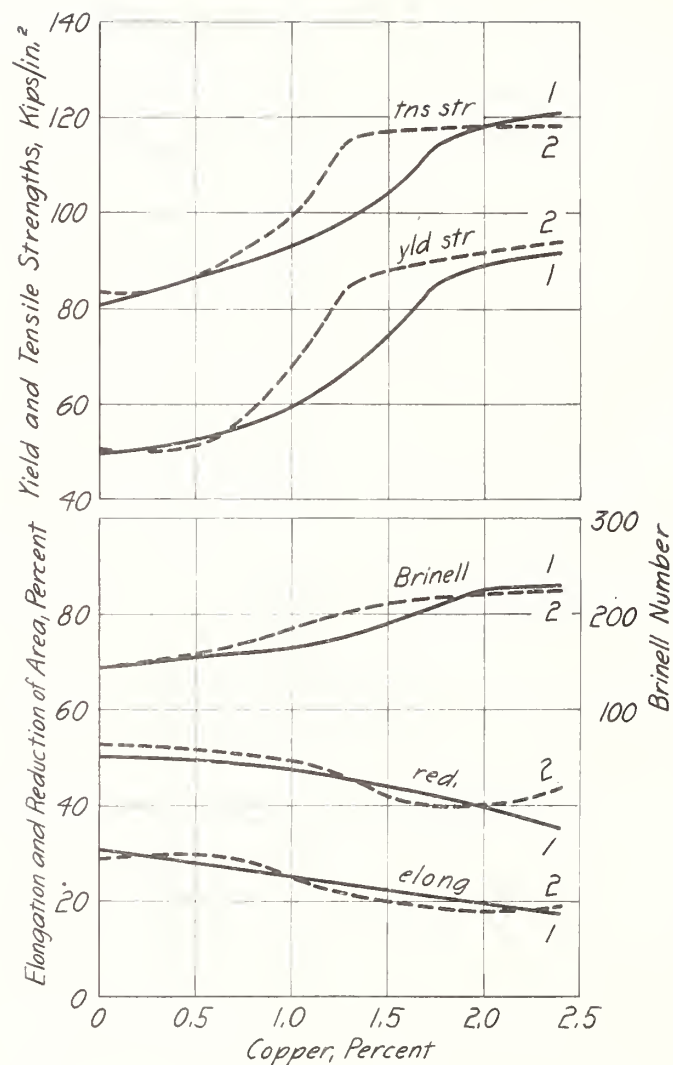


FIGURE 103.—Tensile properties and hardness of cast copper steels (Greenidge and Lorig [671]).

C 0.30-0.32%, Mn 0.65-0.85%, Si 0.35-0.45%.

Curves: 1, normalized at 1650°F; 2, normalized and reheated at 930°-950°F for 3 hours, air-cooled.

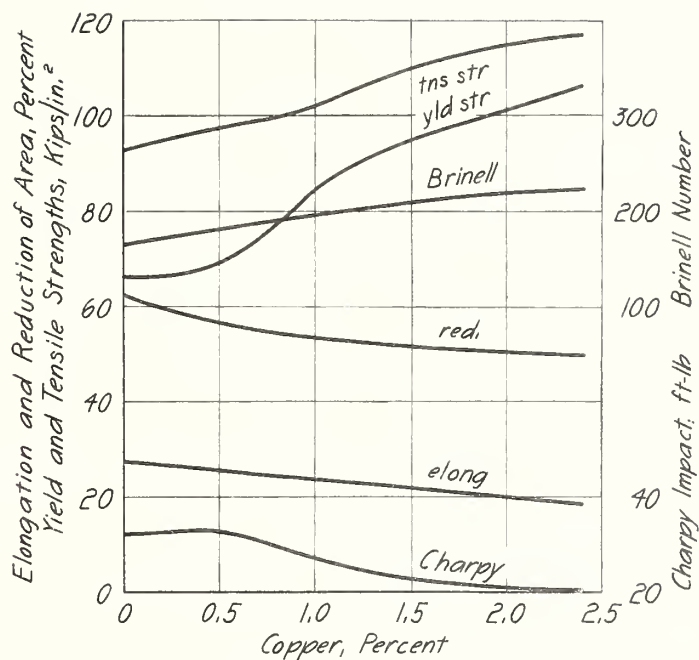


FIGURE 104.—Tensile properties, impact value, and hardness of quenched and tempered cast copper steels (Greenidge and Lorig [671]).

C 0.30–0.35%, Mn 0.75–0.80%, Si 0.40–0.45%.

Water-quenched from 1,600°–1,650°F and tempered at 1,200°F.

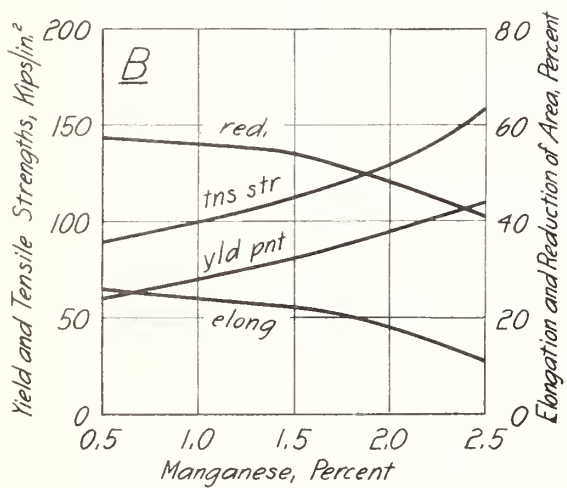
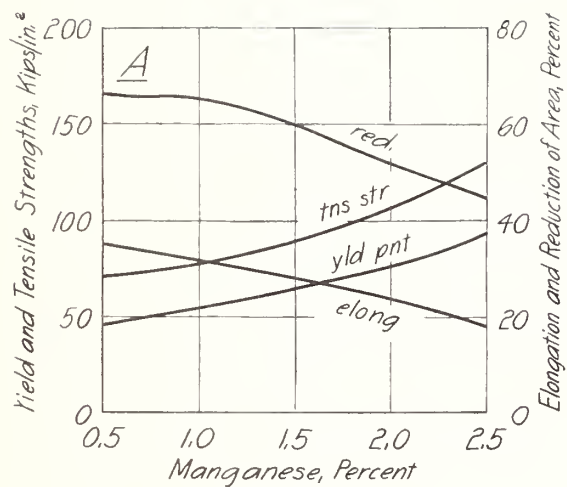


FIGURE 105.—Tensile properties of normalized manganese steels (French [327]).

A, C 0.2%; B, C 0.4%.

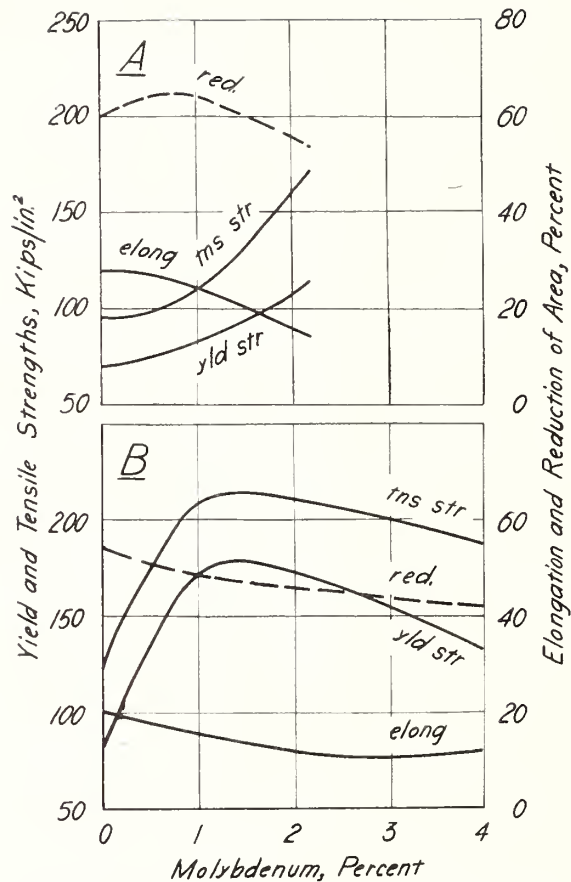


FIGURE 106.—Tensile properties of quenched and tempered molybdenum steels (Gregg [286]).

A, C 0.19-0.30%; B, C 0.44-0.50%.

Oil-quenched and tempered at 930°-1,020°F.

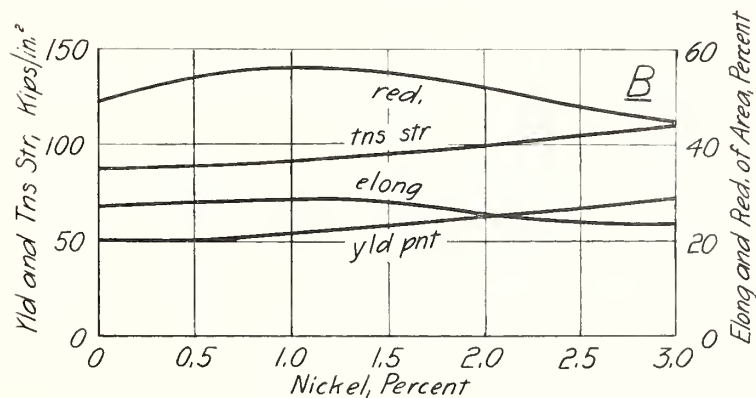
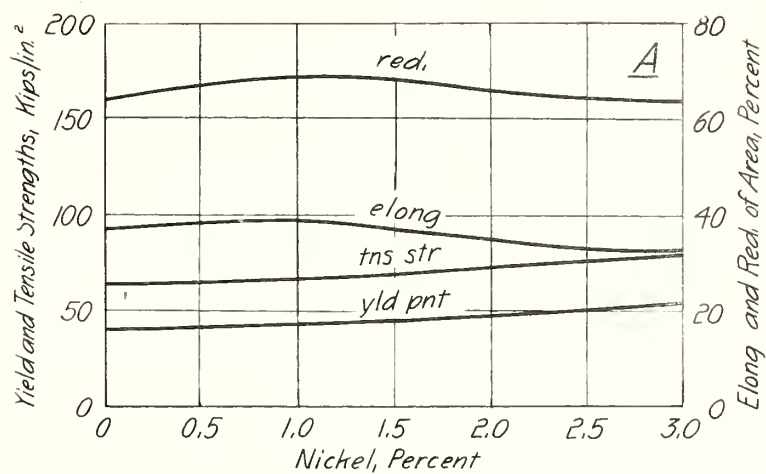


FIGURE 107.—Tensile properties of normalized nickel steels (French [327]).

A. C 0.2%; B. C 0.4%.

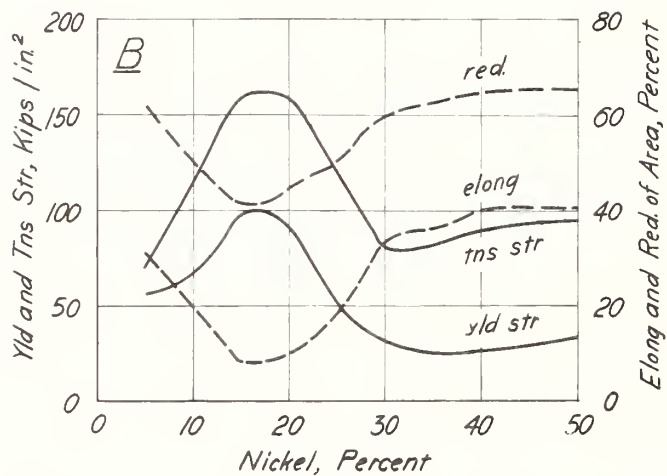
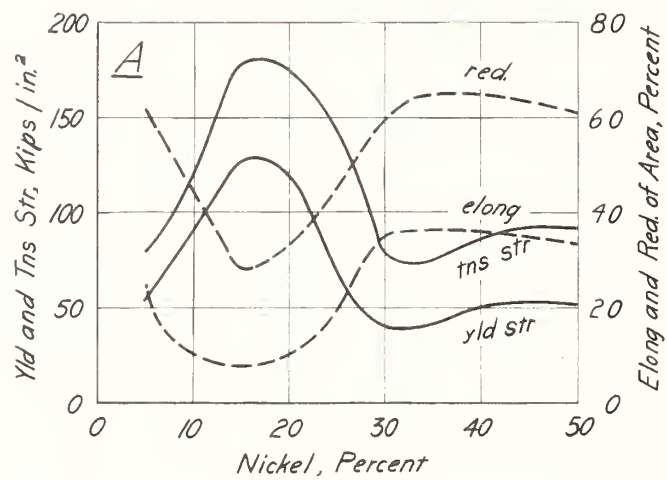


FIGURE 108.—Tensile properties of iron-nickel alloys containing 0.2 percent carbon (Marsh [274]).

A, Hot-rolled; B, annealed.

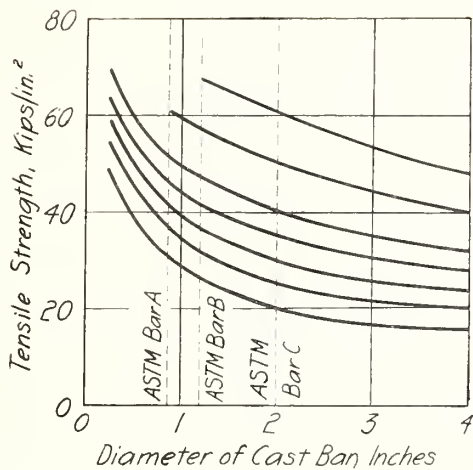


FIGURE 109.—Effect of section thickness on the tensile strength of gray cast iron (Campbell [672]).

Each curve represents a different composition of cast iron. The dotted lines marked ASTM bar A, ASTM bar B, and ASTM bar C represent the three standard sizes of test bars recommended in the ASTM specifications for gray iron castings.

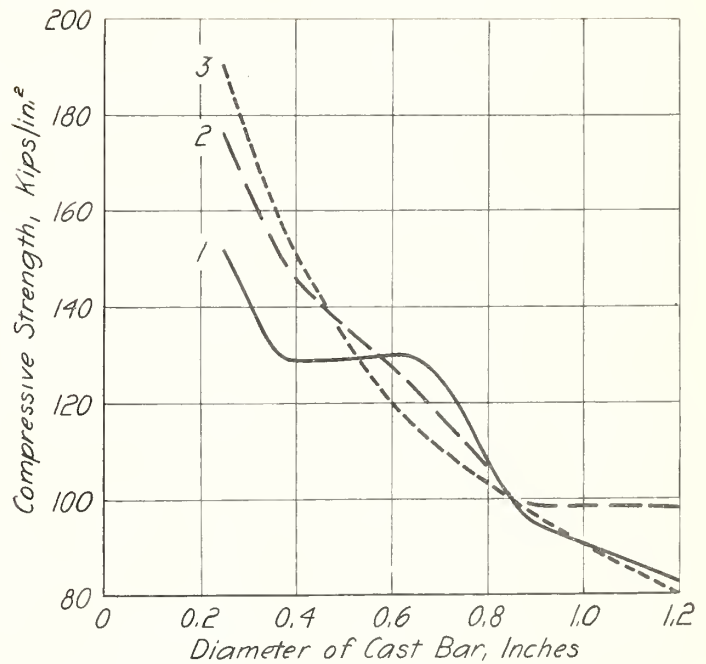


FIGURE 110.—Effect of section thickness on the compressive strength of cast iron (Campbell [672]).

Curve	Total C	Si	Mn	S	P
	Percent	Percent	Percent	Percent	Percent
1.....	3.52	2.47	0.58	0.06	0.41
2.....	3.50	2.58	.59	.07	.44
3.....	3.55	2.74	.66	.07	.40

Separately cast test bars.

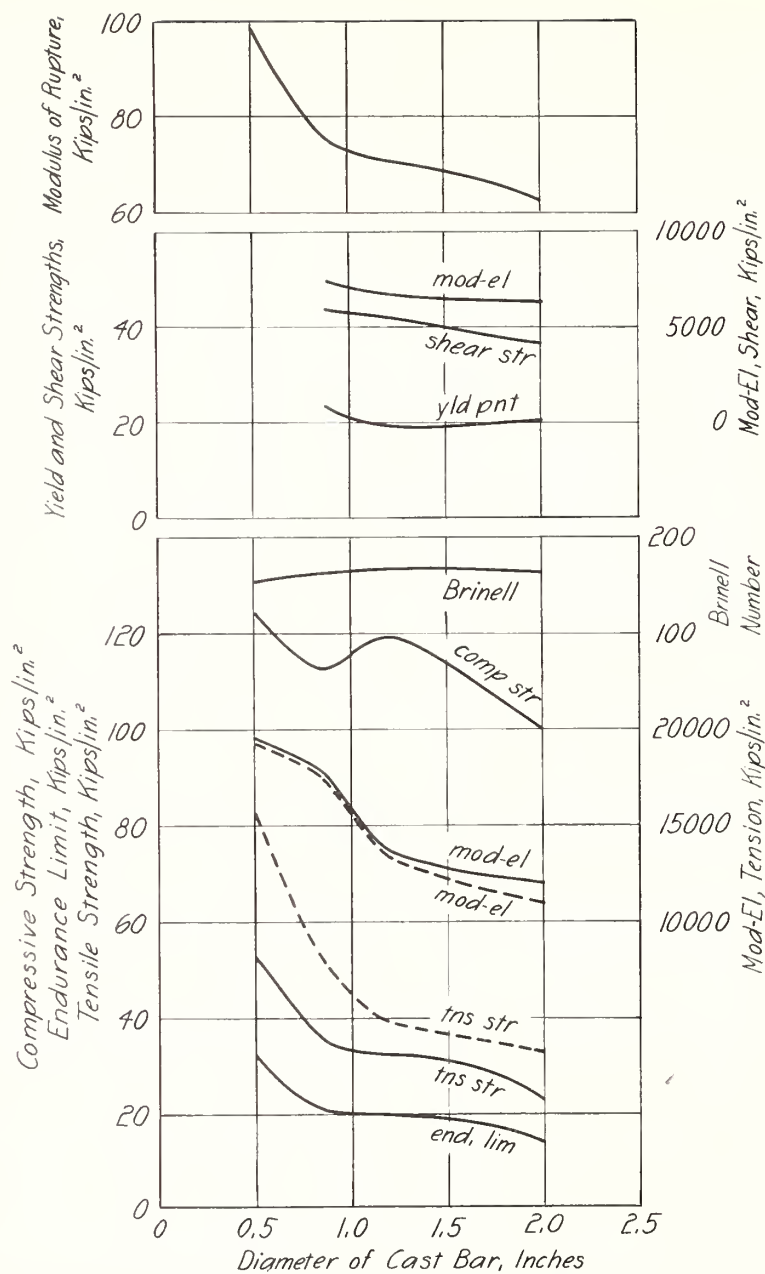


FIGURE 111.—Effect of section thickness on the tensile, compressive, shear, and endurance properties of permanent mold gray cast iron (Schneidewind and Hoenicke [347]).

Typical analysis: TC 3.52%, GC 3.41%, CC 0.11%, Si 2.55%, Mn 1.01%, S 0.086%, P 0.215%. Cast in water-cooled molds and fully annealed to give a structure of ferrite and graphite.

(The broken lines indicate tests on material heated 1 hour at 1,525°F, quenched in oil and tempered 1 hour at 850°F.)

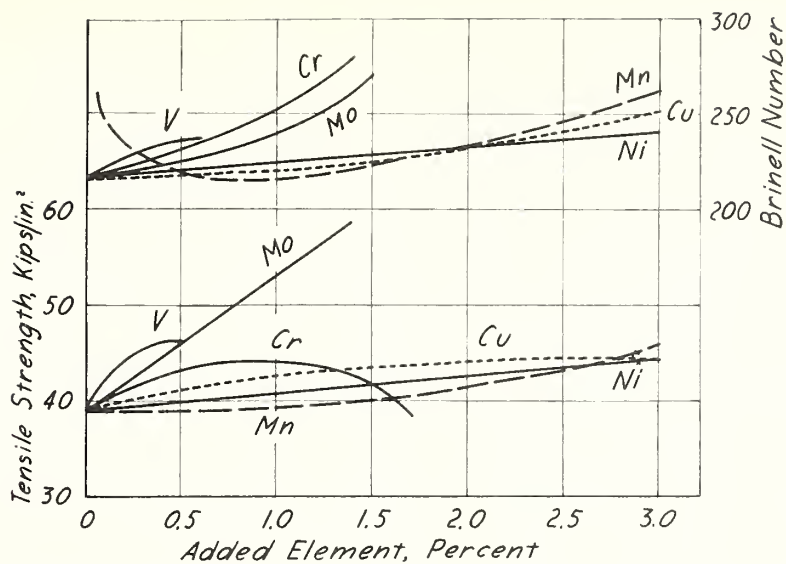


FIGURE 112.— Effect of various elements on the tensile strength and hardness of an electrically melted cast iron [177].

Composition of base iron: TC 3.24%, GC 2.57%, CC 0.67%, Si 1.88%, Mn 0.71%, P 0.17%, S 0.09%.

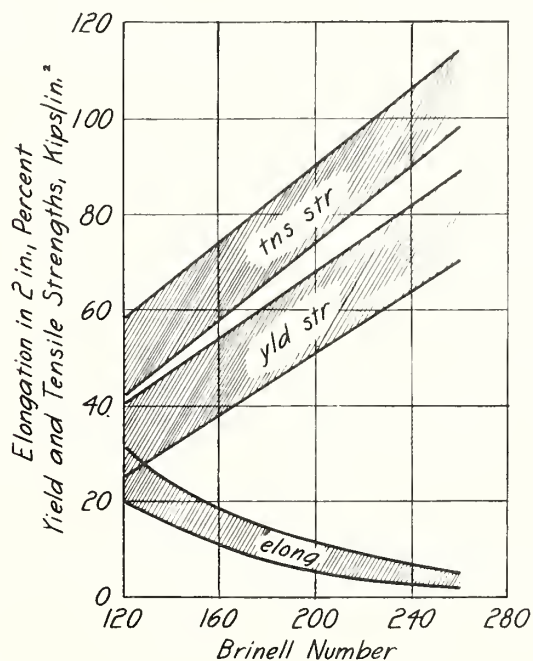


FIGURE 113.—Relation between hardness and tensile properties for malleable cast iron [354].

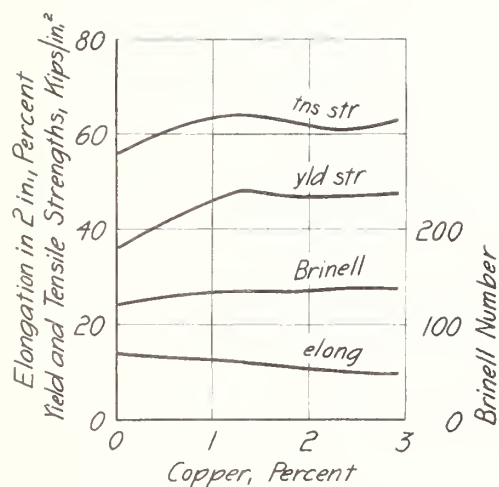


FIGURE 114.—Effect of copper on the tensile properties and hardness of malleable cast iron (Lorig and Smith [358]).

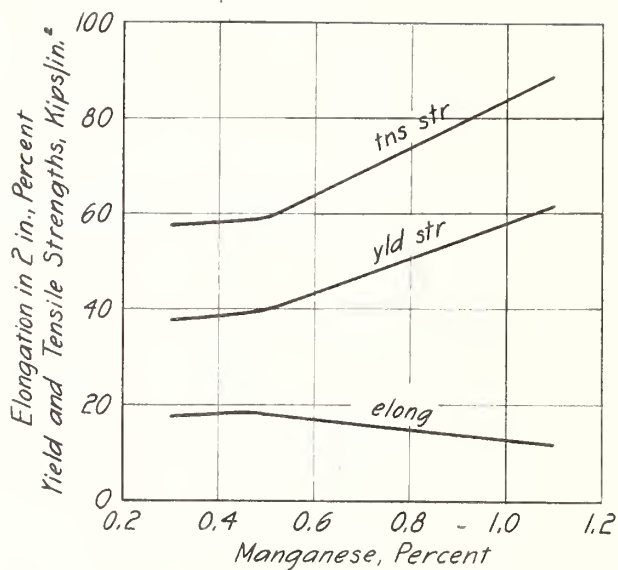


FIGURE 115.—Effect of manganese on the tensile properties of malleable cast iron [354].

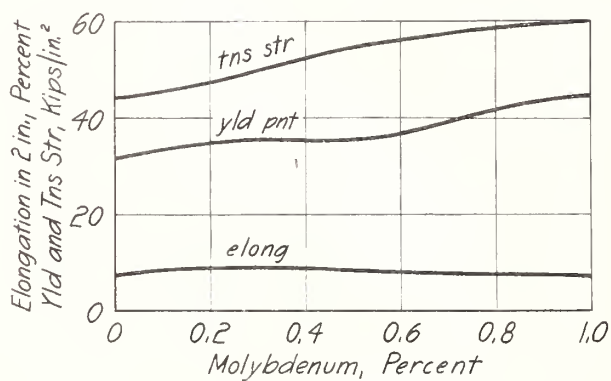


FIGURE 116.—Effect of molybdenum on the tensile properties of malleable cast iron [286].

TABLE 21.—Depression of initial freezing (liquidus) temperature of iron for the impurities and alloying elements usually found in steels^a [228]

[Freezing point of iron = 1,539°C (2,802°F)]

Element	Depression of freezing point per percent by weight		Range of elements in materials investigated percent by weight	Element	Depression of freezing point per percent by weight		Range of elements in materials investigated percent by weight
	°C	°P			°C	°P	
Hydrogen.....	1,300	(2,340)	computed.....	Sulfur.....	25	(45)	0 to 0.08
Nitrogen.....	90	(162)	computed.....	Arsenic.....	14	(25)	0 to 0.5
Oxygen.....	80	(144)	computed.....	Tin.....	10	(18)	0 to 0.03
Carbon.....	Varies as follows:		0 to 0.03	Silicon.....	8	(14)	0 to 0.03
	65	(117)	at 0%.....	Manganese.....	5	(9.0)	0 to 1.5
	70	(126)	at 1%.....	Copper.....	5	(9.0)	0 to 0.3
	75	(135)	at 2%.....	Nickel.....	4	(7.2)	0 to 9
	80	(144)	at 2.5%.....	Molybdenum.....	2	(3.6)	0 to 0.3
	85	(153)	at 3%.....	Vanadium.....	2	(3.6)	0 to 1
	91	(164)	at 3.5%.....	Chromium.....	1.5	(2.7)	0 to 18
	100	(180)	at 4%.....	Aluminum.....	0	(0)	0 to 1
Phosphorus.....	30	(54 )	.....	Tungsten.....	1	(1.8)	18% w with 0.66% C

^aThis table should be used for computing freezing points only within the ranges indicated.

TABLE 22.—Iron and steel, high-temperature properties

[For a discussion of the indefiniteness of values reported for yield strength and particularly for "proportional limit," see pages 5 and 6. Hardness numbers are Brinell numbers unless prefixed H_R , H_C , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed 12 (Izod method).]

Serial number	Composition	Condition	Temperature	Short-time properties						Creep properties			Reference
				"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Impact value	Stress (kips/in. ²) for designated creep rate per 1,000 hours	Duration	
PURE AND INGOT IRONS (SEE ALSO FIGS. 117 AND 119)													
2208a..	Percent Armco iron: C 0.02, Mn 0.043, S 0.03, P 0.013.	wrought.....	59	kips/in. ² 26.9	kips/in. ² 30.1	kips/in. ² 47.5	Percent 41 (2 in.)	Percent	ft-lb	0.01%	0.1%	1.0%	Hours
			212	.....	28.7	54.8	25 (2 in.)	.....	.....	.....	.....	.....	.....
			302	28.7	33.2	59.8	27 (2 in.)	.....	.....	.....	.....	.....	.....
			392	26.9	30.5	64.9	25 (2 in.)	.....	.....	.....	.....	.....	.....
			572	.....	.....	53.6	46 (2 in.)	.....	.....	.....	.....	.....	.....
			752	.....	.....	34.5	54 (2 in.)	.....	.....	.....	.....	.....	.....
932	.....	.....	16.7	93 (2 in.)	.....	.....	.....	.....	.....	.....	.....		
WROUGHT IRON (SEE ALSO FIG. 118)													
2209...	C 0.09, Mn 0.08, Si 0.10.	Forged.....	60	.....	30.9 (yld pnt)	50.0	29	48	.....	.....	.....	.....	.....
			1,472	.....	.....	4.6	54	58	.....	.....	.....	.....	
CARBON STEELS (SEE ALSO FIGS. 119 AND 120)													
2210...	C 0.15, Mn 0.45, Si 0.28, S 0.021, P 0.019 (basic open-hearth; deoxidized with Si and Al).	Bar, 1 in. diam, wrought; ann at 1,550°F, grain size 5-5 (ASTM Std), normal.	85	15.9	34.1 (0.2% perm)	57.3	40 (2 in.)	68	111	42	.....	.....	.....
			750	10.0	17.6 (0.2% perm)	51.5	41 (2 in.)	71	.....	44	.....	.....	.....
			800	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
			1,000	5.0	13.5 (0.2% perm)	30.5	53 (2 in.)	83	.....	30	12.0 17.2 3.30	25.0 6.00	1,000 1,000
			1,200	1.0	7.1 (0.2% perm)	16.3	71 (2 in.)	92	.....	62	0.14	2.10	1,000
			1,400	0	3.6 (0.2% perm)	8.5	79 (2 in.)	78	.....	.....	.....	.....	.....
2211...	C 0.15, Mn 0.50, Si 0.23, S 0.032, P 0.025 (basic electric furnace; deoxidized with Si and Al).	Bar, 1 in. diam, wrought; ann at 1,550°F, grain size 4-5 (ASTM Std), normal.	80	34.5	42.0 (0.2% perm)	52.4	36 (2 in.)	67	123	41	.....	.....	.....
			750	13.1	24.6 (0.2% perm)	58.0	34 (2 in.)	67	.....	36	.....	.....	.....
			800	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
			900	11.2	23.5 (0.2% perm)	45.5	38 (2 in.)	71	.....	29	15.5 12.8	38.5 22.1	1,000 1,000
			1,000	8.8	20.1 (0.2% perm)	36.5	42 (2 in.)	77	.....	30	2.70	5.75	12.1
			1,100	5.0	14.2 (0.2% perm)	27.2	57 (2 in.)	82	.....	39	0.85	1.80	3.85
1,200	1.9	10.2 (0.2% perm)	20.0	54 (2 in.)	89	.....	59	.29	0.62	1.30			
1,400	0	3.8 (0.2% perm)	9.0	70 (2 in.)	77	.....	.....	.....	.....	.....			

TABLE 22.—Iron and steel, high-temperature properties—Continued

Serial number	Composition	Condition	Temperature °F	Short-time properties					Creep properties			Reference
				"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Impact value	Stress (kips/in. ²) for designated creep rate per 1,000 hours		Duration
CARBON STEELS—Continued												
2219...	Percent C 0.51, Mn 0.59, Si 0.17, Ni 0.12, P 0.015, S 0.010.	Bar, 1 in. diam, hot-rolled; normalized.	t_p 61 752 842	$Kt/ps/in.^2$ 39.9 17.2	$Kt/ps/in.^2$ 50.4 (yld pt)	$Kt/ps/in.^2$ 93.7 82.7 72.6	Percent 33 (4/area) 33 (4/area) 32 (4/area)	Percent 45 60 62	f_{t-1b} 12 10 12 34	0.01% 0.1% 21.0	Hours 1,000	[63]
ALUMINUM-CHROMIUM STEEL												
2220...	C 0.30, Al 1.30, Cr 1.21, Ni 0.67, Mn 0.42, Mo 0.18, Si 0.09.	Bar, 3/4 in., wrought; o-q from 1,550°F., tempered at 1,200°F.	t_p 70 800 900 1,000	100 40.0 30.0	124 (yld pt) 87.0 (yld pt) 64.0 (yld pt)	138 104 88.4	19 (2 in.) 21 (2 in.) 25 (2 in.)	54 74 84	286	 30.0 (0.039%) 10.0 (0.027%)	 750 500 750	[63]
CHROMIUM STEELS (SEE ALSO FIGS. 121 TO 124, INCLUSIVE)												
2221...	C 0.37, Cr 0.91, Mn 0.48, Mo 0.24, Si 0.24, S 0.017, P 0.011.	Bar, 1 1/8 in., wrought; o-q from 1,550°F., tempered at 1,300°F.	t_p 70 550 800 1,200	75.5 50.0 43.0 4.5	79.0 (yld pt) 66.0 (yld pt) 55.5 (yld pt) 15.5 (yld pt)	101 108 79.0 35.6	27 (2 in.) 27 (2 in.) 30 (2 in.) 36 (2 in.)	70 68 81 94	198	 40.0 10.0 (0.032%) 4.2	 500 500 500	[63]
2222...	C 0.36, Cr 0.98, Mn 0.72, Si 0.24.	Bar, 7/8 in. diam, wrought; o-q from 1,550°F., tempered 1 hr at 1,050°F.	t_p 70 800 1,000	104 54.1 10.0	110 (yld pt) 71.1 (yld pt) 36.0 (yld pt)	131 102 78.0	19 (2 in.) 24 (2 in.) 28 (2 in.)	64 80 86	270	 10.0 (0.054%) 3.0 (0.11%)	 1,000 1,000	[63]
2223...	C 0.43, Cr 1.06, Mn 0.59, Si 0.35, V 0.18, S 0.016, P 0.015.	Bar, 3/4 in., wrought; o-q from 1,550°F., tempered 1 hr at 1,100°F.	t_p 70 800 1,000	128 55.7 13.9	147 (yld pt) 103 (yld pt) 47.8 (yld pt) 11.0 (yld pt)	158 118 93.7 41.8	19 (2 in.) 21 (2 in.) 25 (2 in.) 39 (2 in.)	58 76 87 93	316	 10.0 (0.014%) 3.0 (0.04%)	 1,000 1,000	[63]
2224...	C 0.35, Cr 1.13, Mn 1.01, Si 0.76, Mo 0.58, Ni 0.16.	Cast and annealed.....	t_p 900 1,000	..... .....	..... .....	..... .....	..... .....	..... .....	..... .....	16.8 2.50	 1,000 1,000	[63]

TABLE 23.—Iron and steel, high-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Short-time properties					Creep properties			Reference	
				*Proportional limit ^a	Yield strength	Tensile strength	Elongation	Reduction of area	Impact value	Stress (kips/in. ²) for designated creep rate per 1,000 hours	Hours		
CHROMIUM STEELS—Continued													
2232....	C 0.08, Cr 5.00, Cu 0.54, Mn 0.55, Ni 0.42, Si 0.35, P 0.012, S 0.011.	Bar, 1 in. diam, hot-rolled; tempered 4 hr at 1,380°F, grain size 8-9 (ASTM Std).	Room temp. { 1,000								0.1% 16.4	1.0% 2,000	[362]
2233....	C 0.24, Cr 5.06, Mn 0.53, Ni 0.35, Si 0.27, S 0.025, P 0.012.	Bar, 1 in. diam, wrought; 9-9 from 1,650°F, tempered 4 3/4 hr at 1,100°F.	70 { 800 { 1,000 { 1,200	87.0 (yld pt) 83.0 (yld pt) 33.0 (yld pt) 11.6 (yld pt)	111 (yld pt) 94.0 (yld pt) 65.5 (yld pt) 28.5 (yld pt)	140 (2 in.) 111 (2 in.) 95.1 (2 in.) 55.0 (2 in.)	19 (2 in.) 18 (2 in.) 24 (2 in.) 29 (2 in.)	68 67 79 89	 30.0 (0.03%)	 10.0 (0.13%) 3.0 (0.056%)	 1,000 1,000	[63]	
2234....	C 0.10, Cr 5.04, Mn 0.55, Ni 0.45, Si 0.18, P 0.017, S 0.017 (deoxidized with Si and Al).	Bar, 1 in. diam, wrought; annealed 1 hr at 1,550°F, grain size 4-5 (ASTM Std).	85 { 900 { 1,000 { 1,100 { 1,200	19.0 (0.2% perm) 11.5 (0.2% perm) 7.5 (0.2% perm) 6.0 (0.2% perm) 1.5 (0.2% perm)	26.2 (0.2% perm) 19.5 (0.2% perm) 17.3 (0.2% perm) 15.4 (0.2% perm) 11.3 (0.2% perm)	66.6 (2 in.) 48.4 (2 in.) 44.5 (2 in.) 34.4 (2 in.) 25.8 (2 in.)	39 (2 in.) 28 (2 in.) 28 (2 in.) 39 (2 in.) 46 (2 in.)	80 77 74 87 91	 11.5 7.60 3.20 1.70	 15.2 10.1 5.85 2.80	 20.5 12.8 1,000 1,000	[63]	
2235....	C 0.15, Cr 5.10, (electric furnace; deoxidized).	Bar, 1 in. diam, wrought; annealed 1,500°F, tempered 168 hr at 1,200°F.	Room temp. { 1,000				38 (2 in.)						[63]
2236....	C 0.20, Cr 5.44, Mn 0.85, Si 0.39, Ni 0.16, P 0.015, S 0.005.	Bar, 3/4 in. diam, forged; a-c from 1,650°F, tempered at 1,140°F.	70 { 800 { 900 { 1,000	79.0 (yld pt) 64.0 (yld pt)	99.7 (yld pt) 78.0 (yld pt)	122 (2 in.) 92.2 (2 in.)	22 (2 in.) 19 (2 in.)	66 68	 30.0 (0.22%) 10.0 (0.052%)	 10.0 (3.6%)	 750 500 750	[63]	
2237....	C 0.11, Cr 5.81, W 0.92, Mn 0.33, Si 0.20 (induction furnace).	Bar, 1 in. diam, wrought; annealed at 1,600°F, f-c to 1,000°F, a-c, grain size 5 (ASTM Std).	Room temp. { 900 { 1,000	.....	29.8 (yld pt) 27.5 (yld pt)	64.1 (2 in.) 39.1 (2 in.)	38 (2 in.) 32 (2 in.)	71 69	 7.00 4.65	 23.7 (0.019%) 6.0 (0.052%)	 1,000 1,000	[63]	
2238....	C 0.27, Cr 5.87, W 0.86, Si 0.53, Mn 0.45, S 0.035, P 0.025.	Cast; 5 hr at 1,800°F, a-c, tempered 5 hr at 1,250°F.	Room temp. { 900 { 1,000		91.1 (yld pt)	117 (2 in.)	19 (2 in.)	51					[63]
2239....	C 0.21, Cr 8.36, Mn 0.80, Ni 0.80, Si 0.52, Mn 0.47 (basic electric furnace).	Cast; normalized at 1,800°F, tempered at 1,270°F.	70 { 1,000 { 1,200	.....	99.3 (yld pt) 45.5 (yld pt)	120 (2 in.) 66.3 (2 in.) 43.2 (2 in.)	21 (2 in.) 31 (2 in.) 34 (2 in.)	49 75 88 .....	..... ..... ..... .....	..... ..... 10.0 (0.24%) 3.0 (0.044%)	 500 500	[63]	

TABLE 22.—Iron and steel, high-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Short-time properties					Creep properties			Reference
				Proportional limit ^a	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Impact value	Stress (kips/in. ²) for designated creep rate per 1,000 hours		Duration
MOLYBDENUM STEELS—Continued												
2254...	Percent C 0.13, Mo 0.52, Mn 0.49, Si 0.25, P 0.011, S 0.010 (basic electric furnace); deoxidized with Si and Al.	Bar, 1 in. diam, hot-rolled; annealed 1 hr at 1,550°F, grain size 8 (ASTM Std).	Room { 85 900 1,000 1,100 1,200 (	kips/in. ² 34.0 (0.2% perm) 23.0 (0.2% perm) 21.2 (0.2% perm) 16.2 (0.2% perm) 13.0 (0.2% perm)	kips/in. ² 62.5 (2 in.) 50.5 (2 in.) 42.5 (2 in.) 37.5 (2 in.) 27.5 (2 in.)	Percent 37 (2 in.) 27 (2 in.) 32 (2 in.) 32 (2 in.) 37 (2 in.)	Percent 65 68 80 73 72 50	121 145	ft-lb 40 29 24 43 61	0.01%	1.0) 15.3 (0.55%) 7.1 3.8	{ [63] 1,000 1,000 1,000 1,000 1,000
2255...	C 0.22, Mo 1.06, Mn 0.50, Si 0.13 (induction furnace).	Bar, 1 1/4 in. square, cast; annealed 1 hr at 1,650°F, grain size 7 (ASTM Std).	Room { 800 900 1,000 (	 43.2 (yld pt)	 70.2 (2 in.)	 (2 in.)	 50	 145	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	{ [63] 1,000 1,000 1,000 1,000
2256...	...do.....	Bar, 3/4 in. diam, wrought; annealed 1 hr at 1,625°F, grain size 7 (ASTM Std).	Room { 900 1,000 (	 43.5 (yld pt)	 73.0 (2 in.)	 28 (2 in.)	 55	 137	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	{ [63] 1,000 1,000 1,000 1,000
2257...	C 0.13, Mo 1.95, Mn 0.33, S 0.022, P 0.011, Si 0.01.	Bar, 1 in. diam, normalized 1/2 hr at 1,650°F, grain size 8-9 (ASTM Std).	Room { 1,000 (	 37.5 (yld pt)	 62.5 (2 in.)	 40 (2 in.)	 68	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	{ [63] 1,000 1,000 1,000 1,000
2258...	...do.....	Bar, 1 in. diam, normalized 5 hr at 1,650°F, tempered 5 hr at 1,400°F, grain size 8-9 (ASTM Std).	Room { 1,000 (	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... 152	 42	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	{ [362] 3,000 3,000 3,000 3,000
2259...	C 0.08, Mo 14.12, Mn 0.18, Si 0.05, P 0.030, S 0.005.	Cast and hot-rolled.....	1,000 { 1,200 (	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	{ [63] 1,000 1,000 1,000 1,000
NICKEL STEELS (SEE ALSO FIGS. 121, 126, AND 127)												
2270...	C 0.24, Ni 1.19, Cr 0.82, Mn 0.62, Mo 0.40, Si 0.36, S 0.032, P 0.030.	Cast; annealed 1,400°F, tempered 2 hr at 1,100°F.	Room { 900 1,000 (	 89.7 (yld pt)	 113	 15 (2 in.)	 34	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	{ [63] 1,000 2,500
2271...	C 0.36, Ni 1.19, Mo 0.58, Cr 0.51, Mn 0.51, Si 0.22, P 0.022, S 0.022 (induction furnace).	Bar, 1 in. diam, hot-rolled; normalized 1 hr at 1,600°F, tempered 3 hr at 1,250°F.	Room { 850 1,000 1,100 1,200 (	 78.5 (yld pt)	 109	 25 (2 in.)	 62	 R _c 18	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	{ [63] 500 1,000 1,000 1,000 250

2272...	C 0.36, Ni 1.33, Mn 0.60, Cr 0.56, Si 0.26, S 0.027, P 0.018 (basic open-hearth; deoxidized with Si and Al).	85 900 1,000 1,200	118 17.5 5.5 1.0	131 (0.2% perm) 62.4 (0.2% perm) 25.5 (0.2% perm) 7.5 (0.2% perm)	141 89.0 62.1 30.3	19 (2 in.) 22 (2 in.) 20 (2 in.) 51 (2 in.)	62 80 82 81	285	41 22 23 74	 0.19	 1.02	 5.20	[63] 500
2273...	C 0.14, Ni 1.85, Mn 0.53, Si 0.28, Mo 0.25, P 0.019, S 0.016 (basic electric furnace; deoxidized with Si and Al).	85 900 1,000 1,200	47.5 14.5 8.0 4.2	59.5 30.4 (0.2% perm) 25.5 (0.2% perm) 12.0 (0.2% perm)	72.4 52.0 43.5 24.8	38 (2 in.) 25 (2 in.) 25 (2 in.) 59 (2 in.)	70 77 82 80	149	62 32 25 70	 4.6	 7.7	 13.0	[63] 500
2274...	C 0.40, Ni 2.03, Cr 0.82, Mn 0.57, Si 0.28, P 0.023, S 0.015, Mo 0.011.	70 550 800 1,000	75.0 61.0 42.5 33.0	86.0 (yld pnt) 75.0 (yld pnt) 66.0 (yld pnt) 51.5 (yld pnt)	115 110 94.8 70.2	21 (2 in.) 18 (2 in.) 22 (2 in.) 26 (2 in.)	47 45 58 74	..... ..... ..... .....	..... ..... ..... .....	..... ..... 20.0 (0.016%) 3.00 (0.026%)	 63.0 38.0 .....	..... ..... ..... .....	[63] 1,000 1,000
2276...	C 0.41, Ni 2.10, Cr 0.86, Mn 0.74, Si 0.19.	Room 1,000	59.0	71.0 (yld pnt)	111	24 (2 in.)	55	R _C 16	64	 2.20	 3.60	 5.80	[63] 1,000
2278...	C 0.42, Ni 2.12, Cr 0.87, Mn 0.73, Mo 0.19, Si 0.18 (induction furnace).	Room 850 1,000 1,100	63.0	81.1 (yld pnt)	118	26 (2 in.)	63	R _C 18	54	 10.6 3.60 1.80	 18.0 6.60 4.80	 12.3	[63] 1,000 1,000
2277...	C 0.31, Ni 2.96, Cr 1.11, Mo 0.65, Mn 0.49, Si 0.26, Cu 0.06, P 0.013, S 0.004.	77 842 1,022	58.2 26.2 12.3	123 (yld pnt) 85.2 (0.2% perm) 46.8 (0.2% perm)	145 111 81.3	24 (4 area) 26 (4 area) 33 (4 area)	69 64 87	313	12 94 12 71 12 56	 18.0 (0.02%)	 41 3.4	 9.2 (0.55%)	[63] 500 500
2278...	C 0.37, Ni 3.03, Mn 0.65, Mo 0.49, Si 0.17, S 0.024, P 0.020 (induction furnace).	Room 1,000	39.8	74.8 (yld pnt)	130	20 (2 in.)	45	R _C 22	12 54	 2.4	 6.0	 15.0	[63] 1,000
2279...	C 0.42, Ni 3.41, Mn 0.66, Si 0.21, S 0.023, P 0.020.	70 800 1,000	58.9 20.0 11.0	62.9 (yld pnt) 38.8 (yld pnt) 25.0 (yld pnt)	99.7 78.2 46.5	26 (2 in.) 30 (2 in.) 39 (2 in.)	46 62 78	195 ..... .....	..... ..... .....	..... ..... .....	..... 12.3	 10.0 (1.9%)	[63] 500 250
2280...	C 0.33, Ni 3.43, Mn 0.63, Si 0.13, P 0.019, S 0.019.	61 572 752 932	51.1 31.8 27.8 10.3	83.6 (yld pnt)	107 109 84.2 56.7	28 (4 area) 32 (4 area) 28 (4 area) 34 (4 area)	64 47 56 69	215	 12 100 12 79 12 45	 65.0 (0.047%) 12.0 (0.027%)	 70.0 22.0 5.0	 9.0	[63] 1,000 1,000
2281...	C 0.45, Ni 14.32, Cr 13.67, W 2.18, Si 0.95, Mn 0.62, S 0.024, P 0.017.	58 1,112 1,292 1,472	..... ..... ..... .....	..... ..... ..... .....	127 79.6 58.5 38.1	30 (4 area) 32 (4 area) 55 (4 area) 58 (4 area)	44 47 58 64	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... 13.5 8.0 (0.42%) 2.2 (0.05%)	 22.8 10.5	[63] 500 500 500

2288...	C 0.67, # 16.79, Cr 3.74, V 1.04, Si 0.14, S 0.042.	Bar, 1 in. square, forged.....	1,112	9.0	26.9 (0.2% perm) 20.2 (0.2% perm)	55.8 (4/area) 60 (4/area) 75 (4/area)	65	.....	.....	.....	11.2 (0.25%)	.....	500	[63]
			1,292	.....	.....	35.4 (4/area)	78	.....	.....	.....	.....	.....	.....	.....
			1,472	.....	.....	13.8 (4/area)	88	.....	.....	.....	.....	.....	.....	.....

CAST IRONS (SEE ALSO FIGS. 128 AND 129)

2289...	TC 3.29, CC 1.10, Si 1.27, P 0.72, Mn 0.28, S 0.12.	Bar, 1 3/16 in. diam, cast....	60	.....	.....	34.3 (4/area) 0.5	.....	249	.....	.....	.....	.....	.....	[63]
			700	.....	.....	35.2 (4/area) 0.5	.....	.....	.....	.....	15.5 (0.02%) 3.65 (0.015%)	.....	1,000	.....
			842	.....	.....	33.1 (4/area) 0.5-1.0	.....	.....	.....	.....	8.00 (0.04%) 1.00 (0.35%)	14.5	1,000	.....
2290...	TC 3.19, CC 0.65, Si 2.13, P 0.80, Mn 0.67, Mn 0.58, Cr 0.34, S 0.08.	...do.....	90	.....	.....	35.8 (4/area) 0.5	.....	.....	.....	.....	.....	.....	.....	.....
			842	.....	.....	31.3 (4/area) 1.0-1.5	.....	.....	.....	.....	7.40 (0.04%)	16.7	1,000	[63]
			1,000	.....	.....	21.1 (4/area) 1.0	.....	.....	.....	.....	1.00 (0.35%)	3.25	1,000	.....
2291...	TC 2.44, CC 0.74, Ni 16.56, Cu 7.30, Cr 3.30, Si 1.11, Mn 0.76, P 0.26, S 0.057.	...do.....	65	.....	.....	25.3 (4/area) 0.5	.....	205	.....	.....	.....	.....	.....	.....
			842	.....	.....	22.6 (4/area) 0.5	.....	.....	.....	.....	8.80 (0.045%) 3.60	.....	1,000	[63]
			1,000	.....	.....	21.5 (4/area) 0.5	.....	.....	.....	.....	8.90	13.6	1,000	.....
2292...	TC 1.75, CC 0.28, Ni 17.72, Si 5.84, Cr 2.10, Mn 0.68, P 0.045, S 0.032.	...do.....	62	.....	.....	25.1 (4/area) 1.5-2.5	.....	134	.....	.....	.....	.....	.....	.....
			842	.....	.....	18.6 (4/area) 0.5-1.5	.....	.....	.....	.....	4.90	9.20	170	[63]
			1,000	.....	.....	17.2 (4/area) 1.5	.....	.....	.....	.....	1.55	3.25	1,000	.....
2293...	TC 2.39, CC 0.08, Si 5.72, Mn 0.67, P 0.30, S 0.063.	...do.....	62	.....	.....	31.8 (4/area) 0.6	.....	245	.....	.....	.....	.....	.....	.....
			700	.....	.....	30.6 (4/area) 0.6	.....	.....	.....	.....	22.5 (0.025%) 6.7	.....	1,000	[63]
			842	.....	.....	31.8 (4/area) 0.5-1.0	.....	.....	.....	.....	.....	.....	1,000	.....
			1,000	.....	.....	19.7 (4/area) 0.5-1.0	.....	.....	.....	.....	3.75 (0.08%)	8.70	1,000	.....

MALLEABLE CAST IRONS

2294 ¹ ...	TC 2.78, CC 0.005, Si 0.91, Mn 0.47, P 0.17, S 0.062.	Cast and malleablized.....	80	21.2	30.5 (0.2% perm) 25.5 (0.2% perm) 23.0 (0.2% perm) 14.5 (0.2% perm)	41.5 (2 in.) 38.7 (2 in.) 33.2 (2 in.) 16.2 (2 in.)	9	8	.....	.....	.....	.....	.....	.....
			600	18.0	.....	5.5 (2 in.)	5	5	.....	.....	21	28	2,000	[366]
			800	14.4	.....	5.5 (2 in.)	5	5	.....	.....	8.3	12	2,000	.....
			1,000	9.3	.....	14.5 (0.2% perm)	11	11	.....	.....	1.2	2.2	2,000	.....
2295...	TC 2.45, Si 1.46.....	Cast; 15 hr at 1,700°F, cooled to 1,525°F in 2 hr, o-o, tempered 2 hr at 1,325°F (pearlitic).	80	38.0	.....	76.2 (2 in.) 4.1 (2 in.)	6.5	.....	.....	7.8	.....	.....	.....	.....
			400	33.8	.....	74.7 (2 in.)	4.1	.....	.....	8.2	.....	.....	.....	.....
			800	20.0	.....	65.8 (2 in.)	6.7	.....	.....	6.3	.....	.....	.....	[357]

¹Modulus of elasticity: 80°F, 23,800 kips/in.²; 600°F, 20,800 kips/in.²; 800°F, 22,500 kips/in.²; 1,000°F, 16,000 kips/in.²

TABLE 22.—Iron and steel, high-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Short-time properties						Creep properties			Reference
				"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Impact value	Stress (kips/in. ²) for designated creep rate per 1,000 hours	Duration	
MALLEABLE CAST IRONS—(Continued)													
2296...	Percent TC 2.45, Si 1.46.....	Cast; 15 hr at 1,700°F., cooled to 1,325°F. in 3 hr and held 20 hr.	$\left\{ \begin{array}{l} 80 \\ 100 \\ 800 \end{array} \right\}$	Kips/in. ² 18.0 13.8 11.7	Kips/in. ²	Kips/in. ² 52.1 18.2 44.5	Percent 15 (2 in.) 8.2 (2 in.) 10 (2 in.)	Percent ..... ..... .....	..... ..... .....	ft.-lb 11 10 8.3	0.01%	0.1%	1.0% [357]
2297...	TC 2.51, Si 1.40, Mo 0.49.	Cast; 15 hr at 1,700°F., cooled to 1,325°F. in 2 hr, 0-9, tempered 2 hr at 1,325°F. (pearlitic).	$\left\{ \begin{array}{l} 80 \\ 400 \\ 800 \end{array} \right\}$	 40.0 29.2	..... ..... .....	77.8 77.8 75.5	3.5 (2 in.) 1.4 (2 in.) 2.8 (2 in.)	..... ..... .....	..... ..... .....	4.0 4.3 3.3	 [357]	..... ..... .....	..... ..... .....
2298...	do.....	Cast; 15 hr at 1,700°F., cooled to 1,325°F. in 3 hr and held 20 hr.	$\left\{ \begin{array}{l} 80 \\ 400 \\ 800 \end{array} \right\}$	 17.5 13.8	..... ..... .....	54.5 52.9 45.6	15 (2 in.) 3.0 (2 in.) 5.5 (2 in.)	..... ..... .....	..... ..... .....	10 9.7 7.0	 [357]	..... ..... .....	..... ..... .....

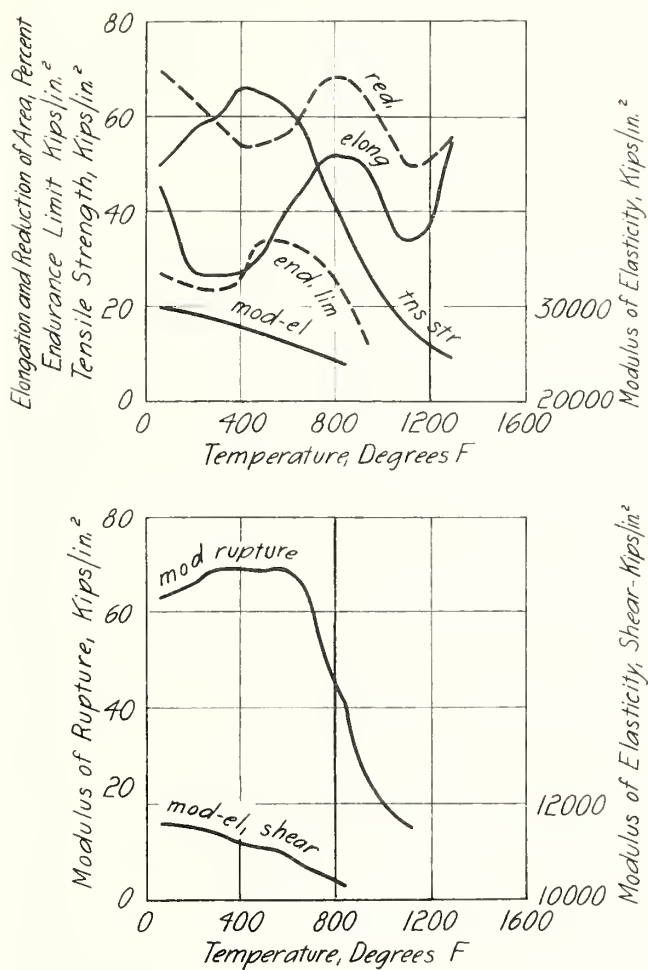


FIGURE 117.—Tensile, shear, rupture, and endurance properties of ingot iron (Armco) at high temperatures (Kenyon [229]).

(Elongation in $4\sqrt{\text{area}}$)

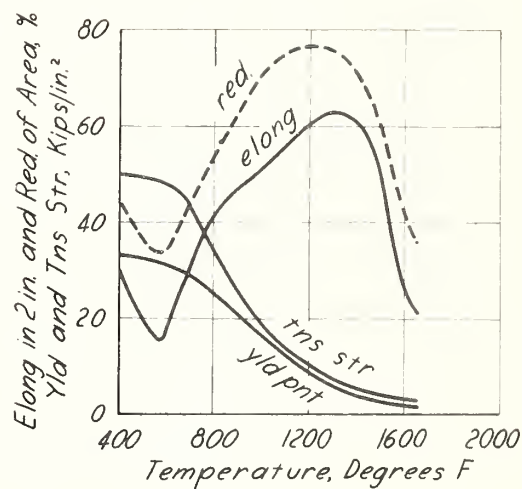


FIGURE 118.—Short-time tensile properties of wrought iron at high temperatures (Green [674]).

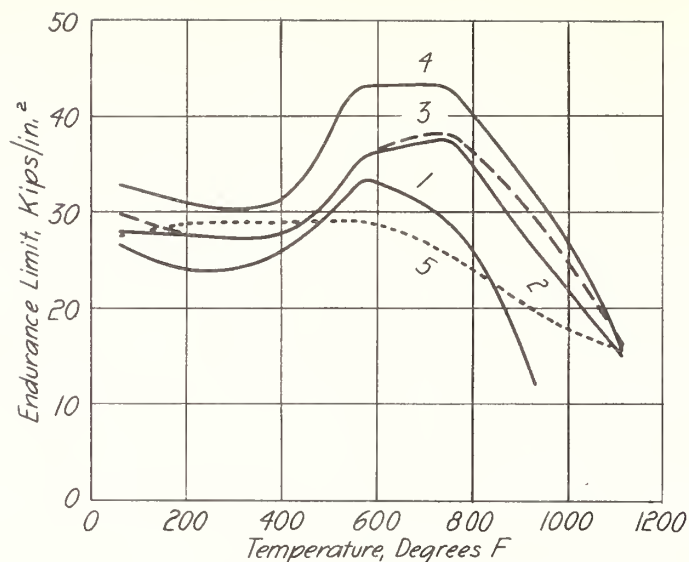


FIGURE 119.—Endurance limit of iron-carbon alloys at high temperatures (Batson and Tapsell [675]).

Curves: 1, ingot iron (Armco); 2, C 0.17%, rolled and normalized; 3, C 0.24%, rolled and normalized; 4, C 0.51%, rolled and normalized; 5, C 0.53%, cast.

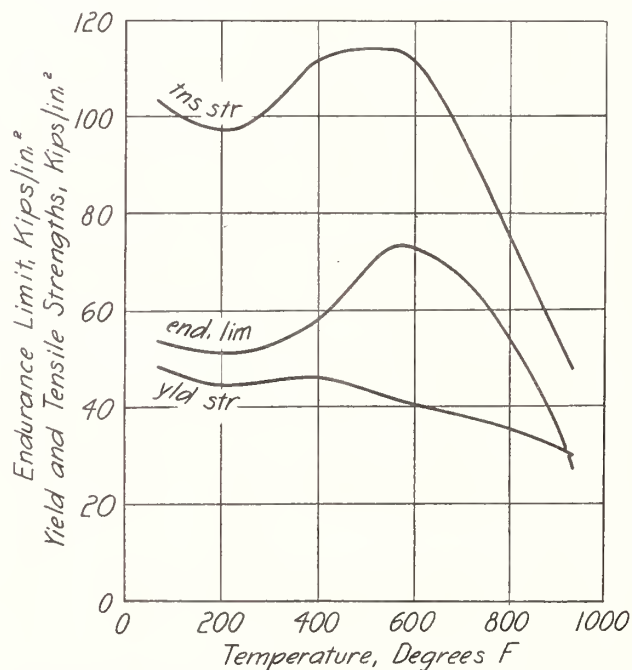


FIGURE 120.—Short-time tensile properties and endurance limit of a carbon steel at high temperatures (Hempel and Tillmanns [676]).

(Yield strength, 0.2%; endurance limit at 2×10^6 cycles)

C 0.58%, Mn 0.72%, Si 0.18%. Annealed 1/2 hour at 1,560°F and furnace-cooled.

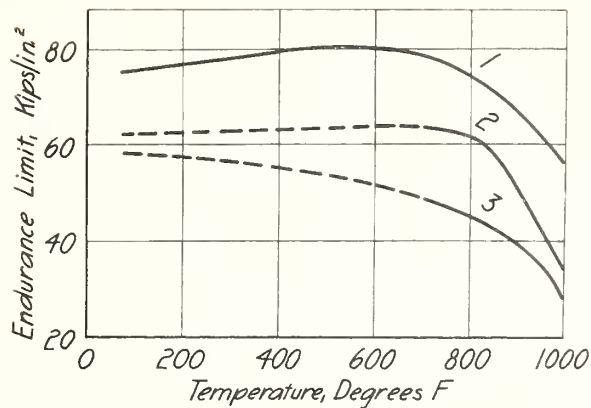


FIGURE 121.—Endurance limit of alloy steels at high temperatures (Kinney [677]).

Curve 1, C 0.4%, Ni 3.5%, Mn 0.8%, Si 0.3% (SAE 2340). Oil-quenched from 1,450°F and tempered 1/2 hour at 800°F.

Proportional limit.... 136 kips/in.²
Tensile strength..... 165 kips/in.²
Elongation in 2 in.... 11%
Reduction of area..... 58%

Curve 2, C 0.27%, Ni 1.99%, Cr 0.86%, Mo 0.41%, Si 0.25%, P 0.015%, S 0.011% (Ni-Cr-Mo steel). 8 hours at 1,740°F, oil-quenched, tempered at 1,200°F.

Yield strength..... 86 kips/in.²
Tensile strength..... 130 kips/in.²
Elongation in 2 in.... 23%
Reduction of area..... 67%

Curve 3, C 0.10%, Cr 12.39%, Ni 0.38%, Mn 0.29%, Si 0.31%, S 0.019%, P 0.014% (Cr steel). 5 hours at 1,175°F, furnace-cooled to 570°F and air-cooled to room temperature.

Yield strength..... 80 kips/in.²
Tensile strength..... 112 kips/in.²
Elongation in 2 in.... 24%
Reduction of area..... 68%

(Properties listed are at room temperature.)

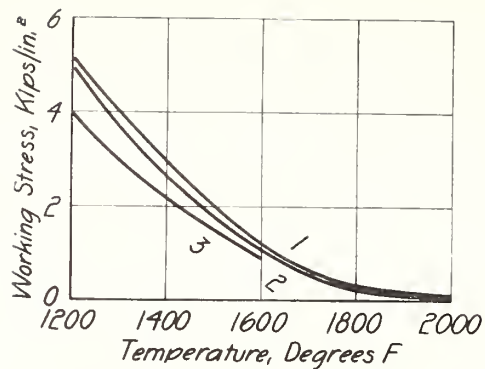


FIGURE 122.—Design strengths for iron-chromium-nickel alloys at high temperatures (Corfield [678]).

Curves: 1, Cr 24%, Ni 12%; 2, Cr 28%, Ni 10%; 3, Cr 18%, Ni 8%.

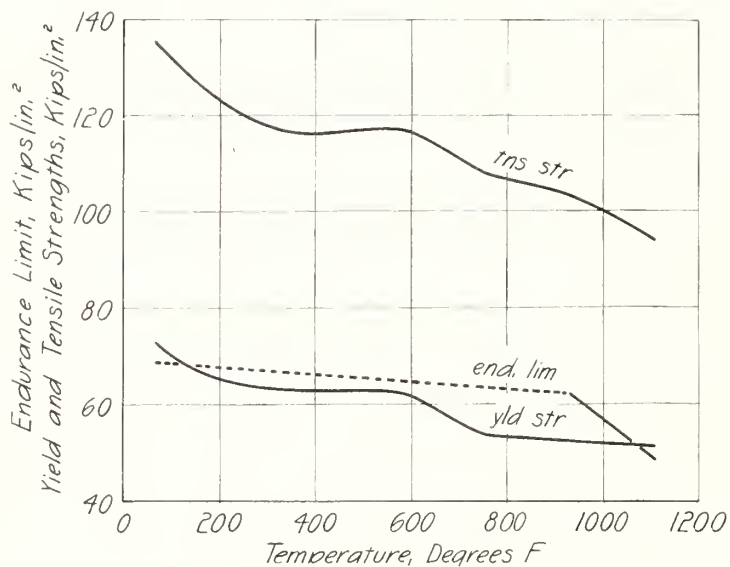


FIGURE 123.—Short-time tensile properties and endurance limit of a chromium-nickel-tungsten steel at high temperatures (Hempel and Tillmanns [676]).

(Yield strength, 0.2%; endurance limit at 2×10^5 cycles)

C 0.56%, Cr 15.5%, Ni 13.3%, W 2.02%, Si 1.58%, Mn 0.52%.

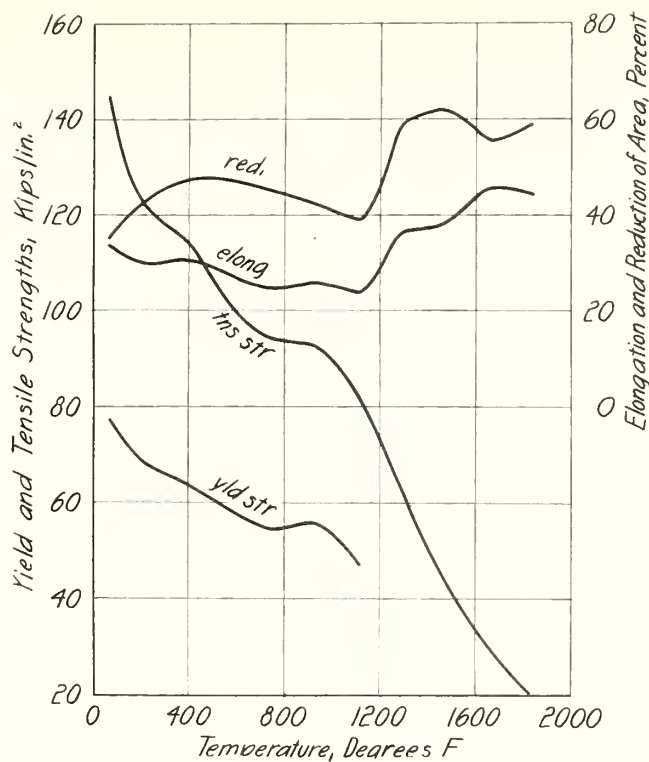


FIGURE 124.—Short-time tensile properties of a chromium-nickel-tungsten steel at high temperatures (Hatfield [383]).

(Yield strength, 0.2%)

C 0.345, Cr 19.16%, Ni 7.57%, W 3.98%, Si 1.24%,
Mn 0.69%. Air-cooled from 1,920°F.

Rate of strain: 0.0085 in. per minute to yield and
0.125 in. per minute thereafter.

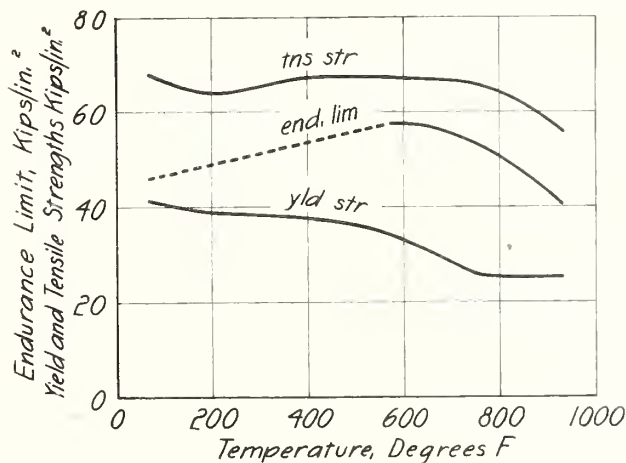


FIGURE 125.—Short-time tensile properties and endurance limit of a molybdenum steel at high temperatures (Hempel and Tillmanns [676]).

(Yield strength, 0.2%; endurance limit at 2×10^6 cycles)

C 0.14%, Mo 0.51%, Mn 0.43%, Si 0.27%. Air-cooled from 1,670°F.

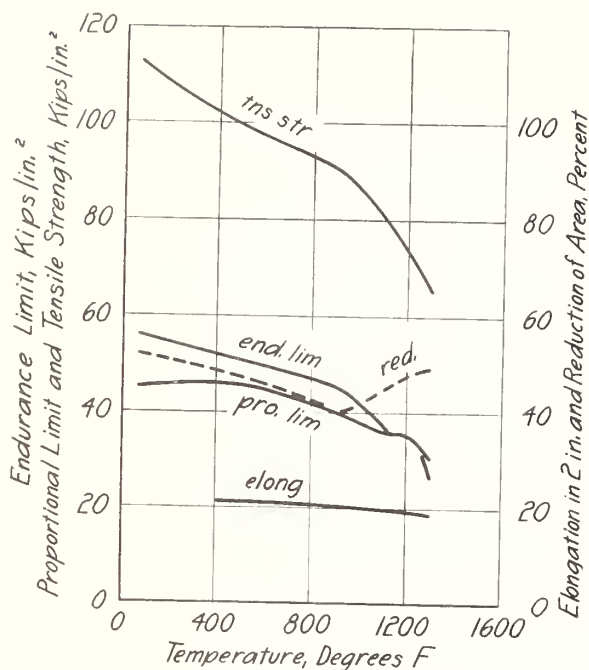


FIGURE 126.—Short-time tensile properties and endurance limit of a nickel-chromium steel at high temperatures (Marsh [274]).

C 0.33%, Ni 19.70%, Cr 8.31%, Si 1.16%, Mn 0.49%.

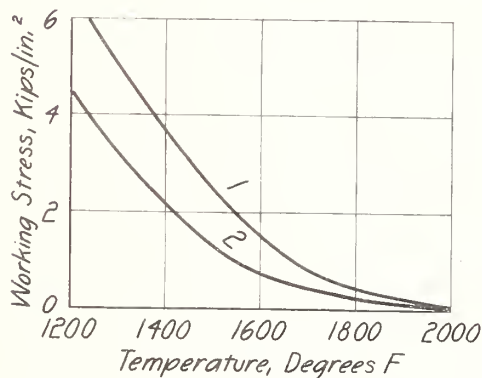


FIGURE 127.—Design strengths for iron-nickel-chromium alloys at high temperatures (Corfield [678]).

Curves: 1, Ni 35%, Cr 15%; 2, Ni 65%, Cr 15%.

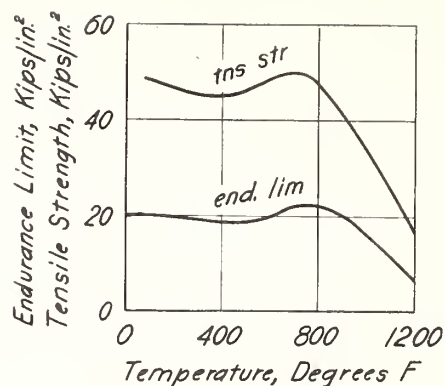


FIGURE 128.—Tensile strength and endurance limit of a cast iron at high temperatures (Collins and Smith [679]).

(Endurance limit at least 2×10^7 cycles)

TC 2.84%, GC 2.10%, CC 0.74%, Si 1.52%, Mn 1.05%, Cu 0.37%, Cr 0.31%, Ni 0.20%, S 0.124%, P 0.07%.

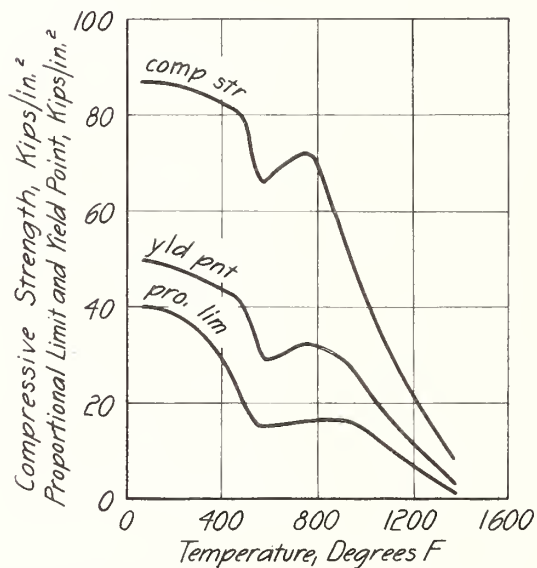


FIGURE 129.—Compressive strength of a cast iron at high temperatures [177].

C 3.5%, Si 1.58%, P 0.72%.

TABLE 23.—Iron and steel, low-temperature properties

[For a discussion of the indefiniteness of values reported for yield strength see page 5. Hardness numbers are Brinell numbers unless prefixed R_{H_0} , R_{H_1} , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed Iz (Izod method).]

Serial number	Composition	Condition	Temperature	Tensile properties					Hardness number	Impact value	Remarks	Reference
				Modulus of elasticity	Yield strength	Tensile strength	Elongation	Reduction of area				
PURE AND INGOT IRONS												
2299...	Percent Fe 99.89, C 0.03, Mn 0.04, Si 0.01.	Forged.....	$\begin{Bmatrix} \text{Room} \\ -423 \end{Bmatrix}$	$Klps/in.^2$ 41.7 (yld pnt)	$Klps/in.^2$ 52.4 117	Percent 25 (10 diam) 0 (10 diam)	Percent 81 0	104	$ft-lb$ ..... ..... .....	..... ..... .....		[66]
2300...	Armco: C 0.035, Mn 0.02, S 0.016, P 0.003.	Bar, 1 in. diam.....	$\begin{Bmatrix} \text{Room} \\ -58 \\ -94 \\ -148 \\ -184 \\ -292 \end{Bmatrix}$	 42.1 (yld pnt) 43.5 (yld pnt) 57.1 (yld pnt) 66.8 (yld pnt)	 45.7 59.4 61.6 66.8 77.1 112	28 (2 in.) 43 (2 in.) 38 (2 in.) 26 (2 in.) 17 (2 in.) 0 (2 in.)	73 74 72 70 68 0	..... ..... ..... ..... ..... .....	Iz 78 Iz 4 Iz 1.5	Tensile specimen, 0.25 in. diam; Impact specimen, 10×10 mm with three 45° notches.		[367]
WROUGHT IRON												
2301...	C 0.009, P 0.24, Si 0.12, Mn 0.03, S 0.01.	Chain, 3/4 in.....	$\begin{Bmatrix} \text{Room} \\ 32 \\ -4 \\ -58 \\ -108 \end{Bmatrix}$	 33.1	 54.9	24 (1 in.)	16 ..... ..... ..... .....	..... ..... ..... ..... .....	65 28 13 5.3 3.0	Impact specimen, Charpy bar with 120° notch.		[368]
CARBON STEELS												
2302...	C 0.09, Mn 0.43, S 0.024, Si 0.02, P 0.018.	Plate, 1 1/4 in., rolled...	$\begin{Bmatrix} \text{Room} \\ -25 \\ -50 \end{Bmatrix}$	 24.5	 45.5	44	76 ..... ..... ..... .....	..... ..... ..... ..... .....	52 41 1.5	..... ..... .....		[25]
2303...	C 0.09, Mn 0.51, Si 0.04, S 0.012, P 0.010.	Water-quenched from 1,625°F, tempered at 1,300°F.	$\begin{Bmatrix} \text{Room} \\ -25 \\ -50 \end{Bmatrix}$	..... ..... ..... ..... .....	..... ..... ..... ..... .....	..... ..... ..... ..... .....	..... ..... ..... ..... .....	..... ..... ..... ..... .....	59 41 6	..... ..... .....		[25]
2304...	C 0.17, Mn 0.79, Si 0.18, P 0.040, S 0.026 (deoxidized with Si).	Bar, 1/2 in. diam, cold-drawn.	$\begin{Bmatrix} \text{Room} \\ -20 \\ -40 \end{Bmatrix}$	 29,800 29,800	 68.5 76.5	18 20	58 56	169	Iz 54 Iz 16 Iz 12	..... ..... .....		[25]
2305...	C 0.19, Mn 1.01, Si 0.11, P 0.040, S 0.033 (deoxidized with Al).	Bar, 1/2 in. diam, cold-drawn.	$\begin{Bmatrix} \text{Room} \\ -20 \\ -40 \end{Bmatrix}$	 30,000 30,000	 76.0 82.5	16 14	52 52	192	Iz 28 Iz 8.5 Iz 6.5	..... ..... .....		[25]
2306...	C 0.23, Mn 0.65, Si 0.35, P 0.020, S 0.015.	Cast; ann at 1,650°F, f-c..	$\begin{Bmatrix} \text{Room} \\ -50 \end{Bmatrix}$	..... ..... ..... ..... .....	..... ..... ..... ..... .....	..... ..... ..... ..... .....	..... ..... ..... ..... .....	..... ..... ..... ..... .....	16 9.5	..... ..... .....		[25]

a -101°F.

a -101°F.

TABLE 23.—Iron and steel, low-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Tensile properties					Hardness number	Remarks	Reference
				Modulus of elasticity	Yield strength	Fensile strength	Elongation	Reduction of area			
				Kips/in. ²	Kips/in. ²	Kips/in. ²	Percent	Percent			
CARBON STEELS—Continued											
2307...	Percent C 0.23, Mn 0.55, Si 0.35, P 0.020, S 0.015.	Cast; a-c from 1,725°F, a-c from 1,600°F, tempered at 1,300°F.	Room (-25 -50 -100 -150)	.....	.....	.....	.....	.....	.....	.....	[25]
2308...	C 0.25, Mn 0.61, Si 0.05, P 0.040, S 0.031 (deoxidized with Si).	Bar, 1/2 in., cold-drawn...	Room (-20 -40)	29,500 29,600	83.0 89.5	99.0 110	12 14	51 49	139 .....	.....	[25]
2309...	C 0.28, Mn 0.67, P < 0.040, S 0.025.	Bar, 3/4 in. diam, cold-drawn.	Room (-40)	.....	..... (0.1% offset) 77.0 (0.1% offset)	89.0 102	16 (4 diam) 16 (4 diam)	51 52	.....	.....	[31]
2310...	C 0.44, Mn 0.70, Si 0.05...	Forged; a-c from 1,650°F...	Room (-40 -94)	.....	.....	.....	.....	.....	174 4.5 1	.....	[25]
2311...	...do.....	Forged; w-1 from 1,525°F, tempered at 940°F.	Room (-40 -94)	.....	.....	.....	.....	.....	228 38 11 7.5	.....	[25]
2312...	C 0.45, Mn 0.77, Si 0.21, S 0.022, P 0.013.	Cold-drawn.....	Room (-40 -108)	.....	86.0 92.0	91.0 106	14 (2 in.) 16 (2 in.)	50 47	R _C 12 R _C 16 R _C 19	Impact specimen, Charpy bar with 120d notch.	[369]
2313...	...do.....	Normalized 1 hr at 1,600°F...	Room (-40 -108)	29,200 28,400	63.0 74.0	113 130	17 (2 in.) 16 (2 in.)	49 44	R _C 16 R _C 20 R _C 22	do.....	[369]
2314...	...do.....	3/4 hr at 1,475°F, w-4, tempered 1 hr at 1,600°F.	Room (-40 -108)	29,600 28,800	125 136	135 152	12 (2 in.) 14 (2 in.)	54 52	R _C 27 R _C 29 R _C 29	do.....	[369]
2315...	C 0.72, Mn 0.75, Si 0.15, P 0.030, S 0.023.	Roller.....	+80 (-40)	.....	.....	.....	.....	.....	.....	Endurance limit 61.0 kips/in. ² Endurance limit 73.0 kips/in. ² .	[195]
2316...	C 0.78, Mn 0.10, Si 0.10, f-c from 1,430°F.	Wrought; a-c from 2,015°F, f-c from 1,430°F.	Room (-205)	.....	.....	116 155	13 0	.....	.....	.....	[66]
2317...	...do.....	Wrought; f-c from 1,470°F..	Room (-423)	.....	95.0 (yld prt)	98.8 123	12 (10 diam) 0.2 (10 diam)	35 0	163 244	.....	[66]
2318...	C 0.18, Mn 0.27, Si 0.15..	Normalized at 1,475°F.....	Room (-40 -105)	.....	60.0 71.5	124 146	12 12	25 22	R _C 22 R _C 26 R _C 26	.....	[25]

ALUMINUM STEEL

2319...	C 0.17, Al 0.85, Mn 0.18, Si 0.10.	Wrought; a-c from 2,015°F, f-c from 1,430°F.	{ Room -295	.....	.....	62.7 125	25 12	.....	.....	.....	[66]
2320...	...do.....	Wrought; f-c from 1,470°F..	{ Room -423	.....	.....	67.2 137	18 (10 diam) 0.1 (10 diam)	66 2.0	137 .....	.....	[66]

CHROMIUM STEELS

2321...	C 0.15, Cr 0.45, Mn 0.58, Si 0.12.	Normalized at 1,830°F.....	{ Room -10 -56	.....	.....	.....	.....	.....	.....	.....	[25]
2322...	...do.....	Water-quenched from 1,650°F, tempered at 1,250°F.	{ Room -10 -55 -85 -108	.....	.....	.....	.....	.....	.....	.....	[25]
2323...	C 0.16, Cr 0.49, Mn 0.89, Si 0.13, Al 0.044.	Normalized at 1,830°F.....	{ Room -40 -85 -108 -247	.....	.....	46.0	68.0 (1.8 in.)	75	.....	.....	[25]
2324...	...do.....	Water-quenched from 1,650°F, tempered at 1,250°F.	{ Room -108 -140 -185 -217	.....	.....	.....	.....	.....	.....	.....	[25]
2325...	C 0.31, Cr 0.69, Mn 0.65, Mo 0.22, Si 0.20, P 0.033, S 0.023.	Bar, 5/8 in., 0-3 from 1,625°F, tempered at 1,100°F.	{ Room -40	30,000 30,000	122 130 (0.1% offset)	128 149	20 (4 diam) 19 (4 diam)	65 64	285 296	1z 81 1z 80	[31]
2326...	...do.....	Bar, 5/8 in., 0-1 from 1,625°F, tempered at 650°F.	{ Room -40	30,000 30,500	136 200 (0.1% offset)	219 228	13 (4 diam) 13 (4 diam)	57 55	429 432	1z 13 1z 14	[31]
2327...	C 0.22, Cr 0.83, Mn 0.50, Si 0.33, Mo 0.22, Ni 0.09, P 0.015, S 0.005.	Water-quenched from 1,560°F, tempered at 1,120°F.	{ 58 -118 -297	.....	.....	114 172	22 (5 diam) 22 (5 diam)	75 57	234 329	b 22 b 15 b 1.3	[370]
2328...	C 0.29, Cr 0.95, Mn 0.69, V 0.17, Si 0.01.	Air-cooled from 1,700°F....	{ Room -10 -105	.....	.....	134 150	13 14	59 53	4z 28 4z 30 4z 30	8 5.3 6.5	[25]
2329...	...do.....	Oil-quenched from 1,625°F, tempered at 1,175°F.	{ Room -40 -105	.....	.....	118 140	12 15	65 56	4z 34 4z 31 4z 35	103 26 16	[25]
2330...	C 0.40, Cr 1.80, Mn 0.64, Mo 0.36, Si 0.24, V 0.19, Ni 0.06, P 0.018, S 0.003.	Oil-quenched from 1,470°F, tempered at 1,155°F.	{ 68 -148 -297 -423	.....	.....	147 200	18 (5 diam) 20 (5 diam)	64 50	285 418	b 15 b 6.5 b 5.0 b 3.5	[370]

^a Notch impact value, m-kg/cm.

TABLE 23.—Iron and steel, low-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Tensile properties				Hardness number	Impact number	Remarks	Reference
				Modulus of elasticity	Yield strength	Tensile strength	Elongation					Reduction of area
CHROMIUM STEELS—Continued											
2331...	<i>Percent</i> C 0.31, Cr 2.36, Mn 0.67, Si 0.29, Mo 0.24, V 0.10, P 0.010, S 0.006.	Oil-quenched from 1,560°F., tempered at 1,130°F.	σ_p { 68 -148 -297 }	$K(ips/in.^2)$ 123 (0.2% perm) 191 (0.2% perm)	$K(ips/in.^2)$ 140 206	<i>Percent</i> 18 (5 diam) 19 (5 diam)	<i>Percent</i> 70 45	294 400	$ft-lb$ b_{18} $b_{7.0}$ $b_{2.0}$	..... ..... ..... .....	[370]
2332...	C 0.28, Cr 2.46, Ni 1.53, Mn 0.64, Si 0.40, Mo 0.23, V 0.09, P 0.01, S 0.01.	Oil-quenched and tempered.	{ 68 -297 }	 133 (0.2% perm)	 150	 17 (5 diam)	63	288	$b_{9.0}$	.....	[370]
2333...	C 0.51, Cr 3.50, Si 2.20, Mn 0.22.	Wrought; a-c from 2,015°F., f-c from 1,430°F.	{ Room -295 }	..... ..... .....	..... 137 157	 15 0	.....	..... ..... .....	..... ..... .....	..... ..... .....	[66]
2334...	do.....	Wrought; f-c from 1,470°F.	{ Room -423 }	 116 (yld pnt)	 141	 16 (10 diam) 0.4 (10 diam)	44 0	272	.....	.....	[66]
2335...	C 0.46, Cr 3.57, Al 1.06, Si 0.34, Mn 0.18.	Wrought; a-c from 2,015°F., f-c from 1,430°F.	{ Room -285 }	..... ..... .....	..... 125 168	 10 5	.....	.....	.....	.....	[66]
2336...	do.....	Wrought; f-c from 1,470°F.	{ Room -423 }	 108 (yld pnt)	 117	 14 (10 diam) 2.0 (10 diam)	48 0	244	.....	.....	[66]
2337...	C 0.85, Cr 5.79, Cu 1.83, Mn 0.50, Si 0.31.	Wrought; a-c from 2,015°F., f-c from 1,430°F.	{ Room -235 }	..... ..... .....	..... 139 172	 12 0	.....	.....	.....	.....	[66]
2338...	do.....	Wrought; f-c from 1,470°F.	{ Room -423 }	 125 (yld pnt)	 134	 10 (10 diam) 0.3 (10 diam)	36 0	262	.....	.....	[66]
2339...	C 0.11, Cr 12.7, Ni 12.0.	Water-quenched from 2,010°F.	{ Room -75 -185 -292 }	 34.0 (yld pnt) 53.8 (yld pnt) 43.5 (yld pnt) 63.2 (yld pnt)	 82.9 133 182 235	 58 (2 in.) 50 (2 in.) 38 (2 in.) 36 (2 in.)	77 72 64 50	..... ..... ..... .....	Iz 118 σ_{Iz} 118 Iz 98 Iz 102	Tensile specimen 0.25 in. diam; impact specimen 10 x 10 mm with three 45° notches.	[367]
2340...	C 0.11, Cr 15.6, Ni 10.5.	do.....	{ Room -292 }	 77.1 (yld pnt)	 232	 30 (2 in.)	 45	.....	Iz 113 Iz 86	do.....	[367]
2341...	C 0.11, Cr 16.2, Ni 11.5.	do.....	{ Room -85 -292 }	 44.8 (yld pnt) 118 (yld pnt)	 33.6 220	 48 (2 in.) 55 (2 in.)	52 75	.....	Iz 118 Iz 118 Iz 118	do.....	[367]
2342...	C 0.11, Cr 16.27, Ni 1.72, Mn 0.44, Si 0.23, S 0.025, P 0.014.	Bar, 5/8 in., 0-1 from 1,800°F., tempered at 850°F.	{ Room -40 -105 }	 157 179	 199 217	 12 14	60 60	R _C 43 R _C 44 R _C 46	19-27 18-20 8-14	.....	[25]

2343...	C 0.10, Cr 17.34, Ni 8.67, Si 0.40.	Sheet, 0.032 in., hard.....	{ Room -40	25,700	157	180	9 (2 in.) (2 in.)	..... .....	..... .....	..... .....	..... .....	[25]
2344...	C 0.19, Cr 17.5, Ni 7.7, Si 0.36, Mn 0.30, P<0.04, S 0.035.	Bar, 1/2 in. square, cold- drawn.	{ Room -40	23,800	166	192	38 (4 diam) 33 (4 diam)	..... .....	..... .....	..... .....	..... .....	[31]
2345...	...do.....	8ar, 1/2 in. square, ann....	{ Room -40	30,000	42.5 (0.1% offset)	123	51 (4 diam)	..... .....	..... .....	..... .....	..... .....	[31]
2346...	C 0.07, Cr 18.22, Ni 8.63, Si 0.50, Mn 0.44, S 0.018, P 0.012.	Water-quenched from 1,900°F.	{ Room -105	.....	35.0	99.0	56	.....	.....	.....	.....	[25]
2347...	...do.....	Hot-rolled (finishing temperature 1,400°- 1,450°F)	{ Room -105	.....	82.0	117	38	.....	.....	.....	.....	[25]
2348...	...do.....	Cold-drawn.....	{ Room -40 -105	.....	91.5	152	22	.....	.....	.....	.....	[25]
2349...	C 0.11, Cr 18.4, Ni 9.6, Si 0.51, Mn 0.41, P<0.03, S<0.03.	Bar, 1/2 in. diam, cold- drawn.	{ Room -40	.....	103	196	29	.....	.....	.....	.....	[31]
2350...	C 0.07, Cr 18.41, Ni 7.88, Mn 2.80, Mn 0.73, Si 0.48, S 0.019, P 0.017.	Cold-drawn.....	{ Room -40 -105	.....	119	133	23	.....	.....	.....	.....	[25]
2351...	C 0.07, Cr 18.58, Ni 8.33, Mn 3.36, Mn 0.33, Si 0.42, P 0.026, S 0.012.	Annealed.....	{ Room -40 -105	.....	52.0	102	42	.....	.....	.....	.....	[25]
2352...	C 0.13, Cr 18.6, Ni 8.5, Mn 0.54, Si 0.18, P 0.02, S 0.02.	Wire, elliptically drawn, 0.193 in. minor axis.	{ Room -40	.....	73.0	153	51	.....	.....	.....	.....	[31]
2353...	C 0.06, Cr 18.60, Ni 8.25, Si 0.43, Mn 0.30.	Sheet, 0.022 in., half-hard	{ Room -40	27,800	107	150	26 (2 in.)	.....	.....	.....	.....	[25]
2354...	C 0.12, Cr 18.8, Ni 8.1, Si 0.43, Mn 0.24.	Wrought; w-q from 2,100°F..	{ Room -123	26,600	102	176	27 (2 in.)	.....	.....	.....	.....	[66]
2355...	C 0.07, Cr 18.97, Ni 10.29, Co 0.95, Mn 0.42, Si 0.32, S 0.028, P 0.027.	Wrought; w-q from 2,000°F..	{ Room -40 -105	.....	58.0 (yld pnt) 125 (yld pnt)	269	25 (10 diam)	.....	.....	.....	.....	[25]
2356...	...do.....	Cold-drawn.....	{ Room -40 -105	.....	50.0	92.0	41	.....	.....	.....	.....	[25]
2357...	C 0.05, Cr 19.04, Ni 9.15, Si 0.62, Mn 0.39, Ti 0.20, S 0.015, P 0.010.	Water-quenched from 1,900°F.	{ Room -40 -105	.....	52.0	146	40	.....	.....	.....	.....	[25]
2358...	...do.....	Cold-drawn.....	{ Room -40 -105	.....	128	145	14	.....	.....	.....	.....	[25]
				.....	135	165	33	.....	.....	.....	.....	[25]
				.....	26.0	86.0	45	.....	.....	.....	.....	[25]
				.....	38.0	143	46	.....	.....	.....	.....	[25]
				.....	85.0	131	22	.....	.....	.....	.....	[25]
				.....	89.0	174	32	.....	.....	.....	.....	[25]

⁹ Notch impact value, m-kg/cm.²

9-85°F.

TABLE 23.—Iron and steel, low-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Tensile properties					Hardness number	Impact value	Remarks	Reference
				Modulus of elasticity	Yield strength	Tensile strength	Elongation	Reduction of area				
CHROMIUM STEELS—Continued												
2359...	Percent C 0.05, Cr 20.8, Mn 8.87, Si 0.64.	Bar, 1/2 in. diam, annealed.	Room	$kips/in.^2$ 28,200	$kips/in.^2$ 35.0	$kips/in.^2$ 83.0	Percent 64	Percent 76	150	$ft-lb$ Iz 118	Impact specimen, round bar.....	[25]
2360...	...do.....	Bar, 1/2 in. diam, cold-drawn.	Room	28,000	43.0	110	58	68	.....	Iz 119		[25]
			Room	27,700	110	132	32	72	296	Iz 68	...do.....	[25]
			Room	27,800	116	151	40	60	.....	Iz 70		
CORAL STEEL												
2361...	C 0.25, Co 1.8, Mn 1.04, Si 0.64.	Wrought; a-c from 2,015°F, f-c from 1,430°F.	Room	.....	.....	76.2	22	.....	.....	.....		[66]
2362...	...do.....	Wrought; f-c from 1,470°F.	Room	.....	.....	86.5	20 (10 diam)	52	166	.....		[66]
			Room	.....	.....	129	0 (10 diam)	0	.....	.....		[66]
COPPER STEELS												
2363...	C 0.19, Cu 0.60, Mn 1.09, Si 0.50, S 0.025, P 0.016.	Furnace-cooled from 1,560°F.	Room	.....	51.0	78.0	26	61	.....	25-30	.....	[25]
			Room							14-18			[25]
2364...	C 0.15, Cu 0.85, Mn 0.87, Cr 0.51, Si 0.36, S 0.026, P 0.022.	...do.....	Room	.....	53.0	75.0	25	66	.....	40-44	.....	[25]
			Room							27-35			[25]
2365...	C 0.09, Cu 1.08, Ni 0.62, Mn 0.60, P 0.108, Si 0.04, S 0.027.	Plate, 1/2 in., rolled.....	Room	.....	57.5	74.5	26	56	153	54	.....	[25]
			Room							40			[25]
2366...	C 0.17, Cu 2.87, Mn 1.04, Si 0.15.	Wrought; a-c from 2,015°F, f-c from 1,430°F.	Room	.....	.....	76.2	20	.....	.....	38	.....	[66]
			Room			150	2.5			36			[66]
2367...	...do.....	Wrought; f-c from 1,470°F.	Room	.....	81.1 (yld pt)	93.4	16	56	185	.....		[66]
			Room	.....	.....	174	0.8	0	.....	.....		[66]
MANGANESE STEELS												
2368...	C 0.25, Mn 2.01, Cu 1.45, Si 0.31.	Wrought; a-c from 2,015°F, f-c from 1,430°F.	Room	.....	.....	98.6	17	62	.....	.....	.....	[66]
2369...	...do.....	Wrought; f-c from 1,470°F.	Room			157	17	39	.....	.....			[66]
			Room	.....	.....	173	0.2 (10 diam)	1.0	208	.....		[66]
2370...	C 1.32, Mn 4.23, Cr 2.02, Si 1.50.	Wrought; a-c from 2,015°F, f-c from 1,430°F.	Room	.....	.....	137	0	.....	.....	.....	.....	[66]
			Room			161	0					

WOLFRAM STEELS

2371...	...do...	Wrought; f-c from 1,470°F..	{ Room -423	.....	.....	123	2.5 (10 diam)	0	363	.....	.....	[66]
2372...	C 1.23, Mn 12.61.....	Wrought; w-q from 1,920°F..	{ Room -295	.....	.....	95.6	0 (10 diam)	.....	.....	.....	.....	[66]
2373...	C 1.27, Mn 12.69, Si 0.12.....	Wrought; w-q from 1,800°F..	{ Room -423	.....	77.3 (yld pnt)	148	44 (10 diam)	49	227	.....	.....	[66]
2374...	C 0.15, Mn 15.27.....	Wrought; w-q from 1,920°F..	{ Room -295	.....	.....	87.4 103	5 2.5	.....	.....	.....	.....	[66]
2375...	...do.....	.....	{ Room -423	.....	.....	95.0	5.5 (10 diam)	0	278	.....	.....	[66]
2376...	C 0.33, Mo 0.24, Mn 1.23..	Cast; w-q from 1,600°F, tempered at 1,275°F.	{ 65 -40 -94	.....	.....	.....	.....	.....	.....	56 34 14	.....	[313]
2377...	C 0.30, Mo 0.35, Mn 1.18..	Cast; a-c from 1,650°F, tempered at 1,200°F.	{ 65 -25 -75	.....	.....	.....	.....	.....	.....	37 22 18	.....	[313]

NICKEL STEELS

2378...	C 0.25, Ni 0.58, Si 0.33, Mn 0.18.....	Wrought; a-c from 2,015°F, f-c from 1,430°F.	{ Room -295	.....	.....	75.0 143	25 15	.....	.....	.....	.....	[66]
2379...	C 0.47, Ni 1.04, Cr 1.04, Mn 0.80, Si 0.29, Mo 0.22.	Furnace-cooled from 1,450°F.	{ Room -40 -105	.....	72.0	96.5	23	67	R _c 11 R _c 14	.....	Impact specimen, Charpy bar with 120° notch.	[25]
2380...	...do.....	Oil-quenched from 1,520°F, tempered at 1,175°F.	{ Room -40 -105	.....	90.0	116	26	62	R _c 18 R _c 26	.....	...do.	[25]
2381...	C 0.05, Ni 2.11, Mn 0.17, Si 0.01.....	Bar, 1 1/8 in. diam, a-c from 1,625°F, tempered at 1,200°F.	{ Room -100 -150 -200	.....	141	157	12	57	R _c 34 R _c 36 R _c 38	37-44 36-40 22-26	.....	[371]
2382...	C 0.34, Ni 2.27, Cr 1.88, Mn 0.45, Mo 0.40, Si 0.27, P 0.012, S 0.009.	Oil-quenched from 1,560°F, tempered at 1,095°F.	{ 68 -148 -297 -423	.....	53.7 (0.5% extn)	176	13	52	.....	58 34 20 4	.....	[370]
2383...	...do.....	.....	{ Room -94 -300	.....	148 164 202	167	17 (5 diam)	65	337	b 12 b 6.5 b 5.5 b 3.5	.....	[25]
2384...	C 0.33, Ni 2.54, Cr 0.67, Mn 0.64, Mo 0.34, Si 0.16, P 0.035, S 0.012.	Oil-quenched from 1,560°F, tempered at 1,185°F.	{ Room -89 -141 -292	.....	138 (yld pnt) 146 (yld pnt) 149 (yld pnt) 184 (yld pnt)	152	14	65	.....	b 12 b 8 b 5.5	.....	[367]

^a -101°F.^b Notch impact value, m-kg/cm².^d Notch impact value, m-kg/cm² at -110°F.
^e -181°F.Tensile specimen 0.25 in. diam;
impact specimen 10 x 10 mm with
three 45° notches.

TABLE 23.—Iron and steel, low-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Tensile properties					Hardness number	Impact value	Remarks	Reference
				Modulus of elasticity	Yield strength	Tensile strength	Elongation	Reduction of area				
NICKEL STEELS—Continued												
2385...	Percent C 0.13, Ni 2.69, Mn 0.44, Si 0.20.	Bar, 3 in. diam, a-c from 1,575°F, tempered at 1,200°F.	{ Room -100 -150 -200	 53.0 (0.5% extn)	 71.2	Percent 36 (2 in.)	Percent 73	114	ft-lb 60 38 36 24	..... ..... ..... .....	[371]	
2386...	C 0.34, Ni 3.30, Mn 0.72, Si 0.26.	Air-cooled from 1,700°F....	{ Room -40 -105	 74.0 79.5	 115 131	16 18	53 52	R _h 22 R _h 25 R _h 26	22 10 7.5	Impact specimen, Charpy bar with ized notch.	[25]	
2387...	...do.....	Air-cooled from 1,475°F, tempered at 1,000°F.	{ Room -40 -105	 126 143	 134 154	14 16	64 60	R _h 32 R _h 35 R _h 36	79-86 56-69 28	...do.....	[25]	
2388...	C 0.35, Ni 3.34, Cr 0.71, Mn 0.56, Si 0.18, P 0.010, S 0.009.	Wrought; o-q from 1,560°F, tempered at 1,200°F.	{ Room -423	 133 (yld pnt)	 146 243	14 (10 diam) 4.5 (10 diam)	60 48	14 284	.....	.....	[66]	
2389...	...do.....	Wrought; o-q from 1,560°F, tempered at 570°F.	{ Room -423	 238 (yld pnt) 297 (yld pnt)	 244 328	6.0 (10 diam) 0.9 (10 diam)	54 0	466 .....	.....	.....	[66]	
2390...	C 0.03, Ni 3.56, Mn 0.57, Si 0.29, P 0.016, S 0.015.	Cast; normalized at 1,750°F, reheated to 1,550°F, a-c, tempered at 1,200°F.	{ Room -100 -150 -200	 30,000 (yld pnt)	 63.6	40 (2 in.)	80	 58 43 26	58 43 26	.....	[372]	
2391...	C 0.05, Ni 3.72, Mn 0.21, Si 0.15, Mn 0.13.	Bar, 1 1/4 in. diam, a-c from 1,600°F, tempered at 1,200°F.	{ Room -100 -150 -200	 43.2 (0.5% extn)	 63.5	40 (2 in.)	78	130	70 43 6-14 4.5	.....	[371]	
2392...	C 0.29, Ni 3.64, Cr 0.26..	Bar, 5/8 in. diam, o-q from 1,500°F, tempered at 1,100°F.	{ Room -40	 29,500 29,500	 112 126	24 22	68 65	243	Iz 80 Iz 75	Impact specimen, round bar,.....	[25]	
2393...	...do.....	Bar, 5/8 in. diam, o-q from 1,500 F, tempered at 650°F.	{ Room -40	 29,400 29,600	 176 192 148 (0.2% perm)	14 15 15 (5 diam)	60 58 61	403 376 426	Iz 12 Iz 9 b 8.0 b 1.5	...do.....	[25]	
2394...	C 0.20, Ni 4.20, Cr 1.56, W 0.79, Mn 0.38, Si 0.18, Mo 0.06, P 0.014, S 0.005.	.....	{ 68 -297	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	.....	[370]	
2395...	C 0.13, Ni 5.13, Mn 0.41, Cr 0.19, Si 0.15, P 0.03, S 0.03.	.....	{ 68 -148 -242 -271 -297 -319	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	..... ..... ..... ..... ..... .....	.....	[373]	
2396...	C 0.09, Ni 5.35, Mn 0.86, Mo 0.34, Si 0.22.	Bar, 2 1/2 in. diam, a-c from 1,575°F, tempered at 1,200°F.	{ Room -100 -150 -200	 51.0 (0.5% extn)	 108	36 (2 in.)	66	217	58-64 35-41 27-35 20-22	.....	[371]	

2397...	C 0.57, Ni 13.0, Mn 6.86, Si 0.31.	Forged.....	68 -297 -423	..... ..... .....	50.5 (0.2% perm) 85.2 (0.2% perm)	103	82 (5 diam) 46 (5 diam)	76 48	184 227	b 39 b 16 b 7.0	.....	[370]
2398...	C 0.11, Ni 13.8, Cr 12.2..	Water-quenched from 2,010°F.	Room -80 -148 -287	..... ..... .....	27.1 (yld pnt) 46.6 (yld pnt) 49.3 (yld pnt) 71.7 (yld pnt)	85.1 106 133 212	52 (2 in.) 60 (2 in.) 56 (2 in.) 44 (2 in.)	76 78 75 58	..... ..... ..... .....	1z 111 c 1z 118	Tensile specimen 0.25 in. diam; Impact specimen 10 x 10 mm with three 45° notches.	[367]
2399...	C 0.83, Ni 14.44, Mn 5.9, Cu 2.25.	Wrought; w-q from 1,920 F..	Room -423	..... .....	61.8 150 (yld pnt)	117 172	54 12 (10 diam) (10 diam)	66 10	174 .....	.....	.....	[66]
2400...	C 0.11, Ni 15.92, Cr 12.25.	Water-quenched from 2,010°F.	Room -80 -186 -292	..... ..... .....	32.5 (yld pnt) 38.5 (yld pnt) 54.9 (yld pnt) 71.7 (yld pnt)	88.3 101 124 177	44 (2 in.) 62 (2 in.) 69 (2 in.) 58 (2 in.)	78 77 73 65	..... ..... ..... .....	1z 115 c 1z 117 1z 118 1z 118	Tensile specimen 0.25 in. diam; Impact specimen 10 x 10 mm with three 45° notches.	[367]
2401...	C 1.0, Ni 17.91, Mn 6.05..	Wrought; w-q from 1,920°F..	Room -423	..... .....	50.8 (yld pnt) 151 (yld pnt)	114 175	51 13 (10 diam) (10 diam)	64 26	159 .....	.....	.....	[66]
2402...	C 1.18, Ni 24.3, Mn 6.05..	...do.....	Room -423	..... .....	58.0 (yld pnt) 181 (yld pnt)	123 194	51 26 (10 diam) (10 diam)	60 50	191 .....	.....	.....	[66]
2403...	C 0.16, Ni 24.51, Mn 1.0, Si 0.30.	Wrought; f-c from 1,470°F..	Room -423	..... .....	..... .....	170 274	15 8.0 (10 diam) (10 diam)	53 36	330 .....	.....	.....	[66]
2404...	C 0.44, Ni 27.3, Cr 14.60, W 3.5, Si 1.62, Mn 1.34.	Wrought; w-q from 1,800°F..	Room -423	..... .....	..... 159 (yld pnt)	124 187	24 25 (10 diam) (10 diam)	42 35	232 .....	.....	.....	[66]
2405...	C 0.70, Ni 31.4, Mn 0.82..	Wrought; f-c from 1,470°F..	Room -423	..... .....	67.2 (yld pnt) 216 (yld pnt)	96.6 265	29 11 (10 diam) (10 diam)	46 16	162 .....	.....	.....	[66]
2406...	C 0.16, Ni 35.8, Mn 0.86, Si 0.08.	Wrought; w-q from 1,920°F..	Room -423	..... .....	52.4 (yld pnt) 127 (yld pnt)	81.1 144	32 20 (10 diam) (10 diam)	58 60	150 .....	.....	.....	[66]
2407...	C 0.04, Ni 35.98, Mn 0.29, Si 0.02.	.....	Room -300 -425	..... .....	60.5 (yld pnt) 91.0 (yld pnt)	75.0 129	28 32 (10 diam) (10 diam)	72 61	149 220	b 22 b 14 b 11	.....	[25]
2408...	C 0.12, Ni 42.06, Mn 0.94, Si 0.24.	.....	Room -300 -425	..... .....	50.5 (yld pnt) 73.0 (yld pnt)	81.5 132	36 41 (10 diam) (10 diam)	70 62	158 205	b 22 b 25 b 22	.....	[25]

^b Notch impact value, m-kg/cm.²

c -85°F.

TABLE 23.—Iron and steel, low-temperature properties—Continued

Serial number	Composition	Condition	Temperature	Tensile properties					Hardness number	Impact value	Remarks	Reference
				Modulus of elasticity	Yield strength	Tensile strength	Elongation	Reduction of area				
SILICON STEEL												
2409...	Percent C 0.40, Si 1.27, Mn 1.9...	wrought; f-c from 1,470°F..	$\left\{ \begin{array}{l} \text{Room} \\ -423 \end{array} \right\}$	$Kt/ps/in.^2$	$Kt/ps/in.^2$	$Kt/ps/in.^2$ 124	Percent 1.0 (10 diam)	Percent 0	266	$ft-lb$ .....	.....	[66]
TUNGSTEN STEELS												
2410...	C 0.26, W 1.99, Cr 0.66, Mn 0.25, Si 0.05.	Wrought; f-c from 1,470°F..	$\left\{ \begin{array}{l} \text{Room} \\ -423 \end{array} \right\}$	.....	68.6 (yld pnt)	91.2	18	60	174	.....	.....	[96]
2411...	C 0.38, W 7.47, Mn 0.20, Si 0.11.	...do.....	$\left\{ \begin{array}{l} \text{Room} \\ -423 \end{array} \right\}$	.....	91.8 (yld pnt)	119	12 (10 diam)	42	228	.....	.....	[66]
PLAIN CAST IRONS												
2412...	TC 3.07, Si 1.26, Mn 0.90, P 0.15, S 0.08.	Cast (processed iron).....	$\left\{ \begin{array}{l} 80 \\ -20 \end{array} \right\}$	.....	.....	.....	.....	.....	.....	.....	Endurance limit 21.0 kips/in. ² . Endurance limit 23.0 kips/in. ² .	[195]
2413...	TC 3.25, Si 1.1, Mn 0.60, P 0.46, S 0.096.	Cast; ann 1/2 hr at 1,040°F, f-c.	$\left\{ \begin{array}{l} 80 \\ -20 \\ -40 \end{array} \right\}$	.....	.....	.....	.....	.....	.....	.....	Endurance limit 9.0 kips/in. ² . Endurance limit 9.5 kips/in. ² . Endurance limit 11.5 kips/in. ² .	[195]
2414...	TC 3.42, G C 2.35, Si 1.24, Mn 0.56, P 0.326, S 0.103.	Cast.....	$\left\{ \begin{array}{l} 73 \\ -4 \\ -112 \end{array} \right\}$	.....	.....	31.1	.....	.....	180	$\left\{ \begin{array}{l} b.62 \\ b.58 \\ b.52 \end{array} \right\}$	Bend str 52.9 kips/in. ² . Deflection (24 in. span) 0.429 in. Bend str 55.1 kips/in. ² . Deflection (24 in. span) 0.425 in.	[374]
2415...	TC 3.44, Si 1.96.....	...do.....	$\left\{ \begin{array}{l} \text{Room} \\ -45 \end{array} \right\}$	.....	.....	.....	.....	.....	.....	$\left\{ \begin{array}{l} 12.39 \\ 12.29 \end{array} \right\}$	Impact specimen 1 1/2 in. diam., unnotched.	[25]
2416...	TC 3.56, G C 3.06, Si 1.80, Mn 0.60, P 0.527, S 0.080.	...do.....	$\left\{ \begin{array}{l} 73 \\ -4 \\ -31 \end{array} \right\}$	.....	.....	20.6	.....	.....	134	$\left\{ \begin{array}{l} b.51 \\ b.51 \\ b.53 \end{array} \right\}$	Bend str 43.0 kips/in. ² . Deflection (24 in. span) 0.420 in. Bend str 44.7 kips/in. ² . Deflection (24 in. span) 0.437 in. Bend str 43.3 kips/in. ² . Deflection (24 in. span) 0.420 in.	[374]
2417...	TC 3.78, G C 3.26, Si 2.03, Mn 0.86, P 0.095, S 0.071.	...do.....	$\left\{ \begin{array}{l} 73 \\ -4 \\ -112 \end{array} \right\}$	.....	.....	18.0	.....	.....	142	$\left\{ \begin{array}{l} b.58 \\ b.54 \\ b.50 \end{array} \right\}$	Bend str 38.7 kips/in. ² . Deflection (24 in. span) 0.468 in. Bend str 40.4 kips/in. ² . Deflection (24 in. span) 0.476 in.	[374]

2418...	2419...	2420...
TC 2.76, Si 2.02, Ni 1.75...	TC 2.76, Si 2.02, Ni 1.75...	TC 2.76, Si 2.02, Ni 1.75...
Cast.	Cast.	Cast.
Room -45	Room -45	Room -45
TC 2.73, Ni 13.76, Cu 5.00	TC 2.73, Ni 13.76, Cu 5.00	TC 2.73, Ni 13.76, Cu 5.00
Cr 1.36, Si 1.59.	Cr 1.36, Si 1.59.	Cr 1.36, Si 1.59.
Room	Room	Room
TC 2.50, Ni 30.00, Cr 4.00,	TC 2.50, Ni 30.00, Cr 4.00,	TC 2.50, Ni 30.00, Cr 4.00,
Si 1.40.	Si 1.40.	Si 1.40.
Room	Room	Room
Iz 44	Iz 44	Iz 44
Iz 38	Iz 38	Iz 38
Iz 55	Iz 55	Iz 55
Iz 50	Iz 50	Iz 50
Iz 41	Iz 41	Iz 41
Iz 70	Iz 70	Iz 70
Impact specimen, 1/2 in. diam, unnotched.	Impact specimen, 1/2 in. diam, unnotched.	Impact specimen, 1/2 in. diam, unnotched.

2421...	TC 3.05, Si 0.85, Wt 0.55, P 0.15, S 0.15,	{ Room -50 -75				4 3 3	} [25]
---------	---	-------------------------	-------------------------	-------------------------	-------------------------	-------------	--------------

[281]

TABLE 24. — *Iron and steel, thermal expansion*

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade											Reference
			20° to 50°C	20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 500°C	20° to 600°C	20° to 700°C	20° to 800°C	20° to 900°C	20° to 1,000°C	
PURE AND INGOT IRONS														
IRON-CARBON ALLOYS														
2422 ^a	C 0.004.....	Percent												
2423 ^b	Armco: Fe 99.75.....	1 hr at 700°C in vacuum, slowly cooled... Sheet.....	11.8	12.2	12.9 12.8	13.4 13.4	13.8 13.9	14.2 14.5	14.6	14.6	14.6	14.8	14.8	[196] [69]
WROUGHT IRON														
2424 ^a	Fe 99.82, C 0.13.....	1 hr at 700°C in vacuum, slowly cooled...	11.7	12.0	12.6	13.2	13.7	14.2	14.5	14.6	.....	.....	.....	[196]
2425 ^a	Fe 99.64, C 0.26.....	do.....	11.6	11.8	12.4	13.0	13.6	14.1	14.4	14.6	.....	.....	.....	[196]
2426 ^a	Fe 99.31, C 0.64.....	do.....	10.8	11.0	11.7	12.4	13.1	13.6	14.1	14.4	.....	.....	.....	[196]
2427 ^a	Fe 98.83, C 1.12.....	do.....	10.1	10.3	11.0	11.9	12.6	13.2	13.7	14.1	.....	.....	.....	[196]
ALUMINUM STEELS														
2429.....	C 0.13, Al 2.17, Mn 0.10, Si 0.05.....	Bar, slowly cooled from 900°C.....	.....	11.7	.....	12.8	.....	13.5	.....	.....	.....	.....	.....	[711]
2430.....	C 0.15, Al 5.66, Si 0.14, Mn 0.10.....	do.....	.....	12.0	.....	13.0	.....	13.8	.....	.....	.....	.....	.....	[711]
CARBON STEELS														
2431 ^b	C 0.08, Mn 0.31, Si 0.08, Ni 0.07, S 0.05, Cr 0.045, As 0.032, P 0.029, Mo 0.02, Al 0.002.	Bar, 1 in. diam, ann at 930°C.....	.....	12.2	13.0	13.5	13.9	14.3	14.7	15.0	.....	.....	.....	[376]
2432 ^b	C 0.435, Mn 0.69, Si 0.20, Cu 0.06, Ni 0.04, S 0.038, P 0.037, Cr 0.03, As 0.024, Mo 0.01, Al 0.006.	Bar, 1 in. diam, ann at 860°C.....	.....	11.6	12.3	13.1	13.7	14.2	14.7	15.1	.....	.....	.....	[376]
2433 ^b	C 0.80, Mn 0.32, Ni 0.13, Si 0.13, Cr 0.11, Cu 0.07, As 0.021, S 0.009, P 0.008, Al 0.004.	Bar, 1 in. diam, ann at 800°C.....	.....	11.1	11.7	12.5	13.2	13.7	14.2	14.7	.....	.....	.....	[376]
2434 ^b	C 1.22, Mn 0.35, Si 0.16, Ni 0.13, Cr 0.11, Cu 0.077, As 0.025, S 0.015, Mo 0.01, P 0.009, Al 0.006.	do.....	.....	10.6	11.3	12.1	12.9	13.5	14.2	14.7	.....	.....	.....	[376]
CHROMIUM STEELS														
2435 ^b	C 0.39, Cr 0.87, Mn 0.51, Mo 0.21, Si 0.19, S 0.029, P 0.015.	Rolled.....	.....	11.2	11.8	12.4	13.0	13.6	.....	.....	.....	.....	.....	[377]
2436.....	C 0.53, Cr 1.02, Mn 0.80, V 0.17, Si 0.15, S 0.020, P 0.015.	3 hr at 860°C, f-c.....	.....	12.4	12.8	13.4	13.9	14.2	14.5	14.7	.....	.....	.....	[378]
2437 ^b	C 0.055, Cr 1.32, Mn 0.45, Si 0.101, S 0.001, P 0.006.	.....	11.2	11.7	12.5	13.2	13.8	14.3	14.6	14.7	.....	.....	.....	[379]
2438.....	C 0.11, Cr 2.90, Mn 0.28, Si 0.18.....	Bar, 1/2 in. diam, forged; ann at 940°C.....	.....	.....	12.4	12.9	13.4	13.8	14.1	14.4	.....	.....	.....	[380]
2439.....	C 0.026, Cr 3.25, Si 0.16, N ₂ 0.032.....	.....	11.4	11.6	12.1	12.6	13.0	13.4	13.6	13.7	13.8	.....	.....	[381]
2440.....	C 0.030, Cr 4.96, Si 0.23, N ₂ 0.067.....	.....	11.4	11.5	11.7	12.1	12.6	12.9	13.1	13.2	.....	.....	.....	[381]
2441 ^b	C 0.09, Cr 5.05, Mn 0.36, Si 0.19, S 0.021, P 0.010.	Annealed at 875°C, f-c to 650°C, a-c.....	10.8	11.0	11.6	12.1	12.6	13.0	13.3	13.4	.....	.....	.....	[379]
2442.....	C 0.020, Cr 7.18, N ₂ 0.049, Si 0.10.....	.....	11.7	11.8	12.0	12.2	12.5	12.8	13.0	13.1	13.2	.....	.....	[381]
2443.....	C 0.028, Cr 9.02, Si 0.11, N ₂ 0.046.....	.....	11.0	11.1	11.3	11.5	11.8	12.2	12.4	12.4	12.5	.....	.....	[381]
2444.....	C 0.022, Cr 10.58, Si 0.07, N ₂ 0.050.....	.....	11.2	11.3	11.5	11.7	11.9	12.3	12.4	12.4	12.6	.....	.....	[712]
2445.....	C 0.09, Cr 12.0, Mn 0.60, Si 0.57, Ni 0.19, P 0.011, S 0.007.	Bar, hot-rolled and ann.....	.....	10.2	10.5	10.9	11.3	11.6	11.9	.....	12.3	.....	.....	[712]

TABLE 24.—Iron and steel, thermal expansion—Continued

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade											Reference
			20° to 50°C	20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 500°C	20° to 600°C	20° to 700°C	20° to 800°C	20° to 900°C	20° to 1,000°C	

NICKEL STEELS—Continued														
2476 ^b	C 0.38, Ni 26.16, Cr 6.95, Si 0.70, Mn 0.44, S 0.016, P 0.013	Cast.....	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	[69]
2477.....	C 0.58, Ni 27.78, Cr 18.50, Si 1.90, Mn 0.83, Al 0.09	Cast at 1,510°C.....	15.2	15.0	15.6	15.9	16.2	16.5	16.9	17.0	17.4	17.7	18.2	[713]
2478.....	C 0.43, Ni 28.28, Mn 0.73, Si 0.25	Normalized.....	.....	.....	13.8	13.5	16.1	16.3	16.3	.....	.....	.....	.....	[274]
2479.....	Ni 30.....	.....	.....	.....	8.8	12.5	14.1	15.0	15.6	16.1	16.6	17.0	17.4	[391]
2480 ^b	C 0.14, Ni 31.52.....	Annealed.....	.....	.....	3.7	6.4	9.2	4.2	12.7	13.6	14.5	.....	.....	[72]
2481 ^b	Invar®: Ni 36.1, Mn 0.39, Cu 0.39.....	.....	.....	.....	1.5	2.1	3.8	6.3	8.3	9.8	11.2	.....	.....	[69]
2482.....	C 0.30, Ni 36, Cr 11, Mn 1.5, Si 0.2.....	Hot-rolled.....	.....	.....	13.6	.....	.....	.....	.....	.....	.....	.....	.....	[713]
2483.....	C 0.42, Ni 36.0, Cr 16.4, Si 1.03, Mn 0.71.....	Hot-rolled at 1,550°C, ann at 1,000°C.....	.....	.....	12.8	14.2	15.2	15.7	16.2	16.5	16.9	17.3	.....	[69]
2484.....	C 0.4, Ni 40, Cr 17, Mn 1, Si 1.....	Cast.....	.....	.....	16.4	.....	.....	.....	.....	.....	.....	.....	.....	[385]
2485.....	C 0.05, Ni 48.10, Co 0.15, Mn 0.09, Si 0.03.....	1 hr at 800°C, slowly cooled.....	.....	.....	.....	.....	.....	8.8	.....	.....	.....	.....	.....	[385]

SILICON STEELS														
2486 ^c	C 0.09, Si 3.70, Cr 1.76, Mn 0.19, Ni 0.05, V 0.005.....	Annealed.....	.....	.....	11.1	.....	12.6	.....	14.0	.....	.....	.....	.....	[391]
2487 ^b	C 0.1, Si 1.....	.....	.....	.....	12.6	13.1	13.4	13.5	13.7	14.0	14.4	14.9	15.4	[340]
2488.....	C 0.8, Si 14.5, Mn 0.35.....	Sand-cast.....	.....	.....	6.5	.....	.....	.....	.....	.....	.....	.....	.....	[375]

TUNGSTEN STEELS														
2489 ^c	C 0.47, W 1.17, Cr 1.03, Si 0.56, Mn 0.16, P 0.014.....	.....	.....	.....	11.5	12.3	13.2	14.2	15.2	16.4	17.8	.....	.....	[72]
2490 ^c	C 0.51, W 1.58, Si 1.45, Mn 0.42, S 0.021, P 0.016.....	Annealed.....	.....	.....	10.1	.....	12.2	.....	.....	14.2	.....	.....	.....	[391]
2491 ^f	C 0.45, W 2.20, Mn 0.22, Si 0.15, P 0.022, S 0.011.....	.....	.....	.....	.....	12.3	13.1	14.0	15.0	16.2	17.6	.....	.....	[72]
2492 ^c	C 0.40, W 3.96, Mn 0.25, S 0.023, P 0.012, Si 0.10.....	Annealed.....	.....	.....	11.1	11.6	12.5	13.2	13.7	14.2	14.5	.....	.....	[391]
2493 ^f	C 0.69, W 6.31, Si 0.24, Mn 0.20, P 0.016, S 0.016.....	.....	.....	.....	9.8	12.6	14.5	15.5	16.1	16.6	.....	.....	.....	[72]
2494 ^f	C 0.73, W 13.50, Cr 3.90.....	.....	.....	.....	10.7	11.8	12.8	13.5	14.1	14.2	.....	.....	.....	[72]

PLAIN CAST IRONS														
2495.....	TC 2.24, Mn 0.15, Si 0.08, P low, S low.....	.....	.....	.....	9.6	9.6	11.0	12.1	13.2	.....	.....	.....	.....	[387]
2496 ^b	TC 3.06, GC 2.75, CC 0.79, Si 1.10, Mn 0.70, P 0.300, S 0.154.....	Cast; ann 1/2 hr at 1,000°F.....	.....	.....	11.1	11.6	12.2	12.7	13.2	.....	.....	.....	.....	[387]
2497 ^b	TC 3.12, GC 2.45, CC 0.66, Si 2.00, Mn 0.93, P 0.255, S 0.151.....	do.....	.....	.....	10.5	11.3	11.9	12.5	13.2	.....	.....	.....	.....	[387]
2498 ^b	TC 3.66, GC 2.88, CC 0.78, Si 1.44, Mn 0.85, P 0.291, S 0.129.....	do.....	.....	.....	10.4	11.1	11.7	12.3	12.9	.....	.....	.....	.....	[387]
2499 ^f	TC 3.8, Mn 0.16, Si 0.05.....	Cast; ann 1/2 hr at 1,000°C.....	.....	.....	8.7	8.5	10.1	11.5	.....	.....	.....	.....	.....	[387]

ALLOY CAST IRONS														
2500.....	TC 3.5-3.8, Al 1.5.....	Cast.....	.....	.....	7.1	9.2	10.9	11.8	12.6	.....	.....	.....	.....	[388]
2501 ^c	TC 3.11, GC 2.41, Cu 3.36, Si 2.48, Mn 0.62, P 0.26, S 0.10.....	do.....	.....	.....	.....	10.4	.....	12.9	.....	14.1	.....	.....	.....	[389]
2502 ^c	TC 3.16, GC 2.50, Si 2.51, Cu 2.46, Mn 0.63, P 0.26, S 0.10.....	do.....	.....	.....	.....	10.4	.....	12.9	.....	14.0	.....	.....	.....	[389]
2503.....	TC 2.98, Ni 2.24, Si 1.28, Mn 0.5.....	Bar, cast; ann.....	.....	.....	11.8	12.2	12.6	12.8	.....	.....	.....	.....	.....	[386]

2504.....	TC 2.95, Ni 4.86, Cr 1.55, Si 0.90, Mn 0.4...	...do.....	h 7.8	j 11.3	k 12.4	.....	.....	.....	.....	[386]
2505.....	TC 3.0, Ni 7.38, Si 1.2, Mn 0.52.....	...do.....	h 13.0	j 13.8	k 13.4	.....	.....	.....	.....	[386]
2506.....	TC 2.8, Ni 10.7, Cu 4.3, Cr 2.0, Si 1.5, Mn 1.0.	...do.....	h 17.4	j 18.6	j 19.0	.....	.....	.....	.....	[386]
2507.....	TC 3.2, Ni 13.96, Cu 6.0, Cr 2.13, Si 1.8, Mn 1.0.	...do.....	h 18.5	j 19.3	j 19.2	.....	.....	.....	.....	[386]
2508.....	TC 2.50, Ni 20.38, Cu 9.08, Cr 2.47, Mn 1.0, Si 1.0.	...do.....	h 14.0	j 16.1	j 16.6	.....	.....	.....	.....	[386]
2509.....	TC 2.36, Ni 25.74, Cr 1.96, Si 1.36, Mn 1.0..	...do.....	h 12.5	j 15.5	j 16.4	.....	.....	.....	.....	[386]
2510.....	TC 2.0, Ni 28.2, Cu 11.3, Cr 4.0, Si 1.5, Mn 1.0.	...do.....	h 8.4	j 10.4	j 12.0	.....	.....	.....	.....	[386]
2511.....	TC 2.27, Ni 30.82, Cu 15.10, Cr 4.19, Si 1.53, Mn 0.95.	...do.....	h 8.6	j 9.9	j 11.1	.....	.....	.....	.....	[386]
2512.....	TC 2.71, Ni 30.96, Cr 2.64, Si 1.59, Mn 0.93..	...do.....	h 6.2	j 9.4	j 11.6	.....	.....	.....	.....	[386]
2513.....	TC 2.50, Ni 34.50, Cr 3.59, Si 1.27, Mn 1.0..	...do.....	h 5.6	j 7.2	j 9.1	.....	.....	.....	.....	[386]
2514.....	TC 2.25, Ni 43.68, Cr 3.21, Mn 1.80, Si 1.65..	...do.....	h 8.6	j 9.6	j 10.1	.....	.....	.....	.....	[386]
2515.....	TC 2.46, Ni 46.45, Cr 3.93, Si 1.40, Mn 0.94..	...do.....	h 8.3	j 9.1	j 10.0	.....	.....	.....	.....	[386]
2516.....	TC 2.25, Si 5.8.....	...do.....	.....	11.3	11.6	12.0	12.5	12.9	13.3	[388]
MALLEABLE CAST IRON										
2517.....	TC 1-2, Si 0.60-1.10, Mn <0.30, P <0.20, S 0.06-0.15.	.....	10.6	11.4	12.3	13.0	13.6	14.2	14.7	[390]

^b Base temperature 0°C instead of 20°C.

^d 20° to 60°C.

^e Base temperature 25°C instead of 20°C.

^f Instantaneous coefficient of linear expansion.

^g Room temperature coefficients of linear expansion for Invars range from about 0 to 2×10⁻⁶.

h 10° to 95°C.
i 10° to 205°C.
j 10° to 315°C.
k 10° to 425°C.

TABLE 25.—Iron and steel, electrical and thermal properties

Serial number	Composition	Condition	Electrical properties			Thermal conductivity	Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity		
PURE AND INGOT IRONS							
2518.....	Percent Impurities under 0.0117.....	Annealed in vacuum 15 minutes at 850°C.....	Percent IACS 17.8 (20°C)	Microhm cm 9.71 (20°C)	per °C × 10 ⁻⁴	Watts cm ⁻¹ °C ⁻¹	[226]
2519.....	...do....	Wire, 0.019 in. diam, ann in vacuum 2 hr at 800°C.	.....	.....	65.1 (0°-100°C)	.....	[226]
2520.....	Fe 99.9887 (rem).....	Cold-rolled.....	17.4 (20°C)	9.90 (20°C)	.....	.....	[227]
2521.....	...do....	Cold-rolled; ann.....	{ 17.5 (20°C) 15.0 (50°C) 11.9 (100°C) 9.7 (150°C)	{ 9.84 (20°C) 11.5 (50°C) 14.5 (100°C) 17.8 (150°C)	.....	.....	[227]
2522.....	...do....	Wire, 0.39 in. diam.....	.....	.....	.....	{ 0.79 (25°C) .70 (150°C)	[227]
2523.....	Electro Iron.....	.....	.....	.....	{ 64 (0°-100°C) 85 (100°-200°C) 111 (200°-400°C) 163 (500°-600°C) 226 (700°-800°C) 90 (800°-900°C) 33 (900°-1,000°C)	.....	[229]
2524.....	...do....	.....	.....	.....	.....	{ .87 (100°C) .77 (200°C) .66 (300°C) .56 (400°C) .50 (500°C)	[392]
2525.....	...do....	.....	{ 2,960 (-271.2°C) 247 (-195.0°C)	0.058 (-271.2°C) .699 (-195.0°C)	.....	.....	[229]
2526.....	Armco: C 0.023, Mn 0.025, S 0.020, P 0.007, SI 0.007.	Rod, 3 in. diam.....	{ 18.0 (0°C) 7.6 (200°C) 4.0 (400°C) 2.5 (600°C) 1.6 (800°C)	{ 9.6 (0°C) 22.6 (200°C) 43.1 (400°C) 69.8 (600°C) 105.5 (800°C)	.....	{ .74 (0°C) .62 (200°C) .49 (400°C) .39 (600°C) .30 (800°C)	[393]
2527.....	C 0.02, P 0.042, Mn 0.03, S 0.005.....	Bar, 1 in., hot-rolled.....	.....	.....	.....	{ .67 (100°C) .61 (200°C) .55 (300°C) .49 (400°C) .44 (500°C)	[394]
2528.....	Ingot Iron.....	.....	.....	.....	{ 56 (0°-100°C) 79 (100°-200°C) 92 (200°-300°C) 122 (300°-400°C) 127 (400°-500°C) 179 (600°-700°C) 193 (700°-800°C)	.....	[229]
2529.....	Armco: C 0.01, Cu 0.05, S 0.040, Mn 0.02, P 0.011.	.....	.....	.....	.....	{ .72 (30°C) .67 (100°C) .63 (150°C) .60 (200°C)	[395]
2530.....	Fe 99.5.....	.....	17	10	.....	.....	[396]

Specimen	Chemical Composition	Condition	Temperature	Yield Point (lb./sq. in.)	Tensile Strength (lb./sq. in.)	Elongation (%)	Reduction of Area (%)	Impact (ft.-lb.)
2531.....	C 0.04, Si 0.255, P 0.136, Mn 0.045, S 0.025.....	Bar, 1 in. diam., hot-rolled.....	.....	.....	.....	.....	.....	.....
2532.....	C 0.08, Mn 0.31, Si 0.08, Ni 0.07, S 0.050, Cr 0.045, As 0.072, P 0.029, Mn 0.020, Al 0.002.....	Rod, 1 in. diam., annealed at 930°C.....	.....	.....	.....	.....	.....	.....
2533.....	C 0.135, Mn 0.60, Si 0.20, Cu 0.06, Ni 0.01, S 0.038, P 0.037, Cr 0.01, As 0.024, Mn 0.01, Al 0.005.....	Bar, 1 in. diam., annealed at 960°C.....	.....	.....	.....	.....	.....	.....
2534.....	C 0.80, Mn 0.32, Si 0.13, Ni 0.13, Cr 0.41, Cu 0.070, As 0.021, Mn 0.01, S 0.009, P 0.008, Al 0.004.....	Bar, 1 in. diam., annealed at 900°C.....	.....	.....	.....	.....	.....	.....
2535.....	C 0.89, Mn 0.27, Si 0.18, P 0.017, S 0.015.....	Bar, 1 in. diam., hot-rolled; 2 hr. at 800°C, f-c.....	.....	.....	.....	.....	.....	.....
2536.....	C 1.10, Mn 0.55.....	.....	.....	.....	.....	.....	.....	.....
2537.....	C 1.22, Mn 0.35, Si 0.1, N 0.11, Cr 0.11, Cu 0.077, As 0.025, P 0.01, Mn 0.009, Al 0.005.....	Bar, 1 in. diam., annealed at 900°C.....	.....	.....	.....	.....	.....	.....
2538.....	C 1.40, Mn 0.53.....	.....	.....	.....	.....	.....	.....	.....
2539.....	C 0.35, Cr 0.88, Mn 0.59, Si 0.26, Ni 0.21, Mn 0.20, Cu 0.12, As 0.039, S 0.031, P 0.028, Al 0.004.....	Bar, 1 in. diam., annealed at 860°C, tempered at 640°C, f-c.....	.....	.....	.....	.....	.....	.....
2540.....	C 0.315, Cr 1.09, Mn 0.69, Si 0.20, Ni 0.073, Cu 0.095, P 0.039, S 0.036, As 0.028, Mn 0.012, Al 0.005.....	Bar, 1 in. diam., annealed at 860°C.....	.....	.....	.....	.....	.....	.....
2541.....	C 0.01, Cr 1.98, Mn 0.04, Si 0.02.....	Forged.....	.....	.....	.....	.....	.....	.....
2542.....	C 0.10, Cr 5.15, Mn 0.15, Si 0.18, S 0.017, P 0.017.....	Bar, 1 1/2 in. diam., hot-rolled; annealed.....	.....	.....	.....	.....	.....	.....

TABLE 25.—Iron and steel, electrical and thermal properties—Continued

Serial number	Composition	Condition	Electrical properties			Thermal conductivity	Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity		
CHROMIUM STEELS—Continued							
2543.....	<i>Percent</i> C 0.42, Cr 7.47, Si 3.5, Mn 0.50, Ni 0.19.....	Oil-quenched from 950°C, tempered at 650°C....	<i>Percent IACS</i> 2.0-2.3 (15°C)	<i>Microhm cm</i> 75-85 (15°C)	<i>per °C × 10⁻⁴</i>	<i>Watts cm⁻¹ °C⁻¹</i> { 0.13 (15°C) .31 (300°C)	{ [383]
2544.....	C 0.44, Cr 8.82, Si 3.36, Mn 0.85, V 0.27.....	Forged.....	.....	.....	.....	{ .22 (30°C) .23 (200°C) .31 (800°C) .31 (1,000°C)	{ [395]
2545.....	C 0.07, Cr 12.00, Ni 0.23, Mn 0.09, Si 0.09, P 0.015, S 0.010.	Bar, 1 in. diam, rolled; ann at 845°C.....	.....	.....	.....	{ .25 (100°C) .28 (400°C)	{ [394]
2546.....	C 0.48, Cr 12.85, Ni 12.23, W 2.88, Mn 1.44, Si 1.22.	Bar, 15/16 in., rolled.....	.....	.....	.....	{ .20 (30°C) .20 (200°C) .27 (800°C) .36 (1,200°C)	{ [395]
2547.....	C 0.13, Cr 12.35, Mn 0.25, Si 0.17, Ni 0.14, Cu 0.050, Al 0.034, S 0.024, P 0.018, As 0.015, V 0.012.	Bar, 1 in. diam, normalized at 950°C, tempered 2 hr at 750°C.	{ 3.4 (0°C) 2.9 (100°C) 2.5 (200°C) 77.1 (300°C) 2.2 (300°C) 2.1 (350°C)	50.0 (0°C) 58.9 (100°C) 68.2 (200°C) 77.1 (300°C) 81.3 (350°C)	.....	{ .27 (0°C) .28 (100°C) .28 (200°C) .28 (300°C) .28 (350°C)	{ [397]
2548.....	C 0.07, Cr 13.08, Mn 0.04, Si 0.02.....	Bar, 15/16 in., rolled.....	.....	.....	.....	{ .26 (30°C) .26 (500°C) .26 (1,100°C)	{ [395]
2549.....	C 1.52, Cr 13.10, Mn 0.38, Si 0.38.....	...do.....	.....	.....	.....	{ .28 (30°C) .28 (200°C) .32 (800°C) .32 (1,100°C)	{ [395]
2550.....	C 0.16, Cr 13.30, Ni 0.50, Mn 0.46, Si 0.26.....	Bar, 15/16 in., rolled; h-t.....	.....	.....	.....	{ .22 (30°C) .23 (200°C) .24 (500°C) .33 (1,100°C)	{ [395]
2551.....	C 0.53, Cr 13.31, Ni 11.90, W 9.92, Mn 1.17, Si 1.07.	Bar, 15/16 in., rolled.....	.....	.....	.....	{ .18 (30°C) .20 (200°C) .19 (1,100°C)	{ [395]
2552.....	C 1.26, Cr 13.35, Co 1.89, Mo 1.13, Mn 0.47, Si 0.46.	...do.....	.....	.....	.....	{ .25 (30°C) .26 (200°C) .27 (800°C) .27 (1,100°C)	{ [395]
2553.....	C 0.40, Cr 13.65, Ni 10.31, W 3.53, Si 0.97, Mn 0.41.	Normalized at 950°C.....	{ 2.2 (15°C) 1.6 (1,000°C)	78 (15°C) 109 (1,000°C)	.....	{ .14 (15°C) .31 (1,000°C)	{ [398]
2554.....	C 0.27, Cr 13.69, Mn 0.28, W 0.25, Ni 0.20, Si 0.18, Cu 0.074, Al 0.031, P 0.022, S 0.022, V 0.022, Mo 0.01, As 0.003.	Bar, 1 in. diam, normalized at 950°C, tempered 2 hr at 750°C.	{ 3.4 (0°C) 3.1 (500°C) 2.9 (100°C) 2.5 (200°C) 2.2 (300°C)	50.4 (0°C) 55.0 (500°C) 59.5 (100°C) 68.8 (200°C) 78.0 (300°C)	.....	{ .25 (0°C) .26 (500°C) .26 (100°C) .27 (200°C) .28 (300°C)	{ [397]
2555.....	C 0.14, Cr 14.60, Ni 0.70, Mn 0.19, Si 0.12, P 0.020, S 0.015.	Bar, 1 in. diam, rolled; ann at 845°C.....	.....	.....	.....	{ .24 (100°C) .25 (300°C) .26 (500°C)	{ [394]
2556.....	Cr 15, Al 5.....	.....	1.4	125	0.9 (20°-100°C)	.....	{ [398]

TABLE 25.—Iron and steel, electrical and thermal properties—Continued

Serial number	Composition	Condition	Electrical properties			Thermal conductivity	reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity		
CHROMIUM STEELS—Continued							
2573.....	Percent C 0.19, Cr 24.50, Ni 1.22, Mn 0.51, Si 0.50.....	Bar, 15/16 in., rolled; h-t.....	Percent IACS.....	Microhm cm.....	per °C × 10 ⁻⁴	Kilts cm ⁻¹ °C ⁻¹ {.21 (30°C) .23 (200°C) .31 (800°C) .43 (1,200°C)}	{ [395] }
2574.....	Cr 25, Ni 12.....	Annealed.....	{ 2.2 (21°C) 1.5 (650°C)	{ 78 (21°C) 115 (650°C)	.....	.13-17 (100°C)	[266]
2575.....	Cr 25, Ni 20.....	.....	{ 2.2 (21°C) 1.5 (650°C)	{ 80 (21°C) 117 (650°C)	.....	.16 (100°C)	[266]
2576.....	C 0.10, Cr 26.00, Si 0.47, Mn 0.40, Ni 0.14, P 0.013, S 0.008.....	Bar, 1 1/2 in. diam. rolled; ann.....	.....	.....	.....	.21 (100°C) .24 (400°C) .24 (500°C)	{ [394] }
2577.....	Cr 27, Al 5.....	.....	1.2	141	0.4 (20°-100°C)	.....	[398]
2578.....	C 0.15, Cr 27.93, Ni 1.73, Si 0.84, Mn 0.80.....	Bar, 15/16 in., rolled; h-t.....	.....	.....	.....	.21 (30°C) .22 (200°C) .33 (800°C) .41 (1,100°C)	{ [385] }
2579.....	C 0.22, Cr 30.4, Si 0.69, Mn 0.56, Ni 0.26.....	Oil-quenched from 1,050°C, tempered at 700°C..	2.2 (15°C)	80 (15°C)	.....	.13 (15°C)	[381]
2580.....	Cr 37.5, Al 7.5.....	.....	1.0	166	2.2 (20°-100°C)	.....	[398]
COBALT STEEL							
2581.....	C 0.07, Co 26.00, Cr 20.47, Si 0.51, Mn 0.42.....	Bar, 15/16 in., rolled.....	.....	.....	.....	{.20 (30°C) .24 (200°C) .33 (800°C)}	{ [385] }
MANGANESE STEELS							
2582.....	C 0.23, Mn 1.51, Si 0.12, Cu 0.105, Cr 0.06, Ni 0.04, S 0.038, P 0.037, As 0.033, W 0.025, Al 0.015.....	Bar, 1 in. diam, ann at 850°C.....	{ 8.8 (0°C) 5.9 (150°C)	{ 13.6 (0°C) 29.2 (150°C)	.....	{.46 (0°C) .46 (150°C)}	{ [397] }
2583.....	C 0.51, Mn 1.65, Si 0.24, Ni 0.10, S 0.023, P 0.016.....	Bar, 1 in. diam, rolled; normalized at 900°C.....	.....	.....	.....	{.40 (100°C) .38 (200°C) .35 (500°C)}	{ [394] }
2584.....	C 1.22, Mn 13.00, Si 0.22, Cu 0.070, Ni 0.07, As 0.038, P 0.038, Cr 0.03, S 0.010, Al 0.004..	Bar, 1 in. diam, a-c from 1,050°C.....	{ 2.6 (0°C) 2.3 (100°C) 2.0 (200°C) 1.9 (300°C) 1.8 (350°C)	{ 67.0 (0°C) 75.8 (100°C) 84.4 (200°C) 92.4 (300°C) 96.0 (350°C)	.....	{.13 (0°C) .15 (100°C) .17 (200°C) .18 (300°C) .19 (350°C)}	{ [397] }
MOLYBDENUM STEEL							
2585.....	C 0.83, Mo 7.5-8.5, Cr 4.0, V 2.0.....	.....	.....	.....	.....	{.20 (150°C) .21 (200°C) .22 (300°C) .24 (400°C) .25 (500°C) .26 (550°C)}	{ [400] }

NICKEL STEELS

2586.....	C 0.06, Ni 0.55, Mn 0.38, Cu 0.08, As 0.039, S 0.035, Mo 0.030, Cr 0.022, P 0.017, Si 0.01, Al 0.001.	Bar, 1 in. diam, ann at 830°C.....	{ 14.5 (0°C) 9.7 (100°C) 5.9 (200°C) }	{ 11.9 (0°C) 17.8 (100°C) 21.9 (200°C) }	.....	{ 0.65 (0°C) .58 (150°C) }	[397]
2587.....	C 0.35, Ni 1.37, Mn 0.56, Cr 0.46, Si 0.02, S 0.020, P 0.015.	Bar, 1 in. diam, rolled; normalized at 900°C.....	.....	.....	.....	{ .41 (100°C) .43 (200°C) .41 (300°C) .37 (500°C) }	[394]
2588.....	C 0.30, Ni 1.5, Mn 0.6, Cr 0.5.....	.....	.....	.....	.....	{ .31 (200°C) .26 (300°C) .24 (500°C) }	[392]
2589.....	C 0.325, Ni 3.41, Cr 0.71, Mn 0.55, Si 0.25, Cu 0.12, Mo 0.08, S 0.025, P 0.018, V 0.01, Al 0.008.	Bar, 1 in. diam, ann at 860°C, tempered at 640°C, f-c.	{ 6.0 (0°C) 5.0 (100°C) 4.2 (200°C) 3.5 (300°C) }	{ 28.5 (0°C) 34.5 (100°C) 41.5 (200°C) 19.9 (300°C) }	.....	{ .33 (0°C) .36 (100°C) .36 (200°C) .36 (300°C) }	[397]
2590.....	C 0.325, Ni 3.47, Mn 0.55, Si 0.18, Cr 0.17, Cu 0.086, Mo 0.04, S 0.034, P 0.032, As 0.023, V 0.01, Al 0.006.	Bar, 1 in. diam, ann at 860°C.....	{ 6.8 (0°C) 5.5 (100°C) 4.5 (200°C) 3.7 (300°C) }	{ 25.5 (0°C) 31.5 (100°C) 38.5 (200°C) 45.8 (300°C) }	.....	{ .36 (0°C) .38 (100°C) .39 (200°C) .39 (300°C) }	[397]
2591.....	C 0.13, Ni 4.5, Cr 1.1, Mn 0.4.....	.....	.....	.....	.....	{ .57 (100°C) .54 (300°C) .52 (500°C) }	[392]
2592.....	C 0.35, Ni 4.5, Cr 1.3, Mn 0.6.....	.....	.....	.....	.....	{ .46 (100°C) .38 (300°C) .30 (500°C) }	[392]
2593.....	Ni 22.1.....	.....	.....	.....	18 (0°-100°C)	.21 (20°-100°C)	[397]
2594.....	C 0.28, Ni 28.37, Mn 0.89, Si 0.15, Cu 0.030, As 0.027, Al 0.012, P 0.009, S 0.009.	Bar, 1 in. diam, w-t from 350°C.....	{ 2.0 (0°C) 1.9 (100°C) 1.8 (200°C) 1.6 (350°C) }	{ 84.0 (0°C) 89.9 (100°C) 95.9 (200°C) 104.8 (350°C) }	.....	{ .13 (0°C) .15 (100°C) .16 (200°C) .18 (350°C) }	[397]
2595.....	Ni 34, Cr 4.....	Cast.....	1.9	91.6	4.06 (20°-500°C)	.....	[401]
2596.....	do.....	Cast; ann 7 hr at 900°C, slowly cooled.....	1.8	93.0	4.92 (20°-500°C)	.....	[401]
2597.....	Ni 34, Cr 10.....	Bar, 3.4 in., hot-rolled.....	.....	.....	.....	{ .13 (100°C) .16 (300°C) .19 (500°C) }	[402]
2598.....	Ni 35.1.....	.....	.....	.....	11 (0°-100°C)	.11 (20°-100°C)	[397]
2599.....	Ni 45.....	.....	3.8	45	.....	.....	[396]
2600.....	Ni 47.1.....	.....	.....	.....	35 (0°-100°C)	.15 (20°-100°C)	[397]

SILICON STEELS

2601.....	C 0.185, Si 1.98, Mn 0.90, Cu 0.637, Ni 0.16, S 0.047, P 0.044, Cr 0.04, As 0.029, Al 0.007..	Bar, 1 in. diam, ann at 930°C.....	{ 4.1 (0°C) 3.9 (50°C) 3.5 (150°C) 3.3 (200°C) 2.9 (300°C) 2.7 (350°C) }	{ 41.9 (0°C) 44.2 (50°C) 49.6 (150°C) 52.7 (200°C) 60.1 (300°C) 64.1 (350°C) }	.....	{ 0.25 (0°C) .28 (100°C) .29 (150°C) .31 (250°C) .31 (350°C) }	[397]
2602.....	C 0.39, Si 3.36, Cr 2.05, Mn 0.48.....	Forged.....	.....	.....	.....	{ .24 (300°C) .27 (500°C) .33 (500°C) .31 (800°C) .31 (1,200°C) }	[395]

TABLE 25.—Iron and steel, electrical and thermal properties—Continued

Serial number	Composition	Condition	Electrical properties				Thermal conductivity	Reference	
			Volume conductivity	Resistivity	Temperature coefficient of resistivity				
SILICON STEELS—Continued									
2603.....	<i>Percent</i> C 0.41, Si 4.33, Cr 2.04, Mn 0.33.....	Forged.....	.....	.....	.....	\text{microhm cm	$\text{per } ^\circ\text{C} \times 10^{-4}$	$\text{Watt cm}^{-1} ^\circ\text{C}^{-1}$ { 0.20 (30°C) .23 (200°C) .28 (500°C) .30 (800°C) .30 (1,000°C) }	{ [395] }
2604.....	Si 9.6, Al 5.1.....	.....	2.1	81.2	.....	.....	.....	.....	[287]
TUNGSTEN STEELS									
2605.....	C 0.35, W 1.04, Mn 0.75, Cr 0.61, P 0.35, Si 0.22, Ni 0.17, S 0.028.	Bar, 1 in. diam, rolled; normalized at 900°C.	.....	.....	.....	.....	.....	{ 0.38 (100°C) .37 (200°C) .36 (300°C) .31 (500°C) }	{ 394 }
2606.....	C 0.715, W 18.45, Cr 4.26, V 1.075, Si 0.30, Mn 0.25, Ni 0.067, Cu 0.064, As 0.035, S 0.028, P 0.018, Al 0.004.	Bar, 1 in. diam, annealed at 800°C.	{ 4.1 (0°C) 3.5 (100°C) 3.1 (200°C) 2.7 (300°C) }	{ 42.2 (0°C) 49.1 (100°C) 56.3 (200°C) 64.1 (300°C) }	.....	.....	.....	{ .24 (0°C) .26 (100°C) .27 (200°C) .28 (300°C) }	{ [397] }
PLAIN CAST IRONS									
2607.....	TC 3.16, Si 1.54, Mn 0.57, P 0.22, S 0.11.....	Bar, 1 3/16 in. diam, cast.....	3.0 (23.5°C)	58.4 (23.5°C)	.....	.....	.....	{ 0.47 (23°C) .45 (100°C) .41 (400°C) }	{ [403] }
2608.....	TC 3.43, C 3.34, CC 0.59, Si 1.40, Mn 0.63, P 0.134, S 0.077.	Bar, 1 1/8 in. diam, sand-cast.....	.....	.....	.....	.....	.....	{ .55 (100°C) .49 (300°C) .43 (500°C) }	{ [394] }
ALLOY CAST IRONS									
2609.....	C 2.70, Al 7.00, Si 0.96, Cr 0.95, Mn 0.58.....	.....	.....	.....	.....	.....	.....	{ 0.33 (100°C) .30 (400°C) }	{ [404] }
2610.....	C 3.15, Si 1.58, Cu 1.45, Mn 0.58, P 0.23, S 0.11.	Bar, 1 3/16 in. diam, cast.....	2.8 (23.5°C)	61.0 (23.5°C)	.....	.....	.....	{ .45 (23°C) .44 (100°C) .40 (400°C) }	{ [403] }
2611.....	C 3.10, Mn 3.11, Si 2.51, Ni 1.00.....	.....	.....	.....	.....	.....	.....	{ .44 (100°C) .41 (400°C) }	{ [404] }
2612.....	C 3.12, Si 2.31, Mo 0.77, Cr 0.54, Mn 0.39.....	.....	.....	.....	.....	.....	.....	{ .50 (100°C) .46 (400°C) }	{ [404] }
2613.....	C 3.41, Ni 1.49, Si 1.03, Mn 0.65, Cr 0.54.....	.....	.....	.....	.....	.....	.....	{ .49 (100°C) .41 (400°C) }	{ [404] }
2614.....	C 2.80, Si 2.51, Ni 1.71, Mn 0.68, Cr 0.54.....	.....	.....	.....	.....	.....	.....	{ .42 (100°C) .39 (400°C) }	{ [404] }
2615.....	C 2.41, Ni 13.70, Cu 6.41, Cr 3.37, Si 1.80, Mn 0.62.	.....	.....	.....	.....	.....	.....	{ .34 (100°C) }	{ [404] }
2616.....	C 1.81, Ni 18.65, Si 5.42, Cr 2.02.....	.....	.....	.....	.....	.....	.....	{ .29 (100°C) .26 (400°C) }	{ [404] }

MAITHEABLE CAST IRONS						
2617.....	C 1.75-2.30, Si 0.85-1.20, Mn <0.40, P <0.20, S <0.12.	.....	5.7	30	.....	[177]
2618.....	C 2.25-2.70, Si 0.80-1.10, Mn <0.40, P <0.20, S 0.07-0.15.	.....	5.4	32	.....	[177]

TABLE 25.—Magnetic properties of commercial permanent magnet alloys (30°)

Serial number	Alloy	Composition	Coercive force (H_c)	Residual induction (B_r)	$B \times H$ maximum
2619.....	Chromium magnet steel.....	C 1, Cr 3.5.....	63	9,000	295,000
2620.....	Tungsten magnet steel.....	C 1, W 5.....	70	10,300	320,000
2621.....	Cobalt magnet steel.....	C 1, Co 36, Cr 3.5.....	210	9,000	330,000
2622.....	Cobalt-nickel-copper alloy.....	Co 41, Cu 35, Ni 24.....	440	5,300	933,000
2623.....	Iron-nickel copper alloy.....	Cu 60, Fe 20, Ni 20.....	150	5,300	1,070,000
2624.....	Comol magnet alloy.....	Mo 17, Co 12, Fe rem.....	245	10,300	1,100,000
2625.....	Alnico IV.....	Ni 24, Al 12, Co 5, Fe rem.....	760	5,200	1,250,000
2626.....	Alnico III.....	Ni 25, Al 12, Fe rem.....	400	7,100	1,330,000
2627.....	Alnico I.....	Ni 20, Al 12, Co 5, Fe rem.....	400	7,100	1,330,000
2628.....	Alnico II.....	Ni 17, Co 12.5, Al 10, Cu 5, Fe rem.....	510	7,200	1,650,000
2629.....	Alnico V.....	Co 24, Ni 14, Al 8, Cu 3, Fe rem.....	525	12,000	4,000,000

VIII. LEAD AND LEAD ALLOYS

(295)

TABLE 27.—Classification of some lead alloys (1942)

[Specifications are changing frequently; the sponsoring organization should be consulted for the latest revision]

Designation		Nominal composition, percent							Serial numbers of corresponding alloys in the tables
Federal	Spec.	Alloy	ASTM	SAE No.	Pb	Sn	Sb	Cu	Ag
			Spec.	Alloy					
LEAD									
BEARING ALLOYS (BABBITTS)									
.....			^a B 29-40T	.....	99.94	.....	.....	.....	2849, 2866.
QQ-1-201, amendment I.....			^b B 29-40T	.....	99.90	.....	.....	.....	2632, 2633, 2850.
.....			^c B 29-40T	.....	99.85	.....	.....	.....	2635, 2637, 2638, 2851, 2867, 2870.
BEARING ALLOYS (BABBITTS)									
.....			B 23-26	12	90	.....	10	^d 0.50	2658, 2674, 2692, 2839.
.....			B 23-26	9	85	5	10	^d 0.50	2659, 2665, 2760.
.....			B 23-26	11	85	.....	15	^d 0.50	2671, 2674, 2895.
.....			B 23-26	10	83	2	15	^d 0.50	2678, 2761, 2762.
QQ-M-161.....			B 23-26	8	80	5	15	^d 0.50	2673, 2675, 2679, 2763, figure 135.
.....			B 23-26	7	75	10	15	^d 0.50	2669, 2764.
QQ-M-161.....			B 23-26	6	63.5	20	15	1.5	2741.
DIE-CASTING ALLOYS									
.....			B 102-39T	5	90	.....	10	^d 0.50	2660.
.....			B 102-39T	4	80	5	15	^d 0.50	2670.
SOFT SOLDER									
QQ-S-571.....			B 32-40T	.....	80	20	.....	.....	2742, 2918.
.....			B 32-40T	4A	75	25	^d 0.12	.....	2745, 2912.
.....			B 32-40T	4B	75	23	^d 2.00	.....	.....
QQ-S-571.....			B 32-40T	.....	70	30	.....	.....	.....
.....			B 32-40T	.....	65	35	.....	.....	.....
.....			B 32-40T	3A	60	40	^d 0.12	.....	2746, 2747, 2748, 2861, 2862, 2920, 2921.
QQ-S-571.....			B 32-40T	3B	60	38	^d 2.00	.....	2750, 2815, 2863, 2884.
.....			B 32-40T	2A	55	45	^d 0.12	.....	2754, 2755, 2821, 2885, 2923.
.....			B 32-40T	2B	55	43.5	^d 1.50	.....	2822, 2823.
.....			B 32-40T	1A	50	50	^d 0.12	.....	2825, 2924.
QQ-S-571a.....			B 32-40T	1B	50	49.25	^d 1.75	.....	2757, 2758, 2759, 2828, 2865, 2869, 2886.
.....					rem	.....	.....	^d 0.08	2829.
AXS-806, rev. 1 ^e									2712.

^aCorroding lead, formerly grade I.^bChemical lead, formerly grade II.^cCommon lead, formerly grade III.^dMaximum.^eOrdnance Department, U. S. Army.

TABLE 28.—Lead and lead alloys, normal-temperature properties

[For a discussion of the indefiniteness of values reported for yield strength and particularly for "proportional limit" see pages 5 and 6. Hardness numbers are Brinell numbers unless prefixed H_B , H_C , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed Iz (Izod method).]

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
PURE AND COMMERCIAL LEAD												
2630..	Percent Sb 0.00024, Fe 0.000193, Zn 0.00008, Cu 0.000057.	Die-cast.....	$k\text{tols/in.}^2$	$k\text{tols/in.}^2$	$k\text{ips/in.}^2$ ^a 0.71 (0.5% extn)	$k\text{tols/in.}^2$ ^a 1.61 (0.5% extn)	Percent 69	Percent 100	$k\text{tols/in.}^2$	ft-lb} .....	.....	[413]
2631..	Sb 0.0030, Bi 0.0030, Fe 0.0006, Zn 0.0007, Ag 0.0004, Cu 0.0003.	do.....	.....	.....	^a 0.86 (0.5% extn)	^a 1.97	64	92	.....	.....	.....	[413]
2632..	Chemical lead.....	do.....	.....	.....	^a 1.64 (0.5% extn)	^a 2.76	50	88	.....	.....	.....	[413]
2633..	do.....	Rod, extruded.....	.....	.....	.....	^b 1.8	40 (8 in.)	.....	.....	.....	.....	[414]
2634..	"Pure" lead.....	do.....	.....	.....	.....	2.1	92 (2 in.)	.....	0.22 (5 x 10 ⁷)	.....	.....	[415]
2635..	Refined lead.....	Cable sheath, 1 in. o-d x 1/8 in. wall, extruded.	.....	.....	.....	^c 2.1	119 (2.5 in.)	.....	0.38 (10 ⁷)	V 4.5	.....	[416]
2636..	Lead.....	do.....	2,500	.....	.....	1.9	31	100	.....	.....	Compressive str.....7.1 kips/in. ² , Mod-el (shear).....1,110 kips/in. ² , Poisson's ratio.....0.45.	[417]
2637..	Commercial lead.....	do.....	.....	.....	.....	3.0	33	.....	.....	4.3	.....	[25]
2638..	do.....	do.....	2,630	.....	.....	.....	.....	.....	.....	.....	.....	[418]
LEAD-ANTIMONY ALLOYS (SEE ALSO FIG. 130)												
2639..	Sb 0.25.....	Extruded.....	.....	.....	.....	.....	.....	.....	^e 0.84 (10 ⁷)	.....	.....	[419]
2640..	Sb 0.48, Cd 0.24.....	Cable sheath, 1 in. o-d x 1/8 in. wall, extruded; aged 122 days at r-t.	.....	.....	.....	^c 3.9	46 (2.5 in.)	.....	1.07 (10 ⁷)	V 9.5	.....	[416]
2641..	Sb 0.5.....	Extruded.....	.....	.....	.....	.....	.....	.....	^e 1.10 (10 ⁷)	.....	.....	[419]
2642..	Sb 0.75.....	do.....	.....	.....	.....	.....	.....	.....	^e 1.32 (10 ⁷)	.....	.....	[419]
2643..	Sb 0.80.....	Cable sheath, 1 in. o-d x 1/8 in. wall, extruded; aged 131 days at r-t.	.....	.....	.....	^c 4.4	32 (2.5 in.)	.....	1.03 (10 ⁷)	V 10	.....	[416]
2644..	Sb 0.98, Cu 0.06.....	Cable sheath, 1 in. o-d x 1/8 in. wall, extruded; aged 111 days at r-t.	.....	.....	.....	^c 5.0	35 (2.5 in.)	.....	1.16 (10 ⁷)	V 13	.....	[416]
2645..	Sb 1.0.....	Extruded; aged 6 months at r-t.	.....	.....	.....	3.0	37 (2 in.)	.....	0.47 (3 x 10 ⁷)	.....	.....	[420]
2646..	do.....	Quenched from 480°F.....	.....	.....	.....	^f 2.8	.....	.....	.....	.....	.....	[421]
2647..	do.....	Quenched from 480°F, aged at r-t.	.....	.....	.....	^f 6.0	.....	.....	.....	.....	.....	[421]

TABLE 28.—Lead and lead alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
LEAD-ANTIMONY ALLOYS—Continued												
2667..	Percent Sb 12.65, As 2.97, Sn 0.65.	Chill-cast.....	kips/in. ²	kips/in. ²	kips/in. ²	kips/in. ²	Percent 1.5 (2 in.)	Percent	22	ft.-lb. .....	.....	[429]
2668..	Stereotype: Sb 13.0, Sn 6.5, Cu 0.18.	Cast.....	.....	.....	.....	.....	4.0 (2 in.)	.....	22	.....	Comp yld str (0.3%)..8.0 kips/in. ² ...	[427]
2669..	Sb 14.5, Sn 10.0, Cu 0.11.	Cast.....	.....	.....	.....	.....	.....	.....	22	.....	Comp yld str (0.125%)..3.6 kips/in. ² ... Comp str (25%).....15.6 kips/in. ² ... Specific gravity.....9.73. Melting range.....464°-514°F.	[425]
2670..	Sb 14.6, Sn 5.40, Cu 0.04, As 0.06.	Die-cast from 750°F into mold at 65°F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	[430]
2671..	Sb 14.8, Cu 0.19, Sn 0.09.	Cast.....	.....	.....	.....	.....	.....	.....	15	.....	Comp yld str (0.125%)..3.0 kips/in. ² ... Comp str (25%).....12.8 kips/in. ² ... Specific gravity.....10.28. Melting range.....471°-504°F.	[425]
2672..	Sb 14.9, Sn 5.05, Cu 0.09, As 0.06.	Cold-rolled; ann.....	4,400	1.1	.....	.....	.....	.....	24	.....	.....	[431]
2673..	Sb 14.9, Sn 5.2, Cu 0.14.	Cast.....	.....	.....	.....	.....	.....	.....	20	.....	Comp yld str (0.125%)..3.4 kips/in. ² ... Comp str (25%).....15.6 kips/in. ² ... Specific gravity.....10.04. Melting range.....459°-522°F.	[425]
2674..	Sb 15.....	do.....	.....	.....	.....	.....	8 (2 in.)	.....	15	.....	Melting range.....476°-504°F.	[177]
2675..	Sb 15, Sn 5, Cu 0.5, As 0.2.	Chill-cast.....	.....	.....	.....	.....	5 (2 in.)	.....	20	.....	.....	[429]
2676..	Sb 15.26, Sn 10.67, Cd 1.83, Cu 1.68, As 0.15, Fe 0.06, Ni 0.01.	Cast.....	4,400	.....	7.5 (0.2%)	10.0 (10 diam)	0.4 (10 diam)	1.0	23	.....	Comp yld str (0.2%)..6.0 kips/in. ² ... Comp str.....18.1 kips/in. ² ...	[432]
2677..	Monotype: Sb 15.3, Sn 8.3.	do.....	.....	.....	.....	.....	4.0 (2 in.)	.....	22	.....	Comp yld str (0.3%)..7.0 kips/in. ² ...	[427]
2678..	Sb 15.7, Sn 2.05, Cu 0.12.	do.....	.....	.....	.....	.....	.....	.....	18	.....	Comp yld str (0.125%)..3.4 kips/in. ² ... Comp str (25%).....15.4 kips/in. ² ... Specific gravity.....10.07. Melting range.....468°-507°F.	[425]
2679..	Sb 16, Sn 5.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Melting range.....471°-513°F. Shrinkage (volume)...2.54%.	[428]
2680..	Monotype: Sb 19.4, Sn 10.3.	Cast.....	.....	.....	.....	.....	2.0 (2 in.)	.....	26	.....	Comp yld str (0.3%)..7.0 kips/in. ² ... Comp str (18.5%).....19.2 kips/in. ² ...	[427]
2681..	Foundry type: Sb 25.0, Sn 12.0, Cu 2.0.	do.....	.....	.....	.....	.....	2.5 (2 in.)	.....	35	.....	Comp yld str (0.1%)..10.0 kips/in. ² ... Comp str (16.1%).....20.6 kips/in. ² ...	[427]
LEAD-BARIUM ALLOYS												
2682..	Ba 0.02.....	Extruded.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[419]

TABLE 3c.—Lead and lead alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
LEAD-CALCIUM ALLOYS—Continued												
2704..	Pb 97.5, (hardeners including Ca and Sn) 2.5.	Cast.....	$k\text{tpsi/in.}^2$	$k\text{tpsi/in.}^2$	$k\text{tpsi/in.}^2$	11.1	5.8	Percent.....	22	$ft\text{-lb}$	Comp yld str (1.0%)...10.8 kips/in. ² Comp str (10%).....14.6 kips/in. ²	[437]
LEAD-COPPER ALLOYS												
2705..	Cu 0.053, Ca 0.031, Ag 0.0062, Ni 0.0044, Sb 0.0007.	Cable sheath, 2.35 in. o-d, 0.117 in. wall (ring specimen).	.....	.....	.....	4.4	19	.....	10	.....	.....	[434]
2706..	Cu 0.06.....	.....	.....	.....	.....	2.2-2.8	50-56	.....	4.5	.....	.....	[438]
2707..	...do.....	Cold-rolled.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[419]
2708..	...do.....	Cold-rolled; 1 hr at 480°F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	[419]
2709..	Cu 0.06, Bi 0.02.....	Cold-rolled.....	2,000	.....	.....	2.3	40 (2 in.)	100	4.5	.....	Specific gravity.....11.33 Melting point.....621°F.	[424]
2710..	Cu 0.06, Te 0.045.....	Rollcd.....	1,500	.....	1.6 (yld pnt)	3.2	40 (2 in.)	.....	6.0	.....	Specific gravity.....11.36 Melting point.....619°F.	[424]
2711..	Cu 0.065, Ag 0.005, Ni 0.0044, Sb 0.0003.	Cable sheath, 2.75 in. o-d x 0.139 in. wall (ring specimen).	.....	.....	.....	2.2	42	.....	4.5	.....	.....	[434]
LEAD-SILVER ALLOYS												
2712..	Ag 2.5.....	Strip, chill-cast.....	.....	.....	.....	5.0	.....	.....	.....	.....	Melting point.....579°F.	[439]
2713..	Ag 2.5, Cu 0.25.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Melting range.....568°-668°F.	[440]
2714..	Ag 2.82.....	Sheet, 0.057 in., ann 1 hr at 480°F.	.....	.....	.....	3.8	24 (2 in.)	.....	V 6.5	.....	.....	[129]
2715..	...do.....	Sheet, 0.040 in., cold-rolled (30% red.).	.....	.....	.....	3.9	25 (2 in.)	.....	V 7.9	.....	.....	[129]
2716..	Ag 4.68.....	Sheet, 0.057 in., ann 1 hr at 480°F.	.....	.....	.....	3.8	15 (2 in.)	.....	V 6.0	.....	.....	[129]
2717..	...do.....	Sheet, 0.040 in., cold-rolled (30% red.).	.....	.....	.....	4.1	26 (2 in.)	.....	V 6.8	.....	.....	[129]
2718..	Ag 5.....	Strip, chill-cast.....	.....	.....	.....	4.9	.....	.....	.....	.....	Melting range.....579°-707°F.	[439]
2719..	Ag 5.5.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Melting range.....579°-715°F.	[440]
LEAD-TELLURIUM ALLOYS												
2720..	Te 0.05.....	Extruded.....	.....	.....	.....	12.1	92 (8 in.)	.....	.....	.....	.....	[441]
2721..	Te 0.06.....	.....	.....	.....	.....	22.8-3.4	32-37	.....	5.8	.....	.....	[438]
2722..	Te 0.067.....	Extruded.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[419]

LEAD-THALLIUM ALLOYS

LEAD-TIN ALLOYS (SEE ALSO FIG. 133)											
2723..	Tl 9, Sb 5, Sn 5.....	Cast.....	.....	.....	.....	.....	.....	.....	.....	.....	Comp str (75%).....16.9 kips/in. ² .. [426]
2724..	Tl 9.5, Sb 5.0.....	...do.....	.....	.....	.....	.....	.....	.....	.....	.....	Comp str (75%).....13.5 kips/in. ² .. [426]
2725..	Sn 0.25, Bi 0.02, Ca 0.02, Mg 0.02.....	Sheet, cold-rolled.....	2,000	.....	.....	4.0	25 (2 in.)	100	.....	8.5	Specific gravity.....11.3..... [424] Melting point.....619°F.
2726..	Sn 0.26, Mg 0.031, Ca 0.025, Bi 0.019, Cu 0.005, Sb 0.002.....	Cable sheath, 2.71 in. o-d x 0.140 in. wall (ring specimen).	.....	.....	.....	5.5	8.8	.....	.....	13	 [434]
2727..	Sn 0.5.....	Cold-rolled.....	.....	.....	.....	.....	.....	.....	.....	.....	..... [419]
2728..	Sn 0.95, Cd 0.65.....	Cast from 975°F into mold at 350°F.	.....	1.3	.....	4.1	24 (5.5 in.)	.....	.....	7.6	 [435]
2729..	Sn 1.0.....	Extruded.....	.....	.....	.....	.....	.....	.....	.....	.....	..... [419]
2730..	Sn 1.2, Cd 0.2, Sb 0.1..	...do.....	.....	.....	.....	.....	.....	.....	.....	5.0	 [442]
2731..	Sn 1.5, Cd 0.25.....	.....	.....	.....	.....	13.8	62	.....	.....	5.7	 [438]
2732..	Sn 1.54.....	Cast from 975°F into mold at 350°F.	.....	0.7	.....	2.7	34 (5.5 in.)	.....	.....	5.4	 [435]
2733..	Sn 1.76, Cd 0.66.....	...do.....	.....	1.6	.....	4.3	25 (5.5 in.)	.....	.....	8.0	 [435]
2734..	Sn 2.0.....	Extruded.....	.....	.....	.....	.....	.....	.....	.....	.....	..... [419]
2735..	Sn 2.65.....	Cast from 975°F into mold at 350°F.	.....	1.0	.....	3.3	30 (5.5 in.)	.....	.....	6.6	 [435]
2736..	Sn 3.0.....	Extruded.....	.....	.....	.....	Extruded	.....	.....	.....	.....	..... [419]
2737..	Sn 10, Ag 2.25.....	Strip, chill-cast.....	5.0	.....	.....	5.0	.....	.....	.....	.....	Melting point.....554°F..... [439]
2738..	Sn 15, Sb 0.12, Bi 0.015, Cu 0.003, Ag 0.0009.....	Annealed 16 hr at 212°F..	.....	.....	.....	5.7	18 (2 in.)	.....	.....	8.7	Shear str.....4.5 kips/in. ² ... [443]
2739..	Sn 15, Bi 5, Ag 1.5.....	Strip, chill-cast.....	.....	.....	.....	5.0	.....	.....	.....	.....	Melting point.....507°F..... [439]
2740..	Sn 15, Bi 5, Ag 1.5, Sb 1.0.....	...do.....	.....	.....	.....	8.0	.....	.....	.....	.....	Melting point.....496°F..... [439]
2741..	Sn 19.8, Sb 14.6, Cu 1.5.....	Cast.....	.....	.....	.....	.....	.....	.....	.....	21	Comp yld str (0.125%)...3.8 kips/in. ² ... [425] Comp str (25%).....11.6 kips/in. ² ... Specific gravity.....9.33... Melting range.....358°-531°F.
2742..	Sn 20, Sb 0.12, Bi 0.015, Cu 0.003, Ag 0.0009.....	Annealed 16 hr at 212°F..	.....	.....	.....	5.8	16 (2 in.)	.....	.....	12	Shear str.....4.7 kips/in. ² ... [443]
2743..	Sn 20, Ag 2.....	Strip, chill-cast.....	.....	.....	.....	5.6	.....	.....	.....	.....	Melting point.....513°F..... [439]
2744..	Sn 23, Cd 9.....	Cast.....	.....	.....	.....	6.2	.....	.....	.....	.....	Melting range.....241°-455°F..... [436]

^e Hatch tension-compression.

Rate of strain 0.25 (in./in.)/minute.

¹Rate of strain 0.018 in./minute.^jRate of strain 0.60 (in./in.)/minute.

*Rate of strain 0.5 in./minute (free head speed).

TABLE 2b.—Lead and lead alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
LEAD-TIN ALLOYS—Continued													
2745..	Percent Sn 25, Sb 0.12, Bi 0.012, Cu 0.002, Ag 0.0009.	Annealed 16 hr at 212°F..	$k/in.^2$	$k/in.^2$	$k/in.^2$	$k/in.^2$ 6.0	Percent 27 (2 in.)	Percent	$k/in.^2$ .....	.....	$ft-lb$ 13	Shear str.....5.3 kips/in. ² ...	[443]
2746..	Sn 29.8, Sb 1.92.....	Cast.....	.....	.....	.....	.....	17.4 (4 in.)	.....	.....	.....	Iz 9-2	Shear str.....5.0 kips/in. ² ...	[444]
2747..	Sn 30, Sb 0.12, Bi 0.012, Cu 0.002, Ag 0.0009.	Annealed 16 hr at 212°F..	.....	.....	.....	6.0	31 (2 in.)	.....	.....	.....	18	Shear str.....5.5 kips/in. ² ...	[443]
2748..	Sn 30.....	Cast.....	.....	.....	.....	6.0	26 (4 in.)	.....	.....	8.7	Iz 12	Shear str.....4.6 kips/in. ² ... Specific gravity.....9.49. Melting range.....361°-495°F.	[445]
2749..	Sn 31.8, Sb 0.94.....	...do.....	.....	.....	.....	16.9	20 (4 in.)	.....	.....	.....	Iz 12	Shear str.....5.0 kips/in. ² ...	[444]
2750..	Sn 35, Sb 0.12, Bi 0.010, Cu 0.002, Ag 0.0009.	Annealed 16 hr at 212°F..	.....	.....	.....	6.3	26 (2 in.)	.....	.....	.....	19	Shear str.....5.6 kips/in. ² ...	[443]
2751..	Sn 39.72, Sb 2.61.....	Cast.....	.....	.....	.....	17.9	32 (4 in.)	.....	.....	.....	Iz 11	Shear str.....5.9 kips/in. ² ...	[444]
2752..	Sn 39.8, Sb 10.5, Cu 1.03, As 0.06, Fe 0.04.	Die-cast from 800°F into mold at 165°F.	.....	.....	.....	11.6	.....	.....	.....	.....	.....	.....	[430]
2753..	...do.....	Cold-rolled; ann.....	4,700	.....	.....	.....	.....	.....	.....	20	.....	.....	[431]
2754..	Sn 40, Sb 0.12, Bi 0.010, Cu 0.002, Ag 0.0009.	Annealed 16 hr at 212°F..	.....	.....	.....	6.2	49 (2 in.)	.....	.....	.....	19	Shear str.....5.7 kips/in. ² ...	[443]
2755..	Sn 40.....	Cast.....	.....	.....	.....	6.2	35 (4 in.)	.....	.....	11	Iz 14	Shear str.....5.0 kips/in. ² ... Specific gravity.....9.34. Melting range.....361°-160°F.	[445]
2756..	Sn 42.4, Sb 1.22.....	...do.....	.....	.....	.....	17.1	36 (4 in.)	.....	.....	.....	Iz 15	Shear str.....5.7 kips/in. ² ...	[444]
2757..	Sn 50, Sb 0.12, Bi 0.010, Cu 0.002, Ag 0.0009.	Annealed 16 hr at 212°F..	.....	.....	.....	6.1	74 (2 in.)	.....	.....	.....	16	Shear str.....5.9 kips/in. ² ...	[443]
2758..	Sn 50.....	Cast.....	.....	.....	.....	6.2	43 (4 in.)	.....	.....	12	Iz 16	Shear str.....5.7 kips/in. ² ... Specific gravity.....8.91. Melting range.....361°-414°F.	[445]
2759..	...do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Comp str (7.2%).....7.8 kips/in. ² ...	[446]

^aRate of strain 0.5 in./minute (free head speed).^bRate of strain 0.1 in./minute.

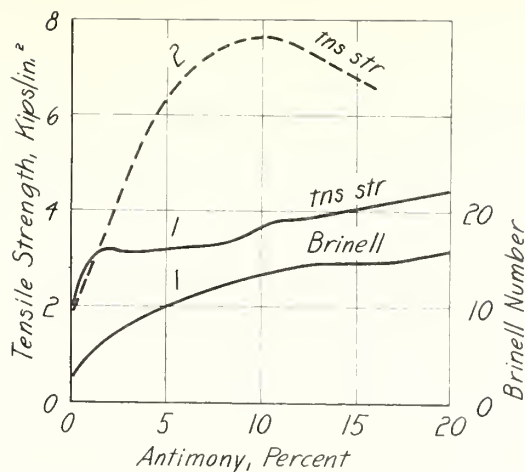


FIGURE 130.—Tensile strength and hardness of lead-antimony alloys (Schumacher and Hiers [421]).

Curves: 1, rod, extruded to 1 1/4 in. diameter and aged approximately 2 weeks at room temperature. Rate of strain, 1/4 in. per minute; 2, cast, rate of strain not given.

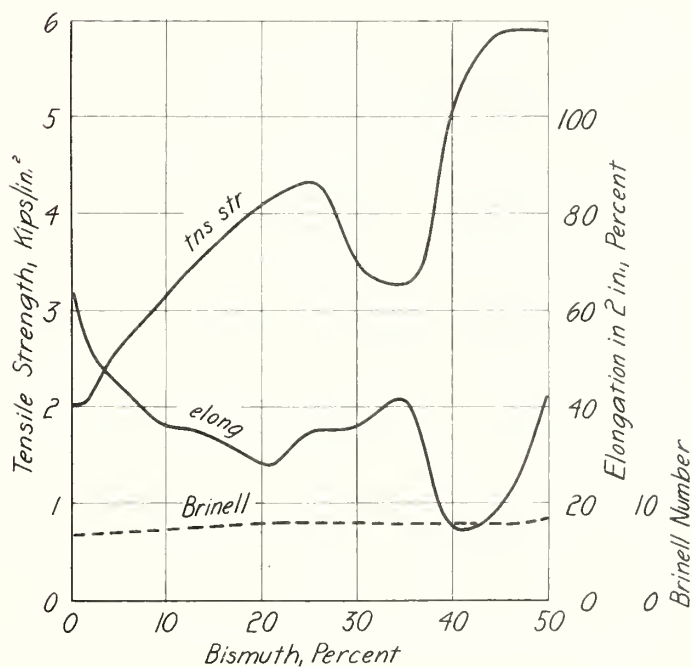


FIGURE 131.—Tensile properties and hardness of lead-bismuth alloys (Thompson [427]).

Test bars, 1/2 in. diameter, chill-cast and containing less than 0.2% impurities.

Rate of strain, 1/2 in. per minute (head speed).

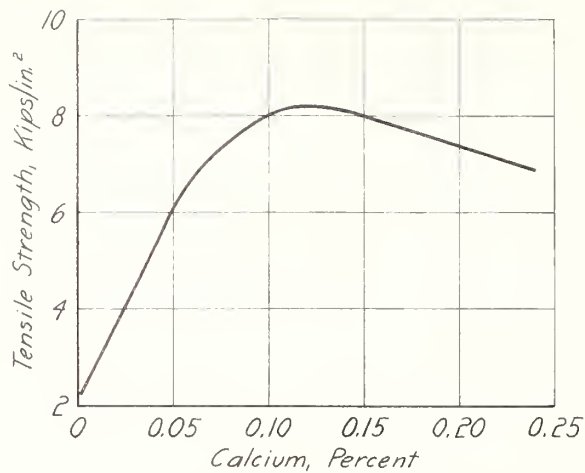


FIGURE 132.—Tensile strength of lead-calcium alloys (Briggs [680]).

Aged at room temperature 1 week, then at 212°F for 18 hours.

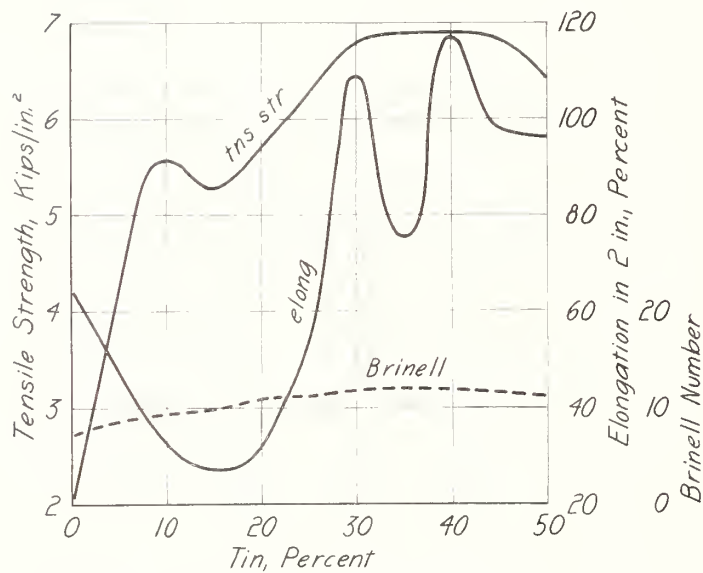


FIGURE 133.—Tensile properties and hardness of lead-tin alloys (Thompson [427]).

Test bars, 1/2 in. diameter, chill-cast.

Rate of strain, 1/2 in. per minute (head speed.)

TABLE 29.—Comparative properties of tin-base, lead-base, and lead-silver-base babbitts [447]

Serial number	Alloy type ^a	Specification	Composition, percent					Brinell number ^a			Ease of bonding	"Ductility" ^e	
			Pb	Ag	Sb	Sn	Cu	As cast ^b	Aged ^c	Aged and tested at 300°F			
										30 sec ^d	300 sec ^d		
2760.....	Lead-base.....	SAE No. 13.....	rem	.....	10	5	.....	21	17	6.4	4.0	.....	Percent
2761.....	do.....	ASTM No. 10.....	rem	.....	15	2	.....	21	16	6.4	5.0	Poor	50
2762.....	do.....	ASTM No. 10.....	rem	.....	15	2	0.2	18	18	7.1	5.4	Fair	40
2763.....	do.....	ASTM No. 8.....	rem	.....	15	5	.....	22	17	5.8	3.7	.....	.....
2764.....	do.....	SAE No. 14.....	rem	.....	15	10	.....	26	18	6.5	4.2	.....	53
2765.....	Lead-silver-base.....	.....	rem	2.6	10	3	.....	21	18	7.2	5.2	Good	59
2766.....	do.....	.....	rem	5.1	15	.....	.2	22	16	6.0	3.8	.....	.....
2767.....	do.....	.....	rem	5.0	15	2	.2	23	21	8.9	6.6	Good	40
2768.....	do.....	.....	rem	4.8	15	5	.....	22	18	6.9	4.7	.....	77
2769.....	do.....	.....	rem	4.8	15	5	.2	25	19	7.2	5.9	.....	57
2770.....	Tin-base.....	ASTM No. 2.....	.....	.....	7.5	rem	3.5	19	17	6.0	4.4	.....	99
2771.....	do.....	ASTM No. 3.....	.....	.....	8.3	rem	8.3	20	20	7.2	5.5	.....	91

^a2.5-mm ball, loads of 2 to 5 kg.^bHardness number determined after 24 hours at room temperature. Load applied for 11 seconds.^cAged for 24 hours at 300°F. Load applied for 11 seconds.^dTime of application of load.^eThe "ductility" was measured by pounding down a specimen of standard size until cracking had occurred. It was measured as percentage reduction in thickness.

TABLE 30. — Properties of soft solders 14-1

Serial number	Composition, percent						Liquidus temperature	Solidus temperature	Tensile strength ^a	Shear strength ^a	Recommended uses
	Sn	Pb	Sb	Cd	Hg	Zn					

BISMUTH-BASE ALLOYS											
2772.....	25	.....	.....	25	50	.....	151	66	.....	.....	Fusible alloy.
2773.....	13	27	.....	10	70	.....	158	70	.....	.....	Fusibility; glass metal.
2774.....	22	28	.....	.....	70	.....	212	100	.....	.....	Lead; tin; Britannia.
2775.....	19	31	.....	.....	50	.....	201	94	.....	.....	Britannia.
2776.....	.....	42.7	.....	7.1	50	.....	190	88	.....	.....	Fusible alloy.
2777.....	33.3	.....	.....	16.7	50	.....	151	66	.....	.....	Do.
2778.....	37.5	.....	.....	12.5	50	.....	151	66	.....	.....	Do.
2779.....	.....	42	.....	15.7	42.3	.....	193	89.5	.....	.....	Do.
2780.....	20	40	.....	.....	40	.....	205	113	.....	.....	Lead; tin; Britannia.

CADMIUM-BASE ALLOYS											
2781.....	.....	.....	.....	95	.....	.....	734	390	639	337	10.6
2782.....	.....	.....	.....	82.6	.....	.....	508	264.4	508	264.4	High-temperature service.
2783.....	5	.....	.....	65	30	.....	561	384	444	229	High-temperature; galvanized.
2784.....	30	.....	.....	50	20	.....	531	277	315	137	.....
2785.....	.....	.....	.....	50	50	.....	619	326	508	264.4	.....

LEAD-BASE ALLOYS											
2786.....	.....	100	.....	.....	.....	.....	621.3	327.4	621.3	327.4	None.
2787.....	.....	98	.....	.....	.....	Ag 2.....	586	308	579	304	Electrical; high-temperature service.
2788.....	.....	98	.....	.....	.....	Tl 2.....	590	310	580	308	Do.
2789.....	.....	97	.....	.....	.....	Cu 0.25, Ag 2.5.....	662	350	572	300	Electrical equipment.
2790.....	.....	95	.....	.....	.....	Ag 5.....	689	365	579	304	Electrical; high-temperature service.
2791.....	5	95	.....	.....	.....	.....	595	313	556	291	General low grade; coating; high-temperature service.
2792.....	.....	95	.....	.....	.....	5	764	418	604	318	High-temperature service.
2793.....	3	93	.....	.....	.....	Hg 4.....	723	384	518	270	Galvanized; sheet iron.
2794.....	.....	91.5	.....	.....	.....	.....	529	276	480	249	Carbon; copper; zinc; iron.
2795.....	.....	90.8	.....	.....	.....	1.4	513	267	459	237	Copper; iron; tin; galvanized.
2796.....	4	90	.....	.....	.....	.....	529	276	462	239	High-temperature service.
2797.....	.....	90	.....	.....	.....	.....	525	274	480	249	.....
2798.....	.....	90	.....	.....	.....	.....	511	266	477	247	Lead cable.
2799.....	10	85	.....	.....	.....	.....	527	275	493	245	General purpose.
2800.....	.....	87.5	.....	.....	.....	5	694	368	455	235	Copper; iron; tin; galvanized.
2801.....	.....	87	.....	.....	.....	.....	477	247	477	247	Lead cable.
2802.....	2	86	.....	.....	.....	.....	504	262	462	239	General purpose.
2803.....	6	86	.....	.....	.....	Hg 8.....	540	282	477	247	Galvanized; sheet iron.
2804.....	5	85	.....	.....	.....	.....	495	257	293	145	General purpose.
2805.....	15	85	.....	.....	.....	.....	545	285	437	225	General low grade; coating; high-temperature service.
2806.....	10	85	.....	.....	.....	.....	500	260	293	145	General purpose.
2807.....	.....	80	.....	.....	.....	.....	198	259	280	249	.....
2808.....	10	80	.....	.....	.....	.....	487	253	293	145	General; electrical; cans; roofing.
2809.....	.....	79.7	.....	.....	.....	.....	462	239	.....	.....	.....
2810.....	15	75	.....	.....	.....	.....	473	245	293	145	Coating and jointing.
2811.....	3	75	.....	.....	.....	.....	459	237	293	145	General purpose.
2812.....	25	75	.....	.....	.....	.....	511	266	361	183	General low grade; filler.
2813.....	.....	70	.....	.....	.....	.....	500	260	480	249	.....
2814.....	23	68	.....	.....	.....	.....	455	225	293	145	Wiping.
2815.....	33	67	.....	.....	.....	.....	486	232	361	183	Do.
2816.....	31	65	.....	.....	.....	.....	435	235	370	188	General purpose.
2817.....	9	65	.....	.....	.....	.....	437	235	293	145	Wiping.
2818.....	37.3	62.7	.....	.....	.....	As 0.1.....	464	240	361	183	Wiping; radiators.
2819.....	37.5	62.5	.....	.....	.....	.....	462	239	361	183	.....

TABLE 31.—*Lead and lead alloys, high-temperature properties*
[See also figs. 134, 135, and 136]

Serial number	Composition	Condition	Temperature	Stress (kips/in. ²) for designated creep rate per 1,000 hours				Duration	Reference
			°F	0.001%	0.01%	0.1%	1.0%	Hours	
2847.....	"Very pure" lead.....	.....	110	.....	0.18	.....	.....	2,000	[63]
2848.....	Vacuum lead.....	.....	110	.....	.06	.....	.....	1,000	[63]
2849.....	Grade I lead.....	.....	110	0.05	.155	.....	.....	1,000	[63]
2850.....	Grade II lead.....	.....	110	.05	.135	0.32	.....	1,000	[63]
2851.....	Grade III lead.....	.....	110	.....	.11	.21	.....	2,000	[63]
2852.....	"St. Joseph" lead.....	.....	110	.05	.12	.....	.....	2,000	[63]
2853.....	Sb 0.75, Pb rem.....	.....	110	.....	.06	.29	.....	1,000	[63]
2854.....	Sb 1.0, Pb rem.....	.....	110	.....	.065	.35	.....	2,000	[63]
2855.....	Ca 0.03, Pb rem.....	.....	110	.078	.185	.36	.....	1,000	[63]
2856.....	Cu 0.04, grade III Pb rem.....	.....	110	.....	.105	.21	.....	8,500	[63]
2857.....	Cu 0.06, grade III Pb rem.....	.....	110	.....	.13	.25	.....	2,000	[63]
2858.....	Cu 0.08, grade III Pb rem.....	.....	110	.....	.11	.....	.....	9,000	[63]
2859.....	Sn 2.0.....	.....	110	.....	.055	.13	.....	2,000	[63]
2860.....	Sn 28.1, Sb 1.7.....	Cast.....	Room 175	.....	.....	.16 .052 (0.42%)	0.31	1,800 1,800	[149]
2861.....	Sn 30.4.....	db.....	Room	.....	.....	.....	.....	4,800	[449]
2862.....	Sn 31.5, Sb 1.8.....	db.....	Room	.....	.....	.21	.13 .34	4,800	[449]
2863.....	Sn 34.3.....	db.....	Room	.....	.....	.....	.19	4,800	[449]
2864.....	Sn 45.1, Sb 2.7.....	db.....	Room 175	.....	.....	.31 .04 (0.42%)	.61	4,800 4,800	[449]
2865.....	Sn 49.5.....	db.....	Room 175	.....	.....	.....	.16	4,800	[449]

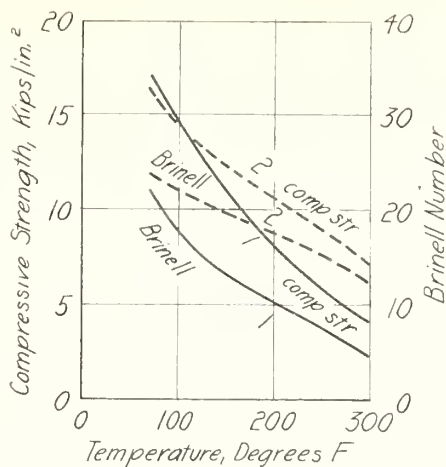


FIGURE 134.—Compressive strength and hardness of a lead-calcium and of a tin-antimony-copper alloy (tin base babbitt) at high temperatures (Melhuish [59]).

Curves: 1, Sn 88%, Sb 8%, Cu 4% (babbitt); 2, Pb 98%, Ca 2%.

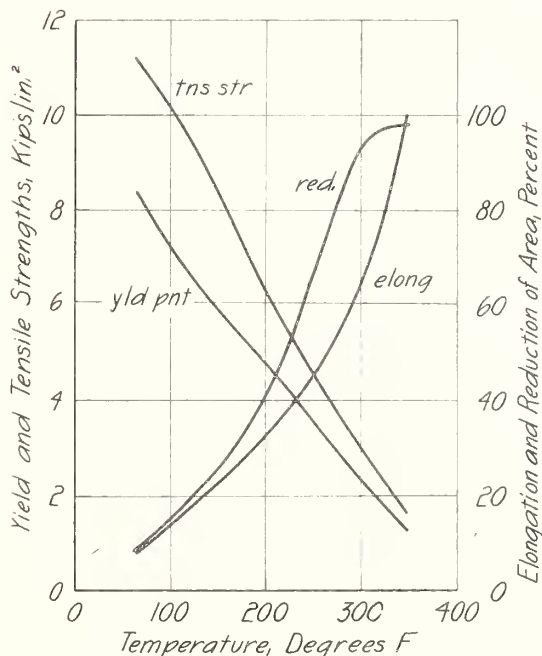


FIGURE 135.—Short-time tensile properties of a lead-antimony-tin alloy (babbitt) at high temperatures (Greenwood [522]).

(Elongation in $4\sqrt{\text{area}}$)

Sb 14.9%, Sn 5.05%, Cu 0.09%, As 0.06%. Chill-cast from 450°F. Rate of strain, 0.013 in./minute.

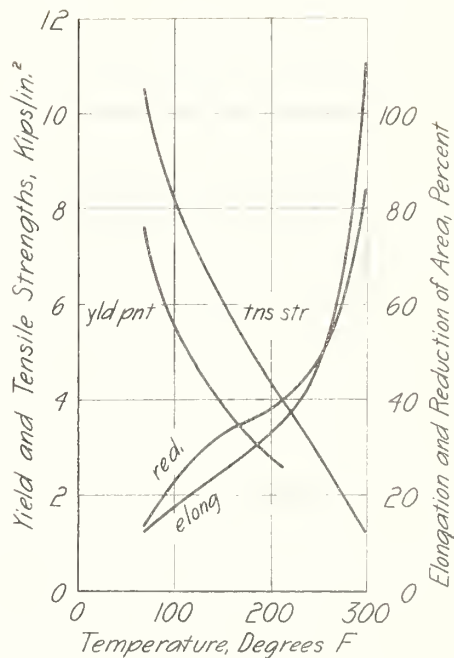


FIGURE 136.—Short-time tensile properties of a lead-tin-antimony alloy at high temperatures (Greenwood [522]).

(Elongation in $4\sqrt{\text{area}}$)

Sn 39.8%, Sb 10.5%, Cu 1.03%, As 0.06%, Fe 0.04%. Chill-cast from 450°F. Rate of strain 0.013 in./minute.

TABLE 52.—Lead and lead alloys, low-temperature properties

Serial number	Composition	Condition	Temperature of test	Tensile properties				Hardness number	Impact value	Remarks	Reference
				Modulus of elasticity	Tensile strength	Elongation	Reduction of area				
2865.....	Pb 99.98..... Percent	.....	of 64 -319	Klbs./in. ² 2,700 3,400	Klbs./in. ²	Percent	Percent .....	.....	ft-lb .....	.....	[450]
2867.....	Commercial lead.....	.....	Room -300 -425	..... ..... .....	3.0 6.2	33 40 .....	..... ..... .....	a 4.3 a 9	b 2.3 b 3.8 b 4.5	.....	[25]
2868.....	Lead.....	 Rolled.....	59 -4 -103	..... ..... .....	3.6 7.2 13.3 15.2	52 40 31 24	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	.....	[451]
2869.....	Pb 47.4, Sn 53.1....	Rod, 1 in. diam, annealed.....	Room -292	..... .....	8.1 15.4	28 4.0 (2 in.) (2 in.)	54 3.8	.....	1z 15 1z 2.0	Impact specimen, 10 × 10 mm with three 45° notches.	[64]

^a Brinell number.^b Notch impact value, m-kg/cm.²

TABLE 33.—Lead and lead alloys, thermal expansion

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade						Reference
			Low temperature miscellaneous	-100° to 20°C	20° to 100°C	20° to 200°C	20° to 300°C		
2870.....	Pb 99.8-99.9..... <i>Percent</i>	Cast.....	$\times 10^{-6}$ { 25.1 (-250° to 20°C) 26.5 (-200° to 20°C)	$\times 10^{-6}$ 28.3	$\times 10^{-6}$ 28.8	$\times 10^{-6}$ 29.1	$\times 10^{-6}$ 30.0	$\times 10^{-6}$ 31.3	[452]
2871.....	Sb 2.9.....	do.....	28.0 (-12° to 20°C)	.....	28.2	28.2	28.3	.....	[453]
2872.....	Sb 4.9.....	do.....	.....	.....	27.3	27.4	27.4	.....	[453]
2873.....	Sb 7.0.....	do.....	26.3 (-12° to 20°C)	.....	26.8	26.7	26.7	.....	[453]
2874.....	Sb 9.8.....	do.....	.....	.....	26.2	26.4	26.2	.....	[453]
2875.....	Sb 11.9.....	do.....	.....	.....	25.7	25.9	25.8	.....	[453]
2876.....	Sb 12, Sn 3.....	Rod, cast ^a.....	.....	.....	.....	^a 25.2	.....	.....	[601]
2877.....	Sb 14.7, Sn 4.9, Cu 2.9.....	.....	.....	.....	.....	.....	28.4	.....	[454]
2878.....	Sb 17.0, Cu 1.5.....	.....	.....	.....	.....	.....	26.5	.....	[454]
2879.....	Sb 23.8.....	Cast.....	.....	.....	23.6	21.6	23.4	.....	[453]
2880.....	Na 0.8, Ca 0.6.....	.....	.....	.....	.....	.....	36.3	.....	[454]
2881.....	Sn 9.71.....	.....	.....	.....	.....	^b 27.9	.....	.....	[72]
2882.....	Sn 14.4, Sb 13.5, Cu 2.7.....	.....	.....	.....	.....	.....	27.4	.....	[454]
2883.....	Sn 16, Sb 16, Cu 3.....	.....	.....	.....	.....	.....	26.5	.....	[454]
2884.....	Sn 33.....	.....	.....	.....	.....	^a 25.1	.....	.....	[456]
2885.....	Sn 38.02.....	.....	.....	.....	.....	^b 24.7	.....	.....	[72]
2886.....	Sn 47.91.....	.....	.....	.....	.....	^b 23.8	.....	.....	[72]

^aBase temperature 0° instead of 20°C.^b15° to 110°C.

TABLE 34.—Lead and lead alloys, electrical and thermal properties

Serial number	Composition	Condition	Electrical properties			Thermal conductivity	Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity		
2887	"Pure" lead	Cast	Percent IACS 33.1 (-190.3°C) 8.8 (0°C)	Microhm cm 5.21 (-190.3°C) 19.7 (0°C)	per °C × 10 ⁻⁴ 38.6 (20° to -190.3°C)	Watts cm ⁻¹ sec ⁻¹ { 0.35 (0°C) 0.33 (100°C) 0.31 (200°C) 0.29 (300°C)	402
2888	Lead	Sheet, rolled					
2889 ^b	do						
2890	Sb 1	Cast					
2891	Sb 5.63						
2892	Sb 10						
2893	Sb 10.56						
2894 ^c	Sb 13						
2895	Sb 14						
2896	Sb 20						
2897	Sb 37.1						
2898	Sb 40						
2899 ^d	Bi 2.04						
2900	Bi 20						
2901	Bi 33.1						
2902	Bi 40						
2903	In 7.5						
2904	In 20.1						
2905	In 40.4						
2906	Ag 2.1						
2907	Ag 21.7						
2908	Ag 34.2						
2909	Tl 3.45						
2910	Tl 9.8						
2911	Tl 10						
2912	Tl 20						
2913	Tl 34.7						
2914	Tl 30						
2915	Tl 39.60						
2916	Sn 8.5						
2917	Sn 10						
2918	Sn 20						
2919	Sn 22.8						
2920	Sn 23.8, Sb 1.92	Cast					

IX. MAGNESIUM AND MAGNESIUM ALLOYS

(317)

TABLE 35.—Classification of some magnesium alloys (1942)

Designation							Nominal composition, percent					Serial numbers of corresponding alloys in the tables	
Army		Navy		ASTM		SAE No.	Dow metal	American Magnesium	Al	Mn	Zn		Others
Spec	Alloy	Spec	Alloy	Spec	Alloy								
SAND-CASTINGS													
AN-QP-M-56	A	AN-QP-M-56	A	B 80-41T	4	50	H	241	4.0	0.3	3.0	.....	2979, 2977, 3060, 3061, 3062; Figure 154.
AN-QP-M-56	C	AN-QP-M-56	C	B 80-41T	17	500	C	241	8.0	.1	2.0	.....	2983, 2984, 2985.
AN-QP-M-56	2	AN-QP-M-56	2	B 80-41T	14	.....	F	250	10.0	.1	1.0	.....	2987.
AN-QP-M-56	3	AN-QP-M-56	3	B 80-41T	2	.....	G	240	10.0	.1	.....	.....	2951, 2952, 2953, 3041, 3042, 3043.
AN-QP-M-56	B	AN-QP-M-56	B	B 80-41T	11	.....	M	245	12.0	.1	.....	.....	2958, 2959.
AN-QP-M-56		AN-QP-M-56	.....	B 80-41T	.....	.....	.....	406	.....	1.5	.....	.....	2968, 3023; Figure 156.
DIE-CASTINGS													
46 M 11		46 M 11	.....	B 91-41T	.....	.....	EX	.....	6.5	0.15	.....	.....	2941.
46 M 11		46 M 11	.....	B 91-40T	12	.....	R	241	8.0	.15	.....	.....	2944.
46 M 11		46 M 11	.....	B 91-40T	13	501	R	250	10.0	.1	.....	.....	2964.
46 M 11		46 M 11	.....	B 91-40T	.....	.....	.....	263	9.0	.2	0.6	.....	2966.
FORGINGS													
1134 ⁶		1134 ⁶	.....	B 91-41T	18	.....	FS	.....	2.8	0.3	1.0	.....	2968.
1134 ⁶		1134 ⁶	.....	B 91-41T	16	.....	L	.....	2.5	.2	.....	.....	2968.
1134 ⁶		1134 ⁶	.....	B 91-41T	15	.....	.....	65S	3.5	.2	.....	.....	2970.
1134 ⁶		1134 ⁶	.....	B 91-41T	8	.....	X	74S	6.5	.2	3.0	.....	3033, 3034.
1134 ⁶		1134 ⁶	.....	B 91-41T	9	.....	O	58S	8.5	.2	0.5	.....	3039.
1134 ⁶		1134 ⁶	.....	B 91-41T	11	.....	M	3S	.....	1.5	.....	.....	.....
EXTRUDED BARS, RODS, AND SHAPES													
M-311C		M-311C	.....	B 107-41T	18	52	FS	52S	2.8	0.3	1.0	.....	2968.
M-311C		M-311C	.....	B 107-41T	15	521	X	74S	3.0	.3	3.0	.....	2971, 2972.
M-311C		M-311C	.....	B 107-41T	8	520	F	53S	4.0	.3	.....	.....	2974, 2978, 3026, 3052; Figure 152.
M-311C		M-311C	.....	B 107-41T	9	.....	O	57S	6.5	.2	0.7	.....	3029, 3035; Figures 153 and 158.
M-311C		M-311C	.....	B 107-41T	.....	.....	G	58S	8.5	.2	0.5	.....	2980, 2981.
M-311C		M-311C	.....	B 107-41T	11	.....	M	59S	10.0	.1	.....	.....	2949, 2950, 3045.
M-311C		M-311C	.....	B 107-41T	.....	.....	.....	3S	.....	1.5	.....	.....	3046, 3047; Figure 156.
ROLLED PLATE, SHEET, AND STRIP													
47 M2		47 M2	.....	B 90-41T	18	52	FS	52S	2.7	0.3	1.0	.....	.....
47 M2		47 M2	.....	B 90-41T	.....	.....	F	53S	4.0	.3	.....	.....	2945, 2946.
47 M2		47 M2	.....	B 90-41T	7	511	R	.....	6.5	.2	.....	.....	3036.
47 M2		47 M2	.....	B 90-41T	8	520	J-1	57S	6.5	.2	0.7	.....	2999, 3000, 3001, 3048.
47 M2		47 M2	.....	B 90-41T	11	51	M	3S	.....	1.5	.....	.....	.....

^a Army Air Corps.

TABLE 36.—*Magnesium and magnesium alloys, normal-temperature properties*

[For a discussion of the indefiniteness of values reported for yield strength and particularly for "proportional limit" see pages 5 and 6. Hardness numbers are Brinell numbers unless prefixed H_R, H_C, etc. (Rockwell R, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed Iz (Izod method).]

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
			<i>Kt/ps/in.²</i>	<i>Kt/ps/in.²</i>	<i>Kt/ps/in.²</i>	<i>Kt/ps/in.²</i>	Percent	Percent	<i>Kt/ps/in.²</i>	<i>ft.-lb</i>		
PURE AND COMMERCIAL MAGNESIUM (SEE ALSO FIGS. 137 AND 138)												
2925..	Fe 0.008-0.01.....	Extruded.....	.....	.....	.....	22.2	11	9.0	.....	.....	.....	[462]
2926..	do.....	Extruded; 1/4 hr at 865°F., a-c.	.....	.....	.....	17.0	3.0	2.1	.....	.....	.....	[462]
2927..	Mg 99.9.....	.....	6,100	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....2,500 kips/in. ² .. Poisson's ratio.....0.33.	[463]
2928..	Si 0.06, Fe 0.03, Cu 0.02.	Rod, hot-rolled from 1 1/2 in. to 1 in. diam at 895°F.	6,250	3.6	.....	35.2	12 (4/area)	.....	.....	.....	.....	[24]
2929..	do.....	Rod, 1 in. diam, hot-rolled; am 5 hr at 660°F.	6,000	.....	19.3 (0.15% offset)	32.0	7.0 (4/area)	.....	.....	.....	.....	[24]
2930..	Fe 0.02, Si 0.02..	Rod, 1/2 in. square, extruded.	6,740	1.2	.....	32.5	6.2 (3 in.)	4.4	7.8 (10 ⁶)	2.9	Compressive str.....34.6 kips/in. ² .. Shear str.....15.5 kips/in. ² ..	[19]
2931..	Mg 99.7.....	Sheet, 0.02 in.....	.....	.....	15.7 (0.2%)	28.4	9	.....	.....	.....	.....	[463]
2932..	Mg.....	Sand-cast.....	.....	0.5	3.0 (0.25% extn)	13.0	6 (2 in.)	6	.....	.....	Compressive str.....32.0 kips/in. ² .. Shear str.....14.0 kips/in. ² ..	[464]
2933..	do.....	Extruded.....	.....	1.0	6.5 (0.25% extn)	28.0	8 (2 in.)	8	.....	.....	Compressive str.....45.0 kips/in. ² .. Shear str.....16.0 kips/in. ² ..	[464]
MAGNESIUM-ALUMINUM ALLOYS ^a (SEE ALSO FIGS. 139, 140, AND 141)												
2934..	Al 4.0, Mn 0.3...	Extruded.....	.....	.....	29.0 (0.2% offset)	40.0	16 (2 in.)	.....	14.0 (5 x 10 ⁶)	47	Compressive str.....59.0 kips/in. ² .. Shear str.....20.0 kips/in. ² ..	[465]
2935..	Al 4.0, Mn >0.20, Si <0.5, Zn <0.3.	Hot-rolled.....	6,500	.....	.....	40	.....	.....	.....	.....	Specific gravity.....1.77.. Melting range.....1,050°-1,150°F.	[466]
2936..	do.....	Annealed.....	6,500	.....	22 (0.2% offset)	36	10 (2 in.)	.....	10 (5 x 10 ⁶)	50	Shear str.....18.5 kips/in. ² ..	[466]
2937..	Al 4.25, Mn >0.20, Si <0.5, Zn <0.3.	Cast.....	6,500	.....	9 (0.2% offset)	24	6 (2 in.)	.....	.....	44	Shear str.....14 kips/in. ² .. Specific gravity.....1.76.. Melting range.....1,050°-1,150°F.	[466]
2938..	Al 4.40, Mn 0.25, Fe 0.03.	Rod, extruded from 2 15/16 in. to 3/4 in. diam at 350°-400°F.	6,100	13.5	.....	39.0	16 (8 in.)	31	15.0 (10 ⁶)	58	Compressive str.....59.9 kips/in. ² .. Shear str.....20.4 kips/in. ² .. Mod-el (shear).....2,200 kips/in. ² .. Specific gravity.....1.77.	[96]
2939..	Al 6.....	Hot-rolled.....	6,600	7.4	25.1 (0.1% offset)	42.6	17 (4/area)	.....	.....	.....	.....	[24]
2940..	do.....	Cold-rolled; am 2 hr at 212°F.	6,200	12.5	37.0 (0.1% offset)	50.4	12 (4/area)	.....	.....	.....	.....	[24]
2941..	Al 6.5, Mn >0.15, Si <0.3, Zn <0.3.	Die-cast.....	6,500	.....	17 (0.2% offset)	27	4 (2 in.)	.....	.....	50	Iz 3	[466]

2942..	Al 6.8, Mn 0.26, Fe 0.04.	Rod, extruded from 2 15/16 in. to 3/4 in. diam at 350°-400°F.	5,200	15.2	.....	44.4	14 (8 in.)	17	15.0 (8 × 10 ⁷)	65	2-9	[96]
2943..	Al 8.0, Mn >0.15, Si <0.3, Zn <0.3.	Cast; heat-treated (T4)	6,500	.....	11 (0.2% offset)	33	10 (2 in.)	.....	7.5 (5 × 10 ⁶)	48	2-2	[466]
2944..	...do.....	Die-cast.....	6,500	.....	17 (0.2% offset)	30	2.5 (2 in.)	.....	.....	59	.....	[465]
2945..	Al 8.68, Fe 0.041, Cu 0.026, Si 0.029.	Billet, 7 in., cast.....	5,900	6.9	.....	28.0	4.0 (8 in.)	0	12.5 (10 ⁷)	61	1.5	[19]
2946..	...do.....	Propeller blade, forged from 7-in. billet.	6,400	11.4	.....	41.3	4.0 (8 in.)	0	15.0 (6 × 10 ⁷)	61	1.8	[19]
2947..	Al 10.....	Sheet, ann.....	.....	7.0	14.5 (0.25% extn)	44.0	3.5 (2 in.)	3.5	.....	70	.....	[22]
2948..	...do.....	Sheet, rolled.....	.....	4.0	13.0 (0.25% extn)	48.0	5 (2 in.)	5	.....	71	.....	[23]
2949..	Al 10, Mn 0.1.....	Extruded; stretched.....	.....	.....	38.0 (0.2% perm)	50.0	10 (2 in.)	.....	16.0 (5 × 10 ⁶)	70	.....	[29]
2950..	...do.....	Extruded; stretched, h-t.	.....	.....	40.0 (0.2% perm)	55.0	3.5 (2 in.)	.....	16.0 (5 × 10 ⁶)	85	.....	[20]
2951..	Al 10, Mn >0.1, Si <0.5, Zn <0.3.	Cast.....	6,500	.....	13 (0.2% offset)	22	2 (2 in.)	.....	9 (5 × 10 ⁶)	54	0.6	[465]
2952..	...do.....	Cast; h-t (T4).....	6,500	.....	12 (0.2% offset)	35	9 (2 in.)	.....	11 (5 × 10 ⁶)	52	2	[465]
2953..	...do.....	Cast; h-t and aged (T6)	6,500	.....	19 (0.2% offset)	36	2 (2 in.)	.....	9 (5 × 10 ⁶)	59	0.7	[466]
2954..	Al 10.08, Mn 0.65, Si 0.13, Cu 0.04.	Rollled; h-t.....	.....	.....	16.1	57.6	1.9	4.7	.....	105	.....	[467]
2955..	Al 10.63, Mn 0.71, Si 0.19, Cu 0.04, Fe 0.03.	Rollled.....	.....	.....	13.0	19.1	11	20	.....	85	.....	[467]
2956..	Al 12.....	Sheet, ann.....	.....	8.0	15.5 (0.25% extn)	45.0	3 (2 in.)	3	.....	82	.....	[23]
2957..	...do.....	Sheet, rolled.....	.....	.....	16.0 (0.25% extn)	53.0	3 (2 in.)	2	.....	81	.....	[23]
2958..	Al 12, Mn >0.1, Si <0.5, Zn <0.3.	Cast.....	6,500	.....	14 (0.2% offset)	19	0.5 (2 in.)	.....	6 (5 × 10 ⁶)	65	0.4	[466]
2959..	...do.....	Cast; h-t and aged (T6)	6,500	.....	20 (0.2% offset)	32	0.5 (2 in.)	.....	7 (5 × 10 ⁶)	85	0.5	[466]

MAGNESIUM-ALUMINUM-CADMIUM ALLOYS^a

2960..	Al 8, Cd 8.....	Hot-rolled.....	6,400	9.8	30.9 (0.1% offset)	48.4	14 (4 in.)	.....	.....	.....	.....	[24]
2961..	...do.....	Cold-rolled.....	6,200	15.5	46.6 (0.1% offset)	59.4	4.5 (4 in.)	.....	.....	.....	.....	[24]

^a For commercial alloys. Dow Chemical Co. [53] recommends the following values: Modulus of elasticity, 5,500 kips/in.²; modulus of elasticity in shear, 2,400 kips/in.²; Poisson's ratio, 0.312.

TABLE 36.—Magnesium and magnesium alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation				
			E , lbs./in.^2	E , lbs./in.^2	E , lbs./in.^2	T , lbs./in.^2	Percent				
MAGNESIUM-ALUMINUM-CADMIUM ALLOYS ^a —Continued											
2962..	Al 8, Cd 3.....	Cold-rolled; am.....	6,200	18.5	41.2 (0.1% offset)	50.7	12 (4/area)	.....	ft-lb	.....	[29]
2963..	Al 8, Cd 8, Ag 2..	Forged; 2 hr at 770°F, water aged 6 days at 255°F.	.....	22.3	43.7 (0.1%)	61.8	4.2 (4/area)	.....	.....	.....	[468]
MAGNESIUM-ALUMINUM-SILICON ALLOYS ^a											
2964..	Al 10.0, Si <1.0, Mn >0.1, Zn <0.3.	Die-cast.....	6,500	.....	22 (0.2% offset)	31	1.0 (2 in.)	.....	62	0.5	[466]
2965..	Al 12.0, Si 0.7, Zn 0.7, Mn 0.1.	Die-cast; h-t and aged..	.....	17.0	29.2 (0.2% perm)	42.1	0.8 (2 in.)	.....	88	0.8	[469]
MAGNESIUM-ALUMINUM-SILVER ALLOYS											
2966..	Al 6.5, Ag 1.5....	Forged.....	6,500	.....	47.7 (0.1%)	61.2	12 (4/area)	.....	.....	.....	[470]
2967..	Al 7.5, Ag 2.68, Zn 0.66, Mn 0.45, Ca 0.3.	Forged; 2 hr at 770°F, aged 3 days at 345°F.	.....	10.8	38.8 (0.1%)	57.8	6.0 (4/area)	.....	.....	.....	[468]
MAGNESIUM-ALUMINUM-ZINC ALLOYS ^a											
2968..	Al 2.8, Zn <1.3, Mn >0.2, Si <0.5.	Extruded.....	6,500	.....	30 (0.2% offset)	40	17 (2 in.)	.....	12 (5 × 10 ⁶)	3.2	[466]
2969..	Al 3, Zn 1.....	Cast.....	.....	.....	4.3 (0.02%) 7.8 (0.2%)	24.2	8	11	7.8	^b 1.0	[463]
2970..	Al 3.0, Zn 3.0, Mn >0.2, Si <0.5.	Forged.....	6,500	.....	24 (0.2% offset)	41	16 (2 in.)	.....	17 (5 × 10 ⁶)	.....	[466]
2971..	...do.....	Extruded.....	6,500	.....	30 (0.2% offset)	42	19 (2 in.)	.....	18 (5 × 10 ⁶)	.....	[466]
2972..	...do.....	Extruded and aged.....	6,500	.....	34 (0.2% offset)	44	13 (2 in.)	.....	17 (5 × 10 ⁶)	.....	[466]
2973..	Al 4.0, Zn 3.0, Mn 0.3.	Sand-cast.....	6,000	.....	5.7 (0.02%) 12 (0.2%)	27	7 (10 diam)	10	9	^b 0.5	[471]
2974..	Al 4.5, Zn 3.5, Mn 0.4.	...do.....	6,200	.....	11.2-13.4 (0.2%)	20.2-24.6	5-8 (2 in.)	8-10	7.8	.....	[468]
2975..	...do.....	Chill-cast.....	6,200	.....	11.2-13.4 (0.2%)	24.6-31.4	7-12 (2 in.)	8-10	7.8	.....	[468]

2976..	Al 6.0, Zn 3.0, Mn >0.15, Si <0.5.	Cast.....	6,500	.....	12 (0.2% offset)	27	6 (2 in.)	.....	11 (5 × 10 ⁸)	55	1.0	Compressive str.....45 kips/in. ² Shear str.....18 kips/in. ² Specific gravity.....1.84. Melting range.....760°-1,115°F.	[466]
2977..	...do.....	Cast; h-t.....	6,500	.....	12 (0.2% offset)	38	11 (2 in.)	.....	11 (5 × 10 ⁸)	55	2.5	Compressive str.....46 kips/in. ² Shear str.....18 kips/in. ²	[466]
2978..	...do.....	Cast; h-t and aged.....	6,500	.....	19 (0.2% offset)	38	5 (2 in.)	.....	10 (5 × 10 ⁸)	70	1.1	Compressive str.....50 kips/in. ² Shear str.....20 kips/in. ²	[466]
2979..	Al 6.3, Zn 0.43, Si 0.12, Fe 0.11.	Extruded.....	6,300	.....	19.8 (0.02%) 34.9 (0.2%)	19.2	15 (10 diam)	21-30	.....	73	.....	Comp yld str (0.2%).....34.5 kips/in. ² Compressive str.....76.8 kips/in. ² Shear str.....23.5 kips/in. ²	[472]
2980..	Al 8.5, Zn 0.5, Mn >0.15, Si <0.5.	...do.....	6,500	.....	35 (0.2% offset)	47	12 (2 in.)	.....	17 (5 × 10 ⁸)	61	2.2	Compressive str.....75 kips/in. ² Shear str.....20 kips/in. ² Specific gravity.....1.81. Melting range.....895°-1,110°F.	[466]
2981..	...do.....	Extruded and aged.....	6,500	.....	38 (0.2% offset)	51	9 (2 in.)	.....	16 (5 × 10 ⁸)	70	1.6	Compressive str.....73 kips/in. ² Shear str.....23 kips/in. ²	[466]
2982..	Al 8.5, Zn 0.5, Mn 0.2-0.5.	Sand-cast.....	6,300	.....	5.7 (0.02%) 15 (0.2%)	36	10 (10 diam)	12	13	60	0.9	Compressive str.....44 kips/in. ² Shear str.....19 kips/in. ²	[471]
2983..	Al 9.0, Zn 2.0, Mn >0.10, Si <0.5.	Cast.....	6,500	.....	14 (0.2% offset)	24	2 (2 in.)	.....	.....	60	Iz 1	Specific gravity.....1.82.....	[466]
2984..	...do.....	Cast; h-t.....	6,500	.....	14 (0.2% offset)	39	10 (2 in.)	.....	.....	79	Iz 4	.....	[466]
2985..	...do.....	Cast; h-t and aged.....	6,500	.....	21 (0.2% offset)	39	3 (2 in.)	.....	.....	77	Iz 1	.....	[466]
2986..	Al 9.0, Zn 0.7, Mn >0.10, Si <0.5.	Die-cast.....	6,500	.....	21 (0.2% offset)	34	5 (2 in.)	.....	.....	60	Iz 2	Specific gravity.....1.81.....	[456]
2987..	Al 10.0, Zn 1.0, Mn >0.10, Si <0.5.	Cast; h-t and aged.....	6,500	.....	22 (0.2% offset)	36	1 (2 in.)	.....	8 (5 × 10 ⁸)	77	Iz 1	Compressive str.....59 kips/in. ² Shear str.....20 kips/in. ² Specific gravity.....1.82.	[466]

MAGNESIUM-CADMIUM ALLOYS (SEE ALSO FIG. 142)

2988..	Cd 3.5, Al 2.5, Mn >0.20, Si <0.5, Zn <0.3.	Forged.....	6,500		26 (0.2% offset)	37	11 (2 in.)		10 (5 × 10 ⁸)	51			[466]
--------	---	-------------	-------	-------	---------------------	----	---------------	-------	------------------------------	----	-------	-------	-------

MAGNESIUM-CALCIUM ALLOYS (SEE FIG. 143)

MAGNESIUM-CERIUM-MANGANESE ALLOY													
2989..	Ce 6, Mn 2.....	Wrought.....	.....	.....	32.7 (0.2%)	37.0	3	.....	11.4	.....	.....	Compressive str.....54.2 kips/in. ²	[483]

MAGNESIUM-COPPER ALLOYS (SEE ALSO FIG. 144)

2990..	Cu 1.95, Fe 0.06, Si 0.04.	Rod, 1 in. diam, forged	.....	14.3	19.7 (0.025% perm)	41.9	8.1 (2 in.)	12	.....	42	.....	Specific gravity.....1.77.....	[473]
2991..	...do.....	Rod, cold w-t from 860°F	.....	14.8	17.5 (0.025% perm)	34.5	8.0 (2 in.)	8.0	.....	44	.....	.....	[473]
2992..	Cu 2.08, Ni 0.65	Chill-cast.....	.....	5.2	7.6 (0.025% perm)	24.2	8.7 (2 in.)	8.9	.....	42	.....	Specific gravity.....1.78.....	[474]

^aFor commercial alloys, Dow Chemical Co. [53] recommends the following values: Modulus of elasticity, 6,500 kips/in.²; modulus of elasticity in shear, 2,400 kips/in.²; Poisson's ratio, 0.342.

^bNotch impact value, m-kg/cm².

TABLE 36.—Magnesium and magnesium alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
MAGNESIUM-COPPER ALLOYS—Continued												
2993..	Percent Cu 3.....	Rod, 1 in. diam, hot-rolled.	Kips/in. ²	Kips/in. ²	Kips/in. ²	Kips/in. ²	Percent 9.0 (4 area)	Percent	Kips/in. ²	ft-lb .....	.....	[24]
2994..	...do.....	Rod, 1 in. diam, hot-rolled; ann 5 hr at 660°F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	[24]
2995..	Cu 4.0, Al 2.0, Cd 2.0, Si 0.5, Zn 0.3, Mn 0.15.	Sand-cast.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[475]
2996..	Cu 9.65, Fe 0.04..	Rod, extruded from 2 15/16 in. to 3/4 in. diam at 350°-400°F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	[96]
2997..	Cu 13.....	Rod, 1 in. diam, hot-rolled.	.....	.....	.....	.....	.....	.....	.....	.....	.....	[24]
MAGNESIUM-MANGANESE ALLOYS ^a												
2998..	Mn 1.20, Si 0.3..	Cast.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[466]
2999..	...do.....	Sheet, ann.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[466]
3000..	...do.....	Sheet, hard-rolled.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[466]
3001..	...do.....	Sheet, extruded.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[466]
3002..	Mn 2.0, Ce 0.5..	Wrought.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[468]
3003..	Mn 2.5.....	Sheet, ann.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[468]
MAGNESIUM-NICKEL ALLOYS (SEE ALSO FIG. 145)												
3004..	Ni 1.08, Cu 1.04..	Rod, forged from 2 1/2 in. to 7/8 in. diam at 660°-840°F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	[474]
3005..	...do.....	Rod, forged and rolled from 2 1/2 in. to 7/8 in. diam at 660°-840°F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	[474]
3006..	...do.....	Rollled; quenched from 840°F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	[474]
MAGNESIUM-SILICON ALLOYS (SEE ALSO FIG. 146)												
3007..	Si 1.3, Mn 0.3...	Cast.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[476]

MAGNESIUM-SILVER ALLOYS (SEE ALSO FIG. 147)

3008..	Ag 5.5, Al 2.6, Zn 2.6, Mn 0.2.	Bar, 1 1/2 in. diam, extruded.	.....	.....	40-50	55-65	6-8	.....	.....	90-95	.....	Specific gravity.....1.89.....	[129]
3009..	...do.....	Forging.....	.....	.....	32-40	40-50	2-6	.....	.....	80-85	.....	.....	[129]

MAGNESIUM-THALLIUM ALLOYS (SEE FIG. 148)

MAGNESIUM-TIN ALLOYS (SEE ALSO FIG. 149)

3010..	Sn 5.86, Ag 1.38..	Extruded.....	.....	.....	24.9 (0.2% offset)	35.3	16 (2 in.)	.....	.....	15	.....	.....	[129]
3011..	...do.....	Extruded; 1 hr at 940°F, w-3, aged 40 hr at 570°F.	.....	.....	26.1 (0.2% offset)	39.0	7.5 (2 in.)	.....	.....	50	.....	.....	[129]

MAGNESIUM-ZINC ALLOYS (SEE ALSO FIG. 150)

3012..	Zn 3, Zr 0.5.....	Sand-cast.....	.....	.....	9.9 (0.2%)	30.0	13	15	8.5	.....	.....	.....	[463]
3013..	Zn 4.22, Al 0.21, Si 0.08, Fe 0.04.	Rolled..... ²	.....	.....	10.1	37.4	16	31	.....	55	.....	Compressive str.....59.1 kips/in. ² Shear str.....16.1 kips/in. ²	[467]
3014..	Zn 4.38, Cu 0.22, Al 0.15, Si 0.11.	Rod, 1 in. diam, hot-rolled.	6,100	10.1	32.3 (0.15% offset)	39.6	13 (4/ATPES)	.....	.....	.....	.....	.....	[24]
3015..	...do.....	Rod, 1 in. diam, hot- rolled; ann 5 hr at 660°F.	6,100	6.0	19.7 (0.15% offset)	34.7	14 (4/ATPES)	.....	.....	.....	.....	.....	[24]

MAGNESIUM-ZIRCONIUM ALLOY

3016..	Zr 0.5.....	Sand-cast.....			{ 6.3 (0.02%) 8.5 (0.2%) }	24.2	18	19	4.3	38	0.85 ^b		[463]
--------	-------------	----------------	-------	-------	-------------------------------------	------	----	----	-----	----	-------------------	-------	-------

^a For commercial alloys, Dow Chemical Co. [53] recommends the following values: Modulus of elasticity, 6,500 kips/in.²; modulus of elasticity in shear, 2,400 kips/in.²; Poisson's ratio, 0.42.

^b Notch impact value, m-kg/cm².

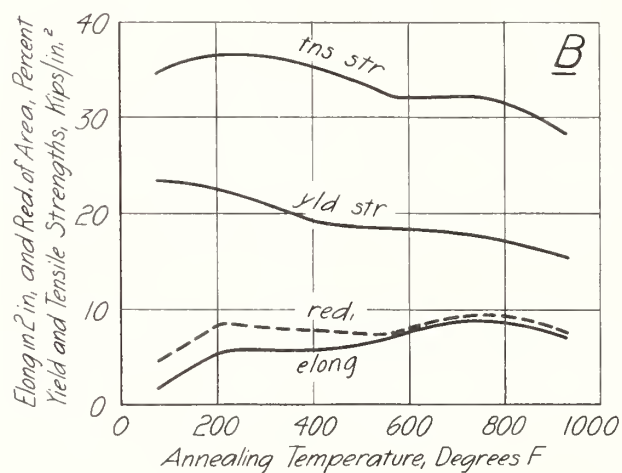
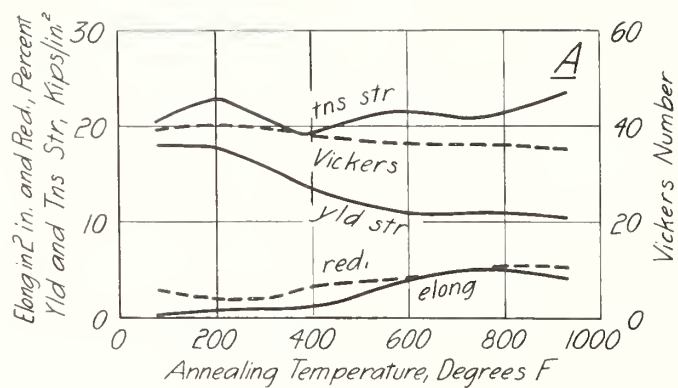


FIGURE 137.—Effect of annealing on the tensile properties and hardness of cold-rolled magnesium (Jones and Powell [681]).

(Yield strength, 0.1% perm)

Sheet, 0.064 in., cold-rolled (25% red.), annealed 1 hour.

A, Parallel to rolling direction; B, perpendicular to rolling direction.

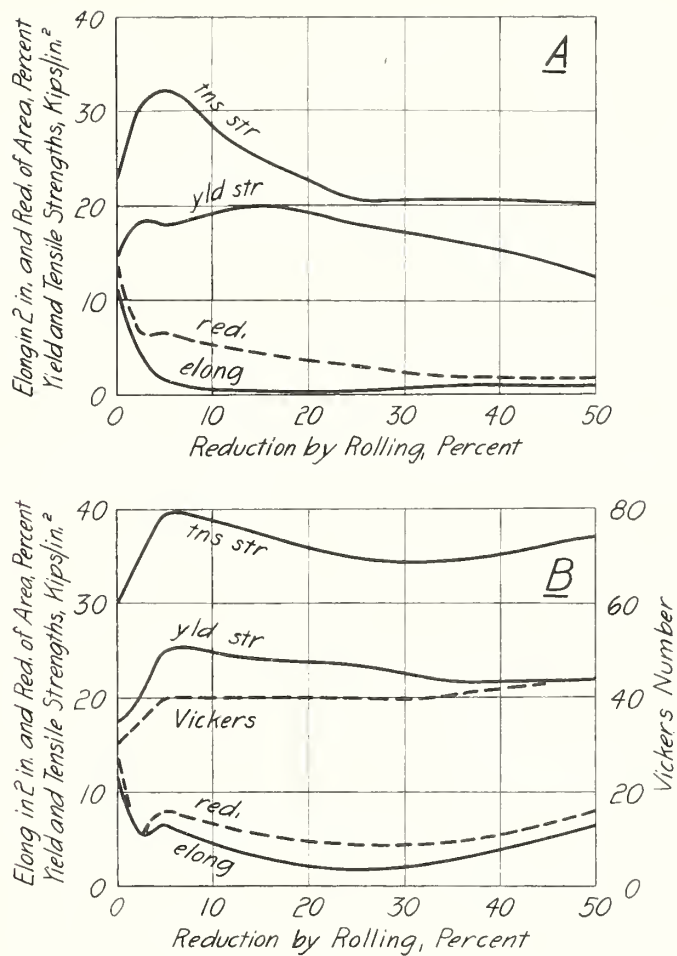


FIGURE 138.—Effect of cold-rolling on the tensile properties and hardness of magnesium (Jones and Powell [681]).

(Yield strength, 0.1% perm)

Sheet, annealed 1 1/2 hours at 840°F and cold-rolled to 0.064 in.

A, Parallel to rolling direction; B, perpendicular to rolling direction.

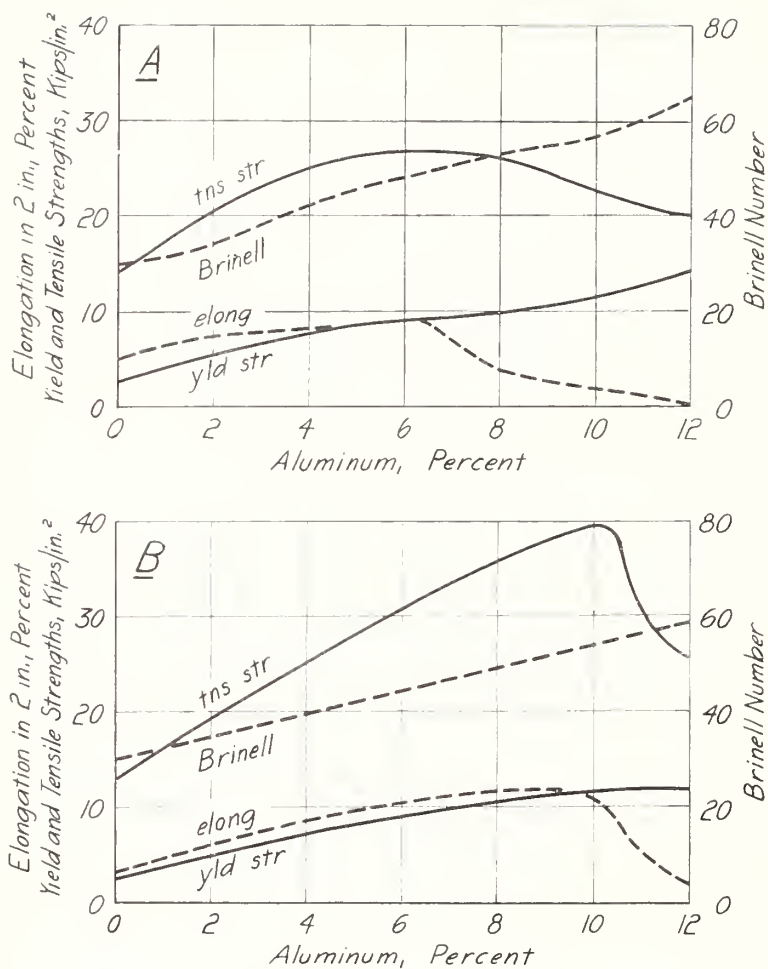


FIGURE 139.—Tensile properties and hardness of magnesium-aluminum alloys containing small amounts of manganese (Wood [882]).

(Yield strength, 0.2% offset)

Mn 0.1-0.3%. A, Sand-cast; B, sand-cast and solution heat-treated.

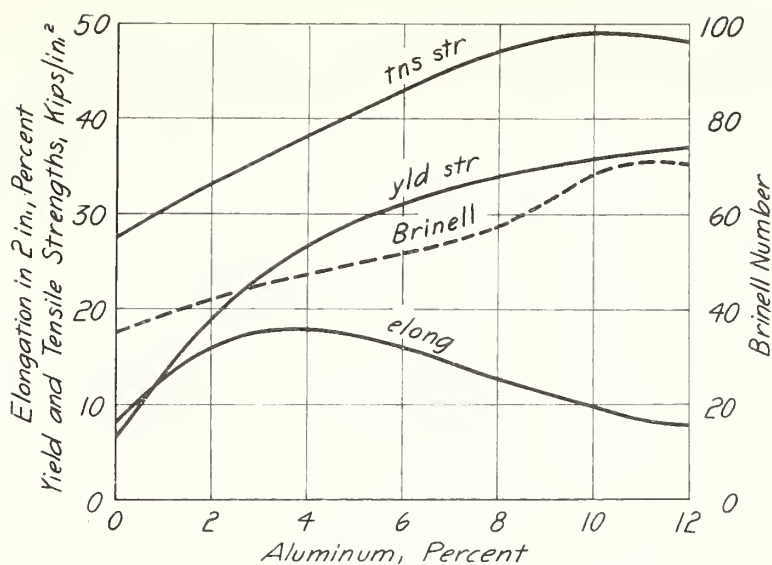


FIGURE 140.—Tensile properties and hardness of extruded magnesium-aluminum alloys containing small amounts of manganese (Wood [682]).

(Yield strength, 0.2% offset)

Mn 0.1-0.3%.

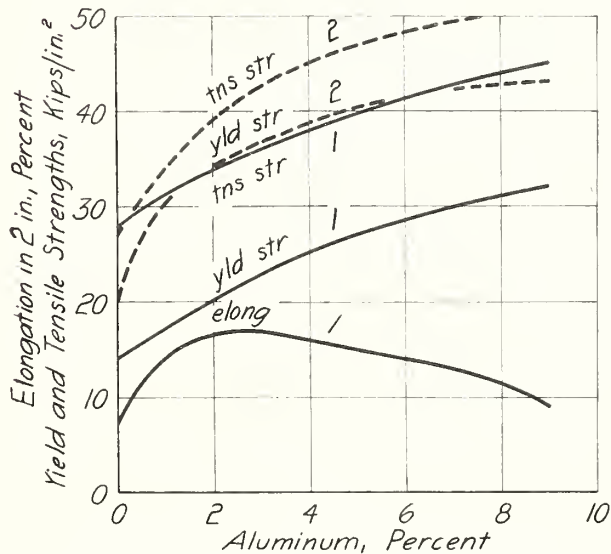


FIGURE 141.—Tensile properties of rolled magnesium-aluminum alloys (McDonald [683]).

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

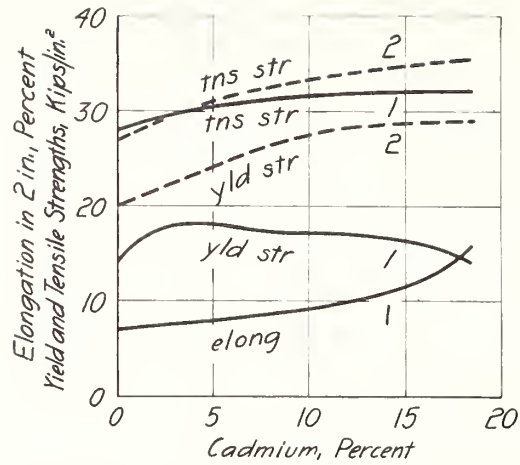


FIGURE 142.—Tensile properties of rolled magnesium-cadmium alloys (McDonald [683]).

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

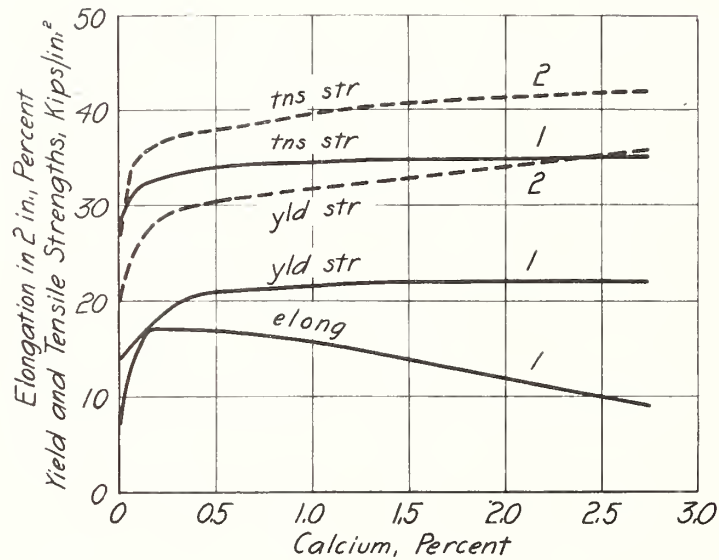


FIGURE 143.—Tensile properties of rolled magnesium-calcium alloys (McDonald [684]).

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

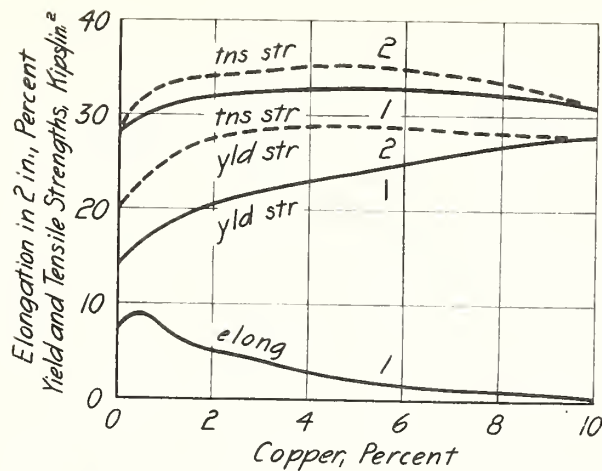


FIGURE 144.—Tensile properties of rolled magnesium-copper alloys (McDonald [683]).

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

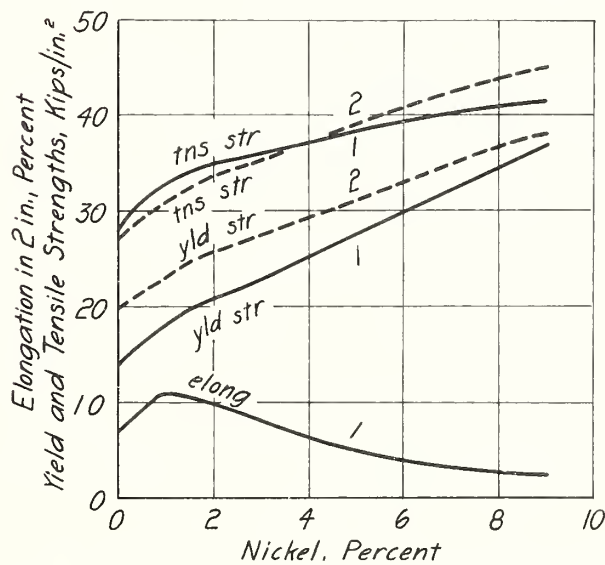


FIGURE 145.—Tensile properties of rolled magnesium-nickel alloys (McDonald [683]).

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

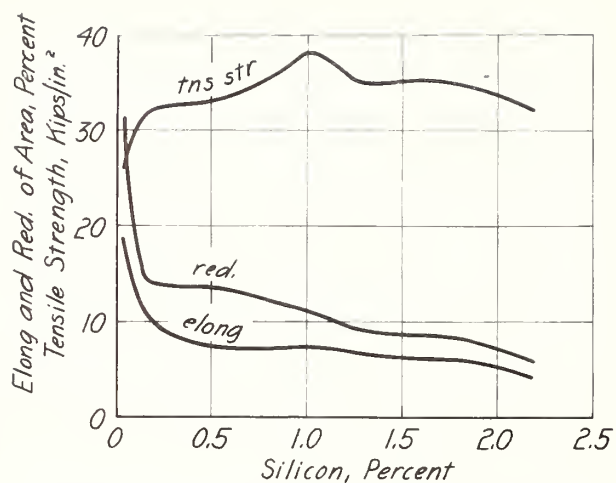


FIGURE 146.—Tensile properties of extruded magnesium-silicon alloys (Aitchison [685]).

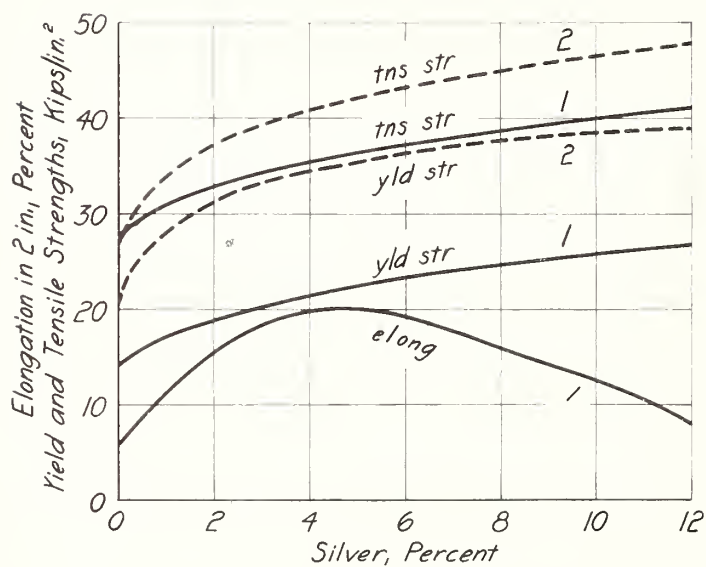


FIGURE 147.—Tensile properties of rolled-magnesium-silver alloys (McDonald [683]).

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

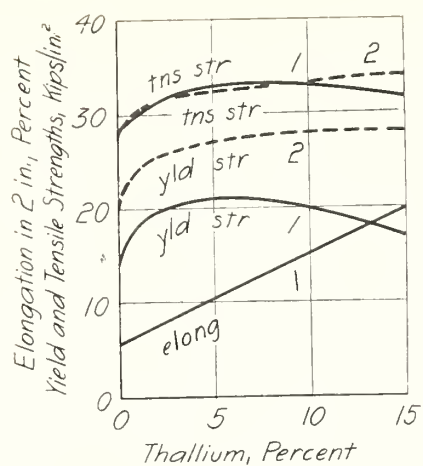


FIGURE 148.—Tensile properties of rolled magnesium-thallium alloys (McDonald [683]).

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

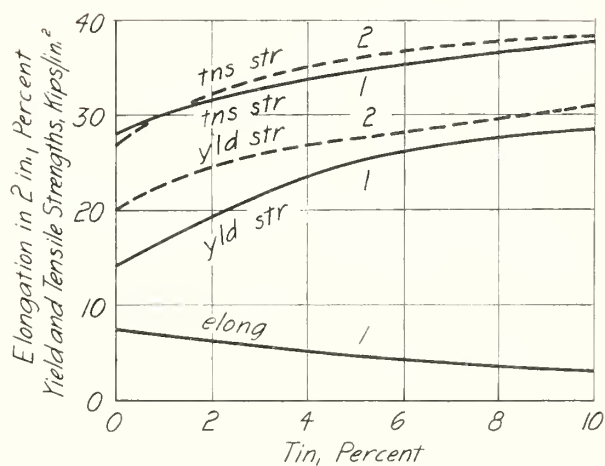


FIGURE 149.—Tensile properties of rolled magnesium-tin alloys (McDonald [683]).

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

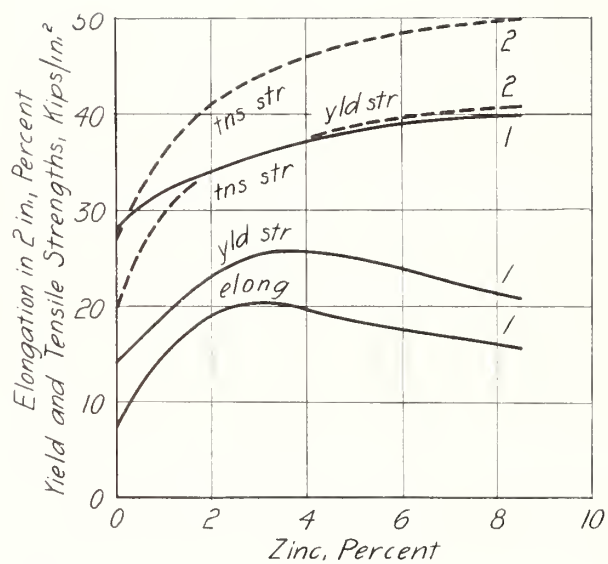


FIGURE 150.—Tensile properties of rolled magnesium-zinc alloys (McDonald [683]).

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

TABLE 37.—*Magnesium and magnesium alloys, high-temperature properties*

[For a discussion of the indefiniteness of values reported for yield strength, see page 5. See also figs. 151 to 157, inclusive.]

Serial number	Composition	Condition	Temperature	Short-time properties		Creep properties		Reference
				Yield strength (0.2%)	Tensile strength	Stress for creep rate of 0.5% per 1,000 hours	Duration	
				Ktpsi/in. ²	Ktpsi/in. ²	Ktpsi/in. ²	Hours	
3017.....	Al 3, Zn 1.....	Rod, 1/2 in. diam, sand-cast.....	302	7.6	20.4	4.9	200	[463]
3018.....	Al 4, Zn 3.....	...do.....	302	9.9	22.1	4.3	200	[463]
3019.....	Al 6, Zn 3.....	...do.....	302	11.9	23.1	2.9	200	[463]
3020.....	Al 8, Zn 0.5.....	Rod, 13/16 in. diam, die-cast.....	302	11.9	27.3	3.1	200	[463]
3021.....	Al 8.5, Zn 0.5.....	Rod, 1/2 in. diam, sand-cast; 24 hr at 715°-770°F, a-c.....	302	12.5	26.9	2.0	200	[463]
3022.....	Al 9.5, Zn 0.5.....	Rod, 13/16 in. diam, die-cast.....	302	13.2	27.6	2.9	200	[463]
3023.....	Mn 2.....	Rod, 1/2 in. diam, sand-cast.....	302	3.8	12.3	3.6	200	[463]
3024.....	Si 1.....	...do.....	302	4.7	12.3	3.4	200	[463]

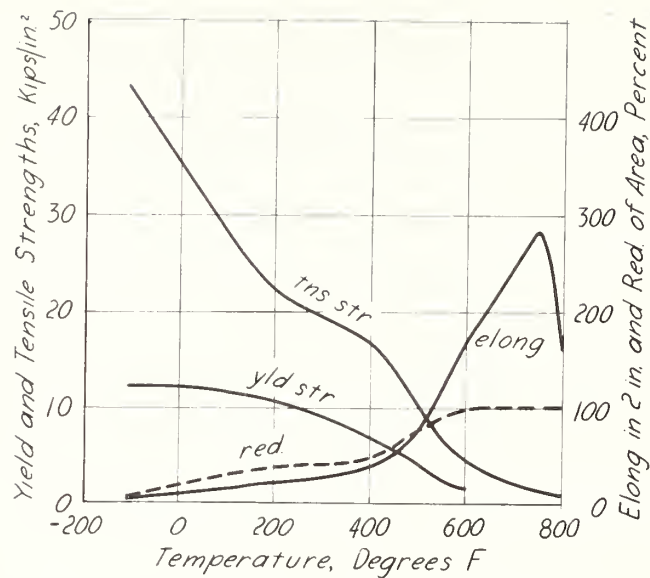


FIGURE 151.—Short-time tensile properties of extruded magnesium at various temperatures (Templin and Paul [477]).

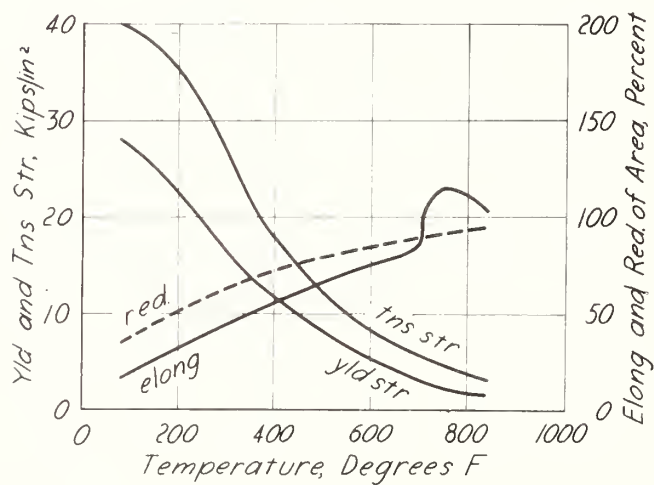


FIGURE 152.—Short-time tensile properties of an extruded magnesium-aluminum alloy at high temperatures (Templin and Paul [477]).

(Yield strength, 0.5% extn)

Al 4%, Mn 0.3%.

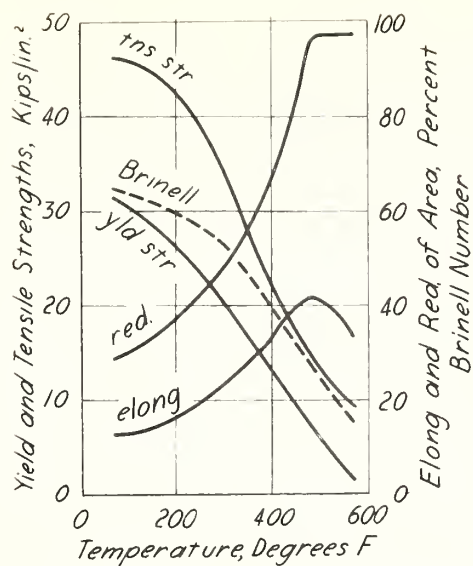


FIGURE 153.—Short-time tensile properties and hardness of a wrought magnesium-aluminum-zinc alloy at high temperatures (Vosskuhler [686]).

(Yield strength, 0.2%)
Al 6%, Zn 1%.

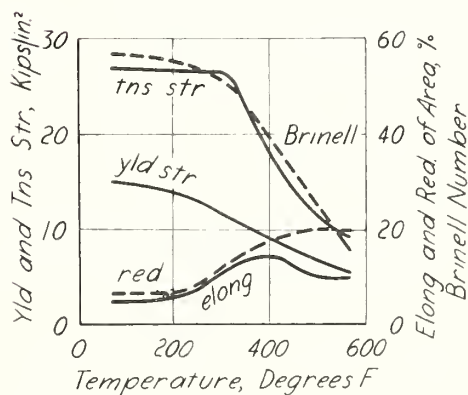


FIGURE 154.—Short-time tensile properties and hardness of a sand-cast magnesium-aluminum-zinc alloy at high temperatures (Vosskuhler [686]).

(Yield strength, 0.2%)
Al 6%, Zn 3%.

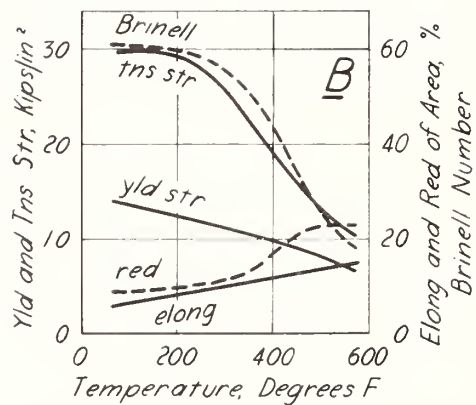
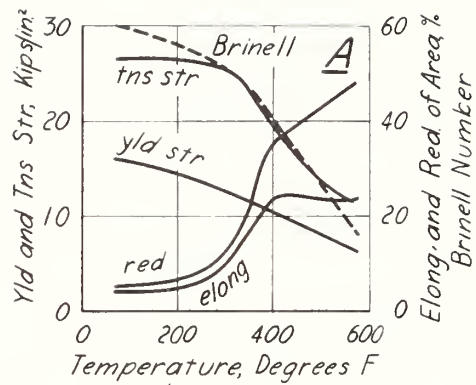


FIGURE 155.—Short-time tensile properties and hardness of a magnesium-aluminum-zinc alloy at high temperatures (Vosskuhler [686]).

(Yield strength, 0.2%)

Al 8%, Zn 0.5%. A, Sand-cast; B, die-cast.

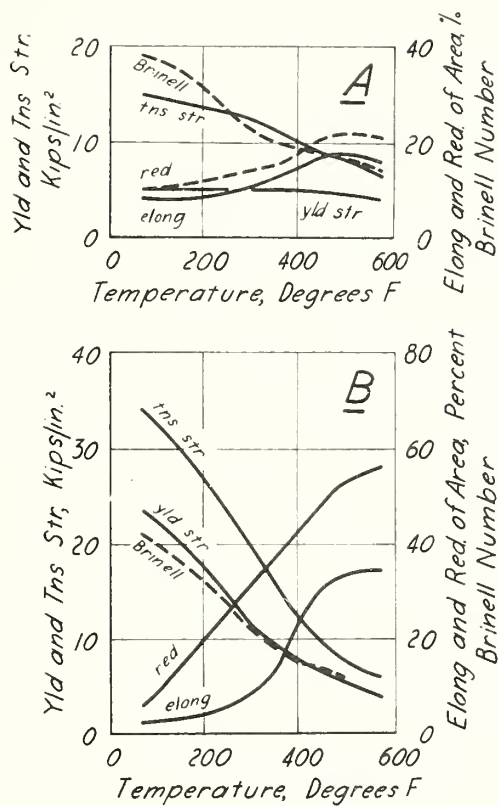


FIGURE 156.—Short-time tensile properties and hardness of a magnesium-manganese alloy at high temperatures (Vosskuhler [686]).

(Yield strength, 0.2%)

Mn 2%. A, Sand-cast; B, wrought.

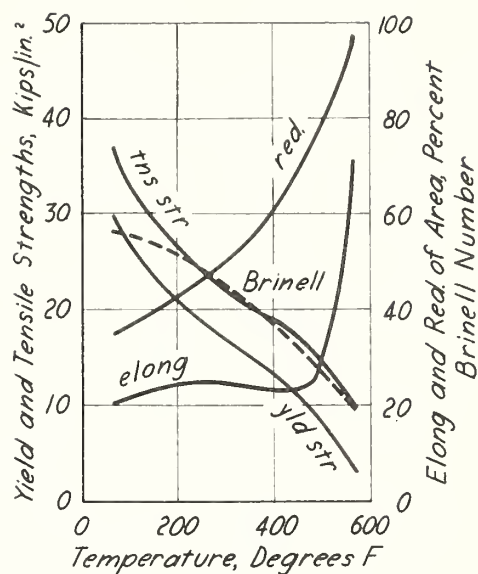


FIGURE 157.—Short-time tensile properties of a wrought magnesium-manganese-cerium alloy at high temperatures (Vosskuhler [686]).

(Yield strength, 0.2%)

Mn 2%, Ce 0.5%.

TABLE 38.—Magnesium and magnesium alloys, low-temperature properties

[For a discussion of the indefiniteness of values reported for yield strength see page 5. Hardness numbers are Brinell numbers unless prefixed R_p , R_c , etc. (Rockwell B, Rockwell C, etc.): (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed Iz (Izod method).]

Serial number	Composition	Condition	Temperature of test	Tensile properties				Hardness limit	Impact value	Remarks	Reference
				Yield strength	Tensile strength	Elongation	Reduction of area				
			$^{\circ}F$	$Kilps/in.^2$	$Kilps/in.^2$	Percent	Percent	$Kilps/in.^2$	$ft-lb$		
3025....	"Pure" Mg.	Extruded.....	$\left\{ \begin{array}{l} 75 \\ -112 \end{array} \right\}$	11.7 12.0	29.0 43.0	15 (2 in.) 7 (2 in.)	24 8	.....	.....	.....	[477]
PURE AND COMMERCIAL MAGNESIUM (SEE ALSO FIG. 151)											
MAGNESIUM-ALUMINUM ALLOYS (SEE ALSO FIG. 158)											
3026....	Al 1, Mn 0.4.....	Extruded.....	$\left\{ \begin{array}{l} 75 \\ -112 \end{array} \right\}$	17.5 (0.1% offset) 20.2 (0.1% offset)	37.7 43.1	20 (2 in.) 6.2 (2 in.)	33 5.6	.....	.....	.....	[477]
3027....	do.....	Forged.....	$\left\{ \begin{array}{l} 75 \\ -112 \end{array} \right\}$	20.3 (0.1% offset) 20.8 (0.1% offset)	34.3 38.7	6.0 (2 in.) 2.3 (2 in.)	5.7 1.7	.....	.....	.....	[477]
3028....	do.....	Chill-cast; h-t.....	$\left\{ \begin{array}{l} 75 \\ -112 \end{array} \right\}$	6.4 (0.1% offset) 7.3 (0.1% offset)	26.9 23.4	10 (2 in.) 5.5 (2 in.)	10 5.1	.....	.....	.....	[477]
3029....	Al 5.8, Zn 1.00, Mn 0.22, Fe 0.06.	Rod, 1/2 in. square, extruded at 720°F.	$\left\{ \begin{array}{l} \text{Room} \\ -40 \\ -105 \end{array} \right\}$	34.0 41.0	47.0 50.5	13 12	11-23 14-18	.....	.....	Impact specimen, Charpy bar with Izod notch.	[25]
3030....	Al 6.3, Zn 2.70, Mn 0.28, Fe 0.02.	Rod, 5/8 in. diam, sand-cast..	$\left\{ \begin{array}{l} \text{Room} \\ -105 \end{array} \right\}$	14.0 15.5	27.0	5 3	5.5 4.5	.....	.....	.....do.....	[25]
3031....	do.....	Rod, 5/8 in. diam, sand-cast; 4 hr at 630°F, 16 hr at 720°F, a-c.	$\left\{ \begin{array}{l} \text{Room} \\ -40 \\ -105 \end{array} \right\}$	14.0 17.0	35.0 37.0	8.5 8	10 10	.....	.....	.....do.....	[25]
3032....	do.....	Rod, 5/8 in. diam, sand-cast; 4 hr at 630°F, 16 hr at 715°F, hot w-4, aged 16 hr at 350°F.	$\left\{ \begin{array}{l} \text{Room} \\ -40 \\ -105 \end{array} \right\}$	22.0 24.5	39.0 35.5	3-6 2.5	5.5 3.5	.....	.....	.....do.....	[25]
3033....	Al 6.35, Zn 0.75, Mn 0.39, Si 0.06, Cu 0.04, Fe 0.03, Cd 0.02.	Bar, 3 1/2 x 4 in., forged.....	$\left\{ \begin{array}{l} \text{Room} \\ -40 \end{array} \right\}$	26.0 (0.2% offset)	46.0	12 (4 diam)	18	15.0 (3 x 10 ⁸) 18.0 (3 x 10 ⁸)	.....	.....	[31]
3034....	Al 6.5, Zn 0.8, Mn 0.20..	Forged.....	$\left\{ \begin{array}{l} \text{Room} \\ -40 \end{array} \right\}$	29.0 (0.2% offset)	43.0	8.5 (1 diam)	10	15.0 (3 x 10 ⁸) 16.0 (3 x 10 ⁸)	.....	Impact specimen 0.5 x 0.5 in. square, V-notch.	[31]
3035....	Al 6.86, Zn 0.97, Mn 0.18, Cu 0.04, Fe 0.04, Si 0.027.	Extruded.....	$\left\{ \begin{array}{l} 68 \\ -31 \\ -85 \end{array} \right\}$	33.4 (0.2%)	45.8	13 (10 diam)	.....	21.3 21.7 22.0	.....	.....	[26]

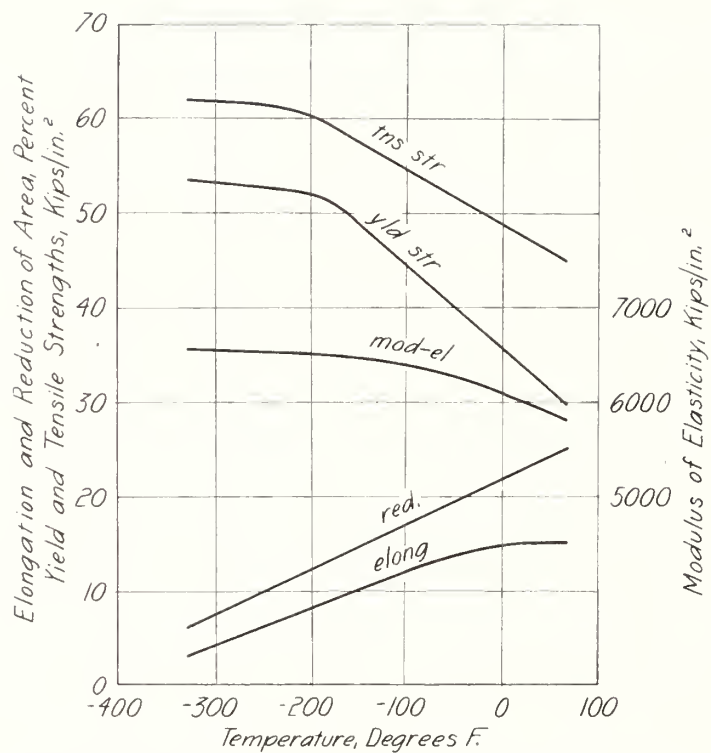


FIGURE 158.—Tensile properties of a wrought magnesium-aluminum-zinc alloy at low temperatures (Beck [463]).

(Yield strength, 0.2%; elongation in 10 diam)

Al 6%, Zn 1%.

TABLE 39.—Magnesium and magnesium alloys, thermal expansion

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade						Reference
			20° to 50°C	20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 500°C	
			× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	× 10 ⁻⁶	
3050 ^a	Fe 0.005, Cu 0.002	Cast in vacuum at 665°C.	.....	26.1	27.0	28.0	28.9	29.9	[478]
3051 ^b	Al 0.02, Fe 0.007, Si 0.004, Cu 0.002	Extruded at 425°C.	.....	26.3	26.7	27.4	28.0	29.0	[478]
3052	Al 4.10, Mn 0.27, Fe 0.025, Si 0.014, Cu 0.011	Extruded at 350°C.	24.9	25.6	26.4	27.2	27.8	28.5	[478]
3053	Al 4.36, Fe 0.018, Cu 0.007, Si 0.004	Extruded at 350°C.	25.5	26.0	26.9	27.8	28.3	28.9	[478]
3054	Al 6.26, Fe 0.026, Cu 0.008, Si 0.008	Extruded at 330°C.	26.0	26.2	27.1	27.9	28.3	28.9	[478]
3055	Al 10.35, Fe 0.040, Cu 0.016, Si 0.016	do.....	24.9	25.9	27.2	28.3	28.9	29.9	[478]
3056 ^c	Al 14.....	do.....	24.4	24.9	26.4	27.9	28.2	28.9	[479]
3057 ^d	Al 30.....	do.....	22.9	23.7	25.1	26.6	28.1	28.9	[479]
3058 ^d	Al 43.....	do.....	21.0	21.8	23.5	25.4	27.7	28.9	[479]
3059 ^d	Al 4, Cd 1, Sn 1, Zn 1	do.....	24.2	25.0	26.3	27.6	28.9	29.9	[479]
3060 ^d	Al 5, Cd 3, Zn 3, Mn 0.4	do.....	24.6	25.4	26.6	27.7	28.9	29.9	[479]
3061 ^d	Al 8.5, Cu 2, Cd 1, Zn 0.5, Mn 0.15	Sand-cast.	24.8	25.4	26.6	27.7	28.9	29.9	[479]
3062	Al 4, Zn 3	do.....	.....	26.2	27.5	28.0	28.9	29.9	[483]
3063	Al 6, Zn 3	do.....	.....	26.4	27.6	28.3	28.9	29.9	[483]
3064	Al 8.5, Zn 0.5	do.....	24.1	24.9	26.3	27.5	28.9	29.9	[479]
3065 ^e	Cd 2	do.....	24.2	25.0	26.4	27.5	28.9	29.9	[479]
3066 ^e	Cd 6	do.....	25.0	26.4	27.6	28.6	29.9	30.9	[479]
3067 ^d	Cu 2	do.....	24.8	25.2	26.4	27.6	28.6	29.9	[479]
3068 ^e	Cu 6	do.....	23.7	24.7	26.1	27.3	28.4	29.9	[479]
3069 ^e	Cu 10	do.....	24.0	24.7	26.1	27.4	28.4	29.9	[479]
3070 ^e	Cu 4, Al 2, Cd 2, Mn 0.2	do.....	26.0	26.3	27.2	27.9	28.9	29.9	[478]
3071	Mn 0.91, Fe 0.020, Al 0.01, Si 0.004, Cu 0.003	Cast at 670°C.	24.0	24.7	26.4	27.6	28.9	29.9	[479]
3072 ^d	Ni 2	do.....	24.0	24.6	25.9	26.9	28.9	29.9	[479]
3073 ^d	Ni 6	Sand-cast.	24.0	24.6	25.9	26.9	28.9	29.9	[479]
3074	Si 1	Cast.	.....	25.2	26.1	27.6	28.9	29.9	[483]
3075	Si 2	do.....	.....	25.7	26.7	27.6	28.9	29.9	[483]
3076	Si 6	do.....	.....	25.7	26.7	27.6	28.9	29.9	[483]
3077 ^d	Si 10	do.....	.....	22.6	23.6	24.6	25.6	26.6	[483]
3078 ^d	Ag 2	do.....	24.4	25.1	26.4	27.4	28.9	29.9	[479]
3079 ^d	Ag 6	do.....	24.2	24.9	26.1	27.4	28.9	29.9	[479]
3080 ^e	Sn 4.7	Annealed.	25.0	25.1	25.8	26.9	28.0	29.0	[480]
3081 ^e	Sn 9.1	do.....	26.2	25.5	26.1	26.1	26.1	26.1	[480]
3082 ^e	Sn 13.1	do.....	24.4	24.0	24.8	24.9	24.8	24.8	[480]
3083 ^e	Sn 20.4	do.....	25.2	24.3	24.8	24.7	24.4	24.4	[480]
3084 ^e	Sn 35.2	do.....	22.1	22.6	22.8	22.5	21.6	21.1	[480]
3085 ^e	Sn 46.3	do.....	21.2	21.1	21.3	21.3	20.7	20.1	[480]
3086 ^e	Zn 2	do.....	24.7	25.5	26.9	28.2	29.1	30.1	[479]
3087 ^d	Zn 4, Cu 0.5	do.....	25.0	25.8	27.1	28.1	28.9	29.9	[479]
3088 ^d	Zn 6	do.....	24.7	25.2	26.7	27.8	28.9	29.9	[479]
3089	Zn 12	Cast and h-t.	.....	26.0	26.7	27.8	28.9	29.9	[483]
3090	Zn 15	do.....	.....	25.7	26.7	27.8	28.9	29.9	[483]
3091 ^d	Zn 20	do.....	.....	25.7	26.7	27.8	28.9	29.9	[481]
3092 ^d	Zn 50	do.....	.....	30.2	31.2	32.2	33.2	34.2	[481]

^a -100° to 20°C = 24.9.^b -183° to 20°C = 21.3; -100° to 20°C = 23.2.^c 20° to 250°C.^d Base temperature 0° instead of 20°C.^e Base temperature 30° instead of 20°C.^f 30° to 550°C.^g Base temperature 40° instead of 20°C.

TABLE 41.—Magnesium and magnesium alloys, electrical and thermal properties

Serial number	Composition	Condition	Electrical properties				Thermal conductivity	Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity			
3093	Mg.....	.....	Percent IACS.....	Microhm cm.....	$per\ ^\circ C \times 10^{-4}$ { 10 (20°C) 50 (25°C) 15 (100°C) 35 (500°C) 100 (600°C) }	$Watts\ cm^{-1}\ ^\circ C^{-1}$ { 1.57 (18°C) }	[161]	
3094	...do.....	.....	{ 44.1 (0°C) 39.9 (18°C) 31.0 (100°C) 21.7 (203°C) 16.3 (325°C) 13.1 (455°C) }	3.91 (0°C) 4.33 (18°C) 5.55 (100°C) 7.27 (203°C) 10.6 (325°C) 13.2 (455°C)	.....	{ 1.72 (0°C) 1.60 (18°C) 1.67 (100°C) 1.63 (203°C) 1.29 (325°C) 1.31 (455°C) }	{ [182] }	
3095	Commercial Mg.....	Cast.....	38.4-39.5 (20°C)	4.39-4.49 (20°C)	.....	.....	[463]	
3096	...do.....	Extruded.....	37.5-38.9 (20°C)	4.43-4.60 (20°C)	.....	.....	[463]	
3097	...do.....	rolled.....	36.1-38.3 (20°C)	4.50-4.77 (20°C)	.....	.....	[463]	
3098	Al 1, Zn 3.....	Sand-cast.....	16.1-16.4	10.5-10.7	14.7-15.4 (0°-100°C)	0.94	[473]	
3099	Al 6.....	Die-cast.....	.....	.....	.....	{ .69 (-100°C) .80 (0°C) .90 (100°C) .97 (200°C) }	{ [463] }	
3100	...do.....	3 hr at 300°C.....	.....	.....	.....	{ .75 (100°C) 75 (200°C) .77 (300°C) }	{ [463] }	
3101	Al 8.5, Zn 0.5.....	Sand-cast; 24 hr at 380°-410°C, a-c.....	10.1-11.0	15.7-17.1	7.4-8.3 (0°-100°C)	.77	[463]	
3102	...do.....	Sand-cast; 24 hr at 380°-410°C, a-c, 10 hr at 150°C, a-c.....	13.1	13.2	11.3 (0°-100°C)	.92	[463]	
3103	Al 9.5, Zn 0.5.....	Die-cast.....	10.8	15.9	8.5 (0°-100°C)	.80	[463]	
3104	Al 12.....	Die-cast.....	.....	.....	.....	{ .45 (-100°C) .49 (0°C) .68 (100°C) .75 (200°C) }	{ [463] }	
3105	Ca 2.82.....	Rod, 9/16 in. diam, hot-forged.....	{ 35.5 (20°C) 32.2 (50°C) 24.5 (150°C) 19.8 (250°C) }	4.85 (20°C) 5.35 (50°C) 7.05 (150°C) 8.7 (250°C)	.....	{ 1.40 (50°C) 1.42 (150°C) 1.42 (250°C) }	{ [482] }	
3106	Ce 3.17, Mn 1.8.....	...do.....	{ 27.6 (20°C) 25.4 (50°C) 20.3 (150°C) 16.8 (250°C) }	6.25 (20°C) 6.8 (50°C) 8.5 (150°C) 10.2 (250°C)	.....	{ 1.17 (50°C) 1.21 (150°C) 1.23 (250°C) }	{ [482] }	
3107	Ce 9, Co 3, Mn 0.5.....	...do.....	{ 28.3 (20°C) 25.9 (50°C) 20.3 (150°C) 16.6 (250°C) }	6.1 (20°C) 6.65 (50°C) 8.5 (150°C) 10.4 (250°C)	.....	{ 1.17 (50°C) 1.21 (150°C) 1.26 (250°C) }	{ [482] }	
3108	Co 2.4, Ce 2.2, Mn 1.6.....	...do.....	{ 32.2 (20°C) 29.2 (50°C) 22.2 (150°C) 17.9 (250°C) }	5.35 (20°C) 5.9 (50°C) 7.8 (150°C) 9.6 (250°C)	.....	{ 1.32 (50°C) 1.32 (150°C) 1.32 (250°C) }	{ [482] }	
3109	Cu 1.....	3 hr at 300°C.....	.....	.....	.....	1.28 (100°C)	[463]	
3110	Cu 3.....	...do.....	.....	.....	.....	1.46 (100°C)	[463]	
3111	Cu 8.....	Die-cast.....	.....	.....	.....	{ 1.05 (-100°C) 1.25 (0°C) 1.30 (100°C) }	{ [463] }	

3112.....	Cu 13.....	3 hr at 300°C.....	.....	.....	.....	.....	1.30 (100°C)	[463]
3113.....	Cu 15.....	Die-cast.....	.....	.....	.....	.....	1.52 (-100°C) 1.54 (0°C) 1.65 (200°C)	[463]
3114.....	Pb 2.5.....	.....	.....	.....	.....	.....	.....	[463]
3115.....	Pb 9.9.....	.....	.....	.....	.....	.....	.....	[463]
3116.....	Mn 2.64.....	Rod, 9/16 in. diam, hot-forged.....	.....	.....	.....	.....	.....	[482]
3117.....	Mn 3.5.....	Die-cast.....	.....	.....	.....	.....	.....	[463]
3118.....	Ni 2.....	Vacuum ann.....	.....	.....	.....	.....	.....	[463]
3119.....	Ni 5.36, Ce 2.65.....	Rod, 9/16 in. diam, hot-forged.....	.....	.....	.....	.....	.....	[482]
3120.....	Ni 5.56.....	..do.....	.....	.....	.....	.....	.....	[482]
3121.....	Si 1.....	Sand-cast.....	.....	.....	.....	.....	.....	[463]
3122.....	Si 1.25.....	.....	.....	.....	.....	.....	.....	[463]
3123.....	Si 3.7.....	.....	.....	.....	.....	.....	.....	[463]
3124.....	Ag 2.2.....	Vacuum ann.....	.....	.....	.....	.....	.....	[463]
3125.....	Ag 2.5.....	.....	.....	.....	.....	.....	.....	[463]
3126.....	Ag 6.....	Vacuum ann.....	.....	.....	.....	.....	.....	[463]
3127.....	Ag 7.7.....	.....	.....	.....	.....	.....	.....	[463]
3128.....	Sn 2.2.....	Vacuum ann.....	.....	.....	.....	.....	.....	[463]
3129.....	Sn 6.4.....	..do.....	.....	.....	.....	.....	.....	[463]
3130.....	Zn 2.1.....	.....	.....	.....	.....	.....	.....	[463]
3131.....	Zn 2.2.....	Vacuum ann.....	.....	.....	.....	.....	.....	[463]
3132.....	Zn 6.1.....	.....	.....	.....	.....	.....	.....	[463]
3133.....	Zn 6.2.....	.....	.....	.....	.....	.....	.....	[463]
3134.....	Zn 9.0.....	.....	.....	.....	.....	.....	.....	[463]

X. NICKEL AND NICKEL ALLOYS

(347)

TABLE 41.—Classification of some nickel alloys (1942)

[Specifications are changing frequently, the sponsoring organization should be consulted for the latest revision.]

Designation				Nominal composition, percent										Serial numbers of corresponding alloys in the tables
Federal		ASTM		Commercial										
Spec	Alloy	Spec	Alloy	Ni ^a	Cu	Fe	Mn	C	Si	S	Cr	Al		
WROUGHT ALLOYS														
.....		B160-4HT...	.....	Nickel.....	99.4	0.1	0.15	0.2	0.1	0.05	0.005	.....	3136 to 3145, inclusive; 3242 to 3245, inclusive; 3310; figures 159, 160, 161, 162, 167.	
.....				"D" nickel.....	95.2	.05	.15	4.5	.1	.05	.005	.....	3216, 3217, 3304, 3346; figure 161.	
A	B164-4HT...	A	.....	Monel.....	67	30	1.4	1.0	.15	.1	.1	.....	3180, 3181, 3182, 3201, 3202, 3203, 3241, 3251, 3253, 3257, 3290, 3332; figures 166 and 170.	
B	B164-4HT...	B	.....	"R" monel.....	67	30	1.7	1.1	.1	.05	.035	.....	3198, 3199, 3200.	
Q-Q-N-281...				"K" monel.....	66	29	0.9	0.85	.15	.5	.005	2.75	3195, 3196, 3197, 3288, 3330, 3331; figure 171.	
Q-Q-N-286...				"KR" monel.....	66	29	.9	.85	.3	.5	.005	2.75	3256.	
.....		B166-4HT...	.....	Inconel.....	79.5	0.2	6.5	.25	.08	.25	.015	13	3158 to 3167, inclusive; 3247, 3248, 3267, 3320, 3321.	
.....		B82-41...	.....	Resistance alloy...	78	.....	b ¹ .0	b ² .5	b ¹ .0	b ¹ .0	b ¹ .030	20	3178, 3169, 3170, 3236, ^d 3250, 3269, 3271, 3325 and 3326; figures 178 and 169.	
.....		B83-41...	.....	Resistance alloy...	^c 57	.....	rem	b ³ .0	b ² .25	b ¹ .0	b ¹ .030	16	^d 3249, 3336, 3340, 3341.	
.....				Alumel ^f	94	.....	0.5	2.5	.....	1.0	.....	2.0	3312 and 3313.	
.....				Chromel P ^e	90	.....	.....	.....	.....	.....	.....	10	3157, 3286, 3318, 3319.	
.....				Constantan ^f	45	55	.....	.....	.....	.....	.....	.....	722 to 728, inclusive (copper section).	
CAST ALLOYS														
.....				Nickel.....	96.7	0.3	0.5	0.5	0.5	1.5	0.01	.....	3229, 3346.	
.....				Monel.....	67	29	1.5	.9	.3	1.25	.015	.....	3184, 3254.	
.....				"H" monel.....	65	29.5	1.5	.9	.1	3.0	.015	.....	3190, 3255.	
.....				"S" monel.....	63	30	2.0	.9	.1	4.0	.015	.....	3194, 3291.	
.....				Inconel.....	77.75	0.25	6.0	.25	.25	2.0	.01	13.5	.....	
.....				Resistance alloy...	^c 57	.....	rem	b ³ .0	b ² .25	b ¹ .0	b ¹ .030	16	^d 3206, ^e 3268.	

^aIncludes small amount of cobalt.^bMaximum.^cMinimum.^dApproximate composition.^eThermocouple material.

TABLE 42.—*Nickel and nickel alloys, normal-temperature properties*

[For a discussion of the indefiniteness of values reported for yield strength and particularly for "proportional limit" see pages 5 and 6. Hardness numbers are Brinell numbers unless prefixed R_B , R_C , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Wickers). Impact value determined by Charpy method unless prefixed Iz (Izod method).]

Serial number	Composition	Condition	Tensile properties						Endurance limit	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
			Kt./in. ²	Kt./in. ²	Kt./in. ²	Kt./in. ²	Percent	Percent	Kt./in. ²	ft.-lb.		
PURE AND COMMERCIAL NICKEL (SEE ALSO FIGS. 159 TO 162 INCLUSIVE)												
3135..	Percent Ni 99.99.....	Unheated electro wire, 0.063 in. diam; ann 28 hr in hydrogen at >2,000°F, cold-drawn (50% red.), ann 1/2 hr at 1,400°F.	.....	4.5	8.5 (0.2% offset)	46.0	28 (2 in.)	.....	.....	.....	.....	[484]
3136..	Fe 0.14, Mn 0.13, C 0.09, Cu 0.07, Si 0.03, S 0.005.	Rod, 1 in. diam, hot-rolled.	.....	.....	20.0 (0.01% offset) 24.0 (0.2% offset)	71.0	44 (2 in.)	63	.....	200	Comp yld str (0.01%).....18.8 kips/in. ² .. Comp yld str (0.2%).....23.2 kips/in. ² ..	[485]
3137..	...do.....	Rod, 7/8 in. diam, cold-drawn (24% red.); stress-relief ann 3 hr at 575°F.	.....	.....	56.4 (0.01% offset) 62.0 (0.2% offset)	86.6	33 (2 in.)	72	.....	204	Comp yld str (0.01%).....14.8 kips/in. ² .. Comp yld str (0.2%).....58.1 kips/in. ² ..	[485]
3138..	Mn 0.20, Fe 0.15, C 0.10, Cu 0.10, Si 0.05, S 0.005.	Cold-drawn; ann 3 hr at 1,450°F, f-c.	30,000	.....	27 (0.2% offset)	73	42 (2 in.)	80	.....	.....	Comp yld str (0.01%).....17 kips/in. ² .. Comp yld str (0.2%).....26 kips/in. ² ..	[483]
3139..	Mn 0.20, Fe 0.15, Cu 0.10, Si 0.05, C 0.02, S 0.005.	Sheet and strip, ann.	.....	.....	20 (0.2% offset)	65	45 (2 in.)	.....	.....	.....	.....	[483]
3140..	Ni + Co 99.4.....	Wrought.....	30,000	.....	.....	.....	.....	.....	.....	.....	.....	[483]
3141..	Fe 0.40, Cu 0.16, C 0.10, Si 0.06, Mn 0.05, S 0.005.	Rod, hot-rolled.....	30,900	22.8	33.4 (yld pnt)	77.2	44 (2 in.)	60	.....	.....	Mod-el (shear).....11,000 kips/in. ² .. Specific gravity.....8.85.	[486]
3142..	...do.....	Rod, ann 4 hr at 1,400°F.	31,100	19.7	26.8 (yld pnt)	76.8	48 (2 in.)	76	.....	.....	Mod-el (shear).....11,300 kips/in. ² .. Poisson's ratio.....0.359.	[131]
3143..	Co 0.48, Fe 0.22, Mn 0.14, Si 0.14, Cu 0.09.	Sheet, 0.020 in., soft	22,600	12.0	.....	72.0	40 (2 in.)	.....	25.0 (10 ⁶)	.....	.....	[131]
3144..	...do.....	Sheet, 0.020 in., rolled (37% red.).	27,000	51.5	.....	114	2.3 (2 in.)	.....	34.5 (10 ⁶)	.....	.....	[20]
3145..	...do.....	Sheet, 0.020 in., rolled (60% red.).	30,300	52.0	.....	122	2.0 (2 in.)	.....	40.5 (10 ⁶)	.....	.....	[20]
3146..	Fe 0.50, C 0.25, S 0.18, Cu 0.12, Mn 0.10, Si 0.06.	Cold-rolled; stress-relief ann 1 hr at 550°F, f-c.	.....	59.0	104 (0.01% perm)	166	14 (2 in.)	22	40.0	.....	Shear str.....94.9 kips/in. ² ..	[93]
3147..	Si 0.53, Fe 0.46, Co 0.34, Mn 0.30, C 0.29, Cu 0.23, S 0.01	Bar, 1 3/8 in., hot-rolled.	.....	40.0	47.5 (yld pnt)	96.0	47 (2 in.)	52	.....	1z 116	.....	[487]
3148..	...do.....	Bar, 3/4 in. diam, forged.	.....	47.5	61.5 (yld pnt)	104	42 (2 in.)	56	.....	.....	.....	[487]
3149..	...do.....	Bar, 3/4 in. diam, ann at 1,900°F.	.....	16.5	46.0 (yld pnt)	92.0	48 (2 in.)	60	.....	.....	.....	[487]

3150.	Nickel.....	30,000	.....	.....	.....	.....	.....	.....	Mod-el (shear) Poisson's ratio.....	[183]
NICKEL-ALUMINUM ALLOYS										
3151..	Al 2.83, C 0.11, Mn 0.11, Si 0.11, Fe 0.07.	Rod, 7/8 in. diam, hot-rolled; annealed at 1,650°F., slowly cooled.	30,000	20.2	32.9 (0.01% offset)	81.5 (4 $\sqrt{\text{area}}$)	38 (4 $\sqrt{\text{area}}$)	.....	.....	[24]
3152..	Al 1.75, Mn 0.26, C 0.17, Fe 0.07, Si 0.05.	do.....	30,000	13.4	26.7 (0.01% offset)	87.6 (4 $\sqrt{\text{area}}$)	43 (4 $\sqrt{\text{area}}$)	.....	.....	[24]
NICKEL-BERYLLIUM ALLOYS										
3153..	Be 2.0,.....	quenched.....	24,000	.....	52.0	114 (2 in.)	38 (2 in.)	.....	.....	[111]
3154..	do.....	quenched; aged 5 hr at 895°F.	26,000	.....	142	101 (2 in.)	8.4 (2 in.)	.....	.....	[111]
3155..	do.....	Cold-rolled (50% red.)	25,000	.....	144	179 (2 in.)	4.1 (2 in.)	.....	.....	[111]
3156..	do.....	Cold-rolled; b-t.....	27,000	.....	228	270 (2 in.)	8.8 (2 in.)	.....	.....	[111]
NICKEL-CHROMIUM ALLOYS (SEE ALSO FIG. 163)										
3157..	Chromel P; Cr 10, Ni 80, Cr 13, Fe rem.	wrought.....	31,000	.....	.....	80	30	.....	.....	[2]
3158..	do.....	Sheet, annealed.....	31,000	.....	.....	78.4	.....	.....	.....	[489]
3159..	do.....	Sheet, half-hard.....	31,000	.....	.....	98.6	.....	.....	.....	[489]
3160..	do.....	Sheet, hard.....	31,000	.....	.....	152	.....	.....	.....	[489]
3161..	do.....	Rod, 1/2 to 1 in. diam, hot-rolled.	.....	.....	.....	96	.....	.....	.....	[183]
3162..	do.....	Rod, 1/2 to 1 in. diam, cold-drawn.	.....	.....	.....	140	.....	.....	.....	[183]
3163..	Cr 13.01, Fe 5.46, Si 0.17, Mn 0.11, Cu 0.10, C 0.06, S 0.005.	Rod, 1 in. diam, hot- rolled.	.....	.....	.....	91.2	42 (2 in.)	.....	.....	[185]
3164..	do.....	Rod, 7/8 in. diam, cold-drawn (24% red); stress-relieved annealed at 575°F.	.....	.....	.....	122	19 (2 in.)	.....	.....	[185]
3165..	do.....	Rod, 7/8 in. diam, cold-drawn; annealed at 1,750°F.	.....	.....	.....	93.2	42 (2 in.)	.....	.....	[185]
3166..	Cr 13.6, Fe 5.7, Mn 0.12, C 0.04.	Annealed.....	.....	.....	.....	102	40 (2 in.)	.....	.....	[17]
3167..	do.....	Cold-drawn.....	.....	.....	.....	178	7 (2 in.)	.....	.....	[17]

TABLE 42.—Nickel and nickel alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation				
			kips/in. ²	kips/in. ²	kips/in. ²	kips/in. ²	Percent (1/4 in.)				
NICKEL-CHROMIUM ALLOYS—Continued											
3168..	Percent Cr 19.04, Fe 0.88, Cu 0.13, Si 0.10, C 0.09, Mg 0.05, S 0.012.	Rod, 1 in. diam, hot-rolled.	31,800	49.3	.....	113	Percent 41 (1/4 in.)	.....	ft.-lb.	.....	[24]
3169..	Cr 20.....	Wrought.....	31,000	.....	63.0 (yld pt)	110	30 (10 in.)	.....	.....	Specific gravity.....8.4..... Melting point.....2,552°F.	[192]
3170..	...do.....	Rollled, ann.....	31,700	49.3	.....	112	40 (1/4 in.)	55	33.6	.....	[51]
3171..	Cr 21, Fe 8, Mo 5, Cu 3, Mn 1.2, Si 0.6, C 0.1.	Hot-rolled, ann.....	27,500	.....	50 (0.2% offset)	100	32 (2 in.)	.....	130	Mod-el (shear).....9,000 kips/in. ² .. Melting point.....2,375°F. Specific gravity.....8.31.	[463]
NICKEL-COBALT ALLOYS											
3172..	Co 17.3, Fe 6.25, Ti 2.22.	Forged, 1 hr at 1,740°F, a-c.	.....	20.0	30.5 (0.2%)	93.1	50 (2 in.)	70	.....	.....	[304]
3173..	...do.....	23 hr at 1,650°F, quenched.	.....	31.2	51.0 (0.2%)	102	37 (2 in.)	50	.....	.....	[304]
3174..	...do.....	1 hr at 1,740°F, w-q, aged 72 hr at 1,200°F.	.....	27.5	58.0 (0.2%)	108	35 (2 in.)	60	.....	.....	[304]
3175..	Co 24.86, Cr 18.74, Fe 1.39, Ti 2.13.	Wrought; 2 hr at 1,740°F, w-q, aged 72 hr at 1,200°F.	29,000	70.0	104 (0.2% perm)	165	29 (2 in.)	37	.....	.....	[710]
3176..	Co 29.50, Cr 9.16, Fe 8.4, Ti 2.1.	1 hr at 1,740°F, w-q, aged 72 hr at 1,200°F.	.....	52.5	99.0 (0.2%)	160	27 (2 in.)	43	.....	.....	[304]
NICKEL-COPPER ALLOYS (SEE ALSO FIGS. 164, 165, AND 166)											
3177..	Cu 21.28, Fe 1.40, C 0.26, Mn 0.26, Si 0.065, P 0.023, S 0.006.	Cold-rolled.....	.....	.....	.....	86.3	29 (2 in.)	57	29.0 (10°)	.....	[36]
3178..	Cu 26.23, Mn 4.31, Fe 1.39, Si 0.40, C 0.20, S 0.028, P 0.024.	Hot-rolled.....	.....	.....	27.5 (0.01% perm)	91.6	48 (2 in.)	66	39.0	Shear str.....55.8 kips/in. ²	[93]
3179..	...do.....	Hot-rolled; ann 1 hr at 1,600°F, f-c.	.....	29.0	35.0 (0.01% perm)	86.8	49 (2 in.)	70	37.8	Shear str.....60.0 kips/in. ²	[93]
3180..	Cu 30.0, Fe 1.4, Mn 1.0, C 0.15, Si 0.10, S 0.01.	Hot-rolled.....	.....	.....	41 (0.2% offset)	84	40 (2 in.)	68	.....	Comp yld str (0.2%).....38 kips/in. ²	[463]
3181..	...do.....	Cold-drawn; stress-relief ann at 525°F.	.....	.....	87 (0.2% offset)	97	27 (2 in.)	96	200	Comp yld str (0.2%).....81 kips/in. ²	[463]

3182..	...do.....	Cold-drawn; ann 3 hr at 1,450°F, f-c.	.....	.....	.....	33 (0.2% offset)	78	41 (2 in.)	66	.....	125	.....	Comp yld str (0.2%).....28 kips/in. ²	[483]
3183..	Cu 28.89, Fe 1.87, Mn 0.52, Si 0.42, Ti 0.36, C 0.18.	Cast.....	.....	.....	.....	42.2 (yld pnt)	91.2	40 (2 in.)	.....	.....	179	Iz 43	.....	[144]
3184..	Cu 29, Fe 1.5, Si 1.25, Mn 0.90, C 0.20, S <0.015.	Sand-cast.....	26,000	.....	.....	35.0 (0.2% offset)	70.0	30 (2 in.)	.....	.....	140	70	Specific gravity.....8.80..... Melting range.....2,400°-2,500°F.	[493]
3185..	Cu 29.0, Be 0.81..	Rollad; w-q from 1,875°F.	.....	33.9	.....	.....	62.6	17	38	.....	130	.....	.....	[494]
3186..	...do.....	Rollad; quenched from 1,875°F, aged 1 hr at 860°F.	.....	107	.....	.....	136	6.6	8.7	.....	310	.....	.....	[494]
3187..	Cu 29.24, Al 3.80, Fe 1.57, Mn 0.38, C 0.18, Si 0.001.	Sheet, 0.020 in., ann.	.....	.....	.....	.....	86.3	38 (2 in.)	.....	25.8 (10 ⁶)	.....	.....	.....	[20]
3188..	...do.....	Sheet, 0.020 in., h-t.	27,700	74.0	.....	.....	153	11 (2 in.)	.....	37.0 (10 ⁶)	R ₀ 102	.....	.....	[20]
3189..	Cu 29.37, Si 1.85, Fe 0.56.	Sheet, 0.018 in.....	29,300	48.5	.....	.....	144	2.7 (2 in.)	.....	37.0 (10 ⁶)	R ₀ 90	.....	.....	[20]
3190..	Cu 29.5, Si 3.0, Fe 1.5, Mn 0.5, C 0.1, S <0.015.	Sand-cast.....	26,000	.....	.....	50 (0.2% offset)	85	15 (2 in.)	.....	.....	190	40	Specific gravity.....8.65..... Melting range.....2,300°-2,400°F.	[495]
3191..	Cu 29.82, Fe 1.62, Mn 1.06, S 0.026.	Sheet, 0.020 in., soft	23,800	21.4	.....	.....	73.7	40 (2 in.)	.....	24.5 (10 ⁶)	R ₀ 25	.....	.....	[20]
3192..	...do.....	Sheet, 0.020 in., rolled (44% red.).	27,300	45.6	.....	.....	116	3.0 (2 in.)	.....	39.5 (10 ⁶)	R ₀ 79	.....	.....	[20]
3193..	...do.....	Sheet, 0.020 in., rolled (56% red.).	25,400	58.2	.....	.....	123	1.7 (2 in.)	.....	37.8 (10 ⁶)	R _B 82	.....	.....	[20]
3194..	Cu 30.0, Si 1.0, Fe 2.0, Mn 0.5, C 0.1, S <0.015.	Sand-cast.....	26,000	.....	.....	90 (0.2% offset)	110	2 (2 in.)	.....	.....	300	4	Specific gravity.....8.50..... Melting range.....2,250°-2,350°F.	[495]
3195..	Cu 30.05, Al 3.22, Fe 0.78, Mn 0.45, Si 0.33, C 0.19, S 0.006.	Rod, 1 in. diam, hot- rolled; w-q from 1,450°F.	.....	.....	.....	41.0 (0.01% offset) 47.0 (0.2% offset)	99.9	42 (2 in.)	64	.....	163	170	Comp yld str (0.01%).....31.0 kips/in. ² Comp yld str (0.2%).....40.4 kips/in. ²	[485]
3196..	...do.....	Rod, 7/8 in. diam, cold-drawn (24% red.); stress-relief ann 3 hr at 575°F.	.....	.....	.....	72.4 (0.01% offset) 85.0 (0.2% offset)	106	26 (2 in.)	50	.....	207	71	Comp yld str (0.01%).....55.4 kips/in. ² Comp yld str (0.2%).....75.6 kips/in. ²	[455]
3197..	...do.....	Rod, 7/8 in. diam, cold-drawn (24% red); aged 10 hr at 1,050°F, f-c.	.....	.....	.....	103 (0.01% offset) 120 (0.2% offset)	158	22 (2 in.)	38	.....	329	42	Comp yld str (0.01%).....102 kips/in. ² Comp yld str (0.2%).....121 kips/in. ²	[485]
3198..	Cu 31.13, Fe 1.13, Mn 1.04, C 0.06, S 0.011, Si 0.01.	Rod, 1 in. diam, hot- rolled.	.....	.....	.....	33.0 (0.01% offset) 35.6 (0.2% offset)	75.6	40 (2 in.)	69	.....	121	187	Comp yld str (0.01%).....26.4 kips/in. ² Comp yld str (0.2%).....33.5 kips/in. ²	[455]
3199..	...do.....	Rod, 7/8 in. diam, cold-drawn (24% red.); stress-relief ann 3 hr at 575°F.	.....	.....	.....	62.0 (0.01% offset) 74.4 (0.2% offset)	83.2	28 (2 in.)	67	.....	180	140	Comp yld str (0.01%).....51.4 kips/in. ² Comp yld str (0.2%).....66.0 kips/in. ²	[485]
3200..	...do.....	Rod, 7/8 in. diam, cold-drawn; ann 3 hr at 1,450°F.	.....	.....	.....	24.8 (0.01% offset) 28.0 (0.2% offset)	73.4	41 (2 in.)	70	.....	116	196	Comp yld str (0.01%).....22.6 kips/in. ² Comp yld str (0.2%).....25.6 kips/in. ²	[485]

TABLE 1.—Nickel and nickel alloys, normal-temperature properties—

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Ref-er-ence	
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation					Reduction of area
NICKEL-COPPER ALLOYS—(Continued)												
3201..	Percent Cu 31.31, Mn 0.90, Fe 0.83, C 0.19, Si 0.04, S 0.007.	Rod, 1 in. diam, hot-rolled.	.....	Kpsi/in. ²	Kpsi/in. ² { 36.6 (0.01% offset) 40.6 (0.2% offset)	Kpsi/in. ² { 83.5 (2 in.) 97.2 (2 in.)	Percent 40 (2 in.) 27 (2 in.)	.....	115	232	Comp yld str (0.01%).....33.0 kpsi/in. ² Comp yld str (0.2%).....36.0 kpsi/in. ²	[485]
3202..	do.....	Rod, 7/8 in. diam, cold-drawn (2½ hr at 575°F); stress-relief ann 3 hr at 575°F.	.....	.....	{ 75.0 (0.01% offset) 96.6 (0.2% offset)	{ 97.2 (2 in.) 101.2 (2 in.)	66 (2 in.)	.....	199	151	Comp yld str (0.01%).....58.0 kpsi/in. ² Comp yld str (0.2%).....60.8 kpsi/in. ²	[485]
3203..	do.....	Rod, 7/8 in. diam, cold-drawn; ann 4 hr at 1,150°F.	.....	.....	{ 27.6 (0.01% offset) 33.4 (0.2% offset)	{ 78.1 (2 in.) 83.5 (2 in.)	44 (2 in.)	56	123	200	Comp yld str (0.01%).....19.2 kpsi/in. ² Comp yld str (0.2%).....26.2 kpsi/in. ²	[485]
3204..	Cu 44.18, Fe 0.44, Mn 0.36, C 0.016, S 0.009, P 0.006, Si 0.002.	Hot-rolled.....	.....	17.3	23.3 (0.01% perm)	65.4 (2 in.)	47 (2 in.)	78	83	.....	Shear str.....47.5 kpsi/in. ²	[93]
3205..	do.....	Hot-rolled; ann 1 hr at 1,500°F, 1-h.	.....	14.5	20.3 (0.01% perm)	62.1 (2 in.)	50 (2 in.)	75	83	.....	Shear str.....47.1 kpsi/in. ²	[93]
3206..	Cu 44.28, Fe 0.34, Mn 0.20, C 0.04, Si 0.02, S 0.005.	Rod, 1 in. diam, hot-rolled.	26,900	13.5	29.8 (yld pt)	55.8 (2 in.)	46 (2 in.)	79	R _B 58	.....	Mod-el (shear).....1,700 kpsi/in. ² Poisson's ratio.....0.357.	[131]
3207..	do.....	Rod, 1 in. diam, ann 4 hr at 1,400°F.	26,800	14.2	25.6 (yld pt)	64.2 (2 in.)	46 (2 in.)	79	R _B 52	.....	Mod-el (shear).....9,400 kpsi/in. ² Poisson's ratio.....0.357.	[131]
NICKEL-IRON ALLOYS												
3208..	Ni 60, Cr 12, Fe rem.	Cast.....	.....	47.0	.....	60.0 (2 in.)	2.0 (2 in.)	.....	190	.....	Specific gravity.....8.36.	[488]
3209..	Ni 60, Cr 12, Si 1.5, C 0.50, Fe rem.	.....	.....	.....	56.0 (yld pt)	111 (2 in.)	33 (2 in.)	47	185	12 ft ²	.....	[287]
3210..	Ni 60, Cr 15, Mo 7, Fe 0.6-1.0, Fe rem.	Quenched.....	22,100	.....	59.4 (yld pt)	125 (4 in.)	39 (4 in.)	.....	195	.....	Specific gravity.....8.3.	[494]
3211..	do.....	Quenched, h-t.....	22,900	.....	70.1 (yld pt)	132 (4 in.)	23 (4 in.)	.....	320	.....	.....	[494]
3212..	do.....	Hard-rolled.....	24,000	.....	199 (yld pt)	213 (4 in.)	2.0 (4 in.)	.....	320	.....	.....	[494]
3213..	do.....	Hot-rolled; h-t.....	26,300	.....	213 (yld pt)	263 (4 in.)	5.0 (4 in.)	.....	430	.....	.....	[494]
NICKEL-MANGANESE ALLOYS (SFF ALSO F.H. 161)												
3214..	Mn 1.89, Fe 0.52, Cu 0.18, C 0.11, Si 0.05, S 0.005.	Rod, hot-rolled.....	31,900	25.7	31.4 (yld pt)	81.8 (2 in.)	16 (2 in.)	61	R _B 69	.....	Mod-el (shear).....11,100 kpsi/in. ² Poisson's ratio.....0.356.	[131]
3215..	do.....	Rod, ann 4 hr at 1,400°F.	31,600	22.0	27.5 (yld pt)	80.7 (2 in.)	50 (2 in.)	74	R _B 63	.....	Mod-el (shear).....11,400 kpsi/in. ² Poisson's ratio.....0.356.	[131]

3216..	Mn 4.63, Fe 0.56, Cu 0.18, C 0.11, Si 0.05, S 0.005.	Hot, hot-rolled.....	32,300	31.4	58.6	86.5	40	53	.....	R ₅ 77	.....	Mod-el (shear) Poisson's ratio.....	10,600 kips/in. ² , 0.339.	[131]
3217..	do.....	Hot, anneal 4 hr at 1,400°F.	31,500	25.8	32.6	95.8	49	72	.....	R ₅ 68	.....	Mod-el (shear) Poisson's ratio.....	10,900 kips/in. ² , 0.339.	[131]
3218..	Mn 15.00, Fe 0.25, Si 0.20, C 0.12, Cu 0.10, S 0.005.	Hot, 1 in. diam, hot- rolled.	.....	.....	38.0 (yld pnt)	95.0	38 (2 in.)	60	.....	175	.....	Torsion str.....	71.0 kips/in. ²	[496]

NICKEL-MOLYBDENUM ALLOYS

3219..	Mo 17, Cr 15, Fe 8.	Cast.....	28,500	.....	45-48 (yld pnt)	72-80	10-15 (2 in.)	11-13	.....	175-215	.....	Specific gravity.....	8.44.....	[497]
3220..	Mo 17, Cr 14, Fe 6, W 5.	do.....	.....	.....	42-47	55-79	3-11	5-15	.....	250	.....	Specific gravity.....	8.94.....	[491]
3221..	Mo 20, Fe 20.....	do.....	27,000	.....	42-45 (yld pnt)	69-78	8-12 (2 in.)	16-18	.....	175-240	Iz 25-35	Melting range.....	2,318°-2,381°F.	[497]
3222..	do.....	Hot-rolled; annealed.	27,000	.....	47-52 (yld pnt)	110-120	40-48 (2 in.)	40-51	.....	200-215	Iz 62-77	Specific gravity.....	8.80.....	[497]
3223..	Mo 28, Fe 7 (Electrolytic Ni and Fe powders, sintered 24 hr at 2,350°F in hydrogen.	Mixed powders; com- pacted at 30 tons/in. ² , sintered 24 hr at 2,350°F in hydrogen.	.....	.....	.....	87.0	20	12	.....	R ₅ 68	.....	Friction.....	10-11 mm.....	[497]
3224..	Mo 28, Fe 7 (Re- duced oxide powders, -325 mesh).	do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Density.....	8.16 g/cm ³	[289]
3225..	Mo 30, Fe 5.....	Cast.....	30,800	.....	55-57 (yld pnt)	75-82	6-9 (2 in.)	10-13	.....	190-230	Iz 11-16	Specific gravity.....	9.24.....	[497]
3226..	do.....	Hot-rolled; annealed.	30,800	.....	60-65 (yld pnt)	130-140	3-14 (2 in.)	10-15	.....	210-235	Iz 68-78	Friction.....	10-11 mm.....	[497]

NICKEL-RHODIUM ALLOY

3227..	Rh 43.....	Hot.....	.....	112	.....	174	2.2 (2 in.)	.....	.....	.....	.....	.....	.....	[499]
3228..	do.....	Annealed.....	.....	37.6	.....	98.0	52 (2 in.)	.....	.....	V 165	.....	.....	.....	[499]

NICKEL-SILICON ALLOYS

3229..	Si 1.25, Fe 0.50, Mn 0.50, C 0.25, Mg 0.1, S 0.01.	Sand-cast.....	30,000	.....	21.0 (0.2° offset)	75.0	22 (2 in.)	.....	.....	120	60	Specific gravity.....	8.85.....	[500]
3230..	Si 10, Cu 3.....	Cast.....	25,800	.....	.....	36-40.5 (2 in.)	0	0	.....	R ₅ 50-55	.....	Melting range.....	2,550°-2,650°F.	[498]

NICKEL-TANTALUM ALLOYS

3231..	Ta 0.37, Fe 0.12..	Hot, 1 in. square, annealed 1 hr at 1,740°F, f-c.	.....	14.0	26.2 (0.2° offset)	70.8	50 (2 in.)	.....	.....	.....	.....	.....	.....	[24]
3232..	Fe 5.14, Fe 0.95..	do.....	.....	24.0	34.3 (0.2° offset)	87.1	47 (2 in.)	.....	.....	.....	.....	.....	.....	[24]

NICKEL-ZIRCONIUM ALLOY

3233..	Zr 1.51, Fe 0.04..	Hot, 1 in. square, annealed 1 hr at 1,740°F, f-c.		13.0	27.6 (0.2° offset)	79.3	36 (2 in.)							[24]
--------	--------------------	--	-------	------	-----------------------	------	---------------	-------	-------	-------	-------	-------	-------	------

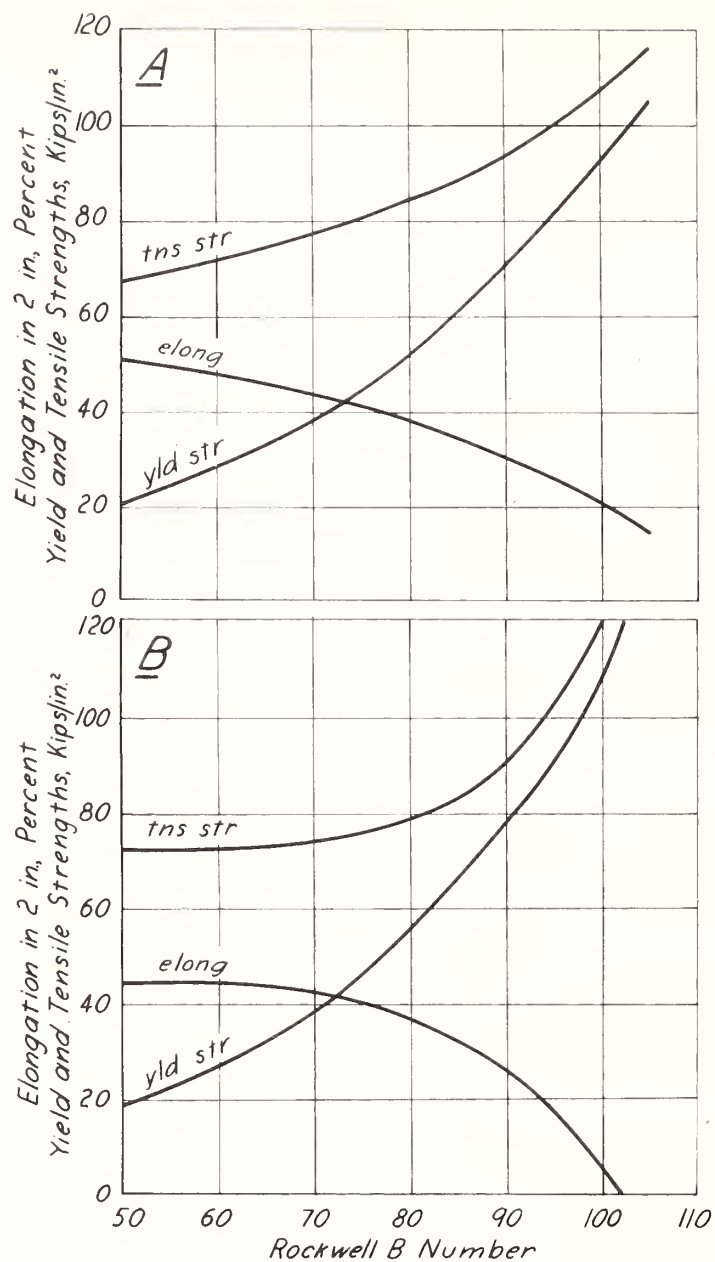


FIGURE 159.—Relation between Rockwell number and tensile properties for commercially pure nickel [687]).

(Yield strength, 0.2%)

A, Rod, hot-rolled and cold-drawn; B, sheet and strip, cold-rolled.

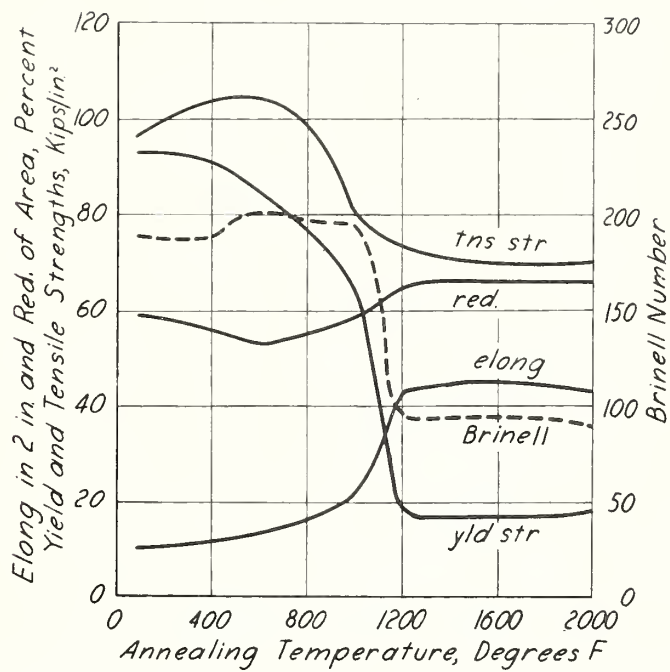


FIGURE 160.—Effect of annealing on the tensile properties and hardness of cold-drawn nickel (Mochel [487]).

Co 0.39%, Cu 0.17%, Mn 0.16%, Fe 0.128%, C 0.10%,
Si 0.026%, P 0.011%. Rod, 7/8 in. diameter.

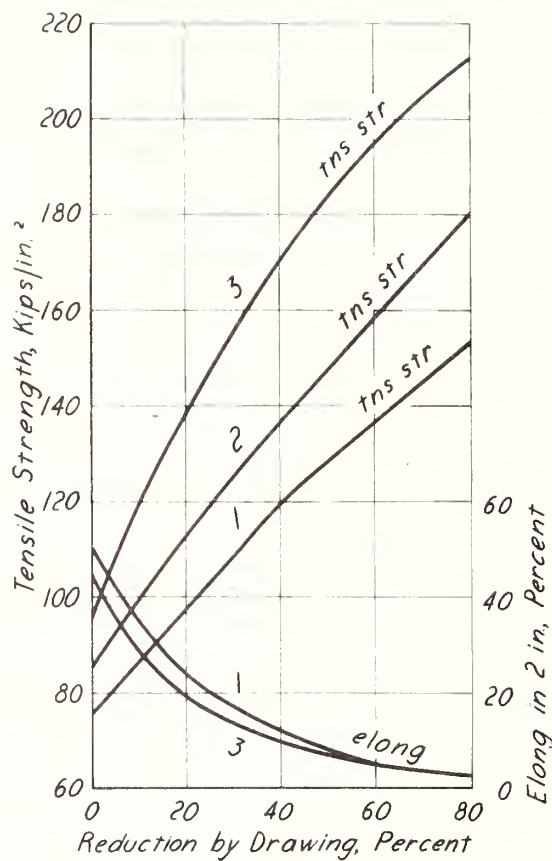


FIGURE 161.—Effect of cold-drawing on the tensile properties of nickel and nickel-manganese alloys (Hudge [496]).

Curves: 1, Fe 0.20%, Mn 0.15%, C 0.10%, Si 0.07%, Cu 0.05%, S 0.005%; 2, Mn 4.65%, Fe 0.20%, Cu 0.10%, C 0.10%, Si 0.10%, S 0.005%; 3, Mn 15.00%, Fe 0.25%, Si 0.20%, C 0.12%, Cu 0.10%, S 0.005%.

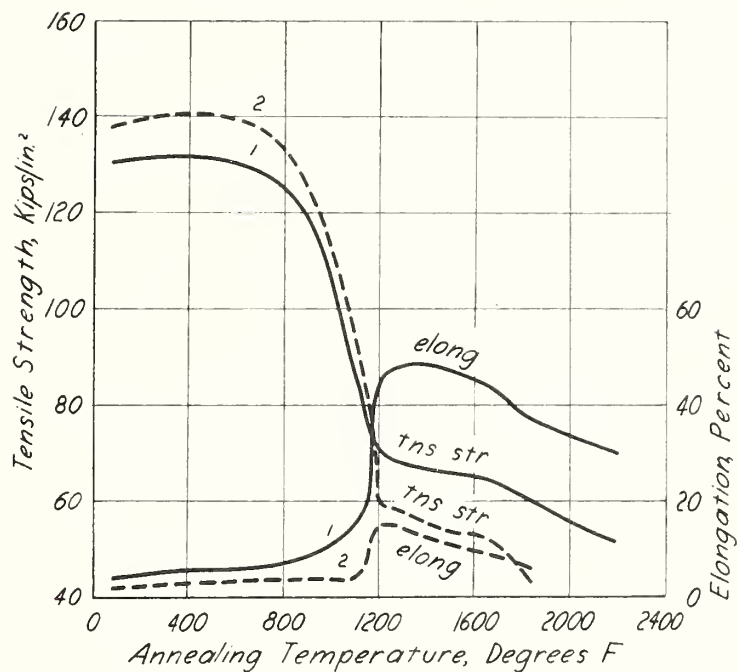


FIGURE 162.—Effect of annealing on the tensile properties of hard-drawn commercial nickel wire (Ransley and Smithells [688]).

(Elongation in 1.6 in.)

Co 0.45%, Si 0.24%, Fe 0.22%, Mn 0.21%, Mg 0.09%, C 0.036%, S 0.033%. Cold-drawn (75% red.), annealed 5 minutes in hydrogen.

Curves: 1, 0.0148-in.-diameter wire; 2, 0.0017-in.-diameter wire.

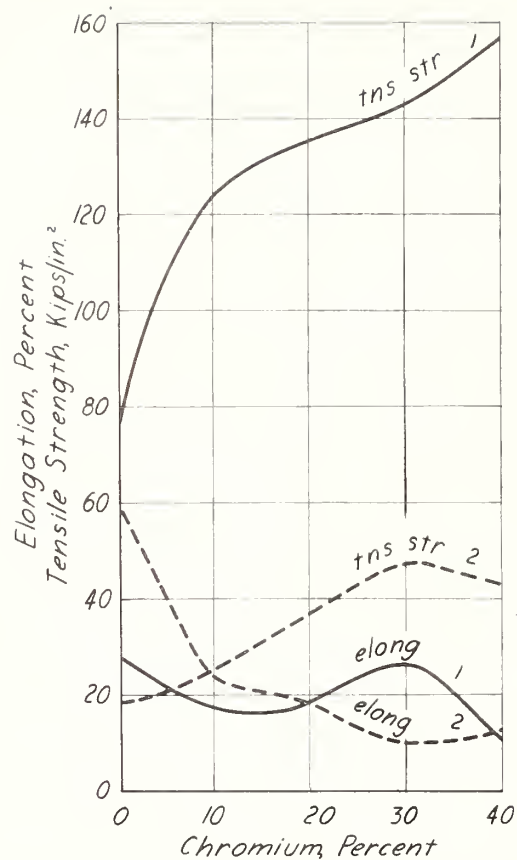


FIGURE 163.—Tensile properties of wrought nickel-chromium alloys at normal and high temperatures (Jenkins, Tapsell, Austin, and Rees [689]).

Rod, 1/2 in. diameter, hot-rolled at 2,280°-2,190°F from 1 1/4 in. diameter.

Curves: 1, tested at room temperature;
2, tested at 1,470°F.

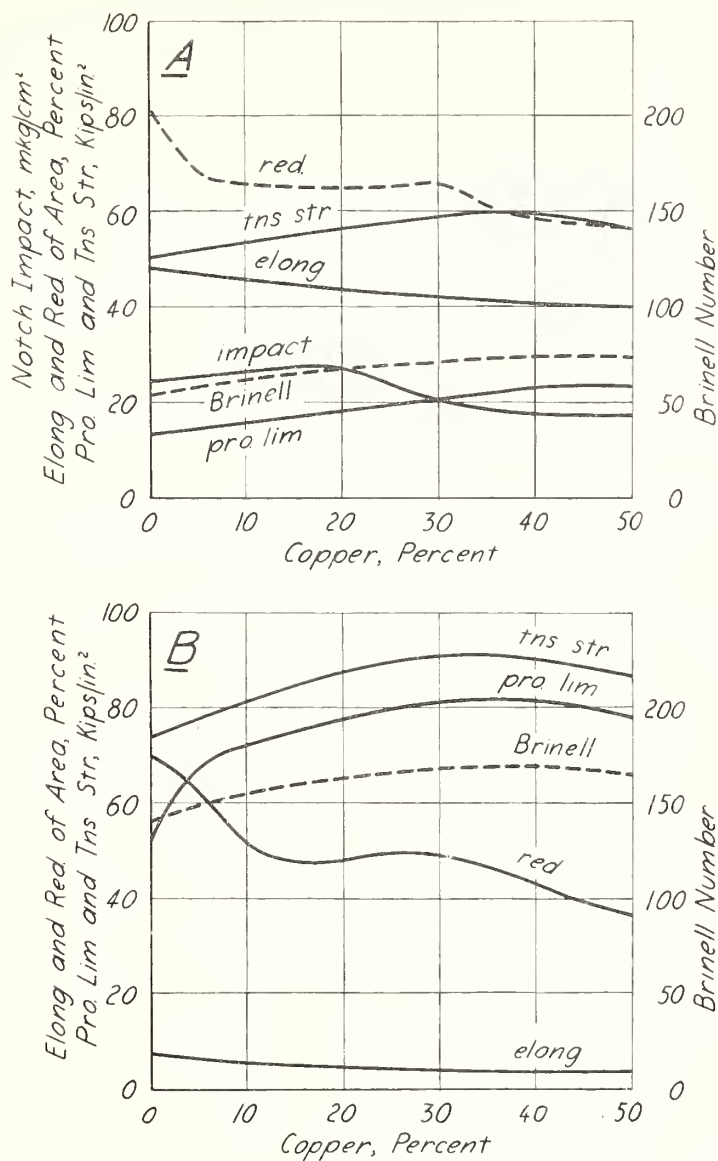


FIGURE 164.—Tensile properties, impact value, and hardness of wrought nickel-copper alloys (Broniewski and Kulesza [648]).

(Elongation in 10 diam)

A, Annealed 1/4 hour at 1,020°F; impact tests on samples forged at 2,010°-1,470°F; B, cold-worked (40% red.).

NOTE: These tests were made on samples from small experimental melts and the properties are somewhat different from those of commercial alloys. See figure 165.

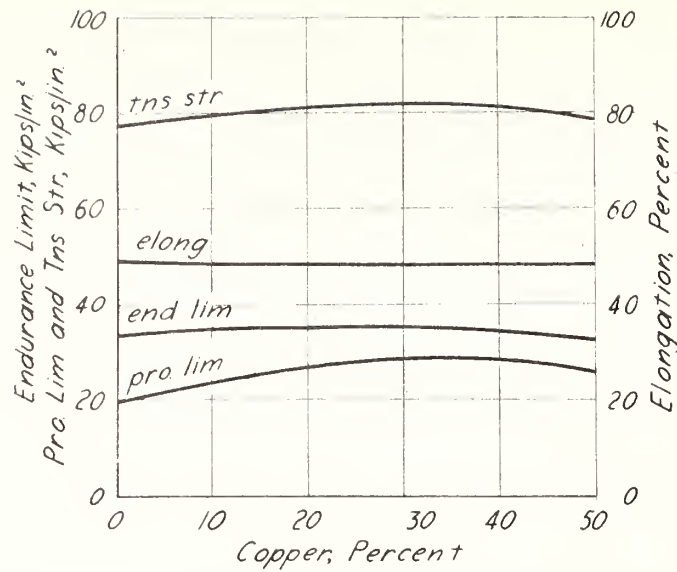


FIGURE 165.—Tensile properties and endurance limit of wrought, annealed commercial nickel-copper alloys (Wise [849]).

(Endurance limit at 10^8 cycles)

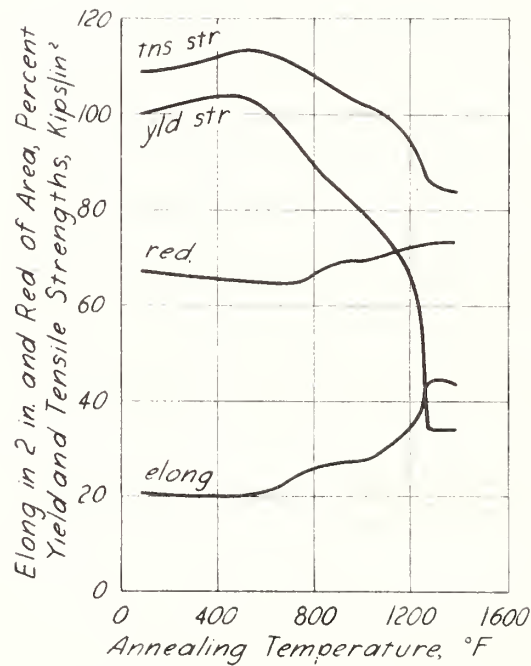


FIGURE 166.—Effect of annealing on the tensile properties of a cold-drawn nickel-copper alloy (Mudge [691]).

(Yield strength, 0.5% extn)

Cu 30%, Fe 1.4%, Mn 1.0%, C 0.15%, Si 0.10%,
S 0.01%.

Rod, 1 1/2 in. diameter, cold-drawn (20% red.), annealed 3 hours.

TABLE 43.—Nickel and nickel alloys, high-temperature properties

[For a discussion of the indefiniteness of values reported for yield strength and particularly for "proportional limit", see pages 5 and 6. Hardness numbers are Brinell numbers unless prefixed H_V , H_C , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). See also figs. 127 and 167 to 173, inclusive.]

Serial number	Composition	Condition	Temperature	Short time properties					Hardness number	Creep properties			Duration	Reference
				"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area		Stress (kips./in. ²) for designated creep rate per 1,000 hours	Strain (kips./in. ²) for designated creep rate per 1,000 hours			
3234....	Percent Fe 0.56, Cu 0.18, C 0.07, Mn 0.03, Si 0.01.	Rod, 7/8 in. diam, hot-rolled.....	70	24.4	41.0 (yld pnt)	70.0	48 (2 in.)	78	156	0.01%	0.1%	1.0%		[53]
			300	23.8	38.6 (yld pnt)	68.3	47 (2 in.)	77	.....	.....	.....	.....		
			550	29.5	38.0 (yld pnt)	69.8	46 (2 in.)	73	.....	.....	.....	.....		
			800	17.5	30.2 (yld pnt)	53.4	52 (2 in.)	70	.....	.....	20.0 (0.25%)	.....	250	
			1,000	14.0	23.4 (yld pnt)	38.7	30 (2 in.)	34	.....	.....	10.0 (0.28%)	.....	500	
			1,200	6.0	15.5 (yld pnt)	27.1	32 (2 in.)	34	.....	.....	.....	.....	.....	
3235....	Ni 58.16, Cr 12.25, Mn 2.37, W 2.05, Si 0.78, C 0.27, P 0.020, S 0.018, Fe rem.	Rod, 3/4 in. diam, rolled.....	70	77.5	103 (yld pnt)	136	18 (2 in.)	35	243					[63]
			800	67.0	91.5 (yld pnt)	118	15 (2 in.)	24	.....	.....	.....	.....	.....	
			1,000	50.0	83.0 (yld pnt)	111	16 (2 in.)	24	.....	.....	.....	.....	.....	
			1,100	.....	.....	.....	.....	.....	.....	10.0 (0.033%)	.....	.....	250	
			1,200	.....	42.5 (yld pnt)	89.5	16 (2 in.)	28	.....	.....	.....	.....	.....	
			1,300	.....	.....	.....	.....	.....	.....	.....	3.0 (0.074%)	.....	500	
3236....	Cr 20.....	Rod, 2/16 in. diam, wrought; 1/4 hr at 1,740°F in hydrogen, a-c.	1,400		31.5 (yld pnt)	58.7	20 (2 in.)	29				3.0 (0.07%)	250	[363]
			1,600	.....	17.0 (yld pnt)	29.8	22 (2 in.)	35	.....	.....	.....	.....	.....	
3237....	Co 17, Fe 7.5, Ti 2.5.....	do.....	1,112								9.0 (0.08%)		250	[363]
3238....	Co 35, Cr 19, Fe 7.5, Ti 2.5.	do.....	1,172								2.25 (0.5%)		250	[363]
3239....	Co 35, Cr 20, Fe 7.....	do.....	1,292								4.0 (0.33%)	6.0 (1.51%)	250	[363]
3240....	Co 25, W 19, Fe 7.5, Ti 2.5.	do.....	1,112								8.0 (0.027)		250	[363]
3241....	Cu 28.46, Fe 1.24, Mn 0.24, C 0.18, Si 0.10, S 0.007.	Wrought.....	Room		122	1.58	12 (2 in.)	64	6, 10 ²					[501]
700	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
800	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
1,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
1,100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
1,300	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

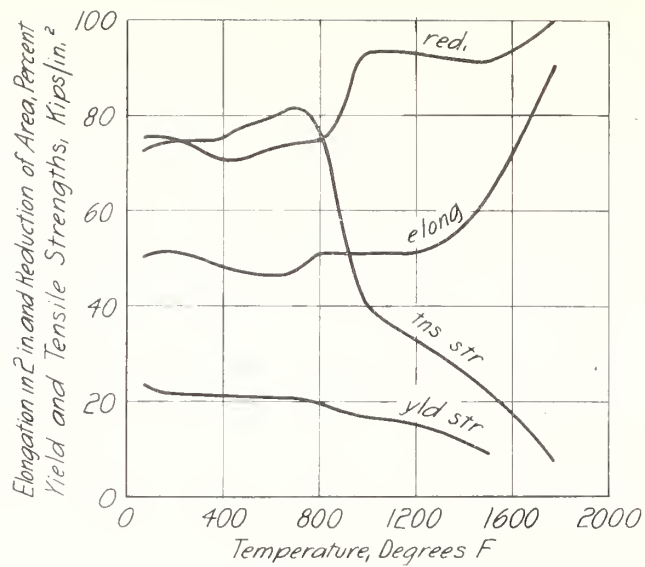


FIGURE 167.—Short-time tensile properties of hot-rolled annealed nickel at high temperatures (Geiger [486]).

(Yield strength, 0.2% offset)

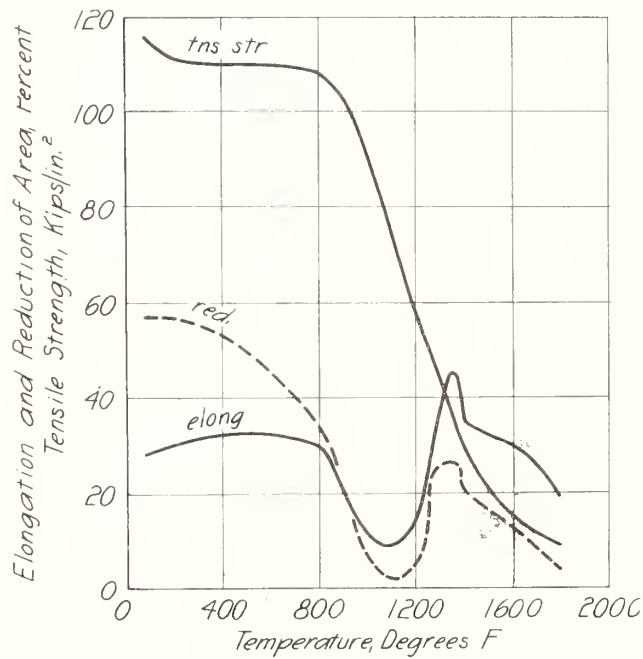


FIGURE 168.—Short-time tensile properties of a nickel-chromium alloy at high temperatures (Quier [692]).

(Elongation in 0.75 in.)

Cr 20.5%, Si 1.25%, Mn 1.0%, Fe 0.5%, C < 0.08%. Rod, 1/4 in. diameter, hot-rolled and annealed.

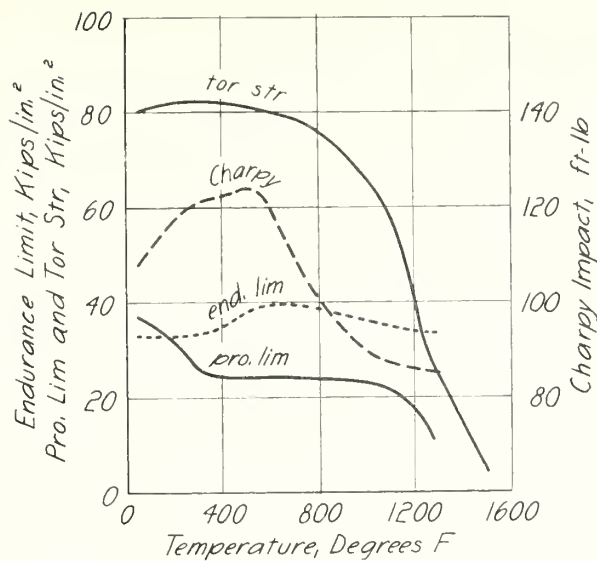


FIGURE 169.—Torsional properties, impact value, and endurance limit of a nickel-chromium alloy at high temperatures (Pilling and Worthington, [693]).

Cr 19.04%, Fe 0.88%, Si 0.10%, C 0.09%, S 0.012%.
Rolled.

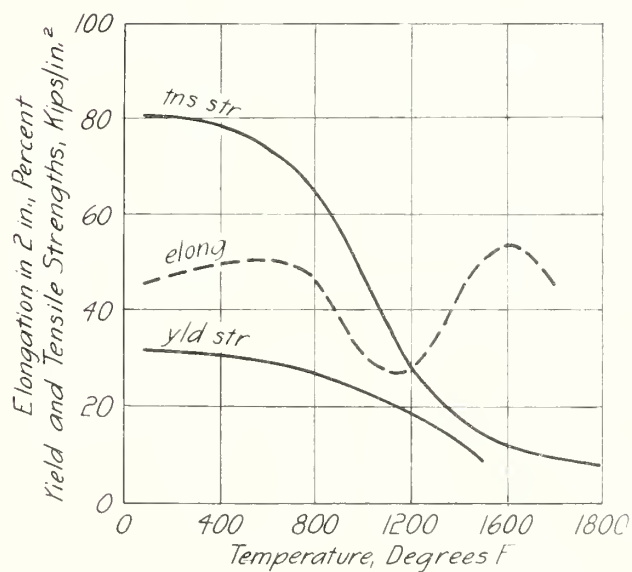


FIGURE 170.—Short-time tensile properties of a hot-rolled nickel-copper alloy at high temperatures [483].

(Yield strength, 0.2% offset)

Cu 30%, Fe 1.4%, Mn 1.0%, C 0.15%, Si 0.10%, S 0.01%.

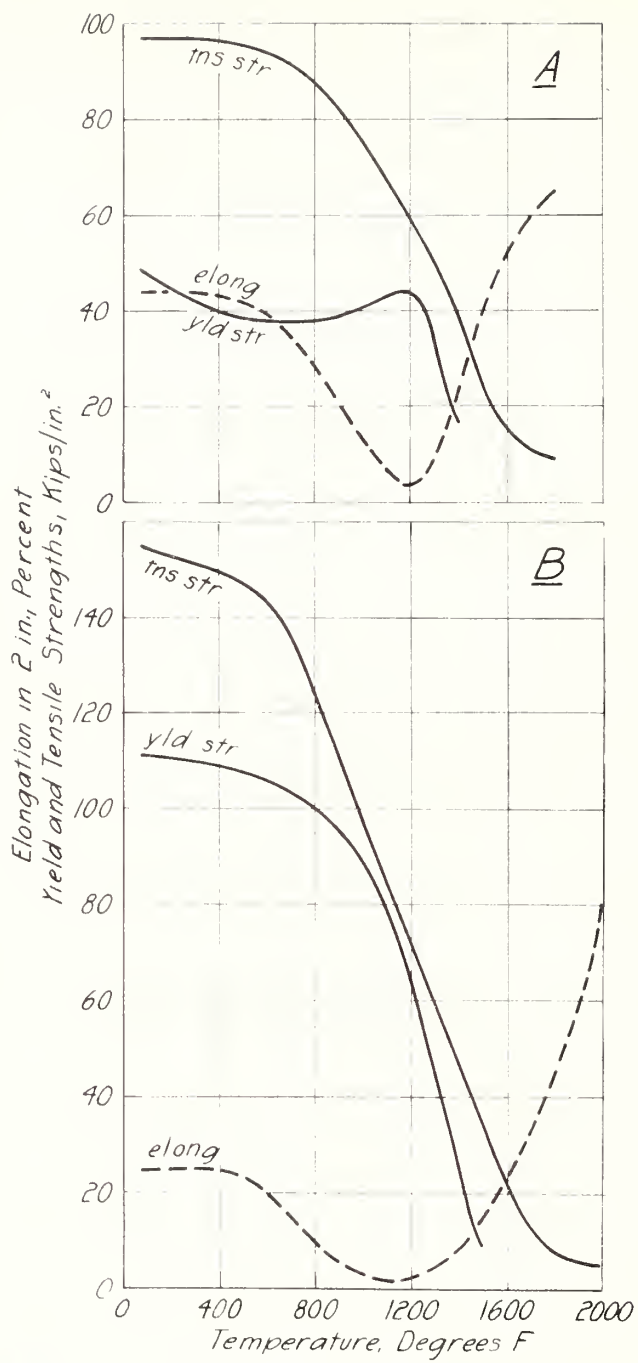


FIGURE 171.—Short-time tensile properties of a nickel-copper-aluminum alloy at high temperatures (483°).

(Yield strength, 0.2% offset)

Cu 29%, Al 2.75%, Fe 0.4%, Si 0.5%, Mn 0.4%, C 0.15%, S 0.005%

A, Hot-rolled; B, hot-rolled and age-hardened.

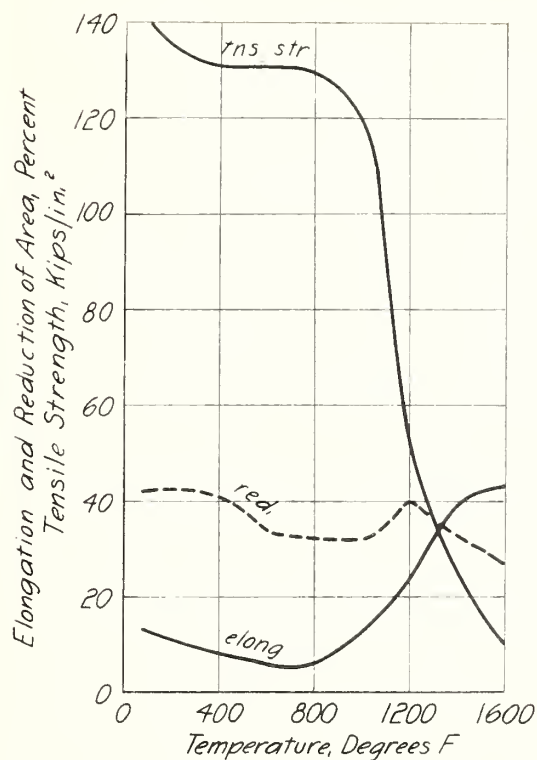


FIGURE 172.—Short-time tensile properties of a nickel-iron-chromium alloy at high temperatures (Quier [692]).

(Elongation in 0.75 in.)

Fe 21.25%, Cr 16.0%, Mn 2.5%, Si 1.25%, C < 0.12%. Rod, 1/4 in. diameter, hot-rolled and annealed.

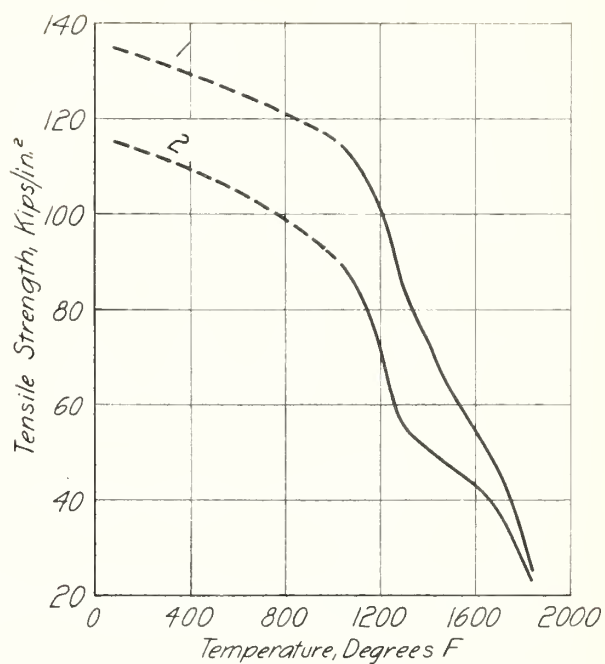


FIGURE 173.—Short-time tensile strengths of nickel-molybdenum-iron alloys at high temperatures (Field [497]).

Curves: 1, Mo 30%, Fe 5%; 2, Mo 20%, Fe 20%. Rolled and annealed.

TABLE 44.—*Nickel and nickel alloys, low-temperature properties*

[For a discussion of the indefiniteness of values reported for yield strength see page 5. Hardness numbers are Brinell numbers unless prefixed R_B , R_C , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed Iz (Izod method).]

Serial number	Composition	Condition	Temperature of test	Tensile properties				Hardness number	Impact value	Remarks	Reference
				Yield strength	Tensile strength	Elongation	Reduction of area				
PURE AND COMMERCIAL NICKEL											
3242....	Fe 0.15.....	Cold-drawn (93% red.).....	$\left\{ \begin{array}{l} \text{Room} \\ -301 \end{array} \right.$	$\left\{ \begin{array}{l} \text{Kips/in.}^2 \\ \text{.....} \end{array} \right.$	$\left\{ \begin{array}{l} \text{Kips/in.}^2 \\ 133 \end{array} \right.$	$\left\{ \begin{array}{l} \text{Percent} \\ 1.1 \\ (2 \text{ in.}) \end{array} \right.$	$\left\{ \begin{array}{l} \text{Percent} \\ 58 \end{array} \right.$	$\left\{ \begin{array}{l} \text{.....} \\ \text{.....} \end{array} \right.$	$\left\{ \begin{array}{l} \text{ft.-lb} \\ \text{.....} \end{array} \right.$	.....	[65]
3243....	Si 0.23, Co 0.14, Fe 0.10, Mg 0.26 (0.0267), S 0.005.	Rod, 1 in. diam, rolled; ann....	$\left\{ \begin{array}{l} \text{Room} \\ -46 \end{array} \right.$	$\left\{ \begin{array}{l} 24.6 \\ 25.3 \end{array} \right.$	$\left\{ \begin{array}{l} 65.5 \\ 71.7 \end{array} \right.$	$\left\{ \begin{array}{l} 42 \\ 45 \\ (2 \text{ in.}) \end{array} \right.$	$\left\{ \begin{array}{l} 78 \\ 72 \end{array} \right.$	$\left\{ \begin{array}{l} \text{.....} \\ \text{.....} \end{array} \right.$	$\left\{ \begin{array}{l} \text{Iz 89} \\ \text{Iz 90} \end{array} \right.$	Tensile specimen 0.25 in. diam; Impact specimen 10 x 10 mm with three 45° notches.	[64]
3244....	Mn 0.24, C 0.14, Fe 0.10, Cu 0.03, Si 0.03.	Rod, 5/8 in. diam, cold-drawn....	$\left\{ \begin{array}{l} \text{Room} \\ -40 \\ -105 \end{array} \right.$	$\left\{ \begin{array}{l} 97.0 \\ \text{.....} \\ 102 \end{array} \right.$	$\left\{ \begin{array}{l} 103 \\ \text{.....} \\ 112 \end{array} \right.$	$\left\{ \begin{array}{l} 16 \\ 22 \\ (2 \text{ in.}) \end{array} \right.$	$\left\{ \begin{array}{l} 68 \\ \text{.....} \\ 61 \end{array} \right.$	$\left\{ \begin{array}{l} R_C 20 \\ R_C 22 \\ R_C 22 \end{array} \right.$	$\left\{ \begin{array}{l} 194-222 \\ 205-223 \\ 202-223 \end{array} \right.$	.....	[25]
3245....	Mn 0.38, C 0.07.....	Forged.....	$\left\{ \begin{array}{l} \text{Room} \\ -423 \end{array} \right.$	$\left\{ \begin{array}{l} 91.2 \\ 117 \\ (\text{yld pnt}) \end{array} \right.$	$\left\{ \begin{array}{l} 105 \\ 144 \\ (10 \text{ diam}) \end{array} \right.$	$\left\{ \begin{array}{l} 12 \\ 22 \\ (10 \text{ diam}) \end{array} \right.$	$\left\{ \begin{array}{l} 71 \\ 64 \end{array} \right.$	$\left\{ \begin{array}{l} \text{.....} \\ \text{.....} \end{array} \right.$	$\left\{ \begin{array}{l} \text{.....} \\ \text{.....} \end{array} \right.$	.....	[56]
3246....	Fe 0.28, Cu 0.20, Mn 0.11, C 0.09.	Wrought.....	$\left\{ \begin{array}{l} 59 \\ -296 \end{array} \right.$	$\left\{ \begin{array}{l} \text{.....} \\ \text{.....} \end{array} \right.$	$\left\{ \begin{array}{l} 65.0 \\ 103 \end{array} \right.$	$\left\{ \begin{array}{l} 43 \\ 51 \\ (10 \text{ diam}) \end{array} \right.$	$\left\{ \begin{array}{l} \text{.....} \\ \text{.....} \end{array} \right.$	$\left\{ \begin{array}{l} \text{.....} \\ \text{.....} \end{array} \right.$	$\left\{ \begin{array}{l} \text{.....} \\ \text{.....} \end{array} \right.$	.....	[66]
NICKEL-CHROMIUM ALLOYS											
3247....	Cr 13.4, Fe 7.4, Mn 0.53, C 0.06.....	Rod, 5/8 in. diam, hot-rolled; heated to 1,750°F, quenched in alcohol.	$\left\{ \begin{array}{l} \text{Room} \\ -40 \\ -105 \end{array} \right.$	$\left\{ \begin{array}{l} 36.0 \\ \text{.....} \\ 42.5 \end{array} \right.$	$\left\{ \begin{array}{l} 94.0 \\ \text{.....} \\ 106 \end{array} \right.$	$\left\{ \begin{array}{l} 37 \\ 40 \end{array} \right.$	$\left\{ \begin{array}{l} 65 \\ \text{.....} \\ 64 \end{array} \right.$	$\left\{ \begin{array}{l} R_E 82 \\ R_E 86 \\ R_E 87 \end{array} \right.$	$\left\{ \begin{array}{l} 130 \\ 135 \\ 133 \end{array} \right.$	.....	[25]
3248....	do.....	Rod, 5/8 in. diam, cold-drawn, tempered at 925°F.	$\left\{ \begin{array}{l} \text{Room} \\ -40 \\ -105 \end{array} \right.$	$\left\{ \begin{array}{l} 147 \\ 155 \\ \text{.....} \end{array} \right.$	$\left\{ \begin{array}{l} 152 \\ 164 \\ \text{.....} \end{array} \right.$	$\left\{ \begin{array}{l} 7 \\ 10 \end{array} \right.$	$\left\{ \begin{array}{l} 49 \\ \text{.....} \\ 51 \end{array} \right.$	$\left\{ \begin{array}{l} R_C 31 \\ R_C 34 \\ R_C 36 \end{array} \right.$	$\left\{ \begin{array}{l} 47-58 \\ 47-71 \\ 33-63 \end{array} \right.$	.....	[25]
3249....	Ni 59.3, Cr 14.40, Mn 2.41, C 0.46, Si 0.21, Fe rem.	Forged.....	$\left\{ \begin{array}{l} \text{Room} \\ -423 \end{array} \right.$	$\left\{ \begin{array}{l} 113 \\ 135 \\ (\text{yld pnt}) \end{array} \right.$	$\left\{ \begin{array}{l} 122 \\ 174 \\ (10 \text{ diam}) \end{array} \right.$	$\left\{ \begin{array}{l} 22 \\ 28 \\ (10 \text{ diam}) \end{array} \right.$	$\left\{ \begin{array}{l} 58 \\ 40 \end{array} \right.$	$\left\{ \begin{array}{l} \text{.....} \\ \text{.....} \end{array} \right.$	$\left\{ \begin{array}{l} \text{.....} \\ \text{.....} \end{array} \right.$	.....	[66]
3250....	Cr 18.9, Mn 1.41, C 0.31, Si 0.20.....	Water-quenched from 1,830°F.....	$\left\{ \begin{array}{l} \text{Room} \\ -123 \end{array} \right.$	$\left\{ \begin{array}{l} 103 \\ 139 \\ (\text{yld pnt}) \end{array} \right.$	$\left\{ \begin{array}{l} 133 \\ 186 \\ (10 \text{ diam}) \end{array} \right.$	$\left\{ \begin{array}{l} 28 \\ 34 \\ (10 \text{ diam}) \end{array} \right.$	$\left\{ \begin{array}{l} 52 \\ 50 \end{array} \right.$	$\left\{ \begin{array}{l} R_C 236 \\ \text{.....} \end{array} \right.$	$\left\{ \begin{array}{l} \text{.....} \\ \text{.....} \end{array} \right.$	.....	[66]

NICKEL-COPPER ALLOYS

3251....	Cu 28.85, Fe 1.78, Mn 0.99, C 0.08, Si 0.01.	Cold-drawn.....	{ Room -40 -112 }	93.3 103	33 (2 in.) 38 (2 in.)	72	208	62 63	[65]
3252....	Cu 28.86, Mn 0.28.....	Rod, 1 in. diam, rolled; annealed.....	{ Room -40 -112 }	70.8 80.0 85.3 91.6 113	41 (2 in.) 47 (2 in.) 40 (2 in.) 41 (2 in.) 51 (2 in.)	75 76 74 74 72	..... ..... ..... ..... .....	..... ..... ..... ..... .....	[64]
3253....	Cu 29.2, Fe 1.7, Mn 1.0, C 0.18, Si 0.06, Al 0.1.	Rod, 5/8 in. diam, cold-drawn.....	{ Room -40 -105 }	94.0 100	18 22	71 70	R _c 19 R _c 22 R _c 25	170-190 180-205 170-190	[25]
3254....	Cu 29.4, Fe 1.95, Si 1.43, C 0.13.....	Cast.....	{ Room -310 }	36.3 (0.1%)	28 (2 in.)	34	135	74 90	[502]
3255....	Cu 29.4, Si 2.69, Fe 1.50, C 0.14.....	do.....	{ Room -310 }	54.7 (0.1%)	15 (2 in.)	28	190	44 47	[502]
3256....	Cu 29.9, Al 3.1, Fe 1.7, Si 0.27, Mn 0.25, C 0.23.	Rod, 5/8 in. diam, cold-drawn; tempered.	{ Room -40 -105 }	126 134	15 17	37 28 41	R _c 33 R _c 35 R _c 36	27 28 28	[25]
3257 ^b ...	Cu 30, Fe 1.4, Mn 1.0, C 0.15, Si 0.1.....	Cold-drawn.....	{ Room -20 }	..... ..... .....	..... ..... .....	..... ..... .....	..... ..... .....	135 136	[502]

NICKEL-IRON ALLOYS

3258....	Fe 15.4, Cr 15.1, Mo 7.18, Mn 1.78.....	.....	{ 68 -287 -423 }	49.3	40 (5 diam)	65	156 206	c 28 c 26 c 22	[370]
3259....	Ni 58.8, Mn 1.64, C 0.27, Si 0.28, Cr 0.15, Fe rem.	Bar, 1 1/8 in. square, forged.....	{ Room -300 }	115	130	43	267	22 22	[25]
3260....	do.....	Bar, 1 1/8 in. square, forged; a-c from 1,700°F.	{ Room -300 }	36	40	51	149	42 58	[25]
3261....	do.....	Bar, 1 1/8 in. square, forged; w-q from 2,050°F.	{ Room -300 }	36.5	40	58	133	54 43	[25]
3262....	Ni 57.5, Mn 1.31, C 0.34, Si 0.14, Fe rem	Forged.....	{ Room -423 }	72.4 (yld pt) 107 (yld pt)	32 (10 diam) 36 (10 diam)	60 54	177 ..... .....	..... ..... .....	[66]

^a -103°F.

^b Endurance limit (6 × 10⁷ cycles): Room, 35.7 kips/in.²; -40°F, 38.4 kips/in.² Modulus of elasticity in shear: 75°F, 9,400 kips/in.²; -50°F, 9,500 kips/in.²

^c Notch impact value, m-kg/cm.

TABLE 45.—*Nickel and nickel alloys, thermal expansion*

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade													Reference
			Low temperature miscellaneous	-100° to 20°C	20° to 50°C	20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 500°C	20° to 600°C	20° to 700°C	20° to 800°C	20° to 900°C	20° to 1,000°C	
3263 ^a	Fe 0.03, Co 0.016, Cu 0.006, Si 0.006, C 0.005, S 0.004, Al 0.0043, Mg 0.0035, Mn 0.001, Cu 0.0005.	Cold-swaged and annealed.	× 10 ⁻⁶	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[503]
3264 ^b		Annealed.	9.8 (-192° to 0°C)	11.4	12.8	13.1	13.7	14.4	15.0	15.2	15.5	15.8	16.0	16.3	.....	[68]
3265 ^c	Fe 1.8-2.0, Ni 1.8-2.0, Cu 0.0005.	Rod or strip.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[110]
3266 ^d	Cr 10, Fe 6, Mn 3, Si 0.005, S 0.004, Cu 0.001, Al 0.001, Mn 0.001, Cu 0.0005.	Wrought.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[126]
3267 ^e	Cr 14, Fe 6, Mn 3, Si 0.005, S 0.004, Cu 0.001, Al 0.001, Mn 0.001, Cu 0.0005.	Cast.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[375]
3268 ^f	Cr 16.3, Fe 6.6, Mn 3.23, Si 2.51, C 0.94, Al 0.01, Cu 0.01.	Sand-cast at 1,480°C.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[713]
3269 ^g	Ni 65, Cr 18, Fe rem., Cu 0.01.	Cast.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[69]
3270 ^h	Cr 19.3, Mn 2.50, Fe 0.55, Si 0.12, C 0.08, Al 0.01, Cu 0.01.	Hot-rolled and slowly cooled.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[713]
3271 ⁱ	Cr 20.40, Mn 1.92, Fe 0.40, Si 0.26, C 0.12, Cu 0.10, Cr 23, Cu 8, Mo 4, W 2, Mn 1.	Hot-rolled.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[713]
3272 ^j	Cr 23, Cu 8, Mo 4, W 2, Mn 1.	Cast.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[375]
3273 ^k	Ni 60, Cr 25, Cu 8, Fe rem., Co 10.	do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[69]
3274 ^l		Rod, 0.2 in. diam, cast; 1 hr at 1,000°C in hydrogen, slowly cooled.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[504]
3275 ^m	Co 10, Fe 10.	do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[504]
3276 ⁿ	Co 19.50, Fe 7.60, Ti 2.86, Si 0.30, Mn 0.14, Cu 0.04, Co 19.9, Fe 10.1.	Hot-rolled.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[69]
3277 ^o		Rod, 0.2 in. diam, cast; 1 hr at 1,000°C in hydrogen, slowly cooled.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[504]
3278 ^p	Co 19.9, Fe 30.1.	do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[504]
3279 ^q	Co 24.83, Cr 18.74, Fe 7.02, Ti 2.19.	Bar, hot-rolled and hot-rolled.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[524]
3280 ^r	Co 29.9, Fe 10.1.	do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[504]
3281 ^s	Co 29.9, Fe 20.1.	Rod, 0.2 in. diam, cast; 1 hr at 1,000°C in hydrogen, slowly cooled.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[504]
3282 ^t	Co 30, Fe 20.1.	do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[504]
3283 ^u	Co 50, Fe 20.1.	do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[504]
3284 ^v	Ni 88.92, Fe 0.30, Mn 0.03, Cu rem.	Rod, 0.32 in. diam, hot-forged; anneal 3 hr at 850°C in vacuum.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[201]
3285 ^w	Ni 78.99, Fe 0.33, Mn 0.04, Cu rem.	do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[201]
3286 ^x	Cu 25, Si 9, Fe 3.5, Mn 0.75, Si 0.75.	do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[723]
3287 ^y	Cu 26.96, Fe 2.70, Mn 2.35, Si 0.54, C 0.13.	Cast.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[69]
3288 ^z	Cu 29, Al 2.75, Fe 0.90, Mn 0.40, Si 0.25, C 0.15, S 0.005.	do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[505]
3289 ^{aa}	Cu 29.57, Fe 1.79, Mn 1.78, C 0.15, Si 0.09, S 0.030.	Rod, 1/4 in. diam, hot-rolled.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[505]
3290 ^{ab}	Cu 29.56, Fe 1.30, Mn 1.07, C 0.14, Si 0.06, S 0.005.	Wrought and annealed.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[502]

TABLE 46.—Nickel and nickel alloys, electrical and thermal properties

Serial number	Composition	Condition	Electrical properties			Thermal conductivity	Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity		
3308.....	Ni 99.99..... Percent	.....	Percent IACS (28.1 (0°C) 25.2 (20°C) 16.7 (100°C)	Microhm cm 6.141 (0°C) 6.844 (20°C) 10.327 (100°C)	$\frac{\text{per } ^\circ\text{C} \times 10^{-4}}{53.6 (20^\circ\text{--}100^\circ\text{C})}$	Watts cm ⁻¹ °C ⁻¹ (0.89 (40°C) .53 (100°C) .73 (200°C) .64 (300°C) .59 (400°C) .62 (500°C)	[484]
3309.....	Fe 0.03, Co 0.016, Cu 0.006, Si 0.006, C 0.005, S 0.004.	Vacuum melted and f-c (large crystals).....	.....	.....	.....	.....	[402]
3310.....	Mn 0.20, Fe 0.15, C 0.10, Cu 0.10, Si 0.05, S 0.005.	Wrought.....	18.3 (20°C)	9.40 (20°C)	47.4 (20°–100°C)	.....	[486]
3311.....	Fe 0.60, Cu 0.14, Mn 0.09.....	Rod, hot-rolled.....	.....	.....	.....	.....	[402]
3312.....	Alumel: Al 2, Mn 2, Si 1.....	Bar, 1 5/8 in. square, hot-rolled.....	.....	.....	.....	.....	[402]
3313.....	do.....	.....	.....	.....	.....	.....	[512]
3314.....	Be 1.8–2.0.....	Strip, soft ann.....	.....	.....	.....	.....	[110]
3315.....	do.....	Strip, ann, h-t.....	.....	.....	.....	.....	[110]
3316.....	do.....	Strip, cold-rolled.....	.....	.....	.....	.....	[110]
3317.....	do.....	Strip, cold-rolled, h-t.....	.....	.....	.....	.....	[110]
3318.....	Chromel P: Cr 10.....	Bar, 1 5/8 in. square, hot-rolled.....	.....	.....	.....	.....	[402]
3319.....	do.....	.....	.....	.....	.....	.....	[512]
3320.....	Cr 12.97, Fe 6.31, Mn 0.24, Cu 0.18, Si 0.15, C 0.067.	Rolled and ann.....	.....	.....	.....	.....	[210]
3321.....	Ni 82.25, Cr 12.98, Mn 0.68, Si 0.75, C 0.09, Fe rem.	Rod, 1 in. diam, rolled.....	.....	.....	.....	.....	[395]
3322.....	Ni 78.55, Cr 13.44, Si 0.27, Mn 0.21, C 0.07, Fe rem.	Air-cooled from 1,050°C.....	1.8 (15°C)	98.8 (15°C)	.....	.....	[383]
3323.....	Cr 15.....	.....	1.8	95	$\left\{ \begin{array}{l} 3 (0^\circ\text{--}200^\circ\text{C}) \\ 0.66 (200^\circ\text{--}1,100^\circ\text{C}) \end{array} \right.$	.....	[509]

XI. TIN AND TIN ALLOYS

(375)

TABLE 48.—*Tin and tin alloys, normal-temperature properties.*

[For a discussion of the indefiniteness of values reported for yield strength and particularly for "proportional limit" see pages 5 and 6. Thinness numbers are Brinell numbers unless prefixed R_{H} , R_{C} , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed Iz (Izod method).]

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
PURE AND COMMERCIAL TIN												
3317..	"Base" tin: 99.95.	Sheet, 0.01 in., 2 days at r-t.	kips/in. ²	kips/in.	kips/in. ²	kips/in. ²	Percent	Percent	kips/in. ²	ft.-lb.	Brinell.....14.0 mm.	[515]
3318..	Sn 99.94.	.....	5,900	.....	.....	2.0	.....	.....	.....	5	Poisson's ratio.....0.33	[513]
3319..	"Strait's" tin.....	Sheet, 0.040 in., annealed at 370°F.	.....	.....	(0.2% offset)	2.2	45 (2 in.)	.....	.....	V 7.2	.....	[120]
3350..	do.....	Sheet, 0.040 in., cold-rolled (30% red.).	.....	.....	(0.2% offset)	2.8	35 (2 in.)	.....	.....	V 8.4	.....	[120]
3351..	"Pure" tin.....	Foil, 0.0015 in.....	.....	.....	.....	2.0	6.5	.....	.....	.....	.....	[511]
3352..	Tin.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-rl (shear).....2,190-2,130 kips/in. ² .	[88]
3353..	Sb 0.0007.	Cast.....	.....	.....	.....	a 2.1	55 (4 in.)	.....	.....	Iz 14	Shear str ^a.....2.9 kips/in. ² .	[111]
TIN-ANTIMONY ALLOYS (SEE ALSO FIG. 174)												
3354..	Sb 0.5.....	Sheet, 0.01 in., aged 2 days at r-t.	.....	.....	.....	.....	.....	.....	.....	.....	Brinell.....13.7 mm.	[515]
3355..	Sb 1.0.....	do.....	.....	.....	.....	.....	.....	.....	.....	.....	Brinell.....11.6 mm.	[515]
3356..	Sb 2.98.	Cast.....	.....	.....	.....	a 4.6	10 (4 in.)	.....	.....	Iz 18	Shear str ^a.....4.6 kips/in. ² .	[44]
3357..	Sb 3.59, Cu 3.4, Al 0.04, Fe 0.05.	do.....	8,500	.....	5.0 (0.2%)	8.2	12 (10 diam)	23	3.0	14	Comp yld str (0.2%).....4.5 kips/in. ² .	[132]
3358..	Sb 4, Cu 2.....	do.....	.....	.....	.....	.....	.....	.....	.....	15	Comp str.....29.9 kips/in. ² .	[516]
3359..	Sb 4, Cu 3.5, Cd 1.0, Pb 0.01.	do.....	.....	.....	.....	10.0	.....	.....	.....	25	.....	[516]
3360..	Sb 4.52, Cu 1.56.....	do.....	.....	.....	.....	.....	.....	.....	.....	17	Comp yld str (0.15%).....4.4 kips/in. ² .	[516]
3361..	Sb 5.17.....	do.....	.....	.....	.....	a 5.9	38 (4 in.)	.....	.....	.....	Comp str (25%).....12.8 kips/in. ² .	[444]
3362..	Sb 6.87, Cu 5.59, Pb 0.19, Fe 0.03, As 0.02.	do.....	8,700	.....	8.2 (0.2%)	12.1	5.2 (10 diam)	11	3.4	23	Specific gravity.....7.34.	[432]
3363..	Britannia metal: Sb 7, Cu 2.	Sheet, 0.241 in., cold-rolled.	.....	.....	.....	7.6	50 (2 in.)	.....	.....	8.0	Melting point.....439°F.	[517]
3364..	do.....	Sheet, 0.241 in., cold-rolled; 1 hr at 400°F, a-c.	.....	.....	.....	8.6	40 (2 in.)	.....	.....	9.5	Comp yld str (0.2%).....25.6 kips/in. ² .	[517]

3365..	Sb 7.1, Cu 3.1, Pb 0.03.	Cast.....	.....	.....	.....	.....	.....	.....	.....	21	.....	Comp yld str (0.125%).....5.1 kips/in. ² .. Comp str.....11.0 kips/in. ² .. Specific gravity.....7.39. Wetting range.....499°-659°F.	[516]
3366..	Sb 8, Cu 2.....	...do.....	.....	.....	.....	.....	.....	.....	.....	22	.....	Comp yld int.....0.9 kips/in. ² .. Comp str (25%).....15.2 kips/in. ²	[516]
3367..	Sb 8, Cu 3.5, Cu 1.0, Pb 0.04.	...do.....	.....	.....	.....	14.7	.....	.....	.....	30	.....	.....	[516]
3368..	Sb 8.2, Cu 8.3, Pb 0.03.	...do.....	.....	.....	.....	.....	.....	.....	.....	27	.....	Comp yld str (0.125%).....6.6 kips/in. ² .. Comp str (25%).....17.5 kips/in. ² .. Specific gravity.....7.46. Wetting range.....491°-742°F.	[516]
3369..	Sb 9.8, Cu 4.21, Pb 0.03, Fe 0.05, As 0.03.	Bar, cast from 750°F into mold at 212°F.	7,700	1.5	.....	.....	.....	.....	.....	28	.....	.....	[431]
3370..	Sb 10.01, Cu 9.86, Pb 0.19, Fe 0.04.	Cast.....	8,500	.....	.....	10.7	0.5 (10 diam)	1.0	3.3	27	.....	Comp yld str (0.2%).....9.8 kips/in. ² .. Comp str.....23.6 kips/in. ²	[432]
3371..	Sb 11.4, Cu 7.11, Pb 0.67, Fe 0.01, As 0.02.	...do.....	8,200	.....	.....	11.8	0.5 (10 diam)	1.0	3.7	27	.....	Comp yld str (0.2%).....9.4 kips/in. ² .. Comp str.....22.9 kips/in. ²	[432]
3372..	Sb 11.6, Pb 10.2, Cu 3.0.	...do.....	.....	.....	.....	.....	.....	.....	.....	24	.....	Comp yld str (0.125%).....5.6 kips/in. ² .. Comp str (25%).....16.2 kips/in. ² .. Specific gravity.....7.52. Wetting range.....359°-589°F.	[515]
3373..	Sb 13.60, Pb 10.28, Cu 5.48, As 0.20, Fe 0.1, Ni 0.02.	...do.....	6,800	.....	.....	11.2	0.8 (10 diam)	1.0	3.4	26	.....	Comp yld str (0.2%).....9.1 kips/in. ² .. Comp str.....21.2 kips/in. ²	[432]

TIN-ARSENIC AND TIN-BERYLLIUM ALLOYS

3374..	As 0.1.....	Sheet, 0.04 in., aged 2 days at r-t.	.....	.....	.....	.....	.....	.....	.....	.....	.....	Etchisen.....11.3 mm.....	[515]
3375..	As 0.5.....	...do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Etchisen.....10.4 mm.....	[515]
3376..	Be 0.2.....	...do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Etchisen.....11.2 mm.....	[515]

TIN-BISMUTH ALLOYS (SEE ALSO FIG. 175)

3377..	Bi 0.055.....	Cast from 180°F into mold at 355°F.	.....	.....	1.5 (yld int)	2.4	.....	100	.....	1.6	.....	Comp yld int.....3.2 kips/in. ²	[518]
3378..	Bi 0.5.....	Sheet, 0.04 in., aged 2 days at r-t.	.....	.....	.....	.....	.....	.....	.....	.....	.....	Etchisen.....12.9 mm.....	[515]
3379..	Bi 1.0.....	...do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Etchisen.....12.9 mm.....	[515]

TIN-CADMIUM ALLOYS (SEE FIG. 176)

TIN-COPPER ALLOYS (SEE ALSO FIGS. 177 AND 178)

3380..	Cu 0.050.....	Cast from 480°F into mold at 355°F.	.....	.....	2.6 (yld int)	3.5	.....	98	.....	5.3	.....	Comp yld int.....2.5 kips/in. ²	[518]
3381..	Cu 1.0.....	Sheet, 0.1 in., cold- rolled; aged 2 months at r-t.	.....	.....	.....	7.1	91 (2 in.)	.....	.....	.....	.....	.....	[510]
3382..	Cu 8, Sb 1.....	Cast.....	.....	.....	.....	.....	.....	.....	.....	24	.....	Comp yld int.....10.8 kips/in. ² .. Comp str (25%).....13.5 kips/in. ²	[746]

* Free-head speed 0.1 in./minute.

TABLE 48.—Tin and tin alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation					Reduction of area
TIN-GERMANIUM ALLOY											
3383..	Pb 0.35.....	Sheet, 0.04 in., aged 2 days at r-t.	Kips/in. ²	Kips/in. ²	Kips/in. ²	Kips/in. ²	Percent	Percent	Kips/in. ²	ft-lb	[515]
											
TIN-IRON ALLOYS (SEE FIG. 177)											
TIN-LEAD ALLOYS											
3384..	Pb 0.253.....	Cast from 450°F into mold at 355°F.	.....	.....	2.4 (yld pnt)	3.9	.....	95	.....	6.7	[516]
3385..	Pb 0.5.....	Sheet, 0.04 in., aged 2 days at r-t.	.....	.....	.....	.....	.....	.....	.....	.....	[515]
3386..	Pb 1.0.....	..do.....	.....	.....	.....	.....	.....	.....	.....	.....	[515]
3387..	Pb 5.0, Sb 0.5.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[520]
3388..	Pb 18.2, Sb 14.1, Cu 2.0.	Cast.....	.....	.....	.....	.....	.....	.....	.....	22	[516]
3389..	Pb 35.1, Sb 0.98.....	..do.....	.....	.....	.....	a 8.7 20 (4 in.)	.....	.....	.....	.....	[444]
3390..	Pb 36.7, Sb 3.4.....	..do.....	.....	.....	.....	a 10.1 18 (4 in.)	.....	.....	.....	.....	[444]
3391..	Pb 37.....	..do.....	.....	.....	.....	7.5 32 (4 in.)	.....	.....	.....	14	[445]
3392..	Sn 63, Sb 0.12, Bi 0.010, Cu 0.002, Ag 0.0006, Pb rem.	Annealed 16 hr at 212°F.	.....	.....	.....	b 7.5 30 (2 in.)	.....	.....	.....	14	[443]
TIN-NICKEL ALLOYS (SEE ALSO FIG. 177)											
3393..	Ni 0.3.....	Sheet, 0.1 in., cold-rolled; aged 2 months at r-t.	.....	.....	.....	5.6 46 (2 in.)	.....	.....	.....	.....	[519]
TIN-SILVER ALLOYS											
3394..	Ag 0.98.....	Sheet, 0.040 in., aged 14 days at r-t.	.....	.....	2.4 (yld pnt)	3.0 57 (2 in.)	.....	.....	.....	.....	[129]
3395..	Ag 1.86.....	..do.....	.....	.....	3.9 (yld pnt)	4.5 47 (2 in.)	.....	.....	.....	.....	[129]
3396..	Ag 3.16.....	Sheet, 0.040 in., am 1 hr at 370°F.	.....	.....	1.7 (0.2% offset)	3.9 50 (2 in.)	.....	.....	.....	V 12	[129]
3397..	..do.....	Sheet, 0.040 in., rolled (30% red.).	.....	.....	3.8 (0.2% offset)	5.2 36 (2 in.)	.....	.....	.....	V 15	[129]

3398..	Ag 3.5, Cd 1.0.....	Sheet, 0.1 in. cold-rolled; aged 2 months at r-t.	.....	.....	.....	10.2	17 (2 in.)	.....	.....	.....	[519]
3399..	Ag 3.65.....	Sheet, 0.040 in., aged 14 days at r-t.	.....	.....	4.5 (yld pnt)	5.3	37 (2 in.)	.....	.....	.....	[129]
3400..	Ag 5.64.....	...do.....	.....	.....	3.6 (yld pnt)	4.6	49 (2 in.)	.....	.....	.....	[129]
3401..	Ag 9.87.....	...do.....	.....	.....	3.6 (yld pnt)	4.8	40 (2 in.)	.....	.....	.....	[129]
3402..	Ag 30, Zn 30.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[184]
3403..	Ag 40, Cu 14, Zn 6.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[184]

TIN-ZINC ALLOYS

3404..	Zn 0.24.....	Cast from 490°F into mold at 355°F.	.....	.....	4.3 (yld pnt)	6.0	.....	74	.....	12	.....	Comp yld pnt.....5.5 kips/in. ² ..	[518]
3405..	Zn 0.5.....	Sheet, 0.04 in., aged 2 days at r-t.	.....	.....	.....	.....	.....	.....	.....	.....	.....	Erichsen.....13.0 mm.....	[515]
3406..	Zn 1.0.....	...do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Erichsen.....13.2 mm.....	[515]
3407..	Zn 8.....	Foil, 0.0016 in.....	.....	.....	.....	8.0	21	.....	.....	.....	.....	.....	[514]
3408..	Zn 8.5, Al 0.15.....	...do.....	.....	.....	.....	10.0	46	.....	.....	.....	.....	.....	[514]
3409..	Zn 9, Al 5.....	Chill-cast.....	.....	.....	.....	12.2	41 (2 in.)	81	.....	.....	.....	.....	[303]
3410..	Zn 15, Al 11, Pb 8, Cu 3, Sb 1.	Cast.....	.....	.....	.....	13.0	1.6 (2 in.)	1.3	.....	.....	.....	.....	[303]
3411..	Zn 18, Al 19, Cu 3, Sb 2, Pb 1.	...do.....	.....	.....	.....	14.5	1.9 (2 in.)	1.5	.....	.....	.....	.....	[303]

^a Free-head speed 0.1 in./minute.

^b Free-head speed 0.5 in./minute.

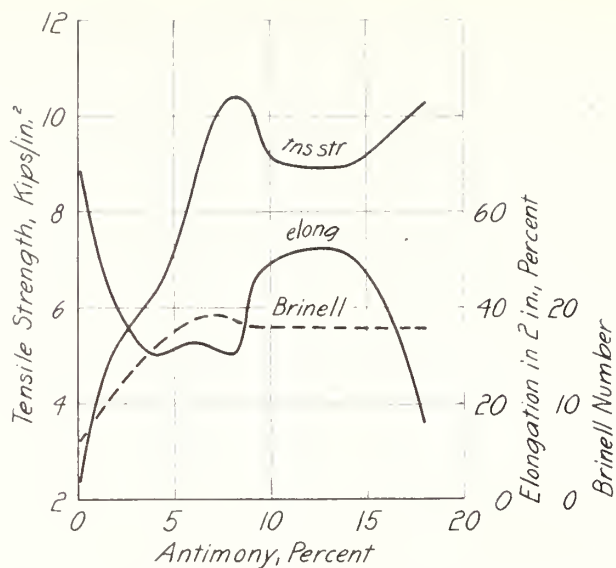


FIGURE 174.—Tensile properties and hardness of tin-antimony alloys (Hanson and Pell-Walpole [696]).

(Rate of strain, 0.1 (in./in.)/minute)

Polled (80% red.) and aged 1 month at room temperature.

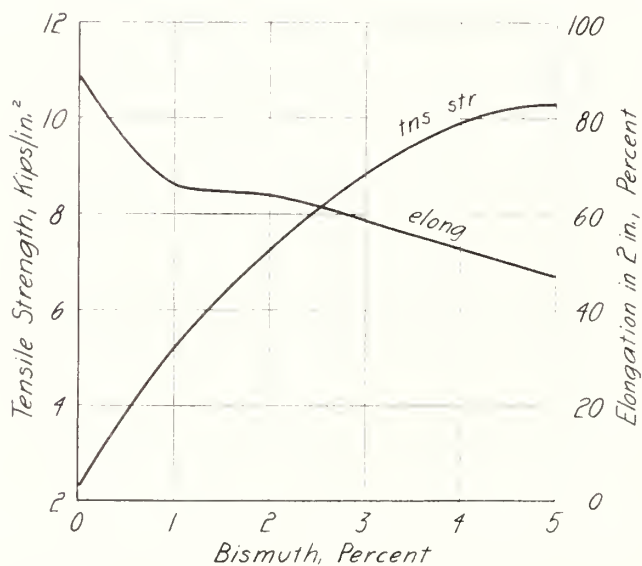


FIGURE 17E.—Tensile properties of tin-bismuth alloys (Hanson and Sandford [897]).

(Rate of strain, 0.4 (in./in.)/minute)

Strip, 0.1 in., cold-rolled from casting (80% red.) and aged 13 days at room temperature.

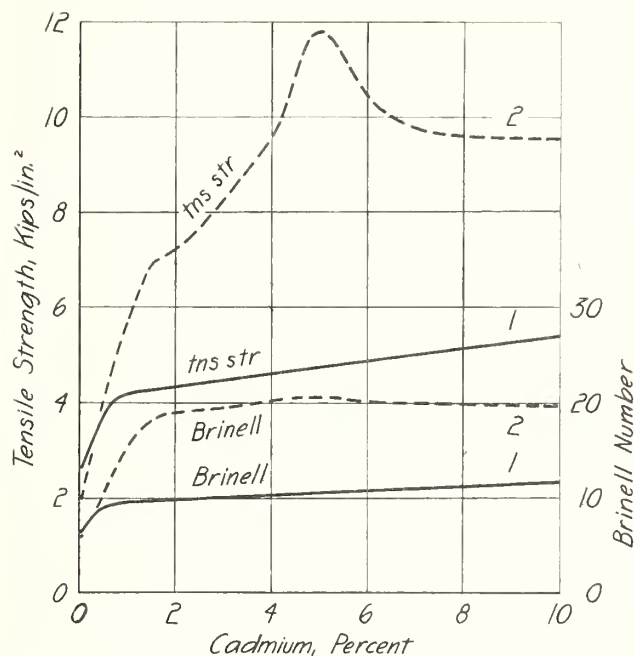


FIGURE 176.—Tensile strength and hardness of tin-cadmium alloys (Hanson and Pell-Walpole [698]).

(Rate of strain, 0.4 (in./in.)/minute)

Strip, 0.1 in.

Curves: 1, cold-rolled from casting (80% red.), aged 2 months at room temperature; 2, quenched from 320°F and aged 3 months at room temperature or quenched and aged 4 hours at 212°F.

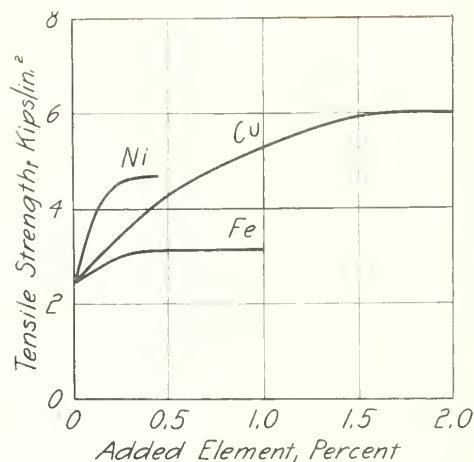


FIGURE 177.—Effect of various elements on the tensile strength of tin (Hanson, Sandford, and Stevens [699]).

(Rate of strain, 1 5/32 in./minute)

Strip, 0.1 in., cold-rolled (80% red.) and aged 15 days at room temperature.

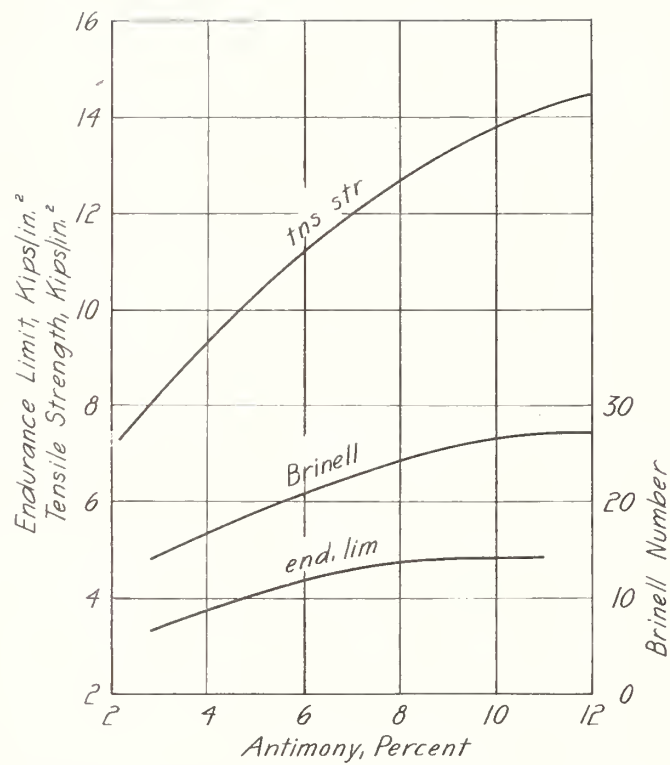


FIGURE 173.—Effect of antimony on the tensile strength, hardness, and endurance limit of a tin-copper alloy (McNaughton [700]).

(Rate of strain, 1.2 in./minute; endurance limit at 2×10^7 cycles)

Cu 3.5%, Pb 0.25%, As 0.03%. Cast from 660°F into mold at 300°F.

TABLE 49.—*Tin and tin alloys, creep properties at room temperature*

Serial number	Composition	Condition	Tensile properties		Creep properties ^a			Reference
			Tensile strength	Elongation (2 in.)	Stress	Elongation	Duration	
			Kips/in. ²	Percent	Kips/in. ²	Percent	Days	
3412.....	Sn 99.99.....	Sheet, 0.1 in., cold-rolled; 30 days at r-t.	^b 2.4	96	0.157	3.5	551	[521]
3413.....	Sb 1.....	..do.....	^b 3.3	57	.3	5.5	340	[521]
3414.....	Sb 5.....	..do.....	^b 6.8	68	.3	1.1	344	[521]
3415.....	Sb 5, Cd 2.....	Sheet, 0.1 in., cold-rolled; ann 2 days at 338°F, f-c.....	^c 10.5	38	3.0	3.44	791	[519]
3416.....	Sb 5, Cd 5.....	..do.....	^c 15.0	32	1.6	3.14	900	[519]
3417.....	Sb 8.5.....	Sheet, 0.1 in., cold-rolled; aged 30 days at r-t.	^b 10.3	63	0.4	1.06	337	[521]
3418.....	Sb 10.....	..do.....	^b 9.2	61	.4	2.02	388	[521]
3419.....	Cd 6.....	Sheet, 0.1 in., cold-rolled; 24 hr at 334°F, quenched, tempered 24 hr at 248°F.	^b 9.3	23	1.0	0.38	481	[521]
3420.....	Ni 0.3.....	Sheet, 0.1 in., cold-rolled; 2 months at r-t.....	5.6	46	0.2	.42	389	[519]
3421.....	Ag 0.1.....	Sheet, 0.1 in., cold-rolled; 30 days at r-t.....	^b 3.0	90	.16	1.5	541	[521]
3422.....	Ag 3.5.....	..do.....	^b 8.1	.....	.7	0.84	220	[521]
3423.....	Ag 3.5, Cd 1.....	Sheet, 0.1 in., cold-rolled; aged 2 months at r-t.....	10.2	17	2.0	1.5	470	[519]

^a Creep data are for specimens which have not fractured in stated time.^b Rate of strain in tensile test 0.4 (in./in.)/minute.^c Rate of strain in tensile test 0.1 (in./in.)/minute.

TABLE 50.—Tin and tin alloys, high-temperature properties

[See also fig. 131]

Serial number	Composition	Condition	Temperature	Short time properties			Creep properties		Reference	
				Tensile strength ^a	Elongation ^b	Reduction of area	Stress (kips/in. ²) for designated creep rate per 1,000 hours	Duration		
3424.....	Percent Sb 3.76, Cu 3.55, Pb 0.30, Fe 0.04, As 0.03.	Rod, 6 x 1/2 x 1/8 in., chill-cast from 840°F.....	64 122 212 302 347	3.5 8.1 5.3 3.8 2.7	20 26 25 32 36	24 34 35 38 41	0.1%	1.0%	[522]	
3425.....	Above + Cd 1.0.....	Rod, 6 x 1/2 x 1/8 in., chill-cast from 1,020°F.....	64 122 212 302 347	11.4 11.0 7.7 4.3 3.0	8.5 16 20 45 63	10 19 26 40 69	..... ..... ..... ..... .....	..... ..... ..... ..... .....	[522]	
3426.....	Sb 7.14, Cu 3.21, Pb 0.47, Fe 0.03..	Rod, 6 x 1/2 x 1/8 in., chill-cast from 750°F.....	68 122 212 302 347	11.2 9.2 6.5 4.0 2.9	18 24 23 32 38	25 27 28 38 44	..... ..... ..... ..... .....	..... ..... ..... ..... .....	[522]	
3427.....	Sb 9.88, Cu 4.21, Pb 0.33, Fe 0.05, As 0.03.	Rod, 6 x 1/2 x 1/8 in., chill-cast from 840°F.....	64 122 212 302 347	13.2 11.1 8.1 4.9 3.1	13 17 23 33 52	17 25 26 43 61	..... ..... ..... ..... .....	..... ..... ..... ..... .....	[522]	
3428.....	Above + Cd 1.0.....	Rod, 6 x 1/2 x 1/8 in., chill-cast from 1,020°F.....	64 122 212 302 347	16.2 13.2 8.0 5.0 4.0	8 13 23 29 45	10 14 28 35 42	..... ..... ..... ..... .....	..... ..... ..... ..... .....	[522]	
3429.....	Sn 62.2, Pb rem.....	Chill-cast.....	Room 175				0.21 .068 (0.42%)	0.41	1,800 4,800	[449]
3430.....	Sn 55.0, Sb 3.6, Pb rem.....	...do.....	Room 175				0.35 .125 (0.42%)	0.58	1,800 4,800	[449]

^a Rate of strain 0.013 in./minute.^b Gauge length = 4/area.

TABLE 51.—*Tin and tin alloys, thermal expansion*

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade						Reference
			30° to 50°C	30° to 100°C	30° to 200°C	30° to 300°C	30° to 400°C	30° to 500°C	
3431 ^a	Pure ^a tin.....	Rod, annealed.....	$\times 10^{-6}$ 23.2	$\times 10^{-6}$ 23.8	$\times 10^{-6}$ 24.2	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	[480]
3432.....	Pb 8.72.....	.....	.....	^b 20.5	.....	.....	.....	.....	[72]
3433.....	Pb 30.5.....	.....	.....	^b 21.6	.....	.....	.....	.....	[72]
3434.....	Pb 42.07.....	.....	.....	^b 21.7	.....	.....	.....	.....	[72]
3435.....	Mg 0.85.....	Rod, annealed.....	25.0	25.8	25.6	.....	.....	.....	[480]
3436.....	Mg 2.2.....	..do.....	21.6	23.2	23.6	.....	.....	.....	[480]
3437.....	Mg 8.1.....	..do.....	18.1	18.7	19.4	.....	.....	.....	[480]
3438.....	Mg 14.9.....	..do.....	16.8	18.0	17.6	.....	.....	.....	[480]
3439.....	Mg 29.1.....	..do.....	16.4	16.2	16.4	.....	.....	.....	[480]
3440.....	Mg 45.0.....	..do.....	19.8	20.0	20.1	16.1 19.8	16.1 19.7	16.8 19.7	[480]

^aGruneisen [720] reports values 22.6×10^{-6} (–183° to 16°C) and 27.0×10^{-6} (19° to 100°C).^b15° to 110°C.

TABLE 52.—Tin and tin alloys, electrical and thermal properties

Serial number	Composition	Condition	Electrical properties			Thermal conductivity	Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity		
3441.....	"Pure" tin.....	.....	Percent IACS (50.7 (-183°C) 19.7 (-74°C) 13.2 (0°C) 15.0 (20°C) 9.47 (91.45°C) 7.29 (176°C) 7.84 (225°C)	Microhm cm 3.40 (-183°C) 8.77 (-74°C) 13.1 (0°C) 11.5 (20°C) 18.2 (91.45°C) 23.6 (176°C) 22.0 (225°C)	per °C × 10 ⁻⁴	Katfis cm ⁻¹ °C ⁻¹ (0.82 (-170°C) .64 (0°C) .64 (15°C) .59 (100°C) .61 (300°C)	[513]
3442.....	...do.....	Cast; am.....	15.82 (0°C)	10.90 (0°C)	15.67 (0°-100°C)	.....	[220]
3443.....	Sb 2.975.....	Cast.....	12.1	11.2	.....	.....	[444]
3444.....	Sb 6.2.....	...do.....	10.4	16.6	.....	.....	[444]
3445.....	Cu 35.30.....	Cast; am.....	13.8 (0°C)	12.5 (0°C)	34.1 (0°-100°C)	.....	[220]
3446.....	Cu 38.70.....	...do.....	15.7 (0°C)	11.0 (0°C)	33.5 (0°-100°C)	.....	[220]
3447.....	Cu 41.02.....	...do.....	13.9 (0°C)	12.4 (0°C)	35.2 (0°-100°C)	.....	[220]
3448.....	Cu 47.98.....	...do.....	16.6 (0°C)	10.1 (0°C)	33.7 (0°-100°C)	.....	[220]
3449.....	In 1.45.....	.....	(48.6 (-190.6°C) 14.1 (0°C) 13.2 (19.5°C)	(3.55 (-190.6°C) 12.2 (0°C) 13.1 (19.5°C)	(37.0 (19.5° to -190.6°C)	.....	[457]
3450.....	In 8.05.....	.....	(25.7 (-190.9°C) 11.3 (0°C) 10.7 (21.0°C)	(6.71 (-190.9°C) 15.2 (0°C) 16.1 (21.0°C)	(29.3 (21.0° to -190.9°C)	.....	[457]
3451.....	Pb 33.9.....	Cast.....	12.2	14.1	.....	.....	[444]
3452.....	Pb 37.36, Sb 3.85.....	...do.....	10.2	16.9	.....	.....	[444]
3453.....	Pb 46.85, Sb 3.00.....	...do.....	9.6	18.0	.....	.....	[444]
3454.....	Ag 1.57.....	Chill-cast; am.....	16.5 (0°C)	10.5 (0°C)	43.6 (0°-100°C)	.....	[523]
3455.....	Ag 5.62.....	...do.....	16.6 (0°C)	10.4 (0°C)	42.3 (0°-100°C)	.....	[523]
3456.....	Ag 9.72.....	...do.....	17.1 (0°C)	10.1 (0°C)	42.1 (0°-100°C)	.....	[523]
3457.....	Ag 30.43.....	...do.....	17.5 (0°C)	9.87 (0°C)	40.0 (0°-100°C)	.....	[523]
3458.....	Ag 41.30.....	...do.....	17.2 (0°C)	10.0 (0°C)	39.0 (0°-100°C)	.....	[523]

^a This value is alpha of the general equation, $R_t = R_0 (1 + \alpha t)$.

XII. ZINC AND ZINC ALLOYS

(389)

TABLE 53.—Classification of some zinc alloys (1942)

[Specifications are changing frequently, the sponsoring organization should be consulted for the latest revision. Single composition values are maximum allowable.]

Designation					Nominal composition, percent								Serial numbers of corresponding alloys in the tables	
Federal		ASTM		SAE	Commercial name	Pb	Fe	Cd	Al	Pb + Fe + Cd	Cu	Mg	Sn	
Spec.	Grade	Spec.	Grade											
SLAB ZINC (SPELTER)														
QZ-2-351a....	A-1	B6-37.....	1a	.....	Special high grade..	0.007	0.005	0.005	None	0.010	.....	.....	.....	3459, 3569, 3580.
QZ-2-351a....	A	B6-37.....	1	.....	High grade.....	.07	.02	.07	..do.....	.10	.....	.....	.....	^a 3583, ^a 3584, 3585; figures 180, 185.
QZ-2-351a....	B	B6-37.....	2	.....	Intermediate.....	.20	.03	.50	..do.....	.50	.....	.....	.....	^a 3463; figure 180.
QZ-2-351a....	C	B6-37.....	3	.....	Brass special.....	.60	.03	.50	..do.....	1.0	.....	.....	.....	Figure 180.
QZ-2-351a....	D	B6-37.....	4	.....	Selected.....	.80	.04	.75	..do.....	1.25	.....	.....	.....	^a 3467, ^a 3468, ^a 3469.
QZ-2-351a....	E	B6-37.....	5	.....	Prime western.....	1.60	.08	.....	.....	.....	.....	.....	.....	Figure 180.
ROLLED ZINC ^b														
.....	.....	B69-39....	.....	.....	.....	0.05	0.010	0.005	.....	.....	0.001	.....	.....	3461, 3462, 3551, 3552, 3553, 3554; figure 179.
.....	.....	B69-39....	.....	.....	.....	0.05-0.12	.012	.005	.....	.....	.001	.....	.....	.....
.....	.....	B69-39....	.....	.....	.....	.30-0.65	.020	0.20-0.35	.....	.....	.005	.....	.....	3465, 3466, 3555 to 3560, inclusive.
.....	.....	B69-39....	.....	.....	.....	.05-0.12	.012	.005	.....	.....	0.65-1.25	.....	.....	3531, 3532, 3535, 3561, 3563.
.....	.....	B69-39....	.....	.....	.....	.05-0.12	.015	.005	.....	.....	.75-1.25	0.007-0.02	.....	3533, 3534, 3536; figure 183.
DIE-CASTINGS														
.....	.....	B86-41T...	XXI	921	.....	0.007	0.10	0.005	3.5-4.5	.....	2.5-3.5	0.02-0.10	0.005	3496, 3497, 3566, 3571, 3588; figure 187.
57-93-2A ^c	A	B86-41T...	XXII	903	.....	.007	.10	.005	3.5-4.3	.....	0.10	.03-0.08	.005	3501, 3505, 3509, 3570, 3586; figure 187.
57-93-2A ^c	B	B86-41T...	XXV	925	.....	.007	.10	.005	3.5-4.3	.....	0.75-1.25	.02-0.08	.005	3486, 3487, 3587; figure 187.
^a Sheet rolled from these materials. ^b Typical compositions, not specification values. ^c Army.														

^aSheet rolled from these materials.^bTypical compositions, not specification values.^cArmy.

An appendix to the American Society for Testing Materials' specification for rolled zinc [525] gives the following tests which have been used in the zinc industry to some extent for the determination of the properties of the material:

(a) "DYNAMIC DUCTILITY TEST

"A1. *Apparatus*.—The dynamic ductility machine for conducting the dynamic ductility test is a modified inclinable power press fitted with an adjustable die.... The speed of the machine shall be 85 to 90 oscillations of the plunger per minute.

"A2. *Test Specimens*.—(a) The test specimen shall consist of a strip cut across the full width of a ribbon or sheet, the width of the strip being approximately 3 1/2 in. When this results in a specimen of less than 12 in. in length, as from narrow, unslit ribbon zinc, two specimens 3 1/2 in. in width shall be cut.

"(b) Test specimens from narrow strips such as ribbon or sheet zinc after slitting shall be cut to 20-in. lengths.

"NOTE.—The construction of the machine will not permit test specimens of greater thickness than 0.060 in.

"A3. *Procedure*.—(a) The temperature of the test specimen, testing machine, and room shall be kept within 70 and 90 F. throughout the test. The specimen shall be inserted in the machine and firmly clamped. The testing shall be started at one end and the strip moved with each successive cup. The series of cups shall be along the middle line of a 3 1/2-in. strip so that clamping will be uniform around the cup as it is formed. With the motor running, the clutch shall be thrown in, lowering the plunger, which, with the die in the clamp base, presses the cup in the test strip. If the cup does not show rupture, the plunger shall be advanced by increments of 0.005 in. and the cupping repeated with each increased depth until rupture occurs. Having determined the rupturing point additional cups shall be formed as a check. The rupturing point shall not be considered to be that point where an open crack is formed, but where the drawing of the bottom of the cup has just caused 'necking' of the surface prior to rupture....

"NOTE.—An experienced operator should be able to determine the point of rupture after two or three trial cups.

"(b) The depth of the cup at which rupture just occurs shall be read from the micrometer attachment on the plunger and reported as the dynamic ductility of the specimen. The average ductility of the test specimens shall be considered the dynamic ductility of the shipment.

"NOTE.—The micrometer attachment on the plunger mechanism measures the distance that the

plunger extends beyond the zero point. The zero point is where no impression would be made on the test strip. The clamp base is adjusted for the varying thicknesses. The micrometer attachment also serves to advance and withdraw the plunger.

(b) "TEMPER TEST

"A4. *Apparatus*.—The apparatus consists of a temper test machine....

"A5. *Test Specimens*.—Duplicate test specimens shall be cut from each sample and shall be rectangular in shape and cut accurately to 1 1/2 in. in width by 4 31/32 in. in length, with the length taken in the direction of rolling. With ribbon zinc the duplicate test specimens shall be cut from adjacent places across the width of a sample.

"NOTE.—The construction of the machine does not permit test specimens of greater thickness than 0.035 in.

"A6. *Procedure*.—(a) The temperature of the test specimens, testing machine, and room shall be kept within 70 and 90 F. throughout the test. The specimens shall be inserted to the full depth of the vise of the mandrel and securely held by tightening the vise. The diameter of the mandrel is 2 1/2 in. Inserting the test specimen as specified to the full depth of the vise leaves extended a length exactly one-half the circumference of the mandrel. In the rotation of the mandrel the test specimen is pressed by the contact arm against the mandrel. When the outer or free end passes the contact arm, it springs out according to its temper. The speed of rotation of the mandrel shall be between 50 and 55 r.p.m. With the motor running, the clutch shall be thrown in, rotating the mandrel counterclockwise. When the outer end of the specimen has passed the contact arm, the rotation of the mandrel shall be stopped by throwing out the clutch. The mandrel shall be turned to the 100 percent position which is indicated by a mark on the mandrel and the fixed pointer, and the percentage of temper shall be read from the position of the outer end of the specimen on the underlying graduated scale, consisting of a half circle graduated counterclockwise from 0 to 100 percent.

"(b) The duplicate specimen shall be similarly tested and, in order to eliminate the effect of the curvature of the specimens due to coiling, shall be inserted in the vise in the reverse position to that of the first specimen. That is, if one specimen is inserted and pressed with its curvature toward the mandrel, the duplicate specimen should be inserted with its curvature away from the mandrel.

"(c) The average of the readings on two test specimens shall be reported as the temper of the material."

TABLE 54.—Zinc and zinc alloys, normal-temperature properties

[For a discussion of the indefiniteness of values reported for yield strength and particularly for "proportional limit" see pages 5 and 6. Hardness numbers are Brinell numbers unless prefixed R_p , R_c , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed Iz (Izod method).]

Serial number	Composition	Condition	Tensile properties					Endurance limit	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area			
			Ktpsi/in. ²	Ktpsi/in. ²	Ktpsi/in. ²	Ktpsi/in. ²	Percent	Percent			
3459..	Percent Cd 0.003, Fe 0.003, Pb 0.001.	Cast from 805°F.	.....	.....	.....	4.0	2.0 (2 in.)	.....	31	ft-lb	[526]
3460..	"Pure" Zinc.....	Foil, 0.0016 in.	.....	.....	.....	15	10	.....	.....	.....	[514]
3461..	Pb 0.05, Cd 0.002...	Sheet, soft; tested parallel to rolling direction.	.....	.....	4.0	20.8	49 (2 in.)	.....	.....	.....	[527]
3462..	...do.....	Sheet, soft; tested perpendicular to rolling direction.	.....	.....	6.3	26.2	36 (2 in.)	.....	.....	.....	[527]
3463..	Pb 0.15, Cd 0.11, Fe 0.017.	Sheet, 0.0185 in., rolled.	.....	.....	.....	29.1	25 (2 in.)	.....	S 24	Dynamic ductility.....0.250 in. Temper.....49%.	[528]
3464..	Pb 0.24, Cd 0.12, Fe 0.011.	Sheet, 0.018 in., rolled..	.....	.....	.....	28.8	23 (2 in.)	.....	S 24	Dynamic ductility.....0.235 in. Temper.....53%.	[528]
3465..	Cd 0.3, Pb 0.3.....	Sheet, soft; tested parallel to rolling direction.	.....	.....	5.2	22.2	35 (2 in.)	.....	.....	.....	[527]
3466..	...do.....	Sheet, soft; tested perpendicular to rolling direction.	.....	.....	10.2	30.9	22 (2 in.)	.....	.....	.....	[527]
3467..	Pb 0.8, Cd 0.15.....	Sheet, soft; tested parallel to rolling direction.	.....	.....	5.8	21.2	43 (2 in.)	.....	.....	.....	[527]
3468..	...do.....	Sheet, soft; tested perpendicular to rolling direction.	.....	.....	10.5	29.5	14 (2 in.)	.....	.....	.....	[527]
3469..	Pb 0.80, Cd 0.09, Fe 0.017.	Sheet, 0.0173 in., rolled.	.....	.....	.....	28.7	16 (2 in.)	.....	S 22	Dynamic ductility.....0.255 in. Temper.....50%.	[528]
3470..	Zinc.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....5,400-5,500 kips/in. ² .	[88]
3471..	...do.....	Sheet, 0.25 in., rolled..	.....	.....	.....	23.8	12 (8 in.)	.....	.....	.....	[526]
3472..	...do.....	Sheet, 0.10 in., rolled...	.....	.....	.....	22.3	19 (8 in.)	.....	.....	.....	[526]

^aJohnson's limit: ("The apparent elastic limit is the point on the stress-diagram ... at which the rate of deformation is 50 percent greater than it is at the origin," J. B. Johnson.)

^bRate of strain: 0.00118 (in./in.)/minute below Johnson's limit; 0.650 (in./in.)/minute at rupture.

^cRate of strain: 0.0010 (in./in.)/minute below Johnson's limit; 0.750 (in./in.)/minute at rupture.

^dRate of strain: 0.0012 (in./in.)/minute below Johnson's limit; 0.60 (in./in.)/minute at rupture.

^eRate of strain: 0.000823 (in./in.)/minute below Johnson's limit; 0.70 (in./in.)/minute at rupture.

^fRate of strain: 0.00107 (in./in.)/minute below Johnson's limit; 0.65 (in./in.)/minute at rupture.

^gRate of strain: 0.00095 (in./in.)/minute below Johnson's limit; 0.75 (in./in.)/minute at rupture.

^hRate of strain: 0.5 in./minute.

TABLE 54.—Zinc and zinc alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
			kips/in. ²	kips/in. ²	kips/in. ²	kips/in. ²	Percent	Percent				
			10,500	5.8		125.5						
			14,800	5.1		126.5	6.5 (8 in.)					
PURE AND COMMERCIAL ZINC—Continued												
3473..	Zinc.....	Sheet, 0.018 in., rolled..										[525]
3474..	...do.....	Sheet, 0.006 in., rolled..										[526]
ZINC-ALUMINUM ALLOYS (SEE ALSO FIG. 181)												
3475..	Al 3, Cu 3.....	Sheet, cold-rolled to 0.039 in. (67% red.)..					22				Bend No. (0.12-in. radius).....36.....	[528]
3476..	Al 4.....	Sand-cast from 840°F.....			14.1 (0.2%)	26.3	3.6		63	J153		[530]
3477..	...do.....	Cast from 840°F into mold at 390°F.....			15.6 (0.2%)	28.3	2.0		66	J215		[530]
3478..	...do.....	Sheet, rolled.....			11.2 (0.2%)	26.0	66		43			[530]
3479..	Al 4, Cu 0.4, Mg 0.04.....	Sand-cast from 860°F.....			17.0 (0.2%)	21.2	<0.5		87	J82		[530]
3480..	...do.....	Cast from 860°F into mold at 390°F.....			17.4 (0.2%)	29.2	0.5		91	J89		[530]
3481..	...do.....	Sheet, rolled.....			23.6 (0.2%)	48.8	27		103			[530]
3482..	Al 4, Cu 0.4, Ni 0.2, Mg 0.04.....	Sand-cast from 885°F.....			17.1 (0.2%)	17.4	<0.5		87	J85		[530]
3483..	...do.....	Cast from 885°F into mold at 390°F.....			17.6 (0.2%)	27.0	<.5		88	J98		[530]
3484..	...do.....	Sheet, rolled.....			24.2 (0.2%)	55.5	7.0		103			[530]
3485..	Al 3.5-4.3, Cu 0.75-1.25, Mg 0.02-0.06.....	Die-cast.....				44.5	3.0 (2 in.)		70-85	17	Compressive str.....87.3 kips/in. ² . Shear str.....38.4 kips/in. ² . Specific gravity.....6.7. Melting point.....717.1°F. Mod rupture.....105 kips/in. ² . Transverse deflection.....0.16 in.	[531]
3486..	Al 4.1, Cu 1.0, Mg 0.04.....	Die-cast; aged 5 weeks at r.t.....				42	4 (2 in.)			18		[532]
3487..	Al 4, Cu 1, Mg 0.04.....	Die-cast; aged 6 months at r.t.....				*47.6						[533]
3488..	Al 4.1, Cu 1.25.....	Die-cast.....				43	5 (2 in.)			22		[532]
3489..	...do.....	Die-cast; aged 5 weeks at r.t.....				41	10 (2 in.)			24		[532]
3490..	Al 4, Cu 2.5, Mg 0.04.....	Sand-cast from 895°F.....			16.7 (0.2%)	19.6	<0.5		112	J102		[530]

3491..	...do.....	Cast from 895°F into mold at 390°F.	.....	19.9 (0.2%)	35.1	0.8	.....	.....	113	J286	.....	[530]
3492..	...do.....	Sheet, rolled.....	.....	20.5 (0.2%)	57.0	19	.....	.....	133	.....	.....	[530]
3493..	Al 4, Cu 2.5, Mg 0.1, Li 0.03.	Sand-cast from 895°F.....	.....	17.1 (0.2%)	19.9	<0.5	.....	.....	114	J67	.....	[530]
3494..	...do.....	Cast from 895°F into mold at 390°F.	.....	19.5 (0.2%)	30.1	<.5	.....	.....	114	J81	.....	[530]
3495..	...do.....	Sheet, rolled.....	.....	25.7 (0.2%)	64.0	4	.....	.....	126	.....	.....	[530]
3496..	Al 3.5-4.5, Cu 2.5-3.5, Mg 0.02-0.10.	Die-cast.....	.....	.....	47.9	5.1 (2 in.)	.....	.....	75-100	19	Compressive str.....93.1 kips/in. ² . Shear str.....45.8 kips/in. ² . Specific gravity.....6.7. Melting point.....715.1°F. Mod rupture.....116 kips/in. ² . Transverse deflection.....0.22 in.	[531]
3497..	Al 4, Cu 3, Mg 0.03.	Die-cast; aged 6 months at r-t.	.....	.....	*52.1	.....	.....	8.5 (10 ⁸)	.....	.....	.....	[533]
3498..	Al 4, Li 0.03.....	Sand-cast from 860°F.....	.....	.....	11.8	<0.5	.....	.....	76	J114	.....	[530]
3499..	...do.....	Cast from 860°F into mold at 390°F.	.....	16.8 (0.2%)	24.1	<.5	.....	.....	79	J96	.....	[530]
3500..	...do.....	Sheet, rolled.....	.....	22.2 (0.2%)	43.7	21	.....	.....	92	.....	.....	[530]
3501..	Al 3.5-4.3, Mg 0.03-0.08.	Die-cast.....	.....	.....	40.3	4.7 (2 in.)	.....	.....	60-90	20	Compressive str.....60.5 kips/in. ² . Shear str.....30.9 kips/in. ² . Specific gravity.....6.6. Melting point.....717.6°F. Mod rupture.....95.0 kips/in. ² . Transverse deflection.....0.27 in.	[531]
3502..	Al 4, Mg 0.04.....	Sand-cast from 840°F.....	.....	.....	14.5	<0.2	.....	.....	74	J101	.....	[530]
3503..	...do.....	Cast from 840°F into mold at 390°F.	.....	18.3 (0.2%)	31.9	.5	.....	.....	81	J74	.....	[530]
3504..	...do.....	Sheet, rolled.....	.....	19.6 (0.2%)	50.2	2	.....	.....	76	.....	.....	[530]
3505..	...do.....	Die-cast; aged 6 months at r-t.	.....	.....	*41.0	.....	.....	6.9 (10 ⁸)	.....	.....	.....	[533]
3506..	Al 4, Mg 0.04, Li 0.03.	Sand-cast from 860°F.....	.....	.....	13.5	0.2	.....	.....	84	J86	.....	[530]
3507..	...do.....	Cast from 860°F into mold at 390°F.	.....	17.8 (0.2%)	24.9	<0.5	.....	.....	87	J96	.....	[530]
3508..	...do.....	Sheet, rolled.....	.....	23.8 (0.2%)	53.3	21	.....	.....	103	.....	.....	[530]
3509..	Al 4.1, Mg 0.04.....	Die-cast; aged 5 weeks at r-t.	.....	.....	37	5 (2 in.)	.....	.....	.....	20	.....	[532]
3510..	Al 5, Cu 3.....	Sheet, cold-rolled to 0.039 in. (67% red.).	.....	.....	48.4	25	.....	.....	.....	.....	Bend No. (0.12-in. radius).....32.....	[529]
3511..	Al 5, Cu 5.....	...do.....	.....	.....	49.8	35	.....	.....	.....	.....	Bend No. (0.12-in. radius).....28.....	[528]
3512..	Al 7, Cu 4.....	...do.....	.....	.....	45.5	40	.....	.....	.....	.....	Bend No. (0.12-in. radius).....34.....	[528]
3513..	Al 7, Cu 4, Mg 0.03.	...do.....	.....	.....	59.7	30	.....	.....	.....	.....	Bend No. (0.12-in. radius).....10.....	[529]

*As die-cast.

^J Impact value, cm-kg/cm.²

ⁱ Rate of strain: 0.5 in./minute.

TABLE 54.—Zinc and zinc alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
ZINC-ALUMINUM ALLOYS—Continued												
3514..	Al 9-11, Cu 1.8-2.0, Mg 0.02-0.05.	Extruded.....	Kips/in. ²	Kips/in. ²	Kips/in. ²	kips/in. ²	Percent 7	Percent 55	Kips/in. ²	ft-lb 12	.....	[534]
3515..	Al 10.....	Sheet, rolled.....	.....	.....	.....	25	130	.....	.....	40	Bend No.....80..... Erichsen.....17 mm.	[534]
3516..	Al 10, Cu 0.3.....	...do.....	.....	.....	.....	36	80	.....	.....	60	Bend No.....50..... Erichsen.....14 mm.	[534]
3517..	Al 10, Cu 0.3, Mg 0.01.	...do.....	.....	.....	.....	53	40	.....	.....	100	Bend No.....35..... Erichsen.....12 mm.	[534]
3518..	Al 10, Cu 0.3, Mg 0.04.	Sheet, 0.1 in.....	14,900	.....	.....	.....	.....	.....	.....	.....	.....	[535]
3519..	Al 10, Cu 2, Mg 0.3.	.....	16,000	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....5,800 kips/in. ² ..	[535]
3520..	Al 12, Mg 0.05.....	Cold-drawn.....	.....	.....	.....	61	5 (10 diam)	41	.....	.....	.....	[536]
3521..	Al 15, Mg 0.05.....	...do.....	.....	.....	.....	64	5.5 (10 diam)	44	.....	.....	.....	[536]
3522..	Al 17, Mg 0.05.....	...do.....	.....	.....	.....	70	5 (10 diam)	39	.....	.....	.....	[536]
ZINC-CADMIUM ALLOYS												
3523..	Cd 0.5.....	Rod, 1 in. diam, cast from 840°F into mold at 480°F; aged 4 weeks at r-t.	.....	.....	.....	13.4	1 (1.25 in.)	1	.....	.....	Specific gravity.....7.14.....	[539]
3524..	...do.....	Rolled (70% red.) at 320°F; aged 3 months at r-t.	.....	.....	.....	27.3	51-82 (1.25 in.)	82	.....	.....	.....	[539]
3525..	Cd 2.....	Quenched.....	.....	.....	.....	20.3	5.7	.....	.....	57	.....	[526]
3526..	...do.....	Quenched and aged 15 days at r-t.	.....	.....	.....	27.3	11	.....	.....	64	.....	[526]
3527..	Cd 3.....	Rod, 1 in. diam, cast from 840°F into mold at 480°F; aged 4 weeks at r-t.	.....	.....	.....	17.4	2 (1.25 in.)	1	.....	.....	Specific gravity.....7.17.....	[539]
3528..	...do.....	Rolled (70% red.) at 320°F; aged 3 months at r-t.	.....	.....	.....	32.3	59 (1.25 in.)	76	.....	.....	.....	[539]
3529..	Cd 6.....	Rod, 1 in. diam, cast from 840°F into mold at 480°F; aged 4 weeks at r-t.	.....	.....	.....	17.7	9 (1.25 in.)	7	.....	.....	Specific gravity.....7.22.....	[539]
3530..	...do.....	Rolled (70% red.) at 320°F; aged 3 months at r-t.	.....	.....	.....	30.0	82 (1.25 in.)	74	.....	.....	.....	[539]

ZINC-COPPER ALLOYS (SEE ALSO FIGS. 182 AND 183)

[531]..	Cu 1-0, Pb 0.084, Fe 0.015, Cd 0.0049.	Sheet, 0.018 in., rolled..	.....	.....	.....	.....	.....	.....	S 20	.....	Dynamic ductility.....0.285 in. Temper.....60%.	[536]
[532]..	Cu 1-0, Pb 0.09, Fe 0.011, Cd 0.0013, Mg 0.0036.	...do.....	.....	.....	.....	.....	.....	.....	S 19	.....	Dynamic ductility.....0.250 in. Temper.....62%.	[537]
[533]..	Cu 1-0, Mg 0.01.....	Sheet, 0.040 in., soft.....	.....	.....	.....	.....	.....	.....	P _F 72	.....	Dynamic ductility.....0.38 in. Temper.....37%.	[537]
[534]..	...do.....	Sheet, 0.040 in., rolled (50% red.) ..	.....	.....	.....	.....	.....	.....	P _F 93	.....	Dynamic ductility.....0.34 in. Temper.....52%.	[537]
[535]..	Cu 1-1, Pb 0.077, Fe 0.012, Cd 0.0047.	Sheet, 0.018 in., rolled..	.....	.....	.....	.....	.....	.....	S 18	.....	Dynamic ductility.....0.300 in. Temper.....44%.	[538]
[536]..	Cu 1-1, Pb 0.09, Fe 0.012, Mg 0.0067, Cd 0.0046.	...do.....	.....	.....	.....	.....	.....	.....	S 21	.....	Dynamic ductility.....0.240 in. Temper.....67%.	[538]
[537]..	Cu 3, Al 1.....	Sheet, cold-rolled to 0.039 in. (67% red.).	.....	.....	.....	.....	.....	.....	.....	.....	Bend No. (0.12-in. radius)....80.....	[539]
[538]..	Cu 3-7-4-0, Pb 0.25-0.40, Mn 0.25-0.40, Al 0.2-0.3, Fe 0.1-0.3, Mg <0.005.	Extruded.....	.....	.....	.....	.....	.....	.....	93	.....	.....	[539]
[539]..	Cu 3-7-4, Bi 0.1-0.15, Wp 0.1-0.2, Al 0.05-0.2, Pb 0.05-0.08, Ti 0.02-0.05.	...do.....	.....	38-40	.....	.....	.....	.....	.....	.....	.....	[539]
[540]..	...do.....	Rod, 1/2 in. diam, extruded and drawn.	.....	.....	.....	.....	.....	.....	85-95	10-12	.....	[539]
[541]..	Cu 4-5, Al 0.2-0.25..	Extruded.....	.....	.....	.....	.....	.....	.....	88	.....	.....	[539]
[542]..	Cu 4-8, Al 0.2.....	Sheet, rolled.....	.....	.....	.....	.....	.....	.....	.....	.....	Bend No.....32..... Erichsen.....18 mm.	[539]
[543]..	Cu 5, Al 1.....	Sheet, cold-rolled to 0.039 in. (67% red.).	.....	.....	.....	.....	.....	.....	.....	.....	Bend No. (0.12-in. radius)....80.....	[529]
[544]..	Cu 5, Al 3.....	...do.....	.....	.....	.....	.....	.....	.....	.....	.....	Bend No. (0.12-in. radius)....34.....	[529]

^mRate of strain: 6%/minute.

¹ Impact value, cm-kg/min.²

Rate of strain: 0.25 in./minute.

TABLE 54.—Zinc and zinc alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
ZINC-MANGANESE-COPPER ALLOY													
3545..	Percent Mn 20, Cu 10.....	Cast.....	Kips/in. ²	Kips/in. ²	Kips/in. ² 75.0	Percent	Percent	Kips/in. ²	R _c 7	ft-lb .....	.....	.....	[540]
3546..	...do.....	Extruded.....	.....	.....	106	.....	.....	.....	R _c 7	.....	.....	.....	[540]
ZINC-SILVER ALLOYS (SEE FIG. 184)													
ZINC-TIN ALLOYS													
3547..	Sn 2.....	Cast.....	.....	.....	.....	4.3-10	.....	.....	.....	.....	.....	.....	[526]
3548..	Sn 6.....	...do.....	.....	.....	.....	11-13	.....	.....	.....	.....	.....	.....	[526]
3549..	Sn 6, Cu 2.75, Al 0.5.	Die-cast.....	.....	.....	.....	19.7	.....	.....	52	.....	Transverse deflection (3-in. span).....	0.18 in.....	[526]
3550..	Sn 30, Ag 20.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod rupture.....	52.7 kips/in. ²	[526]
											Melting range 650°-970°F.....		[184]

^aRate of strain: 0.266 in./minute.

*Rate of strain: 0.266 in./minute.

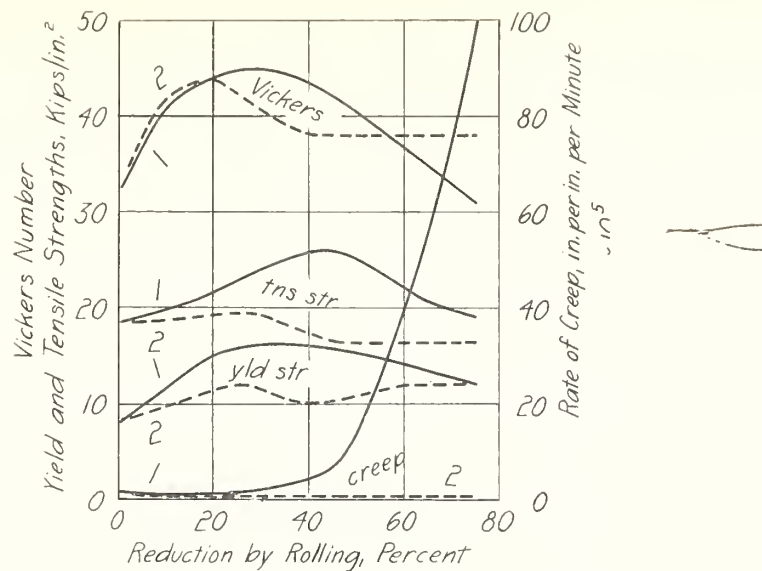


FIGURE 179.—Effect of cold-rolling on the tensile properties and hardness of electrolytic zinc (Chadwick [701]).

(Yield strength, 0.2% permanent set; rate of strain in tensile test, 0.25 in./minute above yield point; rate of creep measured in (in./in.)/minute on 2 in. gage length under load of 5 kips/in.²)

Pb 0.005%, Fe 0.0035%, Cd 0.003%. Curves: 1, as rolled; 2, rolled and aged 1 month at room temperature.

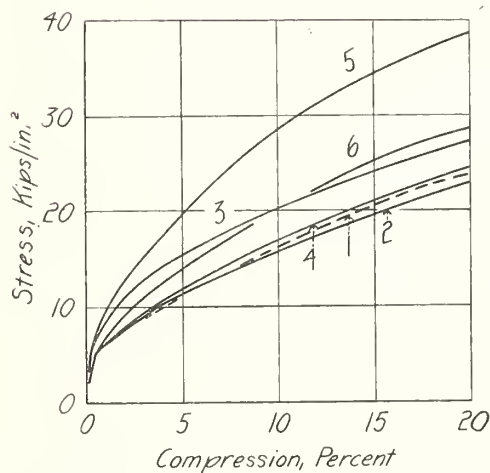


FIGURE 180.—Compressive strength of cast zinc (Rigg and Williams [702]).

(Rate of strain, 0.0319 in./minute; test specimens 1 in. diameter, 2.6 in. long)
Cast from 895°F.

Curves: 1, Pb 0.040%, Fe 0.015%; 2, Pb 0.192%, Fe 0.016%; 3, Pb 0.474%, Fe 0.013%; 4, Pb 0.484%, Fe 0.031%; 5, Pb 0.9%, Fe 0.02%, Cd 0.26%; 6, Pb 1.3%, Fe 0.05%, Cd 0.06%.

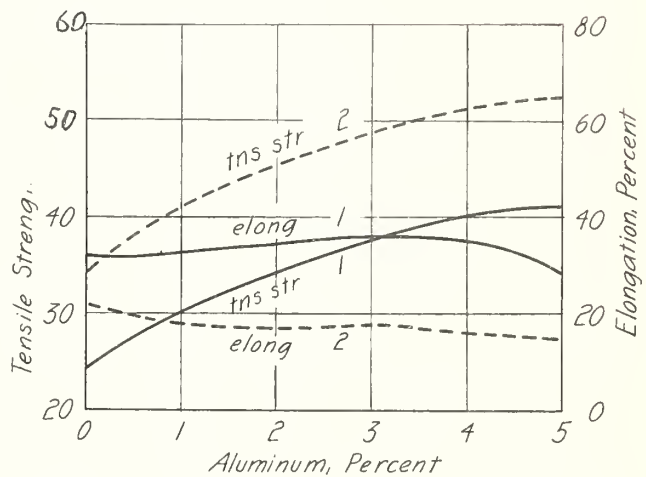


FIGURE 181.—Tensile properties of zinc-aluminum alloys (Bayer [529]).

Sheet, 0.04 in., cold-rolled (67% red.).

Curves: 1, parallel to rolling direction; 2, perpendicular to rolling direction.

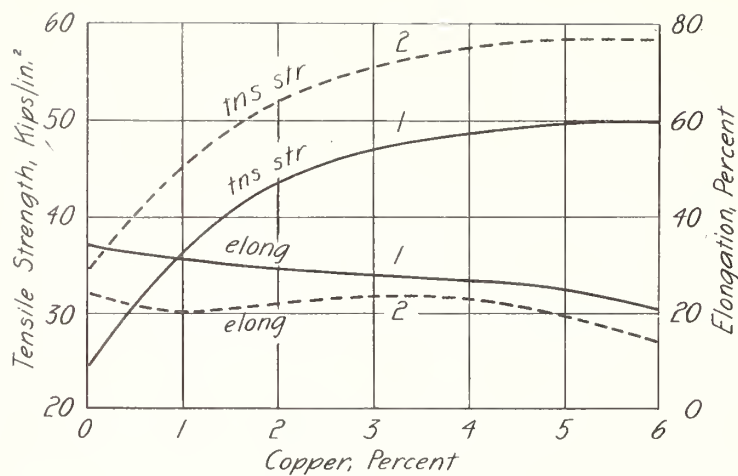


FIGURE 182.—Tensile properties of zinc-copper alloys (Bayer [529]).

Sheet, 0.04 in., cold-rolled (67% red.).

Curves: 1, parallel to rolling direction; 2, perpendicular to rolling direction.

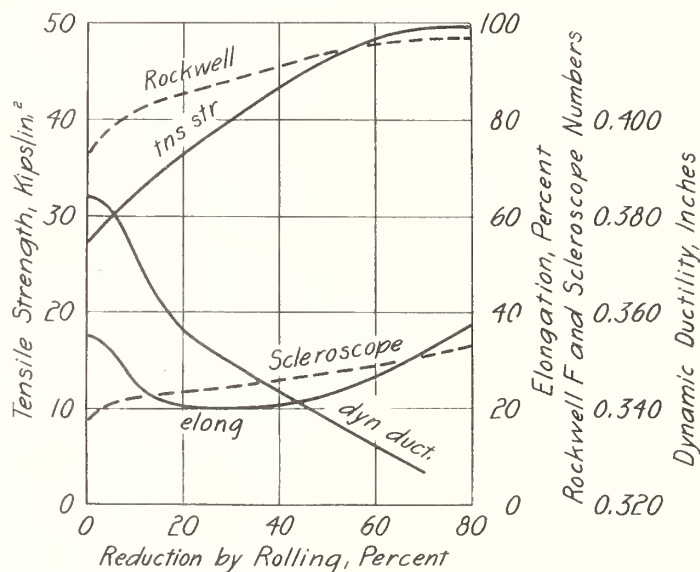


FIGURE 183.—Effect of cold-rolling on the tensile properties, hardness, and dynamic ductility of a zinc-copper-magnesium alloy (Kelton and Edmunds [537]).

Cu 1.0%, Mg 0.01%. Sheet, 0.040 in.

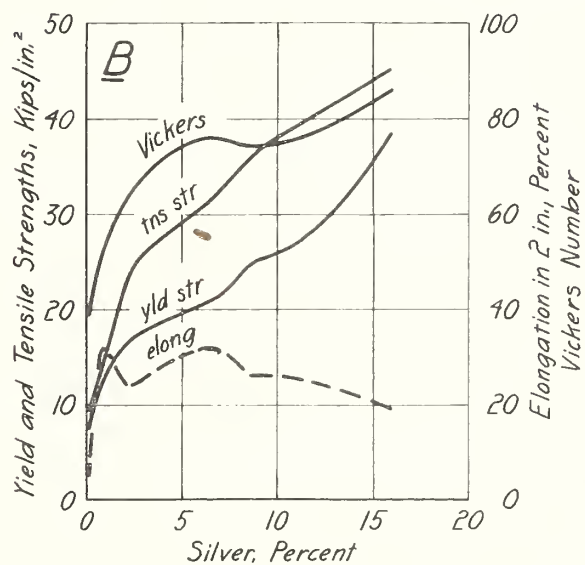
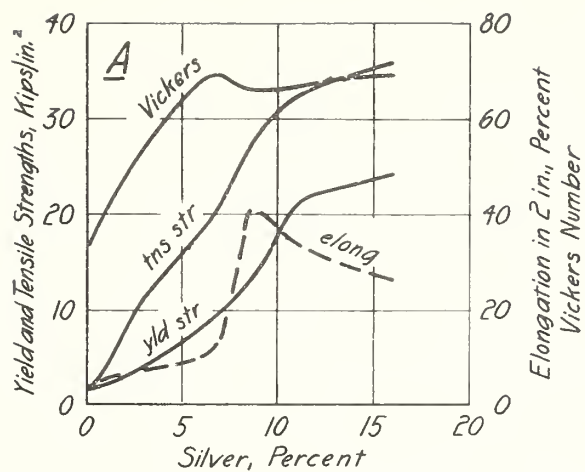


FIGURE 184.—Tensile properties and hardness of zinc-silver alloys (Addicks [129]).

(Yield strength, 0.2% offset)

Sheet, 0.040 in.

A, Annealed 1 hour at 750°F; B, cold-rolled (30% red.).

TABLE 55.—Zinc and zinc alloys, creep properties

[For short-time elevated-temperature properties, see figs. 185, 186, and 187.]

Serial number	Composition	Condition	Temperature	Stress (kips/in. ²) for designated creep rate per hour	0.01%	0.1%	1.0%	Remarks	Reference
3551.....	Pb 0.05, Cd 0.002.....	Percent Rolled, soft.....	68 104 140	0.01% 6.5	8.4 5.8 .....	.....	10.6 9.1 6.5	Tested parallel to rolling direction.....	[527]
3552.....	...do.....	...do.....	68 104 140	7.2	11.1 7.5 .....	.....	15.0 11.7 8.1	Tested perpendicular to rolling direction.....	[527]
3553.....	...do.....	Rolled, hard.....	68 104 140	5.2	7.3 5.0 .....	.....	10.8 7.5 5.2	Tested parallel to rolling direction.....	[527]
3554.....	...do.....	...do.....	68 104 140	.....	9.7 6.2 .....	.....	15.0 10.4 6.5	Tested perpendicular to rolling direction.....	[527]
3555.....	Cd 0.3, Pb 0.3.....	Rolled, soft.....	68 104 140	7.6 5.4 5.0	10.1 8.0 6.3	.....	12.5 11.8 8.8	Tested parallel to rolling direction.....	[527]
3556.....	...do.....	...do.....	68 104 140	11.0 8.4 5.0	15.4 12.1 8.0	.....	..... 16.3 11.1	Tested perpendicular to rolling direction.....	[527]
3557.....	...do.....	Rolled, medium hard.....	68 104 140	6.6 5.0	9.1 5.8 5.2	.....	13.3 10.2 7.3	Tested parallel to rolling direction.....	[527]
3558.....	...do.....	...do.....	68 104 140	8.8 6.2	12.5 9.5 6.2	.....	16.8 14.7 10.7	Tested perpendicular to rolling direction.....	[527]
3559.....	...do.....	Rolled, hard.....	68 104 140	5.3	7.3 5.7 .....	.....	12.0 9.5 5.5	Tested parallel to rolling direction.....	[527]
3560.....	...do.....	...do.....	68 104 140	5.6	7.6 6.2 .....	.....	13.4 9.7 6.3	Tested perpendicular to rolling direction.....	[527]
3561.....	Cu 1.0, Pb 0.084, Fe 0.015, Cd 0.0049.....	Sheet, 0.018 in., rolled....	86	12.1 (0.042%)	.....	.....	.....	Temper.....60%..	[528]
3562.....	Cu 1.0, Pb 0.09, Fe 0.011, Cd 0.0043, Mg 0.0036.	...do.....	86	15.8 (0.042%)	.....	.....	.....	Temper.....62%..	[528]
3563.....	Cu 1.1, Pb 0.077, Fe 0.012, Cd 0.0047.....	...do.....	86	7.6 (0.042%)	.....	.....	.....	Temper.....41%..	[528]
3564.....	Cu 1.1, Pb 0.09, Fe 0.012, Mg 0.0057, Cd 0.0046.	...do.....	86	18.0 (0.042%)	.....	.....	.....	Temper.....67%..	[528]

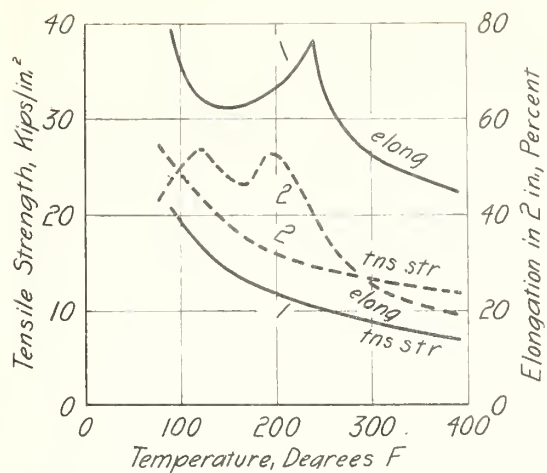


FIGURE 185.—Short-time tensile properties of zinc at high temperatures (Anderson [703]).

(Rate of strain, 0.285 in./minute)

Pb 0.065%, Fe 0.01%.

Curves: 1, with grain; 2, across grain.

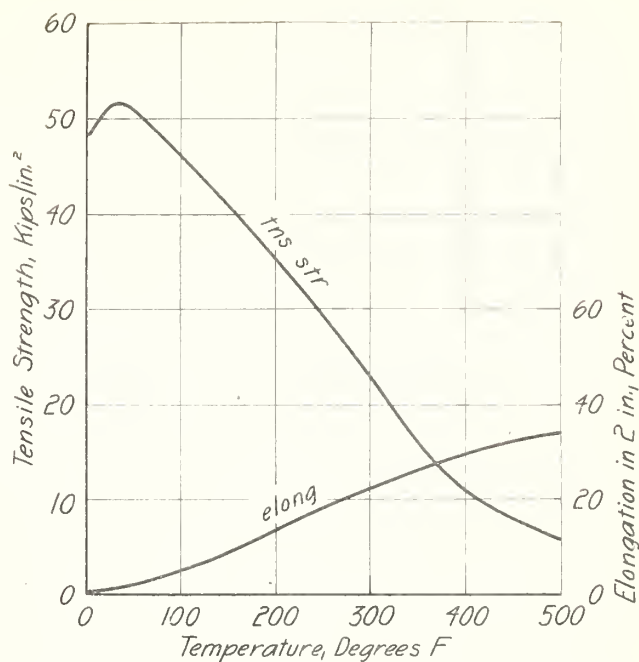


FIGURE 186.—Short-time tensile properties of a die-cast zinc-aluminum-copper-magnesium alloy at various temperatures (Anderson [703]).

(Rate of strain, 0.02 in./minute)

Al 4.67%, Cu 2.89%, Mg 0.09%, Fe 0.015%.

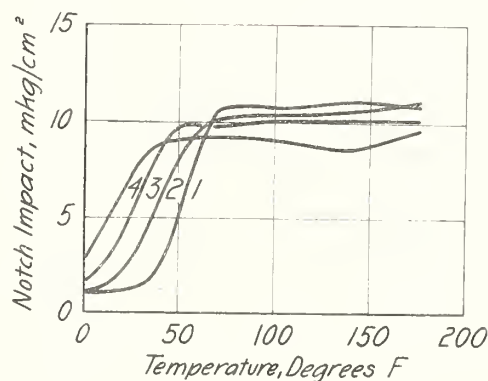


FIGURE 187.—Impact values of zinc-alloy die-castings at various temperatures (Bayer and Burkhardt [536])

Curves: 1, Al 4.0%, Mg 0.04%; 2, Al 4.0%, Cu 0.5%, Mg 0.04%; 3, Al 4.0%, Cu 1.0%, Mg 0.04%; 4, Al 4.0%, Cu 2.7%, Mg 0.04%.

TABLE 56.—Zinc and zinc alloys, low-temperature properties
[See also figs. 146 and 187]

Serial number	Composition	Condition	Temperature of test	Tensile properties				Reference
				Tensile strength	Elongation	Reduction of area	Charpy impact value	
			σ_p	Ktpsi/in. ²	Percent	Percent	ft-lb	
3565.....	Fe 0.2.....		64				2.8	[65]
			-22	.....	.....	.....	1.2	
			-112	.....	.....	.....	1.8	
3566.....	Al 3.88, Cu 2.91, Mg 0.11, Pb 0.004, Cd 0.003, Sn 0.002.....	Die-cast.....	70				2.6	[67]
			32	.....	.....	.....	2.1	
			0	.....	.....	.....	1.1	
3567.....	Al 4.09, Cu 2.10, Mg 0.08, Pb 0.008, Cd 0.003, Sn 0.002.....	...do.....	70				16	[67]
			32	.....	.....	.....	9.9	
			0	.....	.....	.....	2.4	
3568.....	Pb 1.4.....	Extruded.....	68	27.3	30 (5 diam)	83	^a 1.0	[541]
			-22	34.5	10 (5 diam)	10	^a 0.2	
			-103	34.5	7 (5 diam)	5	.....	

^aNotch impact value, m-kg/cm.²

TABLE 57. —Zinc and zinc alloys, thermal expansion

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade			Reference
			20° to 100°C $\times 10^{-6}$	20° to 200°C $\times 10^{-6}$	20° to 300°C $\times 10^{-6}$	
3569 ^a	Cu 0.003, Fe 0.003, Pb 0.001.....	Rod 9/32 in., cast.....	39.5	39.7	^b 39.7	[542]
3570.....	Al 3.5-4.3, Mg 0.03-0.08.....	Die-cast.....	27.2	.....	.....	[177] ^c
3571.....	Al 3.5-4.5, Cu 2.5-3.5, Mg 0.02-0.10.....	do.....	27.7	.....	.....	[177]
3572.....	Al 5.29, Cu 0.02, Fe 0.02, Si 0.01.....	do.....	32.0	37.2	^b 40.7	[707]
3573.....	Al 12.5.....	Rod, 1/4 in. diam.....	26.4	24.1	^c 38.7	[543]
3574.....	Al 22.57, Fe 0.11, Cu 0.05, Si 0.05.....	do.....	26.0	28.3	^b 30.5	[707]
3575.....	Al 50.....	Rod, 1/4 in. diam.....	26.5	27.6	33.7	[543]
3576 ^d	Mg 6.....	do.....	23.2	.....	.....	[481]
3577 ^d	Mg 10.....	do.....	24.0	.....	.....	[481]
3578 ^d	Mg 17.....	do.....	33.2	.....	.....	[481]
3579 ^d	Mg 30.....	do.....	31.5	.....	.....	[481]

^aCoefficient of linear expansion of polycrystalline zinc varies considerably, ranging from 17×10^{-6} to 39×10^{-6} at room temperature, depending on crystal orientation. Gruneisen [720] reports values of 10.1×10^{-6} (-183° to 13°C) and 17.1×10^{-6} (19° to 100°C).

^b20° to 250°C.

^c20° to 290°C.

^dBase temperature 40° instead of 20°C.

TABLE 58.—Zinc and zinc alloys, electrical and thermal properties

Serial number	Composition	Condition	Electrical properties			Thermal conductivity	Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity		
3580.....	Zn 99.999.....	Cast.....	Percent IACS.....	Microhm cm.....	per °C × 10 ⁻⁴	$\left\{ \begin{array}{l} 1.27 \text{ (25°C)} \\ 1.09 \text{ (100°C)} \\ 0.99 \text{ (100°C)} \end{array} \right\}$	[544]
3581.....	Zinc (spectrographically pure).....	Wire, 0.07 in., swaged.....	29.1 (20°C).....	5.916 (20°C).....	.....	.....	[544]
3582.....	..do.....	Wire, 0.0066 in., drawn (87% red.).....	.....	.....	41.9 (10°C-100°C).....	.....	[544]
3583.....	Zn 99.94.....	Hot-rolled.....	28.4.....	6.06.....	.....	.....	[544]
3584.....	..do.....	Cold-rolled.....	28.3.....	6.10.....	.....	.....	[544]
3585.....	Pb 0.04, Fe 0.02.....	Cast.....	.....	.....	.....	$\left\{ \begin{array}{l} 1.12 \text{ (100°C)} \\ 1.08 \text{ (200°C)} \\ 1.05 \text{ (300°C)} \end{array} \right\}$	[402]
3586.....	Al 3.5-4.3, Mg 0.03-0.08.....	Die-cast.....	27 (25°C).....	6.4 (25°C).....	.....	1.1 (25°C-100°C).....	[531]
3587.....	Al 3.5-4.3, Cu 0.75-1.25, Mg 0.02-0.08.....	..do.....	26 (25°C).....	6.7 (25°C).....	.....	1.1 (25°C-100°C).....	[531]
3588.....	Al 3.5-4.5, Cu 2.5-3.5, Mg 0.02-0.10.....	..do.....	25 (25°C).....	6.9 (25°C).....	.....	1.0 (25°C-100°C).....	[531]
3589.....	Cd 0.125.....	Single crystal.....	^a 27.2, ^b 28.9 (20°C).....	^b 5.97, ^a 6.34 (20°C).....	.....	.....	[545]
3590.....	Cu 0.125.....	..do.....	^a 27.2, ^b 28.9 (20°C).....	^b 5.97, ^a 6.35 (20°C).....	.....	.....	[545]
3591.....	Cu 0.500.....	..do.....	^a 26.6, ^b 28.3 (20°C).....	^b 6.09, ^a 6.47 (20°C).....	.....	.....	[545]
3592.....	Au 0.125.....	..do.....	^a 27.1, ^b 28.8 (20°C).....	^b 5.99, ^a 6.36 (20°C).....	.....	.....	[545]
3593.....	Au 0.500.....	..do.....	^a 26.1, ^b 27.7 (20°C).....	^b 6.22, ^a 6.61 (20°C).....	.....	.....	[545]
3594.....	Pb 1.1, Cd 0.05.....	Hot-rolled.....	28.2.....	6.12.....	.....	.....	[544]
3595.....	..do.....	Cold-rolled.....	28.1.....	6.14.....	.....	.....	[544]
3596.....	Ag 0.125.....	Single crystal.....	^a 27.2, ^b 28.8 (20°C).....	^b 5.99, ^a 6.35 (20°C).....	.....	.....	[545]
3597.....	Ag 0.500.....	..do.....	^a 26.1, ^b 27.8 (20°C).....	^b 6.21, ^a 6.60 (20°C).....	.....	.....	[545]

^aParallel to the vertical axis of the crystal.^bPerpendicular to the vertical axis of the crystal.

XIII. MISCELLANEOUS METALS AND ALLOYS

(407)

TABLE 60.—Miscellaneous metals and alloys, normal-temperature properties

[For a discussion of the indefiniteness of values reported for yield strength and particularly for "proportional limit" see pages 5 and 6. Hardness numbers are Brinell numbers unless prefixed by R_B , R_C , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). Impact value determined by Charpy method unless prefixed 1z. (Izod method).]

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
ANTIMONY												
3598..	Percent Antimony.....	.....	Klps/in. ² 11,300	Klps/in. ²	Klps/in. ²	Klps/in. ²	Percent	Percent .....	.....	ft-lb	Specific gravity.....6.62.....	[546]
3599..	Sb 99.45.....	Wire, 0.0991 in. diam.,	11,300	.....	.....	1.5	.....	.....	.....	.....	Mod-el (shear).....2,900 klps/in. ²	[303]
3600..	Antimony (vacuum distilled).	Cast; am at 1,100°F in vacuum.	7,800	.....	.....	.....	.....	.....	.....	.....	.....	[159]
BERYLLIUM AND BERYLLIUM ALLOYS												
3601..	Be 99.962.....	.....	.....	.....	.....	.....	.....	.....	98	.....	Density.....1.816 g/cm ³ at 64.4°F.....	[547]
3602..	Be 99.5.....	Chill-cast.....	42,600	.....	.....	17.0	0	.....	97	.....	.....	[548]
3603..	...do.....	Rod, 3/8 in. diam, forged at 1,900°-1,650°F (77% red.).	40,000	9.4	.....	29.8	0 (4 diam)	0	.....	.....	Comp yll str (0.2%).....35.3 klps/in. ²	[548]
3604..	...do.....	Rod, 3/8 in. diam, forged; am at 1,830°F in hydrogen.	36,800	8.7	23.4 (0.2% offset)	27.0	0 (4 diam)	0	.....	.....	Shear str.....34.6 klps/in. ²	[548]
3605..	Al 28.....	Chill-cast.....	29,000	.....	19.0 (yld pt)	25.0	3.0 (2 in.)	.....	86	.....	Specific gravity.....2.03.....	[548]
3606..	Pb 67.43, Mn 0.90, Fe 0.69, Si 0.34, Cu 0.12, Cr 0.06, Al rem.	Sand-cast.....	20,400	3.7	13.6 (0.1%)	13.7	0 (2 in.)	.....	75	.....	Specific gravity.....2.05.....	[549]
BISMUTH AND BISMUTH ALLOYS												
3607..	Bismuth.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....4,800 klps/in. ²	[88]
3608..	...do.....	Cast.....	4,600	.....	.....	.....	.....	.....	.....	.....	Poisson's ratio.....0.33.....	[546]
3609..	Pb 26.7, Sn 13.3, Cd 10.	Cast.....	.....	.....	.....	6.0	140 (2 in.)	.....	9.2	.....	Specific gravity.....9.80.....	[427]
3610..	Pb 26.7, Sn 13.3, Cd 10, Hg 10.	...do.....	.....	.....	.....	6.0	89 (2 in.)	.....	8.9	.....	Melting point.....158°F.....	[427]
3611..	...do.....	Cast; aged 6 weeks at r-t.	.....	.....	.....	6.0	42 (2 in.)	.....	10	.....	Melting point.....151°F.....	[427]
3612..	Bi 51.8, Pb rem.	.....	.....	.....	.....	5.9	53 (2 in.)	.....	9.6	.....	.....	[427]
CADMIUM AND CADMIUM ALLOYS												
3613..	Cd 99.95+.....	Bar, 1 in. diam, chill-cast from 660°F; aged 3 weeks at r-t.	.....	.....	.....	10.3	50	.....	21-23	.....	Specific gravity.....4.65.....	[550]
3614..	...do.....	Rod, rolled from 1 1/2 in. to 1/2 in., aged 21 days at r-t.	.....	.....	.....	13.7	126 (1.25 in.)	.....	.....	.....	Specific gravity.....4.65.....	[550]

TABLE 60.—Miscellaneous metals and alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
COBALT AND COBALT ALLOYS—Continued												
3637..	Percent Co >47, Cr <34, M <10.	Cast.....	Kt./in. ²	Kt./in. ²	Kt./in. ² 76.0	Percent 0 (2 in.)	Percent	Kt./in. ² .....	.....	ft.-lb.	Compressive str.....1.93 kips/in. ² Specific gravity.....8.40. Melting point.....2,300°F.	[357]
3638..	Co >49, Cr <34, M <14.	...do.....	35,000	.....	.....	47.0	0 (2 in.)	.....	.....	.....	Compressive str.....255 kips/in. ² Specific gravity.....8.59. Melting point.....2,282°F.	[557]
COLUMBIUM; GALLIUM												
3639..	Columbium.....	.....	.....	.....	.....	.....	.....	.....	75	.....	Specific gravity.....8.4.....	[554]
3640..	Gallium: Ga 99.9, Zn 0.07, Cu 0.04, Pb 0.01, Fe 0.006, Ni 0.002.	.....	.....	.....	.....	2.8-5.4	2-40	.....	.....	.....	.....	[555]
GOLD												
3641..	Au 999.9 fine (parts per thousand).	Rod, 0.8 in. diam, rolled; ann 10 min at 830°F, strained 5%.	10,300	2.9	8.1 (0.01%)	17.9	65 (2 in.)	87	.....	.....	.....	[559]
3642..	Gold.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....4,100-5,600 kips/in. ² . Poisson's ratio.....0.42.	[84]
3643..	...do.....	Rod, 1/8 in. diam, cast	.....	<1.0	.....	16.5	34 (3 in.)	.....	.....	.....	.....	[560]
3644..	...do.....	Wire, 0.05 in. diam, cold-rolled (60% red.).	.....	.....	.....	31.4	.....	.....	.....	.....	.....	[561]
3645..	...do.....	Sheet, 0.035 in., ann 1/2 hr at 500°F, f.c.	.....	.....	.....	17.7	33 (1 in.)	.....	4.6 (10 ⁷)	28	.....	[562]
GOLD-CADMIUM ALLOYS												
3646..	Cd 4.6, Cu 2.8, Zn 1.0.	.....	.....	13.2	.....	43.8	55 (2 in.)	.....	44	.....	Melting range.....1,665°-1,646°F.....	[561]
3647..	Au 83.3, Cd 5.9, Cu 3.4, Ag 2.5, Zn 1.3.	.....	.....	27.6	.....	54.8	57 (2 in.)	.....	69	.....	Melting range.....1,416°-1,445°F.....	[561]
GOLD-COPPER ALLOYS												
3648..	Cu 6.3, Ag 2.1....	Strip, 3/8 in., ann 1/3 hr at 1,365°F.	.....	18.8	.....	45.6	35	.....	.....	.....	Melting range.....1,745°-1,794°F. Color.....dark golden-yellow.	[563]
3649..	Cu 10.0, Pt 0.08, Ag 0.04.	Rod, 1/8 in. diam, cast	11,000	17.5	.....	48.0	31 (3 in.)	.....	.....	.....	Melting range.....1,700°-1,725°F.....	[560]
3650..	...do.....	Strip, 0.006 in., w-q from 1,280°F.	13,000	21.0	.....	55.0	29 (3 in.)	.....	.....	.....	.....	[560]
3651..	Cu 11.2, Cd 7.3, Ag 5.0, Zn 1.5.	.....	.....	36.1	.....	57.5	57 (2 in.)	.....	90	.....	Melting range.....1,450°-1,436°F.....	[561]

TABLE 60.—Miscellaneous metals and alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference	
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
GOLD-COPPER ALLOYS—Continued													
3674..	Percent Cu 35.54, Ni 23.85	Sheet, 0.045 in., rolled (50% red.); ann 1/3 hr at 1,300°F, a-c.	$Kt/ps/in.^2$	$Kt/ps/in.^2$	$Kt/ps/in.^2$ 104 (yld pnt)	$Kt/ps/in.^2$ 111	Percent 19 (1.25 in.)	Percent 18	$Kt/ps/in.^2$	R_B 100	ft-lb	Melting point.....2,045°F. Color.....blue-white.	[566]
3675..	Cu 35.65, Ni 2.20, Ag 2.0, Zn 1.85.	do.....	.....	.....	38.0 (yld pnt)	66.6	58 (1.25 in.)	44	.....	R_B 64	.....	Melting point.....1,740°F. Color.....orange-pink.	[565]
3676..	Cu 36.28, Zn 2.84, Ag 2.58.	do.....	.....	.....	35.0 (yld pnt)	61.0	60 (1.25 in.)	42	.....	R_B 55	.....	Melting point.....1,690°F. Color.....red-pink.	[565]
3677..	Cu 41.86, Ag 15.36, Zn 3.07, Ni 1.21.	Sheet, 0.050 in., rolled (50% red.); 1/2 hr at 1,290°F, w-q.	.....	.....	49.7 (yld pnt)	83.3	34 (2 in.)	.....	.....	.....	.....	Color.....yellow	[564]
3678..	do.....	Sheet, 0.050 in., rolled (50% red.); 1/2 hr at 1,290°F, w-q.	.....	.....	110 (yld pnt)	117	6.5 (2 in.)	.....	.....	.....	.....	Color.....yellow	[564]
3679..	Cu 49.....	Quenched from 1,470°F.	16,800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[56]
3680..	do.....	Quenched from 1,470°F, aged 20 hr at 570°-750°F.	18,100	.....	.....	.....	.....	.....	.....	.....	.....	.....	[56]
GOLD-NICKEL ALLOYS													
3681..	Ni 14, Zn 6.....	Sheet, 0.050 in., rolled (50% red.); 1/2 hr at 1,200°F, a-c.	.....	.....	.....	112	20 (2 in.)	31	.....	.....	.....	Color.....white	[564]
3682..	Ni 16, Zn 5, Cu 4.	Sheet, 0.050 in., rolled (50% red.); 1/2 hr at 1,350°F, a-c.	.....	.....	86.4 (yld pnt)	103	35 (2 in.)	.....	.....	.....	.....	Color.....white	[564]
3683..	Ni 17.0, Cu 16.0, Zn 8.65.	do.....	.....	.....	64.5 (yld pnt)	105	43 (2 in.)	.....	.....	.....	.....	Color.....white	[564]
3684..	Ni 18.4, Zn 4.3, Cu 1.9, Mn 0.4, Fe 0.2.	Wrought; 10 minutes at 1,290°F, w-q.	.....	92.0	.....	128	16 (2 in.)	.....	.....	V 261	.....	Melting point.....1,688°F.	[567]
GOLD-PALLADIUM ALLOYS													
3685..	Pd 16.1, Pt 7.0, Ir 1.2, Zn 0.07.	Strip, 0.006 in., w-q from 1,290°F.	20,000	50.0	.....	88.0	4.6 (8 in.)	.....	.....	.....	.....	Melting point.....2,415°F.	[560]
3686..	Pd 19.4, Pt 13.3, Ir 0.5, Cu 0.2, Ag 0.2, Zn 0.1.	Wire, 0.035 in. diam, w-q from 1,290°F.	20,000	80.0	.....	126	2.9 (8 in.)	.....	.....	.....	.....	Melting point.....2,505°F.	[560]
3687..	Pd 19.6.....	do.....	17,100	.....	.....	.....	.....	.....	.....	.....	.....	Mod- ϵ l (shear).....6,000 kips/in. ² , Poisson's ratio.....0.41.	[55]
3688..	Pd 22.9, Ag 18.5, Cu 15.7, Zn 0.6.	Wire, 0.040 in. diam, w-q from 1,290°F.	.....	42.9	.....	87.3	30 (8 in.)	.....	.....	.....	.....	.....	[568]
3689..	do.....	Wire, 0.040 in. diam, w-q from 1,290°F, aged 1/4 hr at 840°F.	.....	87.6	.....	147	7.8 (8 in.)	.....	.....	.....	.....	.....	[568]

3690..	Pt 31.8, Pt 1.0...	Strip, 0.006 in., w-q from 1,290°F.	14,000	13.0	48.0	24 (8 in.)	.....	.....	.....	Melting point.....2,370°F.....	[560]
GOLD-PLATINUM ALLOYS											
3691..	Pt 9.3, Ag 0.1, Zn 0.02, Ni 0.01.	Strip, 0.006 in., w-q from 1,290°F.	10,000	9.0	.....	35.0 (8 in.)	.....	.....	.....	Melting point.....2,010°F.....	[560]
3692..	Pt 10.62, Cu 9.9, Ag 7.1, Sn 0.83, Ir 0.14, Zn 0.08.	Rod, 1/8 in. diam. cast; w-1 from 1,290°F.	13,000	50.0	.....	61.5 (3 in.)	.....	.....	.....	Melting range.....1,665°-1,850°F....	[560]
3693..	Pt 13.1, Ag 11.0, Cu 8.9, Pd 5.9, Zn 0.72, Ir 0.2, Sn 0.14.	Strip, 0.006 in., w-q from 1,290°F.	16,000	58.0	.....	98.0 (8 in.)	.....	.....	.....	Melting point.....1,870°F.....	[560]
3694..	...do.....	Strip, 0.006 in., f-c from 840° to 480°F in 1 1/2 hr.	18,000	116	.....	157 (8 in.)	.....	.....	.....	.....	[560]
3695..	Pt 15.2, Ag 15.0, Cu 8.6, Ni 1.5.	Wire, 0.035 in. diam. w-1 from 1,290°F.	16,000	63.0	.....	102 (8 in.)	.....	.....	.....	Melting point.....1,750°F.....	[560]
3696..	...do.....	Wire, 0.035 in. diam. f-c from 840° to 480°F in 1 1/2 hr.	17,000	76.0	.....	123 (8 in.)	.....	.....	.....	.....	[560]
3697..	Pt 18.3, Cu 13.0, Ag 7.7, Pd 1.6, Ir 0.2.	Wire, 0.035 in. diam. w-q from 1,290°F.	18,000	84.0	.....	124 (8 in.)	.....	.....	.....	Melting point.....1,850°F.....	[560]
3698..	...do.....	Wire, 0.035 in. diam. f-c from 840° to 480°F in 1 1/2 hr.	19,000	133	.....	175 (8 in.)	.....	.....	.....	.....	[560]
3699..	Pt 21.1, Ag 15.5, Cu 13.3, Zn 0.5.	Wire, 0.040 in. diam. quenched from 1,650°F.	.....	69.1	.....	124 (8 in.)	.....	.....	.....	.....	[568]
3700..	...do.....	Wire, 0.040 in. diam. quenched from 1,650°F. aged 1/4 hr at 840°F.	.....	113	.....	174 (8 in.)	.....	.....	.....	.....	[568]
3701..	Pt 22.8, Ag 9.3, Cu 4.5, Pd 0.5, Ir 0.4, Fe 0.2, Zn 0.1, Ni 0.02.	Strip, 0.006 in., w-q from 1,290°F.	16,000	31.0	.....	86.0 (8 in.)	.....	.....	.....	Melting point.....1,950°F.....	[560]
3702..	...do.....	Strip, 0.006 in., f-c from 840° to 480°F in 1 1/2 hr.	15,000	44.0	.....	90.0 (8 in.)	.....	.....	.....	.....	[560]
GOLD-SILVER ALLOYS											
3703..	Ag 1.6, Cu 3.7....	Rod, 1/8 in. diam, cast	.....	11.0	.....	34.5 (3 in.)	.....	.....	.....	Melting range.....1,775°-1,875°F....	[560]
3704..	Ag 7.3, Pt 7.0, Cu 4.3, Zn 0.1.	Strip, 0.006 in., w-1 from 1,290°F.	13,000	25.0	.....	59.0 (8 in.)	.....	.....	.....	Melting point.....1,850°F.....	[560]
3705..	Ag 8.1, Cu 6.8, Zn 2.1, Sn 2.0.	Rod, 1/8 in. diam, cast	11,000	20.5	.....	37.5 (3 in.)	.....	.....	.....	Melting range.....1,375°-1,595°F....	[560]
3706..	Ag 10.0, Pt 6.1, Cu 5.9, Ir 0.1.	Rod, 1/8 in. diam, cast; w-q from 1,290°F.	11,000	22.5	.....	48.0 (3 in.)	.....	.....	.....	Melting range.....1,725°-1,875°F....	[560]
3707..	Ag 12.1, Cu 10.0, Zn 3.0, Sn 2.0.	...do.....	11,000	24.0	.....	36.0 (3 in.)	.....	.....	.....	Melting range.....1,390°-1,535°F....	[560]
3708..	...do.....	Rod, 1/8 in. diam, cast; f-c from 840° to 480°F in 1 1/2 hr.	12,000	61.5	.....	70.0	.....	.....	.....	.....	[560]

TABLE 60.—Miscellaneous metals and alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation						Reduction of area
GOLD-SILVER ALLOYS—Continued												
3709..	Percent Ag 12.75, Cu 6.25, Pt 6.0.	Sheet, 0.035 in., 1/2 hr at 1,400°F, w-q.	.....	.....	49.1 (yld pnt)	Kips/in. ² 71.8	Percent 2.6 (1 in.)	Percent 28.5 (10')	115	ft-lb .....	.....	[562]
3710..	Ag 15.4, Cu 12.4, Zn 3.9, Sn 3.1.	Rod, 1/8 in. diam, cast; w-q from 1,290°F.	11,000	27.0	.....	42.5	14 (3 in.)	.....	.....	.....	Melting range.....1,375°-1,415°F.	[560]
3711..	do.....	Rod, 1/8 in. diam, cast; f-c from 840° to 480°F in 1/2 hr.	12,000	55.0	.....	63.0	1 (3 in.)	.....	.....	.....	.....	[560]
3712..	Ag 15.5, Cu 13.2, Pt 7.0, Zn 0.5.	Wire, 0.040 in. diam, quenched from 1,290°F.	.....	61.7	.....	95.1	14 (8 in.)	.....	.....	.....	.....	[568]
3713..	do.....	Wire, 0.040 in. diam, quenched from 1,290°F, aged 1/4 hr at 840°F.	.....	86.5	.....	134	3.6 (8 in.)	.....	.....	.....	.....	[568]
3714..	Ag 17.7, Pt 12.3, Cu 6.7, Zn 0.1, Ni 0.08.	Strip, 0.006 in., w-q from 1,290°F.	15,000	56.0	.....	90.0	10 (8 in.)	.....	.....	.....	Melting point.....1,805°F.	[560]
3715..	do.....	Strip, 0.006 in., f-c from 840° to 480°F in 1/2 hr.	16,000	89.0	.....	118	2.2 (8 in.)	.....	.....	.....	.....	[560]
3716..	Ag 21.8, Cu 3.2...	Rod, 1/8 in. diam, cast	11,000	11.0	.....	36.0	19 (3 in.)	.....	.....	.....	Melting range.....1,700°-1,825°F.	[560]
3717..	Ag 36.4, Cu 9.4, Pd 8.3, Mn 3.8, Zn 0.3, Mg 0.1, Pt 0.1.	Wire, 0.035 in. diam, w-q from 1,290°F.	17,000	64.0	.....	94.0	11 (8 in.)	.....	.....	.....	Melting point.....1,645°F.	[560]
3718..	do.....	Wire, 0.035 in. diam, a-c from 1,290°F.	17,000	87.0	.....	124	3.6 (8 in.)	.....	.....	.....	.....	[560]
INDIUM; IRIDIUM												
3719..	Iridium; In 99.9..	Rod, 3/8 in. diam, cast	.....	.....	.....	0.43	.....	99	.....	.....	.....	[606]
3720..	Iridium.....	Hard.....	74,700	.....	.....	.....	.....	.....	.....	.....	Specific gravity.....22.4	[570]
3721..	do.....	Cast.....	.....	.....	.....	.....	.....	.....	163-217	.....	.....	[499]
3722..	do.....	Forged.....	.....	.....	.....	.....	.....	.....	V 255	.....	.....	[499]
MANGANESE AND MANGANESE ALLOYS												
3723..	Electro manganese	Cold-worked.....	23,000	.....	.....	120	.....	.....	.....	.....	Specific gravity.....7.20	[571]
3724..	do.....	Annealed.....	23,000	.....	.....	55	.....	.....	.....	.....	.....	[571]
3725..	Cu 3.7.....	Rod, 1/2 in. diam, quenched from 2,010°F.	.....	.....	.....	80	43 (1.25 in.)	.....	R _B 80	.....	.....	[572]
3726..	Cu 10.2.....	do.....	.....	.....	.....	78	42 (1.25 in.)	65	R _B 61	.....	.....	[572]
3727..	do.....	Rod, 1/2 in. diam, quenched from 2,010°F, tempered 4 hr at 840°F.	.....	.....	.....	76	0 (1.25 in.)	1.3	R _B 84	.....	.....	[572]

3728..	Cu 18, Zn 2.....	Annealed.....	.....	.....	.....	70	.....	.....	.....	.....	[573]
3729..	Cu 18, Ni 10.....	.....	17,400	.....	.....	110	6.5	.....	.....	.....	[574]
3730..	Cu 20, Zn 10.....	Cold-worked.....	.....	.....	.....	125	.....	.....	.....	.....	[573]
3731..	...do.....	Annealed.....	.....	.....	.....	42	.....	.....	.....	.....	[573]
3732..	Cu 22.4.....	Roll, 1 1/2 in. diam, quenched from 1,470°F.	.....	.....	.....	67	44	70	R ₅ 53	.....	[572]
3733..	...do.....	quenched from 1,470°F, tempered 2 hr at 840°F.	.....	80.1 (0.2% offset)	.....	93	29 (1.25 in.)	54	R ₅ 72	.....	[572]
3734..	Cu 35, Zn 10.....	Cold-worked.....	.....	.....	.....	90	.....	.....	.....	.....	[573]
3735..	...do.....	Annealed.....	.....	.....	.....	51	.....	.....	.....	.....	[573]

MOLYBDENUM; OSMIUM

3736..	Molybdenum.....	Wire, hard-drawn.....	.....	.....	.....	200-350	2-5	.....	.....	.....	[52]
3737..	...do.....	Wire, annealed.....	.....	.....	.....	171	10-25	.....	.....	.....	[52]
3738..	...do.....	.....	50,000	.....	.....	.....	.....	.....	140-185	Specific gravity.....	[52]
3739..	...do.....	.....	41,200	.....	.....	.....	.....	.....	.....	.....	[575]
3740..	Osmium.....	Cast.....	.....	.....	.....	.....	.....	.....	V 350	Specific gravity.....	[576]

PALLADIUM AND PALLADIUM ALLOYS (SEE ALSO FIGS. 188 AND 189)

3741..	Palladium.....	Hard.....	17,000	.....	.....	47.0	.....	.....	.....	.....	Specific gravity.....	[570]
3742..	...do.....	Annealed.....	13,800	.....	.....	20.0	.....	.....	.....	109	.....	[570]
3743..	...do.....	Wire.....	18,300	.....	.....	.....	.....	.....	.....	46	.....	[303]
3744..	...do.....	Wire, 0.05 in. diam, hard (50% red.)	.....	31.8	.....	46.8	1.5 (2 in.)	92	.....	109	.....	[576]
3745..	...do.....	Wire, 0.05 in. diam, ann	.....	4.9	.....	30.0	40 (2 in.)	90	.....	49	.....	[576]
3746..	Cu 33.....	Quenched from 1,470°F.	17,900	.....	.....	.....	.....	.....	.....	.....	.....	[55]
3747..	...do.....	Quenched from 1,470°F, 20 hr at 370°-750°F.	16,600	.....	.....	.....	.....	.....	.....	.....	.....	[55]
3748..	Au 10.....	Annealed at 1,470°F.	.....	.....	.....	34.0	.....	.....	.....	.....	.....	[499]
3749..	...do.....	Cold-worked (66% red.)	.....	.....	.....	57.0	.....	.....	.....	.....	.....	[498]
3750..	Pt 25.....	Hard.....	.....	.....	.....	.....	.....	.....	.....	150	.....	[570]
3751..	...do.....	Annealed.....	.....	.....	.....	43.0	.....	.....	.....	80	.....	[570]
3752..	Rh 3, Ru 2.....	Wire, 0.05 in. diam, cold-drawn (50% red.)	.....	46.0	.....	61.0	2.0 (2 in.)	88	.....	.....	.....	[577]
3753..	...do.....	Wire, 0.05 in. diam, ann 5 min at 1,830°- 2,010°F.	.....	15.8	.....	43.5	33 (2 in.)	90	.....	.....	.....	[577]
3754..	Ru 1, Rh 1.....	Wire, 0.05 in. diam, cold-drawn (50% red.)	.....	46.3	.....	71.5	3.0 (2 in.)	84	.....	.....	.....	[577]
3755..	...do.....	Wire, 0.05 in. diam, ann 5 min at 1,830°- 2,010°F.	.....	24.5	.....	57.0	24 (2 in.)	84	.....	.....	.....	[577]

^e 200-g load, 10 sec.

^f Gamma modification, stable between 2,175°F and the melting point.

TABLE 60.—Miscellaneous metals and alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties						Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area					
PLATINUM AND PLATINUM ALLOYS (SEE ALSO FIGS. 190 TO 194, INCLUSIVE)													
3756..	Pt 99.9 +	wire, 0.05 in. diam, cold-drawn (50% red.).	ktps/in. ²	ktps/in. ² 27.0	ktps/in. ²	ktps/in. ² 36.0	Percent 2.5 (2 in.)	Percent 95	ktps/in. ² .....	.....	ft-lb .....	.....	[577]
3757..	...do.	wire, 0.05 in. diam, ann 5 min at 1,650°-1,850°F.	.....	5.3-10	.....	23.0	24-34 (2 in.)	92	.....	.....	.....	.....	[577]
3758..	Platinum.....	Hard.....	24,100	.....	.....	34.0	.....	.....	.....	97	.....	Erichsen.....7.8 mm. Specific gravity.....21.45.	[570]
3759..	...do.	Annealed.....	21,400	.....	.....	17.0	.....	.....	.....	42	.....	Erichsen.....12.2 mm. Mod-el (shear).....8,500-10,000 kips/in. ² . Poisson's ratio.....0.38.	[570]
3760..	...do. ....	.....	22,700-24,900	.....	.....	.....	.....	.....	.....	.....	.....	.....	[303]
3761..	Cu 3.....	Hard.....	.....	48.1	.....	80.1	3.0 (2 in.)	92	.....	.....	.....	Specific gravity.....20.5	[578]
3762..	...do.	Annealed.....	.....	15.6	.....	53.1	32 (2 in.)	95	.....	.....	.....	.....	[578]
3763..	Cu 4.5.....	Cold-drawn (50% red.)..	.....	54.2	.....	91.6	2.5 (2 in.)	64	.....	.....	.....	.....	[576]
3764..	...do.	Annealed.....	.....	23.0	.....	65.0	26 (2 in.)	86	.....	.....	.....	.....	[576]
3765..	Cu 10.....	Hard.....	.....	84.1	.....	119	3 (2 in.)	.....	.....	.....	.....	.....	[499]
3766..	...do.	Annealed.....	.....	19.4	.....	79.4	32 (2 in.)	.....	.....	.....	.....	.....	[499]
3767..	Cu 49.....	Quenched from 1,470°F..	16,800	.....	.....	.....	.....	.....	.....	.....	.....	.....	[55]
3768..	Au 5.....	Cold-worked (50% red.)..	.....	40.5	.....	63.5	2.0 (2 in.)	.....	.....	155	.....	.....	[499]
3769..	...do.	Annealed at 1,830°F....	.....	13.0	.....	45.0	23 (2 in.)	.....	.....	92	.....	.....	[499]
3770..	Au 10.....	Cold-worked (50% red.)..	.....	63.5	.....	90.0	1.25 (2 in.)	.....	.....	222	.....	.....	[499]
3771..	...do.	Annealed at 1,830°F....	.....	46.0	.....	77.5	12.5 (2 in.)	.....	.....	.....	.....	.....	[499]
3772..	Ir 5.....	Wire, 0.05 in. diam, cold-drawn (50% red.).	.....	53.5	.....	69.1	2.0 (2 in.)	92	.....	.....	.....	.....	[577]
3773..	...do.	wire, 0.05 in. diam, ann 5 min at 2,010°-2,190°F.	.....	20.5	.....	40.2	22-32 (2 in.)	91	.....	.....	.....	.....	[577]
3774..	Ir 10.....	Wire, 0.05 in. diam, cold-drawn (50% red.).	.....	54.0	.....	82.2	2.5 (2 in.)	94	.....	.....	.....	.....	[577]
3775..	...do.	Wire, 0.05 in. diam, ann 5 min at 2,010°-2,190°F.	.....	33.0	.....	54.0	26 (2 in.)	94	.....	.....	.....	.....	[577]
3776..	Ir 20.....	Wire, 0.05 in. diam, cold-drawn (50% red.).	.....	101	.....	140	2.5 (2 in.)	84	.....	.....	.....	.....	[577]

3777..	...do.....	Wire, 0.05 in. diam, ann 5 min at 2,190°- 2,550°F.	.....	60.5	.....	97.5	20 (2 in.)	88	.....	.....	.....	[577]
3778..	...do.....	Annealed at 1,110°F....	.....	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear) .....9,950 kips/in. ²	[55]
3779..	Ni 5.....	Wire, 0.05 in. diam, cold-drawn (50% red.).	.....	70.0	.....	103	2.0 (2 in.)	84	.....	.....	.....	[577]
3780..	...do.....	Wire, 0.05 in. diam, ann at 1,830°F.	.....	33.0	.....	65.0	24 (2 in.)	94	.....	.....	.....	[577]
3781..	Os 5.....	Annealed.....	.....	.....	.....	.....	.....	.....	.....	120	.....	[570]
3782..	Os 10.....	...do.....	.....	.....	.....	.....	.....	.....	.....	175	.....	[570]
3783..	Pt 20, Rh 5.....	Wire, 0.05 in. diam, cold-drawn (50% red.).	.....	51.9	.....	85.0	1.8 (2 in.)	87	.....	.....	.....	[577]
3784..	...do.....	Wire, 0.05 in. diam, ann 5 min at 1,830°- 2,040°F.	.....	20.2	.....	55.0	26 (2 in.)	92	.....	.....	.....	[577]
3785..	Rh 10.....	Wire, 0.05 in. diam, cold-drawn (50% red.).	.....	55.6	.....	84.3	3.0 (2 in.)	90	.....	.....	.....	[577]
3786..	...do.....	Wire, 0.05 in. diam, ann 5 min at 2,010°- 2,190°F.	.....	19.5	.....	48.0	25-37 (2 in.)	94	.....	.....	.....	[577]
3787..	Ru 5.....	Hard.....	.....	.....	.....	115	.....	.....	.....	210	.....	[570]
3788..	...do.....	Annealed.....	.....	.....	.....	60.0	.....	.....	.....	130	.....	[570]
3789..	Ru 10.....	Hard.....	.....	.....	.....	150	.....	.....	.....	280	.....	[570]
3790..	...do.....	Annealed.....	.....	.....	.....	85.0	.....	.....	.....	190	.....	[570]
3791..	Ag 5.....	...do.....	.....	.....	.....	52.0	.....	.....	.....	80	.....	[570]
3792..	Ag 10.....	...do.....	.....	.....	.....	78.0	.....	.....	.....	125	.....	[570]
3793..	Ag 20.....	...do.....	.....	.....	.....	128	.....	.....	.....	172	.....	[570]

RHODIUM; RUTHENIUM

3794..	Rhodium.....	Hard.....	42,500	.....	.....	.....	.....	.....	.....	390	Specific gravity .....12.44	[570]
3795..	...do.....	Annealed.....	.....	.....	.....	.....	.....	.....	.....	135	.....	[570]
3796..	Ruthenium.....	Cast.....	.....	.....	.....	.....	.....	.....	.....	220	.....	[499]
3797..	...do.....	Hot-forged.....	.....	.....	.....	.....	.....	.....	.....	V 390	.....	[499]

SILVER AND SILVER ALLOYS (SEE ALSO FIGS. 195 TO 198, INCLUSIVE)

3798..	Ag, 1,000 fine (parts per thousand).	Rod, 0.8 in. diam, rolled; ann 10 min at 930°F.	10,300	0.7	1.5 (0.01%)	21.5	65 (2 in.)	92	.....	.....	.....	[559]
3799..	Ag, 999 fine (parts per thousand).	Sheet, 0.032 in., rolled (50% red.).	.....	.....	44.3 (yd pnt)	54.3	2.4 (2 in.)	.....	.....	R _F 91	.....	[579]
3800..	...do.....	Sheet, 0.032 in., ann 1/2 hr at 1,400°F.	.....	.....	7.8 (yd pnt)	22.5	48 (2 in.)	.....	.....	R _F 9.8	.....	[579]
3801..	Silver.....	Hard-drawn.....	10,900	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....3,900 kips/in. ² Poisson's ratio.....0.382. Specific gravity.....10.49.	[579]
3802..	...do.....	Annealed.....	10,600	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....3,900 kips/in. ² Poisson's ratio.....0.389. Specific gravity.....10.49.	[579]

^cRate of strain 0.05 (in./in.)/minute.

TABLE 60.—Miscellaneous metals and alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation ^a				
			Kt./sq. in.	Kt./sq. in.	Kt./sq. in.	Kt./sq. in.	Percent				
SILVER AND SILVER ALLOYS—Continued											
3803.	Silver.....	Chill-cast.....	.....	2.0	1.7 (yld pnt)	15.4	Percent 60	.....	ft.-lb.	Compressive str (40%).....50.1 kips/in. ² ...	[303]
3804.	...do.....	Sand-cast.....	.....	1.0	3.4 (yld pnt)	15.3	41 (2 in.)	38	.....	Compressive str (40%).....48.1 kips/in. ² ...	[303]
3805.	Ag 94.7, Al rem...	Sheet, 0.064 in., annealed 1/2 hr at 1,200°F.	.....	.....	.....	41.0	70 (1 1/2 in.)	.....	.....	Specific gravity.....9.28..... Melting point.....1,508°F.	[580]
3806.	Sb 5.8.....	Sheet, 0.040 in., cold-rolled (30% red.)	.....	.....	50.6 (0.2% offset)	51.6	.....	.....	V 113	.....	[129]
3807.	...do.....	Sheet, annealed 1 hr at 1,200°F.	.....	.....	5.8 (0.2% offset)	31.4	69 (2 in.)	.....	V 45	.....	[129]
3808.	As 2.28.....	Sheet, 0.040 in., cold-rolled (30% red.)	.....	.....	40.4 (0.2% offset)	44.0	15 (2 in.)	.....	V 97	.....	[129]
3809.	...do.....	Sheet, annealed 1 hr at 1,200°F.	.....	.....	4.4 (0.2% offset)	28.1	71 (2 in.)	.....	V 32	.....	[129]
3810.	Cd 18-20, Zn 15-17, Cu 14-16.	Cast.....	.....	.....	44.8 (yld pnt)	67.2	35	.....	.....	.....	[581]
3811.	Cr 0.14.....	Sheet, 0.064 in., annealed 1/2 hr at 1,200°F.	.....	.....	.....	27.5	48 (1 1/2 in.)	.....	.....	Specific gravity.....10.48.....	[580]
3812.	Cr 0.77.....	...do.....	.....	.....	.....	28.5	41 (1 1/2 in.)	.....	.....	Specific gravity.....10.45.....	[580]
3813.	Cu 5.75, Cd 1.75.	Sand-cast.....	.....	5.1	14.1 (yld pnt)	29.5	40 (2 in.)	50	73	Compressive str (40%).....73.6 kips/in. ² ...	[303]
3814.	Cu 7.5.....	Sheet, 1 hr at 1,400°F, w-q.	.....	.....	22.9 (0.2% offset)	39.3	42 (2 in.)	.....	V 56	.....	[129]
3815.	...do.....	Sheet, 0.040 in., cold-rolled (30% red.)	.....	.....	51.7 (0.2% offset)	54.0	12 (2 in.)	.....	V 119	.....	[129]
3816.	...do.....	Sand-cast.....	.....	10.6	18.2 (yld pnt)	31.6	41 (2 in.)	55	60	Compressive str (40%).....71.0 kips/in. ² ...	[303]
3817.	Ag 92.1, Cu rem...	Sheet, 0.064 in., annealed 1/2 hr at 1,200°F.	.....	.....	.....	44.0	46 (1 1/2 in.)	.....	.....	Specific gravity.....10.33..... Melting point.....1,643°F.	[580]
3818.	Cu 8.8, Fe-0.5.	Hard-drawn.....	.....	.....	.....	.....	.....	.....	.....	Shear str.....13.5 kips/in. ² .. Mod-el (shear).....4,300 kips/in. ² .. Specific gravity.....10.05.....	[16] [184]
3819.	Cu 16, Zn 4.	Cast.....	.....	.....	.....	50.1	16 (2 in.)	.....	.....	Specific gravity.....9.60.....	[184]
3820.	Cu 20, Zn 15.	...do.....	.....	.....	.....	64.8	34 (2 in.)	.....	.....	.....	[184]
3821.	Cu 25, Zn 5.	...do.....	.....	.....	.....	50.3	9.5 (2 in.)	.....	.....	.....	[184]
3822.	Cu 27-29.5, Zn 9-11	...do.....	.....	.....	48.2 (yld pnt)	56.0	16	.....	.....	Melting range.....1,274°-1,355°F...	[581]
3823.	Cu 30.	...do.....	.....	.....	.....	57.5	25 (2 in.)	.....	.....	.....	[184]

TABLE 60. —Miscellaneous metals and alloys, normal-temperature properties—Continued

Serial number	Composition	Condition	Tensile properties					Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area				
			Kips/in.^2	Kips/in.^2	Kips/in.^2	Kips/in.^2	Percent	Percent	Kips/in.^2	ft-lb		
TANTALUM; TELLURIUM; THORIUM; TITANIUM—Continued												
3852..	Thorium.....	Wire.....	.....	.....	.....	.....	.....	Percent	.....	.....	Specific gravity.....11.3-11.7.....	[554]
3853..	Titanium.....	Wire, 0.01 in. diam.....	12,100	.....	.....	80.0	.....	.....	.....	.....	Specific gravity.....4.5.....	[585]
3851..	Ti 99.8.....	.....	.....	.....	.....	.....	.....	.....	180-200	.....	.....	[586]
TUNGSTEN AND TUNGSTEN ALLOYS (SEE ALSO FIG. 199)												
3855..	W 99.95.....	.....	.....	.....	.....	120	.....	.....	R _B 105	.....	Specific gravity.....19.3.....	[588]
3856..	W 99.9.....	.....	.....	.....	.....	160	.....	.....	R _B 105	.....	.....	[598]
3857..	Tungsten.....	.....	60,000	.....	.....	.....	.....	.....	350	.....	Specific gravity.....19.3.....	[52]
3858..	...do.....	Wire, 0.006 in. diam, drawn.....	37,000	.....	.....	384	.....	.....	.....	.....	.....	[52]
3859..	...do.....	Wire, 0.001 in. diam, drawn.....	48,500	.....	.....	547	.....	.....	.....	.....	.....	[52]
3860..	...do.....	Wire.....	19,500-53,000	.....	.....	.....	.....	.....	.....	.....	Mod-el (shear).....12,800-31,300 kips/in. ²	[587]
3861..	...do.....	Wire, hard-drawn.....	.....	.....	.....	250-600	1-4	.....	.....	.....	.....	[52]
3862..	...do.....	Wire, annealed.....	.....	.....	.....	150	0	.....	.....	.....	.....	[52]
3863..	Co 3, WC rem.....	Cemented.....	.....	.....	.....	.....	.....	.....	R _A 92	.....	Mod rupture.....125 kips/in. ²	[583]
3864..	Co 6, WC rem.....	...do.....	.....	.....	.....	.....	.....	.....	R _A 91	.....	Compressive str.....680-730 kips/in. ²	[583]
3865..	Co 9, WC rem.....	...do.....	.....	.....	.....	.....	.....	.....	R _A 90	.....	Mod rupture.....205 kips/in. ²	[583]
3866..	Co 13, WC rem.....	...do.....	79,000	.....	.....	.....	.....	.....	R _A 88	.....	Specific gravity.....14.82.....	[583]
3867..	Co 20, WC rem.....	...do.....	.....	.....	.....	.....	.....	.....	V 755	.....	Mod rupture.....540 kips/in. ²	[583]
3868..	Ni 6, Cu 4, W rem.....	Mixed powders, compacted at 5.6 tons/in. ² and sintered at 2,550°F in hydrogen.....	32,000	.....	82.9 (yld pt)	80.6	4 (1 in.)	.....	290	.....	Compressive str.....300 kips/in. ²	[583]
											Mod-el (shear).....17,200 kips/in. ²	
											Specific gravity.....14.10.....	
											Specific gravity.....12.54.....	[543]
											Specific gravity.....17.1.....	[589]
URANIUM; ZIRCONIUM												
3869..	Uranium.....	Fused.....	.....	.....	.....	.....	.....	.....	R _B 93	.....	Specific gravity.....18.9.....	[554]
3870..	...do.....	Cold-worked.....	.....	.....	.....	.....	.....	.....	R _B 112	.....	Specific gravity.....19.07.....	[554]
3871..	Zirconium.....	Wire, 0.01 in. diam.....	10,700	.....	.....	.....	.....	.....	.....	.....	Specific gravity.....6.52.....	[585]
3872..	...do.....	Rod, 0.02 in. diam, annealed at 1,830°F.....	.....	.....	42.7	15	.....	.....	.....	.....	Specific gravity.....6.51.....	[590]
3873..	...do.....	Rod, 0.02 in. diam, cold swaged.....	.....	.....	121	2.5	.....	.....	.....	.....	.....	[590]

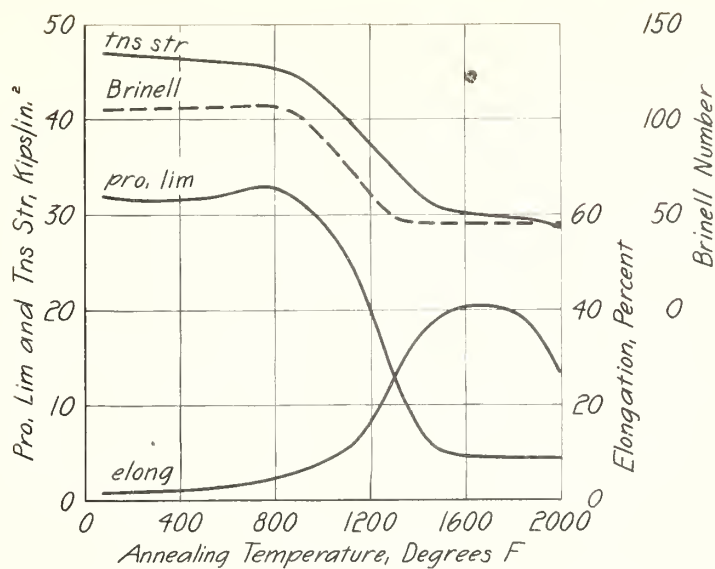


FIGURE 188.—Effect of annealing on the tensile properties and hardness of hard-drawn palladium (Vines [499]).

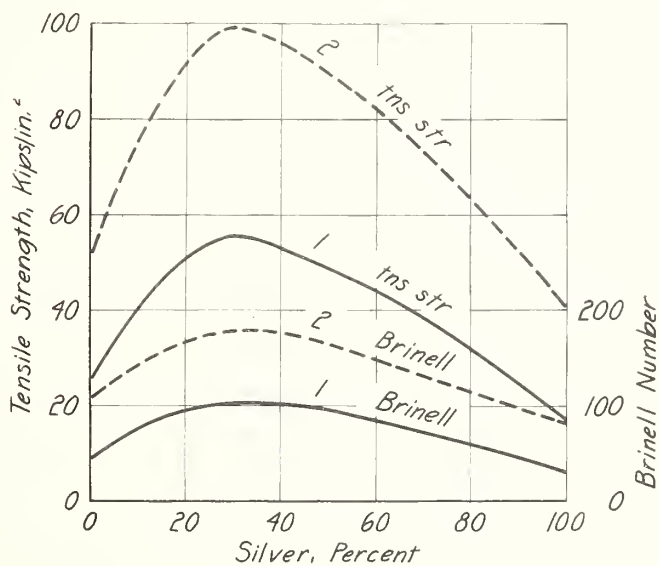


FIGURE 189.—Tensile strength and hardness of palladium-silver alloys (Vines [499]).

Curves: 1, annealed; 2, hard.

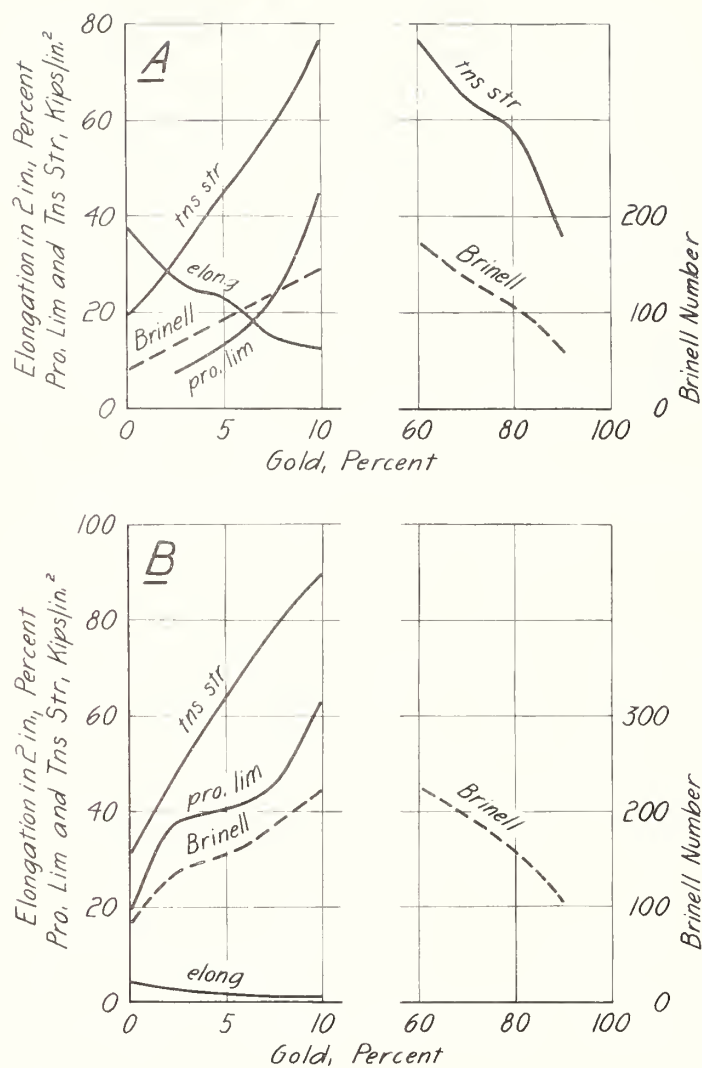


FIGURE 190.—Tensile properties and hardness of platinum-gold alloys (Vines [499]).

A, Annealed; B, hard-rolled (50% red.).

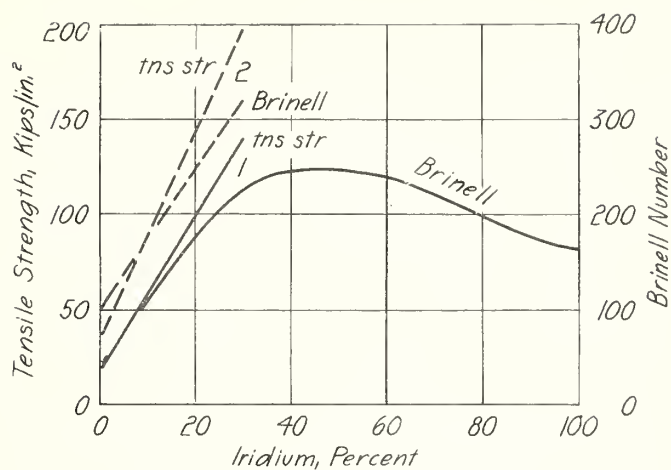


FIGURE 191.—Tensile strength and hardness of platinum-iridium alloys (Vines [499]).

Curves: 1, annealed; 2, hard.

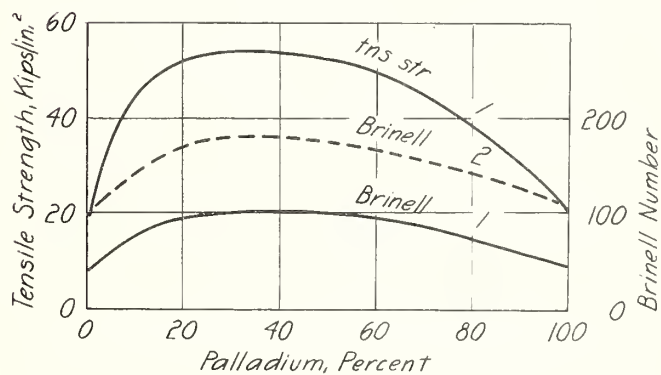


FIGURE 192.—Tensile strength and hardness of platinum-palladium alloys (Vines [499]).

Curves: 1, annealed; 2, hard.

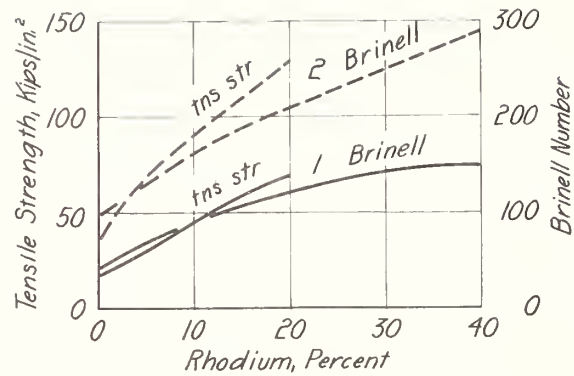


FIGURE 193.—Tensile strength and hardness of platinum-rhodium alloys (Vines [499]).

Curves: 1, annealed; 2, hard.

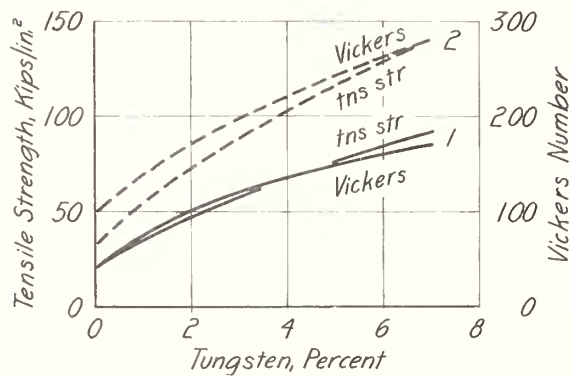


FIGURE 194.—Tensile strength and hardness of platinum-tungsten alloys (Vines [499]).

Curves: 1, wire or sheet annealed 5 minutes at 2,190°F; 2, wire or sheet, cold-worked (50% red.).

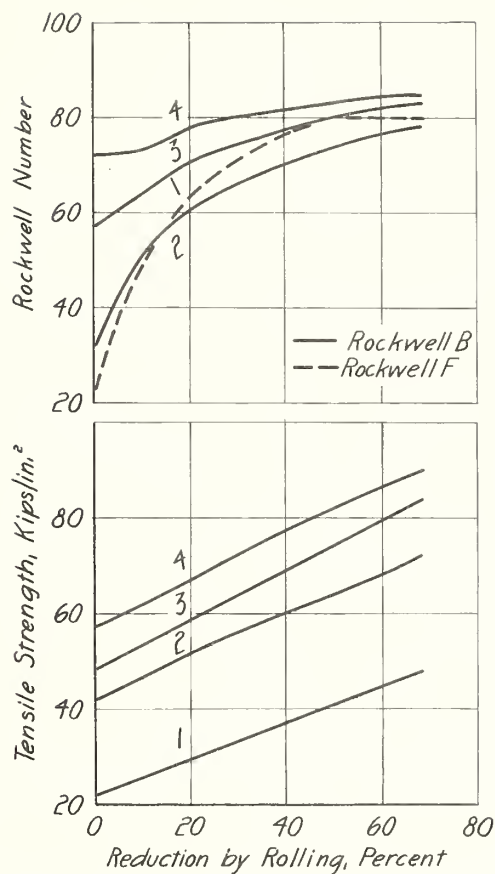


FIGURE 195.—Effect of cold-rolling on the tensile strength and hardness of annealed silver and silver-copper alloys (Leach and Christie [704]).

Curves: 1, Fine silver; 2, Sterling silver, Cu 7.5%; 3, 800 fine, Cu 20%; 4, 720 fine, Cu 28%.

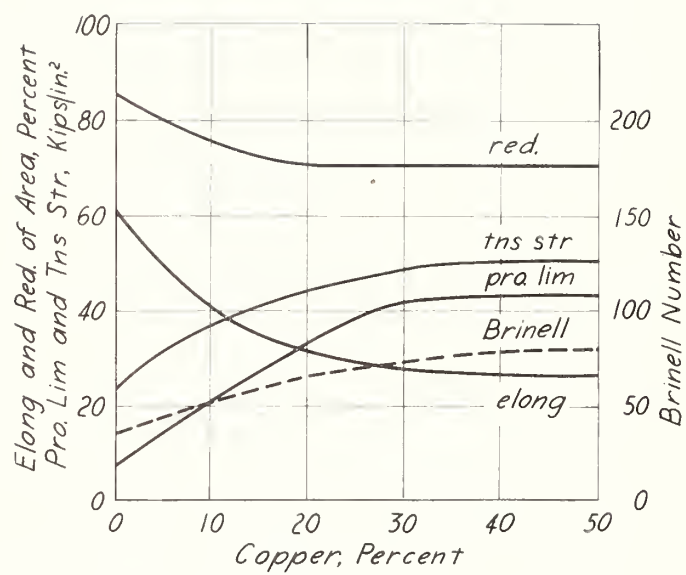


FIGURE 196.—Tensile properties and hardness of wrought silver-copper alloys (Broniewski [651]).

(Elongation in 10 diam)

Annealed 12 hours at 1,200°F and air-cooled.

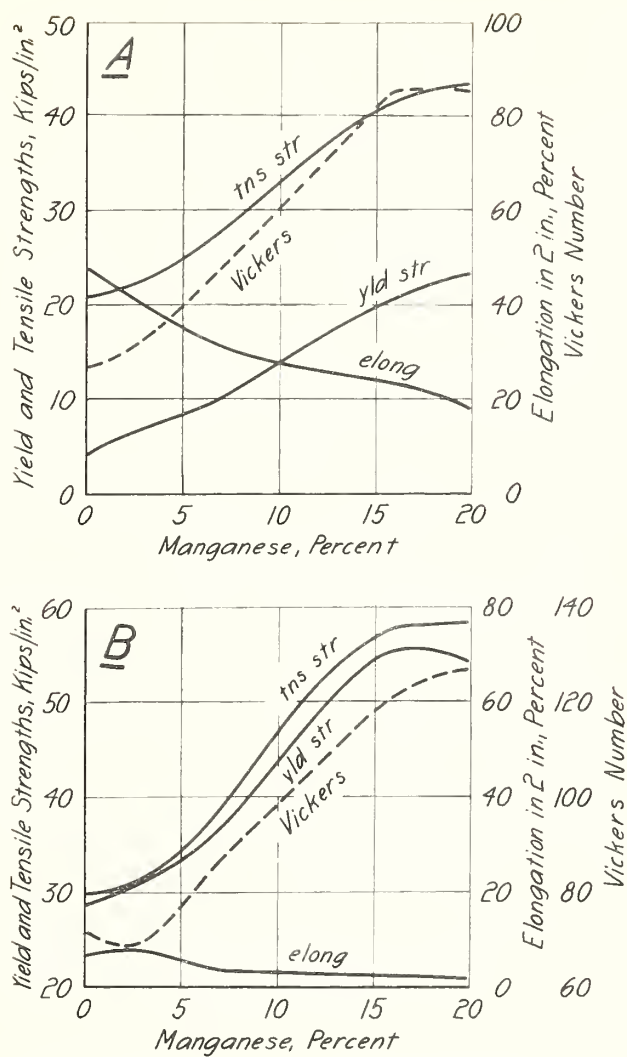


FIGURE 197.—Tensile properties and hardness of silver-manganese alloys (Addicks [129]).

(Yield strength, 0.2% offset)

Prepared with electrolytic manganese.

A, Sheet, annealed 1 hour at 1,290°F; B, sheet, 0.040 in., cold-rolled (30% red.).

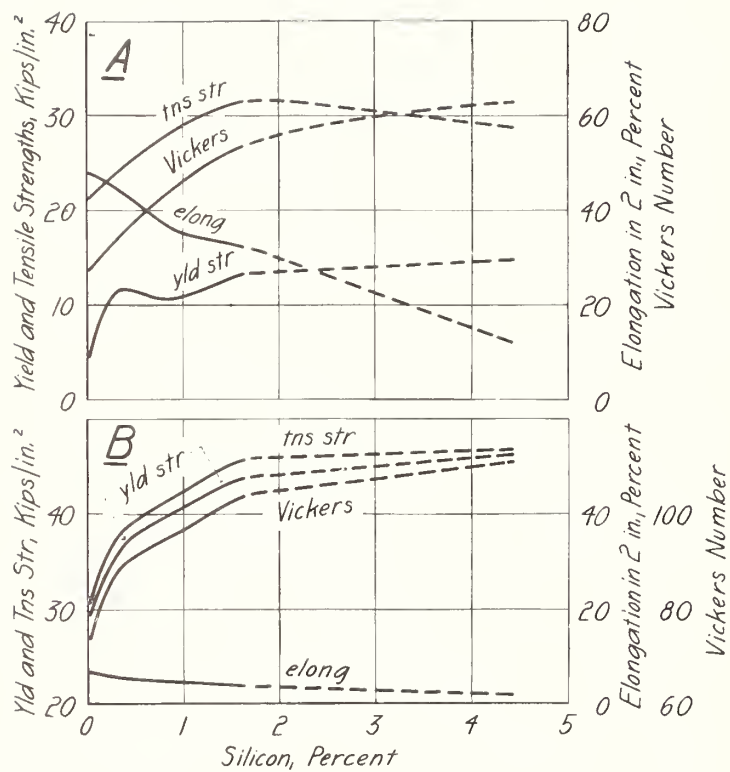


FIGURE 198.—Tensile properties and hardness of silver-silicon alloys (Addicks [129]).

(Yield strength, 0.2% offset)

A, Sheet, annealed 1 hour at 1,290°F; B, sheet, 0.040 in., cold-rolled (30% red.).

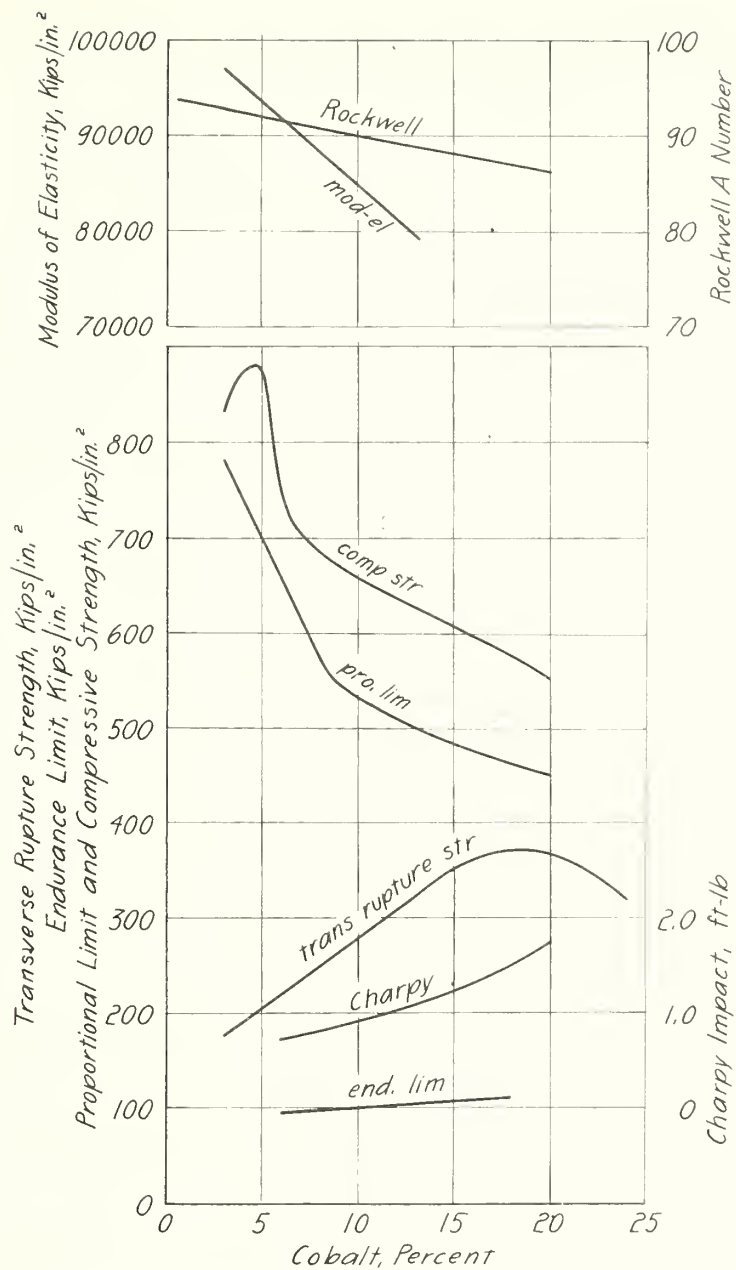


FIGURE 199. — Effect of cobalt binder on the compressive properties, transverse rupture strength, endurance limit, impact value, and hardness of tungsten carbide (Engle [52]).

(Endurance limit at 2×10^7 cycles; impact value measured on unnotched specimens approximately 1/4 in. square, broken in a Charpy machine)

TABLE 61.—*Low-melting alloys* [591]
[Arranged in order of increasing melting point.]

Serial number	Name	Composition, percent					Melting point	
		Bi	Cd	Pb	Sn	Other	$^{\circ}P$	$^{\circ}C$
3874.....	Anatomical alloy.....	53.5	.....	17	19	Hg 10.5	140	60
3875.....	Wool's alloy ^a	50	12.5	25	12.5	.....	154.4	68
3876.....	Lipowitz's alloy ^b	30.1	10	26.6	13.3	.....	154.4	68
3877.....	Quaternary eutectic alloy.....	49.5	10.10	27.27	13.13	.....	158	70
3878.....	Fusible tenspoons.....	44.5	.....	30	16.5	Hg 5-10	158	70
3879.....	Fusible alloy.....	38.4	15.4	30.8	15.4	.....	159.8	71
3880.....	.....	50	6.2	34.5	9.3	.....	170.6	77
3881.....	Eutectic alloy (Bi-Cd-Pb).....	51.6	8.1	40.2	.....	.....	196.7	91.5
3882.....	Newton's alloy.....	50	.....	31.2	18.8	.....	201.2	94
3883.....	Eutectic alloy (Bi-Pb-Sn).....	52.5	.....	32	15.5	.....	204.8	96
3884.....	.....	10	.....	20	40	.....	212	100
3885.....	Alloy for fine castings ^c	50	.....	32.2	17.8	.....	212	100
3886.....	Rose's alloy.....	50	.....	28	22	.....	212	100
3887.....	Eutectic alloy (Bi-Cd-Sn).....	53.9	20.2	.....	25.9	.....	217.4	103
3888.....	Matrix alloy ^d	48	.....	28.5	14.5	.....	221	105
3889.....	Bismuth solder.....	40	.....	40	20	.....	235.4	113
3890.....	Eutectic alloy (Bi-Pb).....	55.5	.....	44.5	.....	.....	255.2	124
3891.....	.....	30.8	.....	38.4	30.8	.....	266	130
3892.....	Eutectic alloy (Bi-Sn).....	57	.....	.....	43	.....	280.4	138
3893.....	Eutectic alloy (Cd-Pb-Sn).....	.....	18.2	30.6	51.2	.....	287.6	142
3894.....	Eutectic alloy (Bi-Cd).....	60	10	.....	.....	.....	291.2	144
3895.....	.....	25	.....	50	25	.....	300.2	149
3896.....	.....	13.7	.....	44.8	41.5	.....	320	160
3897.....	.....	11.7	.....	46.8	41.5	.....	332.6	167
3898.....	Eutectic alloy (Cd-Sn).....	.....	32	.....	68	.....	350.6	177
3899.....	Eutectic alloy (Pb-Sn).....	.....	.....	38	62	.....	361.4	183

^a Melting point also given as 119.9°F (65.5°C).

^b Melting point also given as 149°F (65°C).

^c Melting point also given as 203°F (96.3°C).

^d Melting range 221°-248°F (105°-120°C).

TABLE 62.—*Melting ranges of hard solders and brazing materials [592]*

Serial number	Composition, percent							Liquidus temperature		Solidus temperature	Color
	Ag	Cu	Zn	Cd	P	Sn	Ni				
SILVER SOLDERS											
3900 ^a	10	52	38	<0.5	.....	.....	.....	1,600	870	1,510	Yellow.
3901.....	15	80	.....	.....	5	.....	.....	1,300	705	1,190	.....
3902 ^a	20	45	35	<0.5	.....	.....	.....	1,500	815	1,430	Yellow.
3903 ^a	20	45	30	5	.....	.....	.....	1,500	815	1,430	Do.
3904 ^a	45	30	25	nil	.....	.....	.....	1,370	745	1,250	Nearly white.
3905 ^a	50	34	16	nil	.....	.....	.....	1,425	775	1,280	Do.
3906.....	50	15.5	16.5	18	.....	.....	.....	1,175	635	1,160	.....
3907 ^a	65	20	15	nil	.....	.....	.....	1,325	720	1,280	White.
3908 ^a	70	20	10	nil	.....	.....	.....	1,390	755	1,335	Do.
3909 ^a	80	16	4	nil	.....	.....	.....	1,460	795	1,360	Do.
BRAZING ALLOYS											
3910 ^b.....	.....	50-53	rem	.....	.....	.....	.....	1,620	880	1,585	Brass-yellow.
3911 ^b.....	.....	52-53	rem	.....	.....	.....	.....	1,620	880	1,600	Do.
3912.....	.....	rem	45-50	.....	.....	3-5	.....	.....	.....	1,575	Yellow to pale yellow.
3913 ^c.....	.....	rem	57-65	.....	.....	5-9	.....	1,440	780	1,385	Gray to black.
3914.....	.....	rem	55-59	.....	.....	.....	7-9	.....	.....	1,600	White.
3915.....	.....	17	rem	.....	.....	.....	11	.....	.....	1,700	Do.
3916.....	.....	93	.....	.....	rem	.....	.....	1,526	800	1,304	Gray.
3917.....	.....	rem	.....	.....	0.03-0.09	.....	.....	1,981	1,083	1,981	Copper-red.

^aImpurities 0.15 percent maximum.^bLead 0.50 percent maximum, iron 0.10 percent maximum.^cIron 1 percent maximum.

TABLE 63.—Miscellaneous metals and alloys, high-temperature properties

[For a discussion of the indefiniteness of values reported for yield strength see page 5. Hardness numbers are Brinell numbers unless prefixed R_B , R_C , etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers). See also Figs. 200 to 209, inclusive.]

Serial number	Composition	Condition	Temperature	Short time properties				Hardness number	Creep properties		Reference
				Modulus of elasticity	Yield strength	Tensile strength	Elongation		Stress (kips/in. ²) for designated creep rate per 1,000 hours	Duration	
3918...	Beryllium-aluminum alloy: Be 67.43, Mn 0.90, Fe 0.69, Si 0.34, Cu 0.12, Cr 0.06, Al rem.	Bar, sand-cast.....	$\left. \begin{array}{l} \text{Room} \\ 500 \end{array} \right\}$	$\left. \begin{array}{l} \text{kips/in.}^2 \\ 20,400 \end{array} \right\}$	$\left. \begin{array}{l} \text{kips/in.}^2 \\ 13.6 \\ (0.1\%) \end{array} \right\}$	$\left. \begin{array}{l} \text{kips/in.}^2 \\ 13.7 \\ (2 \text{ in.}) \end{array} \right\}$	$\left. \begin{array}{l} \text{Percent} \\ 0 \\ (2 \text{ in.}) \end{array} \right\}$	75	$\left. \begin{array}{l} 0.1\% \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} 1.0\% \\ \dots\dots\dots \end{array} \right\}$	[549]
3919 ^a ..	Cadmium-nickel alloy: Ni 1.3.....	Cast.....	$\left. \begin{array}{l} 82 \\ 212 \\ 392 \\ 572 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 11.7 \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 10.5 \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} 16.4 \\ (2 \text{ in.}) \\ 19 \\ (2 \text{ in.}) \\ 36 \\ (2 \text{ in.}) \\ 111 \\ (2 \text{ in.}) \\ 162 \\ (2 \text{ in.}) \end{array} \right\}$	$\left. \begin{array}{l} 43 \\ 52 \\ 76 \\ 78 \end{array} \right\}$	$\left. \begin{array}{l} 33 \\ 22 \\ 6.5 \\ 1.8 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	[551]
3920 ^b ..	Cadmium-nickel alloy: Ni 3.0.....	...do.....	$\left. \begin{array}{l} 82 \\ 212 \\ 392 \\ 572 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 16.8 \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 22.9 \\ 14.3 \\ 3.3 \\ 0.7 \end{array} \right\}$	$\left. \begin{array}{l} 6 \\ (2 \text{ in.}) \\ 13 \\ (2 \text{ in.}) \\ 65 \\ (2 \text{ in.}) \\ 213 \\ (2 \text{ in.}) \end{array} \right\}$	$\left. \begin{array}{l} 6 \\ 17 \\ 42 \\ 82 \end{array} \right\}$	$\left. \begin{array}{l} 48 \\ 28 \\ 8.3 \\ 1.9 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	[551]
3921...	Cadmium-silver-copper alloy: Ag 2, Cu 0.5.	...do.....	$\left. \begin{array}{l} \text{Room} \\ 212 \\ 300 \\ 400 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 18.0 \\ (2 \text{ in.}) \\ 12.0 \\ 8.0 \\ 4.4 \end{array} \right\}$	$\left. \begin{array}{l} 50 \\ (2 \text{ in.}) \\ 13 \\ (2 \text{ in.}) \\ 68 \\ (2 \text{ in.}) \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	40	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	[129]
3922...	Cadmium-silver alloy: Ag 5.....	Rod, 1/4 in. diam.....	$\left. \begin{array}{l} \text{Room} \\ 300 \\ 425 \\ 500 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 16.4 \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} 31 \\ (2 \text{ in.}) \\ 94 \\ (2 \text{ in.}) \\ 94 \\ (2 \text{ in.}) \\ 22 \\ (2 \text{ in.}) \end{array} \right\}$	$\left. \begin{array}{l} 81 \\ 91 \\ 68 \\ 11 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	[129]
3923...	Cobalt-iron-titanium alloy: Co 85, Fe 11.25, Ti 3.75.	Rod, 3/16 in. diam, wrought; annealed at 1,742°F in hydrogen, a-c.	$\left. \begin{array}{l} 1,112 \\ 1,292 \\ 1,472 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} 4.0 \\ (0.16\%) \\ 4.0 \\ (0.58\%) \\ 2.0 \\ (0.43\%) \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 250 \\ \dots\dots\dots \\ 250 \\ \dots\dots\dots \\ 250 \end{array} \right\}$	[363]
3924...	Cobalt-iron-nickel-titanium alloy: Co 69.18, Fe 14.38, Ni 13.20, Ti 2.53.	Bar, w-i from 1,740°F, aged 72 hr at 1,200°F.	$\left. \begin{array}{l} \text{Room} \\ 1,112 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 80.0 \\ (0.2\%) \\ 72.0 \\ (0.2\%) \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 130 \\ (2 \text{ in.}) \\ 103 \\ (2 \text{ in.}) \end{array} \right\}$	$\left. \begin{array}{l} 30 \\ (2 \text{ in.}) \\ 16 \\ (2 \text{ in.}) \end{array} \right\}$	$\left. \begin{array}{l} 53 \\ 19 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	[548]
3925...	Cobalt-nickel-iron-titanium alloy: Co 51.08, Ni 31.76, Fe 13.31, Ti 2.82.	...do.....	$\left. \begin{array}{l} \text{Room} \\ 1,112 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 101 \\ (0.2\%) \\ 93.5 \\ (0.2\%) \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 160 \\ (2 \text{ in.}) \\ 113 \\ (2 \text{ in.}) \end{array} \right\}$	$\left. \begin{array}{l} 26 \\ (2 \text{ in.}) \\ 55 \\ (2 \text{ in.}) \end{array} \right\}$	$\left. \begin{array}{l} 36 \\ 10 \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ \dots\dots\dots \end{array} \right\}$	[548]
3926...	Cobalt-nickel-chromium-iron-titanium alloy: Co 47, Ni 25, Cr 20, Fe 7.5, Ti 2.5.	Rod, 3/16 in. diam, wrought; annealed at 1,742°F in hydrogen, a-c.	1,472	$\left. \begin{array}{l} \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \end{array} \right\}$	$\left. \begin{array}{l} \dots\dots\dots \\ 2.2 \\ (0.9\%) \end{array} \right\}$	$\left. \begin{array}{l} 250 \end{array} \right\}$	[363]

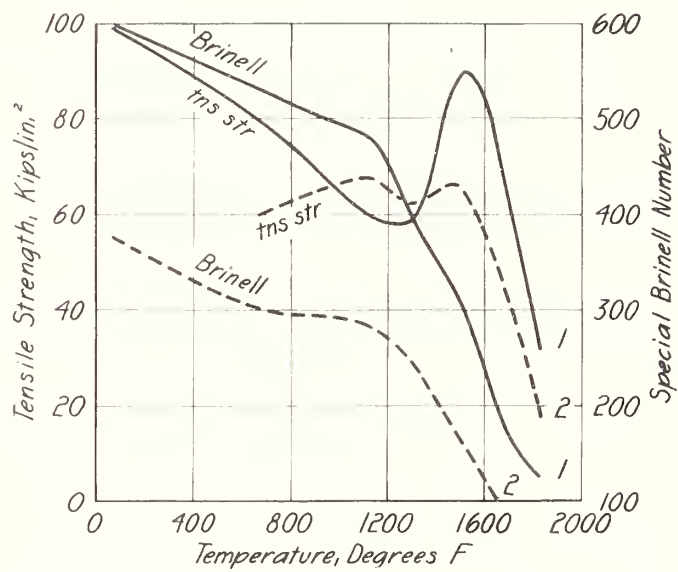


FIGURE 200.—Short-time tensile strength and hardness of cobalt-chromium-tungsten alloys at high temperatures (Wissler [557]).

Curves: 1, Co 45-55%, Cr 30-35%, W 12-17%; 2, Co >55%, Cr <33%, W <6%.

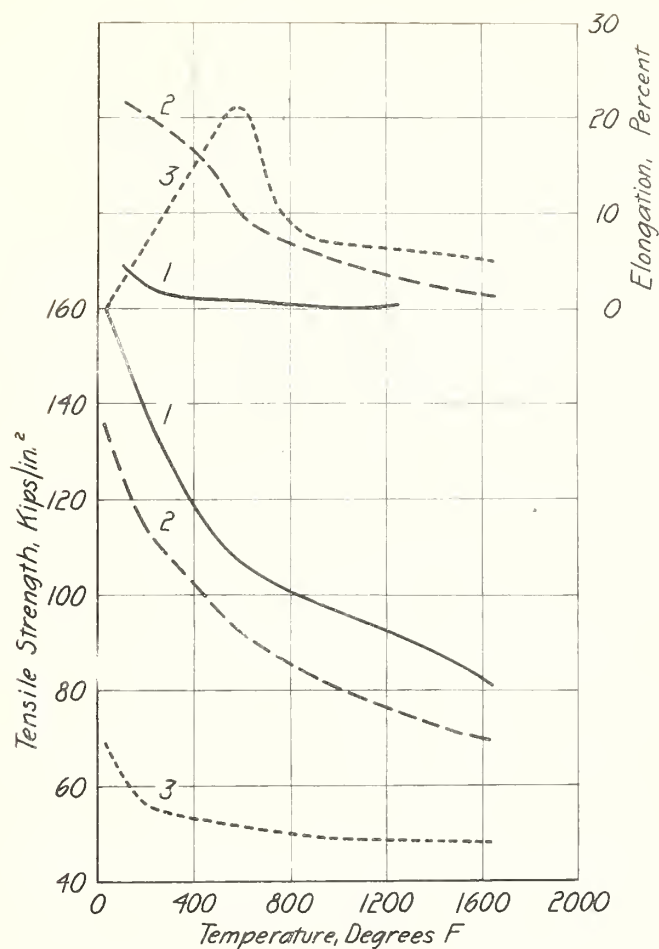


FIGURE 201.—Short-time tensile properties of molybdenum wire at high temperatures (Highriter [52]).

Curves: 1, wire, drawn (93% red.) at 1,830°-2,375°F, not recrystallized, fibrous in structure; 2, material 1, heated 2 seconds in hydrogen at 65% of fusion current, average grain diameter 0.0053 mm; 3, material 1, heated 5 seconds in hydrogen at 90% of fusion current, average grain diameter 0.03 mm

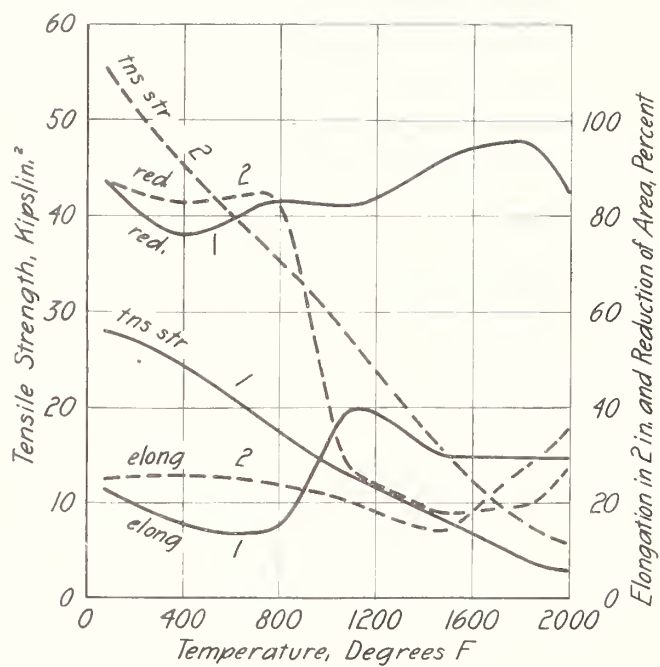


FIGURE 202.—Short-time tensile properties of palladium and a palladium-rhodium-ruthenium alloy at high temperatures (Wise and Eash [705]).

(Rate of strain, 1/2 in./minute cross-head speed)

Wire, 0.050 in. diameter, annealed 5 minutes at 2,010°F.

Curves: 1, Pd 99.9%; 2, Ru 4%, Rh 1%.

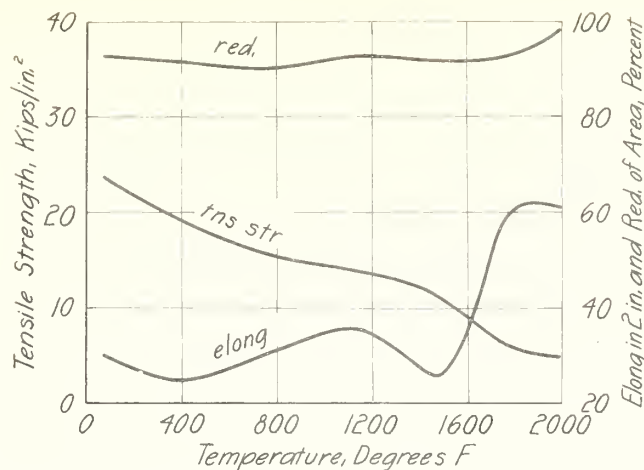


FIGURE 203.—Short-time tensile properties of platinum at high temperatures (Wise and Eash [705]).
(Rate of strain, 1/2 in./minute cross-head speed)
Pt 99.9%. Wire, 0.050 in. diameter, annealed 5 minutes at 2,010°F.

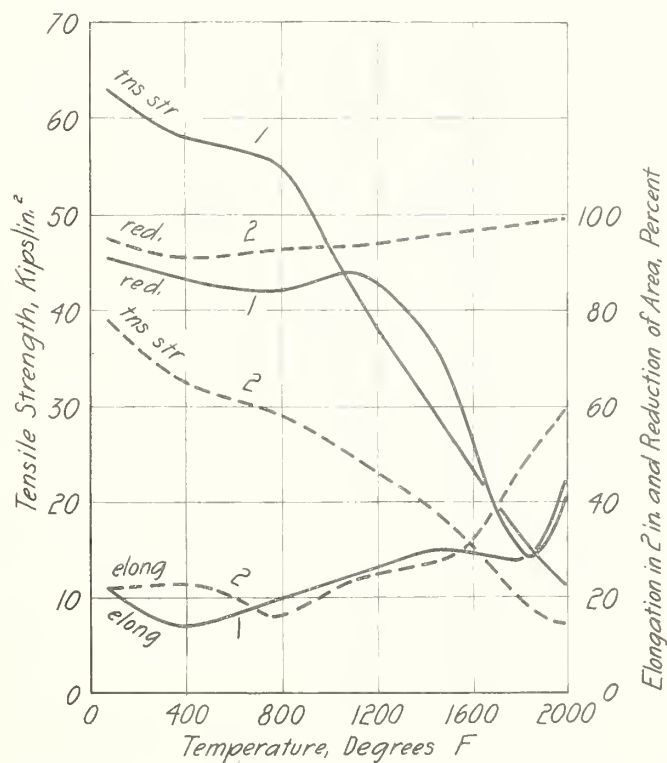


FIGURE 204.—Short-time tensile properties of a platinum-iridium and a platinum-nickel alloy at high temperatures (Wise and Eash [705]).

(Rate of strain, 1/2 in./minute cross-head speed)

Wire, 0.050 in. diameter, annealed 5 minutes at 2,010°F.

Curves: 1, Ni 4.5-5.0%; 2, Ir 5 ± 0.1%.

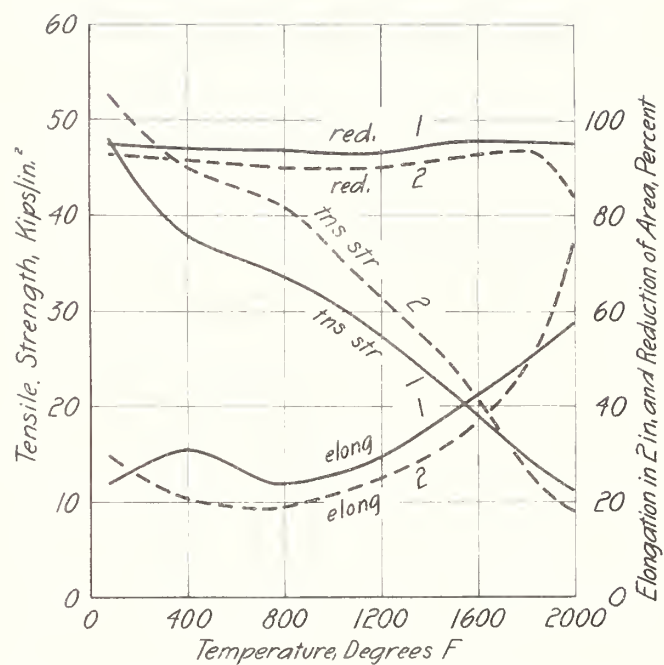


FIGURE 205. — Short-time tensile properties of a platinum-rhodium and a platinum-palladium-rhodium alloy at high temperatures (Wise and Eash [705]).

(Rate of strain, 1/2 in./minute cross-head speed)

Wire 0.050 in. diameter, annealed 5 minutes at 2,010°F.

Curves: 1, Rh 10 ± 0.1%; 2, Pd 20 ± 0.2%, Rh 5 ± 0.1%.

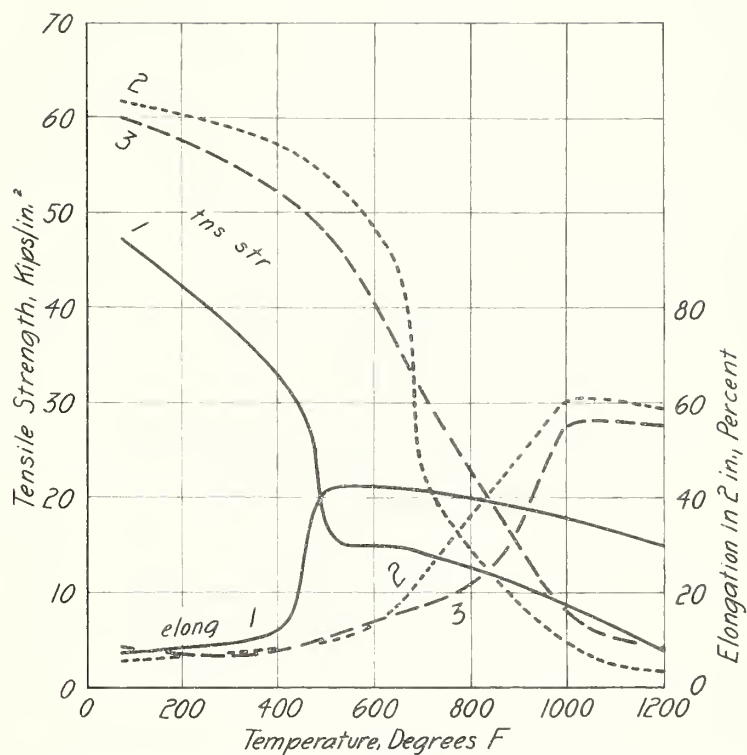


FIGURE 206.— Short-time tensile properties of silver and silver-copper alloys at high temperatures (Leach [706]).

Sheet, 0.064 in., cold-rolled (50% red.).

Curves: 1, Fine silver, Ag 99.9+%; 2, sterling silver, Cu 7.3%; 3, coin silver, Cu 10.0%.

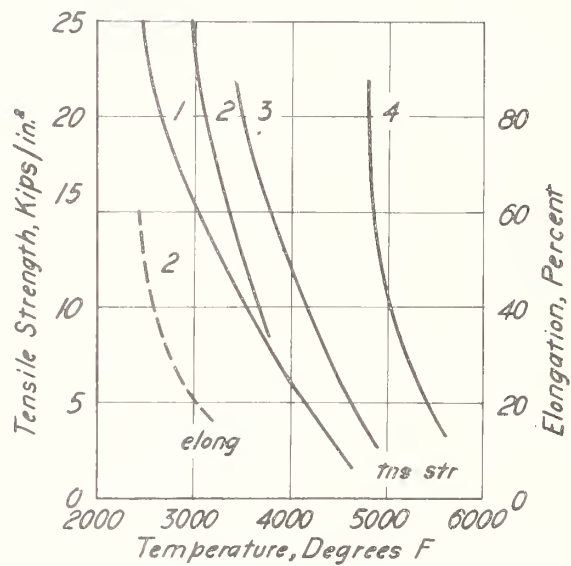


FIGURE 207.—Short-time tensile properties of tungsten wire at high temperatures (Highriter [52]).

Curves: 1, thoria-free wire; 2, thoriated wire, ThO_2 0.75%; 3, thoriated wire, ThO_2 1.5%; 4, Pintsch single-crystal wire, ThO_2 2%.

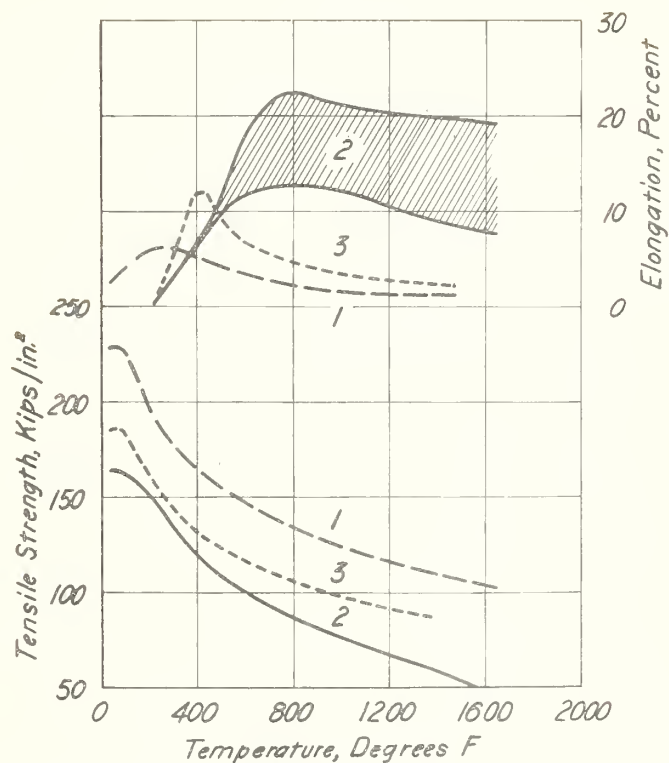


FIGURE 208.—Short-time tensile properties of tungsten wire containing 0.75 percent ThO_2 at high temperatures (Hightiter [52]).

Curves: 1, 0.025 in. diameter, cold-drawn (97.5% red.), not recrystallized; 2, material 1 recrystallized in hydrogen at 3,625°F; 3, 0.028 in diameter, cold-drawn (56% red.), not recrystallized.

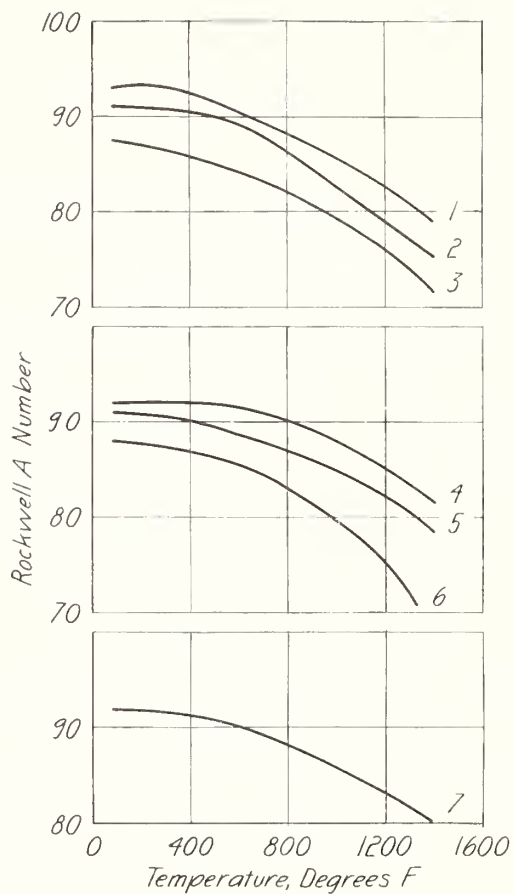


FIGURE 209.—Hardness of commercial cemented carbide alloys at high temperatures (Engle [52]).

Curves: 1, predominantly WC with TiC+7% Co; 2, predominantly WC with TaC+TiC + 11% Co; 3, predominantly WC with TaC + 13% Co; 4, WC 94%, Co 6% (fine grain); 5, WC 94%, Co 6% (coarse grain); 6, WC 87%, Co 13%; 7, predominantly WC with TaC+TiC+6% Co.

TABLE 64.—Miscellaneous metals and alloys, low-temperature properties

Serial number	Composition	Condition	Temperature °F	Tensile properties				Hardness number ^a	Reference
				Modulus of elasticity Kips/in. ²	Tensile strength Kips/in. ²	Elongation Percent	Reduction of area Percent		
3931.....	Antimony (vacuum distilled).....	Cast; ann at 1,100°F in vacuum.....	{ 64 -319	7,800 8,400	.....	.....	.....	.....	[450]
3932.....	Cadmium.....	.....	{ 59 -4 -103	.....	10.1 18.8 26.5 30.6	12 9.5 8 5	.....	.....	[451]
3933.....	Cobalt.....	.....	{ 68 -305	.....	.....	.....	.....	174 222	[65]
3934.....	Molybdenum: Mo 99.9.....	Annealed.....	{ 77 -301	.....	63.0 96.0	0 0	0	.....	[65]
3935.....	...do.....	Drawn at 2,190°-2,370°F.....	{ 77 -301	.....	118 212	4.7 0	68 0	.....	[65]
3936.....	Mercury.....	Cast.....	{ -72 -202	.....	0.4	56 (3 1/2 in.)	.....	.....	[594]
3937.....	...do.....	...do.....	{ -319	13,900	.....	44 (3 1/2 in.)	.....	.....	[55]
3938.....	Tungsten.....	Wire, drawn.....	{ Room -301	.....	420 510	.....	.....	.....	[587]

^a Brinell number.

TABLE 65.—Miscellaneous metals and alloys, thermal expansion

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade													Ref-er-ence
			Low temperature miscellaneous	-100° to 20°C	20° to 50°C	20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 500°C	20° to 600°C	20° to 700°C	20° to 800°C	20° to 900°C	20° to 1,000°C		High temperature miscellaneous
ANTIMONY; BISMUTH; CADMIUM; CHROMIUM																
3389 ^a ..	<i>Percent</i> Sb 94.8-94.9 +	Send-cast.....	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶	 x10 ⁻⁶
3390 ^a ..	Bismuth.....	Rod.....	 13.0 (-183° to 15°C)	 10.8	 11.0	 11.3	 11.4	 11.5	 11.6	 11.6	 11.6	 11.6	 11.6	 11.6	 11.6	 11.6
3391 ^a ..	Cadmium.....	.....	..... { 29.5 (-180° to 20°C) 30.8 (-20° to 20°C)	 30.3	 31.8	 31.8	 31.8	 31.8	 31.8	 31.8	 31.8	 31.8	 31.8	 31.8	 31.8	 31.8
3392 ^a ..	do.....	.....	..... { 4.1 (-216° to 0°C) 5.5 (-60° to 0°C) 5.6 (-20° to 0°C)	 5.1	 6.6	 7.3	 7.9	 8.4	 8.8	 9.1	 9.1	 9.1	 9.1	 9.1	 9.1	 9.1
3393 ^e ..	Cr 98.7-99.3.....	Annealed.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3394...	Electro chromium...	Worked and ann at 1,000°C in vacuum.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
COBALT AND COBALT ALLOYS																
33945...	Co 99.2, Fe-0.47, Mn 0.26, Si 0.03, C 0.02.	Rod, 1/4 in. diam, ann at 800°C.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33946...	Cr 20.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33947...	Cr 26.54, W 13.88, C 2.60, Ni 0.34.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33948...	Cr 29.64, W 14.53, C 2.63, Ni 0.28.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33949...	Cr 35, W 10.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33950...	Cr 40, W 3, C 2.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33951...	Fe 20.3, Ni 10.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33952...	Fe 30.2, Ni 10.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33953...	Fe 40.7.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33954...	Ni 5.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
COLUMBIUM; GALLIUM																
33955 ^e ..	Sn 0.33, Fe 0.26, Cb rem.	Annealed.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33956...	In 0.15, Zn 0.10, Pb 0.01, Ga rem.	Heat-treated (solid).	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
GOLD AND GOLD ALLOYS																
33957...	Au 99.99 +	Annealed.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33958 ^a ..	Gold (spectrographically pure).	1 hr at 950°C, slowly cooled.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33959...	Cu 8.33.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

[illegible]

TABLE 65.—Miscellaneous metals and alloys, thermal expansion—Continued

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade													Reference	
			Low temperature miscellaneous	-100° to 20°C	20° to 50°	20° to 100°	20° to 200°	20° to 300°	20° to 400°	20° to 500°	20° to 600°	20° to 700°	20° to 800°	20° to 900°	20° to 1,000°		High temperature miscellaneous
PLATINUM AND PLATINUM ALLOYS																	
3977...	Pt 80.49 + .....	.....	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	[608]
3978*	Platinum (spectrographically pure).	Slowly cooled from 1,000°C.	$\left\{ \begin{array}{l} 3.1 \text{ (-185° to 0°C)} \\ 3.9 \text{ (-50° to 0°C)} \end{array} \right\}$	8.7	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	[196]
3979*	Ir 20.....	.....	.....	.....	89.0	94.1	9.2	9.3	9.4	9.6	9.8	9.9	10.0	10.2	.....	.....	$\left\{ \begin{array}{l} 9.9 \text{ (0° to 1,200°C)} \\ 10.2 \text{ (0° to 1,400°C)} \\ 10.5 \text{ (0° to 1,600°C)} \end{array} \right\}$
3980...	Ru 20.....	.....	.....	.....	8.3	8.3	8.5	8.6	8.8	8.9	9.0	9.2	9.3	9.5	.....	.....	[722]
3980...	Ru 20.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[72]
RHODIUM; SELENIUM																	
3981*	Rhodium.....	.....	.....	.....	8.0	8.5	9.0	9.3	9.6	9.8	10.0	10.1	10.3	10.6	10.8	$\left\{ \begin{array}{l} 11.2 \text{ (0° to 1,200°C)} \\ 11.8 \text{ (0° to 1,400°C)} \\ 12.1 \text{ (0° to 1,500°C)} \end{array} \right\}$	[610]
3982...	Rhodium, "pure"....	.....	$\left\{ \begin{array}{l} 6.8 \text{ (-195° to 0°C)} \\ 8.2 \text{ (-20° to 0°C)} \end{array} \right\}$	7.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[721]
3983...	Selenium.....	.....	37.2° (-180° to 0°C)	.....	13.9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[456]
SILVER AND SILVER ALLOYS																	
3984...	Ag 99.999.....	.....	$\left\{ \begin{array}{l} 17.1 \text{ (-186° to 0°C)} \\ 15.5 \text{ (-50° to 0°C)} \end{array} \right\}$	18.1	19.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[608]
3985*	Silver (spectrographically pure).	Furnace-cooled from 900°C.	.....	.....	19.6	19.6	19.8	20.0	20.3	20.6	21.0	21.4	21.8	22.4	.....	.....	[196]
3986*	Cu 23.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[72]
3987*	Cu 30.36, Zn 20.70, Sn 1.11.	Cast.....	.....	.....	.....	19.0	19.2	19.6	20.4	21.3	.....	.....	.....	.....	.....	.....	[66]
3988*	Cu 82.33, Zn 9.25, Sn 5.71.	do.....	.....	.....	.....	20.0	20.3	20.6	21.0	22.0	.....	.....	.....	.....	.....	.....	[69]
3989*	Pt 33.....	do.....	.....	.....	15.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[456]
SODIUM; TANTALUM AND TANTALUM CARBIDE																	
3990...	Sodium.....	Crystal.....	$\left\{ \begin{array}{l} 60.1 \text{ (-190° to 0°C)} \\ 68.1 \text{ (-50° to 0°C)} \end{array} \right\}$	66.4	78.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[611]
3991...	Pa 99.9 +	Forged.....	6.8 (-190° to 20°C)	6.4	6.5	6.5	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	[612]
3992...	Tantalum carbide....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	[200]

TITANIUM; TUNGSTEN AND TUNGSTEN ALLOYS

3993 ^a ..	Fe 1.11, Si 1.05 C 0.22, Cu 0.2, V 0.17, Mn 0.01, Cu 0.01, Ti rem. Mo 0.015, Cu 0.005, As 0.002, W rem. Co 5.9, WC rem.....	Cast; h-t.....	$\left\{ \begin{array}{l} 6.8 \text{ (-190° to 20°C)} \\ 8.3 \text{ (-80° to 20°C)} \end{array} \right\}$	.....	8.8	9.1	9.5	9.7	10.0	10.4	10.7	.....	.....	[909]
3994 ^a..	.....	Rod, 3/16 in. diam..	4.3 (-50° to 0°C)	4.2	4.3	4.4	4.5	4.5	4.6	.....	.....	.....	.....	[613]
3995....	.....	Rod, 1/4 in. diam, ce- mented electrically.	.....	.....	4.5	4.8	5.0	5.2	.....	.....	.....	.....	.....	[614]
3996....	.....	...do.....	.....	.....	5.0	5.5	5.7	6.0	.....	.....	.....	.....	.....	[614]
3997 ^a ..	Co 12.9, WC rem..... Cu 40, W rem.....	Prepared from powders	.....	.....	.....	8.3	8.7	9.1	9.6	10.2	.....	.....	.....	[52]

ZIRCONIUM

3998....	Zirconium.....		$\left\{ \begin{array}{l} 5.0 \text{ (-195° to 0°C)} \\ 5.8 \text{ (-20° to 0°C)} \end{array} \right\}$	5.5										[721]
----------	----------------	-------	---	-----	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

^aBase temperature 0°C instead of 20°C.
f_{100°} to 0°C.
h_{0°} to 50°C.
h_{0°} to 100°C.
u_{0°} to 25°C.

v_{0°} to 95°C.
w_{0°} instantaneous value at 0°C.
x_{0°} to 800°C.
y_{0°} to 17°C.

TABLE 66.—Miscellaneous metals and alloys, electrical and thermal properties

Serial number	Composition	Condition	Electrical properties			Thermal conductivity	Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity		
ANTIMONY AND ANTIMONY ALLOYS							
3999.....	Antimony.....	.....	Percent IACS.....	Microhm cm.....	per °C x 10 ⁻⁴	Watts cm ⁻¹ °C ⁻¹ { 0.37 (-190°C) .22 (-80°C) .19 (0°C) .18 (100°C)	[459]
4000.....	Antimony.....	.....	.....	.....	.....	.....	[615]
4001.....	Pb 29.7.....	.....	.....	.....	.....	.....	[421]
4002.....	Pb 45.9.....	.....	.....	.....	.....	.....	[421]
4003.....	Ag 13.78.....	.....	.....	.....	.....	.....	[615]
4004.....	Ag 31.70.....	.....	.....	.....	.....	.....	[615]
BERYLLIUM							
4005.....	Be 99.5.....	.....	.....	.....	.....	.....	[616]
4006.....	do.....	.....	.....	.....	.....	.....	[110]
BISMUTH AND BISMUTH ALLOYS							
4007.....	Pb 0.06, Fe 0.01, Ag 0.01, 84 rem.....	.....	.....	.....	.....	.....	[617]
4008.....	Cd 2.0.....	do.....	.....	.....	.....	.....	[617]
4009.....	Cd 12.0.....	do.....	.....	.....	.....	.....	[617]
4010.....	Cd 40.0.....	do.....	.....	.....	.....	.....	[617]
CADMIUM AND CADMIUM ALLOYS							
4011.....	Cd 99.9.....	.....	.....	.....	.....	.....	[617]
4012.....	Bi 45.....	.....	.....	.....	.....	.....	[617]
CALCIUM							
4013.....	Calcium.....	.....	.....	.....	.....	.....	[618]
CHROMIUM							
4014.....	Electro chromium.....	.....	.....	.....	.....	.....	[479]
COBALT AND COBALT ALLOYS							
4015.....	Co 99.91.....	.....	.....	.....	.....	.....	[460]

TABLE 86.—Miscellaneous metals and alloys, electrical and thermal properties—Continued

Serial number	Composition	Condition	Electrical properties			Thermal conductivity	Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity		
INDIUM AND INDIUM ALLOYS							
4052.....	Indium.....	.....	Percent IACS { 41.5 (-132.0°C) 20.6 (0°C) 19.0 (20.9°C)	Microhm cm 2.04 (-132.0°C) 5.37 (0°C) 9.46 (20.9°C)	per °C × 10 ⁻⁴ { 30.4 (20.9° to -132.0°C)	Watts cm ⁻¹ °C ⁻¹	[157]
4053.....	..do.....	.....	6.0 (135°C)	29 (135°C)	.....	.....	[563]
4054.....	Pb 22.4.....	.....	{ 15.4 (-191.4°C) 9.5 (0°C) 9.1 (20.0°C)	{ 10.9 (-191.4°C) 18.2 (0°C) 19.0 (20.0°C)	{ 20.9 (20.0° to -191.4°C) .....	.....	[157]
4055.....	Pb 18.3.....	.....	{ 9.1 (-190.2°C) 6.2 (0°C) 6.0 (20.6°C)	{ 19.0 (-190.2°C) 27.7 (0°C) 28.6 (20.6°C)	{ 16.6 (20.5° to -190.2°C) .....	.....	[157]
4056.....	Sn 14.9.....	.....	{ 22.2 (-191.4°C) 11.8 (0°C) 11.3 (20.0°C)	{ 7.75 (-191.4°C) 14.5 (0°C) 15.3 (20.0°C)	{ 24.3 (20.0° to -191.4°C) .....	.....	[457]
4057.....	Sn 36.5.....	.....	{ 16.1 (-191.6°C) 9.3 (0°C) 8.9 (19.5°C)	{ 10.7 (-191.6°C) 18.5 (0°C) 19.4 (19.5°C)	{ 22.0 (19.5° to -191.6°C) .....	.....	[457]
4058.....	Sn 43.3.....	.....	{ 16.0 (-189.6°C) 9.1 (0°C) 9.0 (19.6°C)	{ 10.8 (-189.6°C) 18.3 (0°C) 19.1 (19.6°C)	{ 21.6 (19.6° to -189.6°C) .....	.....	[457]
IRIDIUM							
4059.....	Iridium.....	.....	{ 35.0 (0°C) 32.5 (20°C) 25.2 (100°C) 11.4 (500°C)	4.32 (0°C) 5.3 (20°C) 6.85 (100°C) 15.1 (500°C)	39.2 (0°-100°C) 39.8 (0°-200°C) 40.4 (0°-300°C) 40.8 (0°-400°C) 41.4 (0°-500°C)	0.59 (17°C) .57 (104°C)	[499]
MANGANESE ALLOYS							
4060.....	Cu 4.....	Quenched.....	2-2	79	.....	.....	[215]
4061.....	Cu 5, Ni 5.....	Rod, 1/4 in. diam. cold-swaged.....	{ 1.5 (25.0°C) 1.4 (98.7°C)	110 (25.0°C) 122 (98.7°C)	{ 15.2 (25.0°-98.7°C) .....	.....	[621]
4062.....	..do.....	Rod, 1/4 in. diam. cold-swaged; 12 hr at 450°C.....	1.6 (25.0°C)	111 (25.0°C)	.....	.....	[621]
4063.....	Cu 10.....	Quenched.....	1.5	112	.....	.....	[215]
4064.....	Cu 10, Ni 10.....	Rod, 1/4 in. diam. cold-swaged.....	{ 1.1 (25.0°C) 1.1 (98.7°C)	156 (25.0°C) 163 (98.7°C)	{ 6.0 (25.0°-98.7°C) .....	.....	[621]
4065.....	Cu 20.....	Quenched.....	1.1	163	.....	.....	[215]
4066.....	Cu 25, Ni 25.....	Rod, 1/4 in. diam. cold-swaged.....	{ 0.98 (32.7°C) .99 (98.4°C)	175 (32.7°C) 174 (98.4°C)	{ -0.8 (32.7°-98.4°C) .....	.....	[621]
4067.....	Cu 29.....	Quenched.....	.84	183	.....	.....	[215]
4068.....	Cu 30, Ni 5.....	Rod, 1/4 in. diam. cold-swaged.....	{ .90 (32.6°C) .91 (98.4°C)	191 (32.6°C) 189 (98.4°C)	{ -1.0 (32.6°-98.4°C) .....	.....	[621]
4069.....	Cu 38.....	Quenched.....	.92	188	.....	.....	[215]
4070.....	Cu 50.....	..do.....	1.0	170	.....	.....	[215]

4071.....	Ni 15.....	Rod, 1/4 in. diam, cold-swaged.....	{ 1.3 (25.0°C) 1.2 (98.7°C)	132 (25.0°C) 140 (98.7°C)	{ 8.1 (25.0°-98.7°C)	.....	[621]
4072.....	Ni 25.....	Rod, 1/4 in. diam, cold-swaged.....	{ 1.1 (25.0°C) 1.0 (98.7°C)	163 (25.0°C) 166 (98.7°C)	{ 2.7 (25.0°-98.7°C)	.....	[621]
4073.....	Ni 25, Cu 10.....	do.....	{ 0.91 (32.2°C) .92 (98.4°C)	189 (32.2°C) 188 (98.4°C)	{ -0.7 (32.2°-98.4°C)	.....	[621]
4074.....	Ni 40.....	do.....	{ .93 (27.9°C) .94 (98.4°C)	185 (27.9°C) 184 (98.4°C)	{ -.5 (27.9°-98.4°C)	.....	[621]
4075.....	do.....	Rod, 1/4 in. diam, cold-swaged; 12 hr at 450°C.....	1.1 (27.9°C)	160 (27.9°C)	.....	.....	[621]
4076.....	Pd 18.....	.....	0.52 (20°C)	330 (20°C)	.....	.....	[499]

MOLYBDENUM; OSMIUM

4077.....	"Pure" molybdenum.....	Filament.....	.....	.....	.....	{ 1.08 (827°C) 0.86 (1,127°C) .84 (1,327°C) .66 (1,627°C)	[622]
4078.....	do.....	.....	33.3 (0°C)	5.17 (0°C)	.....	.....	[623]
4079.....	Molybdenum.....	.....	30 (20°C)	5.7 (20°C)	.....	.....	[311]
4080.....	Osmium.....	.....	18.1 (20°C)	9.5 (20°C)	50.0 (0°-140°C) 42 (0 -100°C)	.....	[499]

PALLADIUM AND PALLADIUM ALLOYS

4081.....	Pd 99.98.....	Rod, 0.08 in. diam, 3 days at 985°C.....	{ 59.84 (-183°C) 13.93 (0°C) 6.83 (300°C) 4.42 (700°C) 3.66 (1,000°C)	2.68 (-183°C) 12.38 (0°C) 25.24 (300°C) 39.02 (700°C) 47.08 (1,000°C)	.....	.....	[620]
4082.....	Palladium.....	Annealed.....	16.0 (20°C)	10.8 (20°C)	{ 37.7 (0°-100°C) 36.1 (0°-200°C) 34.5 (0°-400°C) 23.6 (0°-1,200°C)	0.67 (0°C) .70 (18°C) .71 (100°C)	[499]
4083.....	Cr 2.5.....	.....	7.0	24.7	.....	.....	[499]
4084.....	Cr 5.0.....	.....	4.2	41	.....	.....	[499]
4085.....	Cr 23.....	Slowly cooled.....	1.3 (100°C)	133 (100°C)	.....	.....	[499]
4086.....	Co 12.....	.....	4.5 (40°C)	38 (40°C)	.....	.....	[499]
4087.....	Co 36.....	.....	1.7 (600°C)	100 (600°C)	.....	.....	[499]
4088.....	Cu 28.....	Annealed.....	3.7	47	.....	.....	[499]
4089.....	Cu 40.....	Agcd.....	43.1	4	.....	.....	[499]
4090.....	Au 38.....	Rod, 0.08 in. diam.....	{ 7.4 (-183°C) 6.0 (0°C) 4.4 (500°C) 3.7 (977°C)	23.4 (-183°C) 28.7 (0°C) 38.9 (500°C) 46.8 (977°C)	.....	.....	[620]
4091.....	Ir 5.....	.....	12.1	11.3	.....	.....	[499]
4092.....	Ir 10.....	.....	7.4	23.3	.....	.....	[499]
4093.....	Ir 20.....	.....	4.3	40	.....	.....	[499]
4094.....	Fe 16.....	Slowly cooled from 350°C.....	.....	.....	85.5 (25°-100°C)	.....	[499]
4095.....	Mn 34.....	.....	1.8 (20°C)	96 (20°C)	.....	.....	[499]
4096.....	Os 3.....	.....	10.4	16.6	.....	.....	[499]
4097.....	Os 10.....	.....	6.6	20	.....	.....	[499]
4098.....	Os 25.....	.....	8.6	20	.....	.....	[499]
4099.....	Rh 10.....	Annealed.....	6.6	26	.....	.....	[499]
4100.....	Ag 40.....	.....	4.1	42	.....	.....	[499]
4101.....	Ag 44.....	.....	.....	.....	0.2 (0°-100°C)	.....	[499]
4102.....	Pt 25.....	.....	8.0 (20°C)	21.6 (20°C)	11 (0°-160°C)	.....	[570]

*This value is alpha of the general equation, $R_t = R_0 (1 + \alpha t)$.

TABLE 88.—Miscellaneous metals and alloys, electrical and thermal properties—Continued

Serial number	Composition	Condition	Electrical properties			Thermal conductivity	Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity		
PLATINUM AND PLATINUM ALLOYS							
4103.....	Pt 99.99 +	Annealed.....	Percent IACS { 17.6 (0°C) 6.48 (500°C) 4.00 (1,000°C) 3.11 (1,500°C)	Microhm cm 9.81 (0°C) 27.88 (500°C) 43.07 (1,000°C) 55.38 (1,500°C)	{ 39.2 (0°-100°C)	Watts cm-100-1	[493]
4104.....	..do.....	.....	.....	.....	{ 35.18 (0°-500°C) 33.09 (0°-1,000°C) 29.95 (0°-1,500°C)	.....	[499]
4105.....	Platinum.....	.....	{ 99.1 (-200°C) 29.3 (-100°C)	1.74 (-200°C) 5.89 (-100°C)	.....	.....	[499]
4106.....	..do.....	.....	.....	.....	.....	{ 0.69 (18°C) .72 (100°C)	[499]
4107.....	Pt 99.....	.....	12 (20°C)	15 (20°C)	38 (0°-100°C)	.....	[499]
4108.....	Cr 2.....	.....	5.7 (20°C)	30.4 (20°C)	.....	.....	[499]
4109.....	Cr 3.8.....	.....	2.6 (25°C)	65 (25°C)	.....	.....	[499]
4110.....	Co 3.....	quenched.....	5.7	30	.....	.....	[499]
4111.....	Co 7.....	.....	.....	.....	11.5 (25°-100°C)	.....	[499]
4112.....	Co 15.....	quenched.....	.....	.....	.....	.....	[499]
4113.....	Co 40.....	..do.....	3.8	15.8	.....	.....	[499]
4114.....	Cu 10.....	..do.....	5.1	33.8	.....	.....	[499]
4115.....	Cu 25.....	..do.....	2.9	60	2.3	.....	[499]
4116.....	..do.....	Aged.....	1.9	92	.....	.....	[499]
4117.....	Cu 40.....	quenched.....	8.6	20	2.3	.....	[499]
4118.....	..do.....	..do.....	2.4	73	.....	.....	[499]
4119.....	Ir 5.....	.....	.....	.....	2.7	.....	[499]
4120.....	Ir 20.....	.....	9.0 (20°C)	19.1 (20°C)	20 (10°-160°C)	.....	[570]
4121.....	Ir 35.....	.....	5.5 (20°C)	31.5 (20°C)	8 (10°-160°C)	.....	[570]
4122.....	Fe 21.....	quenched.....	4.8 (20°C)	36 (20°C)	5.8 (0°-100°C)	.....	[493]
4123.....	..do.....	Slowly cooled.....	.....	.....	8 (25°-100°C)	.....	[499]
4124.....	Mo 2.2.....	.....	5.5 (25°C)	31.5 (25°C)	41 (25°-100°C)	.....	[499]
4125.....	Ni 30.....	quenched.....	4.1	42	10.1 (25°-100°C)	.....	[499]
4126.....	Os 5.....	.....	7.2 (20°C)	24 (20°C)	.....	.....	[499]
4127.....	Pd 10.....	.....	8.7 (20°C)	19.9 (20°C)	14 (0°-160°C)	.....	[570]
4128.....	Pd 30.....	.....	6.1 (20°C)	28.2 (20°C)	10 (0°-160°C)	.....	[570]
4129.....	Rh 5.....	.....	9.9 (20°C)	17.4 (20°C)	20 (25°-100°C)	.....	[570]
4130.....	Rh 10.....	wire, ann.....	9.1 (20°C)	19 (20°C)	17 (0°-100°C)	.....	[624]
4131.....	Rh 13.....	.....	{ 9.1 (0°C) 7.8 (100°C) 5.2 (500°C) 3.8 (1,000°C) 3.0 (1,500°C)	{ 19.0 (0°C) 22.0 (100°C) 33.1 (500°C) 45.9 (1,000°C) 57.3 (1,500°C)	.....	.....	[499]
4132.....	Rh 15, Ru 5.....	.....	5.7 (20°C)	30.3 (20°C)	8 (0°-100°C)	.....	[525]
4133.....	Ru 39.....	wire, ann.....	9.8 (20°C)	17.5 (20°C)	14 (0°-100°C)	.....	[624]
4134.....	Ru 5.....	.....	5.5 (20°C)	31.5 (20°C)	8.5 (25°-100°C)	.....	[499]
4135.....	Ru 10.....	.....	4.0 (20°C)	43 (20°C)	8.3 (25°-100°C)	.....	[499]
4136.....	Ag 45.....	quenched.....	2.8	61	3.0	.....	[499]

RHODIUM AND RHODIUM ALLOYS

4137.....	Rhodium.....	40 (0°C) 28 (100°C) 21 (199.1°C) 17 (309.5°C) 12 (510.7°C)	4.3 (0°C) 6.2 (100°C) 8.2 (199.1°C) 10.4 (309.5°C) 14.9 (510.7°C)	45.7 (0°-100°C)	{ 0.89 (0°C) 48 (17°C) 80 (100°C) }	[499]
4138.....	Pt 18.....	21 (20°C)	8.3 (20°C)	25.5 (0°-100°C)	.....	[524]
4139.....	Pt 38.....	14.6 (20°C)	11.8 (20°C)	19.2 (0°-100°C)	.....	[524]

SILVER AND SILVER ALLOYS

4140.....	Silver.....	114 (0°C)	1.51 (0°C)	40.50 (0°-100°C)	.....	[523]
4141.....	..do.....	.....	.....	.....	{ 4.26 (-183°C) 4.21 (-78.5°C) 4.18 (0°C) }	[579]
4142.....	..do.....	.....	.....	.....	{ 3.91 (100°C) 3.62 (300°C) 3.77 (550°C) }	[579]
4143.....	Al 1.3.....	15.6 (0°C)	11.05 (0°C)	5.7 (0°-100°C)	.....	[490]
4144.....	..do.....	3.7 (0°C)	46.7 (0°C)	4.4 (0°-100°C)	.....	[490]
4145.....	Al 15.7.....	6.6 (0°C)	26.3 (0°C)	9.2 (0°-100°C)	.....	[490]
4146.....	..do.....	17.8 (0°C)	9.71 (0°C)	15.6 (0°-100°C)	.....	[490]
4147.....	Al 37.5.....	13.5 (0°C)	12.8 (0°C)	15.3 (0°-100°C)	.....	[615]
4148.....	Sb 2.00.....	.....	180 (0°C)	1.70 (0°-100°C)	.....	[615]
4149.....	Sb 27.04.....	0.96 (0°C)	.....	.....	{ 1.65 (0°C) 1.32 (100°C) }	[459]
4150.....	Cd 5.9.....	.....	.....	.....	{ 0.80 (0°C) 0.96 (100°C) }	[459]
4151.....	Cd 20.5.....	.....	.....	.....	.....	[459]
4152.....	Cu 5.....	90.1 (25°C)	1.91 (25°C)	37.4 (25°-100°C)	3.52 (62°C)	[460]
4153.....	Cu 6.2.....	.....	.....	.....	3.30 (62°C)	[459]
4154.....	Cu 25.....	.....	.....	.....	3.11 (62°C)	[459]
4155.....	Cu 40.....	90.1 (25°C)	1.91 (25°C)	38.0 (25°-100°C)	.....	[460]
4156.....	Cu 41.8.....	75.3 (0°C)	2.29 (0°C)	26.6 (0°C)	.....	[460]
4157.....	Au 3.51.....	24.8 (0°C)	6.96 (0°C)	9.1 (0°C)	.....	[460]
4158.....	Au 31.3.....	75.2 (23.4°C)	2.29 (23.4°C)	.....	.....	[460]
4159.....	Pb 0.96.....	80.6 (25°C)	2.14 (25°C)	32.1 (25°-100°C)	.....	[460]
4160.....	Mg 0.1.....	27.5 (25°C)	6.28 (25°C)	.....	.....	[460]
4161.....	Mg 2.91.....	28.5 (0°C)	6.05 (0°C)	9.1 (0°-199°C)	.....	[460]
4162.....	Pt 10.....	.....	.....	.....	1.44 (25°C)	[459]
4163.....	..do.....	.....	9.18	.....	1.00 (25°C)	[460]
4164.....	Pt 10.39.....	.....	25.0 (0°C)	.....	.....	[460]
4165.....	Sn 8.40.....	18.8 (0°C) 6.9 (0°C)	.....	3.90 (0°-100°C)	.....	[523]

TANTALUM; THALLIUM; TITANIUM; ZIRCONIUM

4166.....	Tantalum.....	{ 13.73 (0°C) 3.91 (727°C) 2.76 (1,227°C) 2.19 (1,727°C) 1.59 (2,727°C) }	12.56 (0°C) 44.1 (727°C) 82.1 (1,227°C) 78.9 (1,727°C) 108.7 (2,727°C)	38.2 (0°-100°C)	.....	[526]
4167 ^b	..do.....	.....	.....	.....	{ 0.54 (0°C) 0.73 (1,427°C) }	[459]
4168.....	Thallium.....	.....	.....	.....	{ .39 (50°C) .40 (100°C) .39 (150°C) .44 (200°C) }	[459]

^bThe temperature coefficient of thermal conductivity is -1.0 (0°-100°C) and 3.4 (1,427°-1,827°C).

TABLE 66.—Miscellaneous metals and alloys, electrical and thermal properties—Continued

Serial number	Composition	Condition	Electrical properties			Thermal conductivity	Reference
			Volume conductivity	Resistivity	Temperature coefficient of resistivity		
TANTALUM; THALLIUM; TITANIUM; TUNGSTEN; ZIRCONIUM—Continued							
4169.....	Titanium.....	.....	Percent IACS 2.2 (0°C)	Microhm cm 80 (0°C)	per °C × 10 ⁻⁴ 46.9	Watts cm ⁻¹ °C ⁻¹	[627]
4170.....	Tungsten.....	.....	31 (20°C)	5.5 (20°C)	51.0 (0°-170°C)	.....	[511]
4171.....	...do.....	Filament.....	.....	.....	.....	(1.17 (827°C) 1.11 (1,227°C) 1.03 (1,727°C)	[622]
4172.....	Zirconium.....	.....	1.21 (0°C)	11.0 (0°C)	43.8	.....	[627]

XIV. APPENDIX

(457)

TABLE 67.—Some physical properties of the elements

Element	Symbol	Atomic number	Atomic weight	Density at 20°C	Melting point (International temperature scale)	Specific heat at r-t	Latent heat of fusion	Coefficient of linear thermal expansion per °C at r-t	Thermal conductivity at r-t	Electrical resistivity	Modulus of elasticity
Actinium.....	Ac	89	227	.....	^a 1,600	.....	.....	.....	.....	.....	.....
Aluminum.....	Al	13	26.97	2.70	960.0 ±0.1	0.226	93	22.9	2.18	2.65 (20°C)	10,300
Antimony.....	Sb	51	121.76	6.62	530.5 ±0.1	.049	38.3	b 8.5-10.8	0.19	39.0 (0°C)	11,300
Argon.....	A	18	39.944	1.6626×10 ⁻³	-189.3 ±0.5	.125	6.7	.....	1.70×10 ⁻⁴	.....	.....
Arsenic.....	As	33	74.91	5.73	614	.082	.....	4.7	.....	35 (20°C)	.....
Barium.....	Ba	56	137.35	3.5	714 ±20	.068	.....	.....	.....	.....	.....
Beryllium.....	Be	4	9.02	1.82	1,290 ±40	.425	.....	11.4	1.64	5.88 (0°C)	42,600
Bismuth.....	Bi	83	209.00	9.80	271.3 ±0.1	.029	12.5	13.3	0.084	106.8 (0°C)	4,600
Boron.....	B	5	10.82	2.3	2,300 ±300	.369	.....	2	.....	1.8×10 ⁻² (0°C)	.....
Bromine.....	Br	35	79.916	3.12	77.2 ±0.2	.070	16.2	.....	.....	.....	.....
Cadmium.....	Cd	48	112.41	8.65	320.9 ±0.1	.065	13.2	29.8	.91	6.83 (0°C)	8,000
Calcium.....	Ca	20	40.06	1.54	850 ±20	.157	.....	25	.....	3.43 (0°C)	3,000
Carbon (Graphite).....	C	6	12.010	2.22	3,700 ±100	.155	.....	e 0.6-4.3	.24	1,375 (0°C)	700
Cerium.....	Ce	58	140.13	6.9	900 ±50	.05	.....	.....	.....	78 (20°C)	.....
Cesium.....	Cs	55	132.91	1.9	28 ±2	.052	3.8	97.	.....	18.83 (0°C)	.....
Chlorine.....	Cl	17	35.457	.....	-101 ±2	.226	23.0	.....	.....	.....	.....
Chromium.....	Cr	24	52.01	7.14	1,800 ±50	.12	75.6	5.2	.....	14.1 (20°C)	.....
Cobalt.....	Co	27	58.94	8.9	1,490 ±20	.089	58.4	12.3	.69	5.60 (0°C)	30,000
Columbium.....	Cb	41	92.91	8.57	2,000 ±50	.....	.....	7.1	.....	.....	.....
Copper.....	Cu	29	63.57	8.96	1,083.2 ±0.1	.092	60.6	16.5	3.94	1.67 (20°C)	16,000
Dysprosium.....	Dy	66	162.46	.....	.....	.....	.....	.....	.....	.....	.....
Erbium.....	Er	58	167.2	.....	.....	.....	.....	.....	.....	.....	.....
Europium.....	Eu	63	152.0	.....	.....	.....	.....	.....	.....	.....	.....
Fluorine.....	F	9	19.00	.....	-223 ±10	.....	10.1	.....	.....	.....	.....
Gadolinium.....	Gd	64	156.9	.....	.....	.....	.....	.....	.....	.....	.....
Gallium.....	Ga	31	69.72	5.91	29.76 ±0.02	.079	19.2	18	.....	53.4 (0°C)	.....
Germanium.....	Ge	32	72.60	5.36	958 ±10	.073	.....	.....	.....	89.10 ^s (0°C)	.....
Gold.....	Au	79	197.2	19.3	1,063.0 ±0.0	.031	16.1	14.2	2.95	2.19 (0°C)	10,300
Helium.....	He	2	4.003	11.4	^a 1,700	.....	.....	.....	.....	.....	.....
Hydrogen.....	H	1	1.0080	0.069375×10 ⁻³	-273.15 ±0.02	1.25	.....	.....	13.9×10 ⁻⁴	.....	.....
Iodine.....	I	53	126.92	4.93	-113 ±1	.....	.....	.....	17.0×10 ⁻⁴	.....	.....
Iridium.....	Ir	77	193.1	22.4	1,539 ±3	.108	65	.....	.....	8.37 (0°C)	.....
Iron.....	Fe	26	55.85	7.87	1,539 ±3	.108	65	.....	.....	1.3×10 ⁻⁵ (20°C)	74,700
Krypton.....	Kr	36	83.7	3.486×10 ⁻³	-157 ±0.5	.....	.....	.....	.....	5.3 (20°C)	28,500
Lanthanum.....	La	57	138.92	6.15	926 ±5	.045	.....	.....	.....	9.71 (20°C)	.....
Lead.....	Pb	82	207.21	11.34	327.4 ±0.1	.030	6.3	28.7	.35	59 (18°C)	.....
Lithium.....	Li	3	6.940	0.53	156 ±5	.79	159	66	.71	20.65 (20°C)	2,600
Lutetium.....	Lu	71	174.99	.....	.....	.....	.....	.....	.....	8.55 (0°C)	.....
Magnesium.....	Mg	12	24.32	1.74	650 ±2	.249	70.0	25.2	1.55	4.33 (18°C)	6,500
Manganese.....	Mn	25	54.93	7.44	1,950 ±20	.107	64.8	23	.....	.....	23,000
Mercury.....	Hg	80	200.51	13.55	2,700	.....	.....	.....	.....	.....	.....
Molybdenum.....	Mo	42	95.95	10.2	-38.87 ±0.02	.083	2.7	.....	.....	94.1 (0°C)	.....
Neodymium.....	Nd	60	144.27	7.05	940 ±40	.045	.....	.....	.....	5.17 (0°C)	60,000
Neon.....	Ne	10	20.183	0.6087×10 ⁻³	-248.6 ±0.3	.....	.....	.....	.....	79 (18°C)	.....
Nickel.....	Ni	28	58.69	8.9	1,455 ±1	.112	73.8	.....	.....	.....	.....
Nitrogen.....	N	7	14.008	1.1549×10 ⁻³	-210.0 ±0.3	.247	6.2	13.3	4.57×10 ⁻⁴	6.84 (20°C)	30,000
Osmium.....	Os	76	190.2	22.48	-210.0 ±0.3	.031	.....	.....	.....	.....	.....
Oxygen.....	O	8	16.0000	1.3318×10 ⁻³	-218.8 ±0.3	.218	3.3	6.1	2.47×10 ⁻⁴	9.5 (20°C)	.....
Palladium.....	Pd	46	105.7	12.0	-218.8 ±0.3	.059	34.2	11.8	0.70	10.8 (20°C)	17,000

^aComputed.^bValue depends on the crystal orientation in polycrystalline material.^cFrom 20° to 60°C.^dAt 36 atmospheres.^eFrom 20° to 100°C.^fAt 30 atmospheres.

2. ABBREVIATIONS USED IN THIS CIRCULAR

a-c	air-cooled.
ann.....	annealed.
ASTM.....	American Society for Testing Materials.
Btu	British thermal unit.
°C	degree centigrade.
cal	calorie.
CC.....	combined carbon.
cm	centimeter.
cm-kg/cm ²	centimeter kilogram per square centimeter.
comp.....	compression.
diam	diameter.
deg.....	degree.
dyn duct.	dynamic ductility.
electro.....	electrolytic.
el lim.....	elastic limit.
elong.....	elongation.
end. lim.....	endurance limit.
extn ⁴	extension under load.
°F	degree Fahrenheit.
f-c.....	furnace-cooled.
ft-lb.....	foot-pound.
g	gram.
GC	graphitic carbon.
hr	hour.
h-t.....	heat-treated.
IACS.....	International Annealed Copper Standard.
in.	inch.
Iz ⁵	Izod.
long.	longitudinal.
min	minute.
m-kg/cm ²	meter kilogram per square centimeter.
mm	millimeter.
mod-el.....	modulus of elasticity.
No.	number.
norm.....	normalize.
o-d	outside diameter (tubing).
o-q.....	oil-quenched.
perm ⁴	permanent set.
pro lim.....	proportional limit.
R _B , R _C , etc. ⁵	Rockwell B number, Rockwell C number, etc.
red. ⁶	reduction of area.
rem.....	remainder.
r-t.....	room temperature.
S ⁵	Scleroscope number.
SAE.....	Society of Automotive Engineers.
sec	second.
soln h-t.....	solution heat-treated.
spec.....	specification.
str.....	strength.

⁴Used in yield strength column.

⁵Used as a prefix.

⁶Used also for reduction in thickness in rolling sheet or for reduction in area in rolling or drawing rod or wire.

TC.....	total carbon.
tns str.....	tensile strength.
tor str.....	torsional strength.
trans.....	transverse.
V ⁵	Vickers number.
w-q.....	water-quenched.
yld pnt.....	yield point.
yld str.....	yield strength.

⁵Used as a prefix.

3. CONVERSION FACTORS

Multiply	By	To obtain
cm	0.03281	ft
cm	.3937	in.
cm ³	.3531×10 ⁻⁴	ft ³
cm ³	.0610	in. ³
ft ³	28,317	cm ³
ft ³	1,728	in. ³
in. ³	16.387	cm ³
in. ³	0.5787×10 ⁻³	ft ³
ft	30.48	cm
ft-lb	0.1383	m-kg
g	2.2046×10 ⁻³	lb
g/cm ³	62.43	lb/ft. ³
g/cm ³	0.03613	lb/in. ³
in.....	2.540	cm.
kg	2.2046×10 ⁻³	kips
kg	0.984×10 ⁻³	long tons ⁷
kg/mm ²	1.4223	kips/in. ²
kg/mm ²	0.6349	long tons/in. ² ⁷
kips	453.59	kg
kips	1000	lb
kips	0.4464	long tons ⁷
kips/in. ²	.7031	kg/mm ²
long tons ⁷ ...	1016	kg
long tons ⁷ ...	2.24	kips
long tons/in. ² ⁷	1.5749	kilograms/mm ²
m-kg	7.2330	ft-lb
microhm-cm ...	6.015	ohms/circular-mil-foot
mm	0.03937	in.
lb/ft ³	.01602	g/cm ³
lb/ft ³	.5787×10 ⁻³	lb/in. ³
lb/in. ³	27.68	g/cm ³
cm ²	1.076×10 ⁻³	ft ²
cm ²	0.1550	in. ²
in. ²	6.452	cm ²
in. ²	6.944×10 ⁻³	ft ²
watts cm ⁻¹ °C ⁻¹	0.2389	cal sec ⁻¹ cm ⁻¹ °C ⁻¹
watts cm ⁻¹ °C ⁻¹	.1926	Btu sec ⁻¹ ft ⁻² °F ⁻¹ in.
watts cm ⁻¹ °C ⁻¹	693.36	Btu hr ⁻¹ ft ⁻² °F ⁻¹ in.
watts cm ⁻¹ °C ⁻¹	57.78	Btu hr ⁻¹ ft ⁻¹ °F ⁻¹

Miscellaneous

Temperature conversion:

$$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32).$$

$$^{\circ}\text{F} = 1.8^{\circ}\text{C} + 32.$$

⁷Used in Great Britain for strength values.

CONVERSION FACTORS—Continued

Coefficients (thermal expansion, electrical and thermal conductivity):

$$\alpha/^{\circ}\text{C} = \alpha/^{\circ}\text{F} \times 1.8$$

$$\alpha/^{\circ}\text{F} = \alpha/^{\circ}\text{C} \times 5/9$$

Electrical conductivity:

$$\text{Percent IACS} = \frac{1.7241}{\text{microhm-cm}} \times 100.$$

Atomic to weight percentages in binary systems:

$$x = \frac{100y}{y + \frac{A}{B} (100-y)},$$

where

x = weight percentage of element of atomic weight A ,

y = atomic percentage of element of atomic weight A ,

$100 - y$ = atomic percentage of element of atomic weight B .

TABLE 66.—Temperature interconversion ($^{\circ}\text{C} \longleftrightarrow ^{\circ}\text{F}$) [673]
a.—Conversion table: degrees centigrade to degrees Fahrenheit

												°C		°F																	
°C	0	10	20	30	40	50	60	70	80	90		°C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
-200	-328	-346	-364	-382	-400	-418	-436	-454	-472	-490	.....	2000	3632	3650	3668	3685	3704	3722	3740	3758	3776	3794									
-100	-148	-163	-184	-202	-220	-238	-256	-274	-292	-310	.....	2100	3812	3830	3848	3865	3884	3902	3920	3938	3956	3974									
-0	+32	+14	-4	-22	-40	-58	-76	-94	-112	-130	.....	2200	3992	4010	4028	4046	4064	4082	4100	4118	4136	4154									
0	32	50	68	86	104	122	140	158	176	194	.....	2300	4172	4190	4208	4225	4244	4262	4280	4298	4316	4334									
100	212	230	248	266	284	302	320	338	356	374	.....	2400	4352	4370	4388	4405	4424	4442	4460	4478	4496	4514									
200	392	410	428	446	464	482	500	518	536	554	.....	2500	4532	4550	4568	4586	4604	4622	4640	4658	4676	4694									
300	572	590	608	626	644	662	680	698	716	734	.....	2600	4712	4730	4748	4766	4784	4802	4820	4838	4856	4874									
400	752	770	788	806	824	842	860	878	896	914	.....	2700	4892	4910	4928	4946	4964	4982	5000	5018	5036	5054									
500	932	950	968	986	1004	1022	1040	1058	1076	1094	.....	2800	5072	5090	5108	5126	5144	5162	5180	5198	5216	5234									
600	1112	1130	1148	1166	1184	1202	1220	1238	1256	1274	.....	2900	5252	5270	5288	5306	5324	5342	5360	5378	5396	5414									
700	1292	1310	1328	1346	1364	1382	1400	1418	1436	1454	.....	3000	5432	5450	5468	5485	5504	5522	5540	5558	5576	5594									
800	1472	1490	1508	1526	1544	1562	1580	1598	1615	1634	.....	3100	5612	5630	5648	5665	5684	5702	5720	5738	5756	5774									
900	1652	1670	1688	1706	1724	1742	1760	1778	1796	1814	.....	3200	5792	5810	5828	5845	5864	5882	5900	5918	5936	5954									
1000	1832	1850	1868	1885	1904	1922	1940	1958	1976	1994	.....	3300	5972	5990	6008	6025	6044	6062	6080	6098	6116	6134									
1100	2012	2030	2048	2066	2084	2102	2120	2138	2156	2174	.....	3400	6152	6170	6188	6205	6224	6242	6260	6278	6296	6314									
1200	2192	2210	2228	2246	2264	2282	2300	2318	2336	2354	.....	3500	6332	6350	6368	6386	6404	6422	6440	6458	6476	6494									
1300	2372	2390	2408	2426	2444	2462	2480	2498	2516	2534	.....	3600	6512	6530	6548	6565	6584	6602	6620	6638	6656	6674									
1400	2552	2570	2588	2605	2624	2642	2660	2678	2696	2714	.....	3700	6692	6710	6728	6746	6764	6782	6800	6818	6836	6854									
1500	2732	2750	2768	2786	2804	2822	2840	2858	2876	2894	.....	3800	6872	6890	6908	6925	6944	6962	6980	6998	7016	7034									
1600	2912	2930	2948	2966	2984	3002	3020	3038	3056	3074	.....	3900	7052	7070	7088	7105	7124	7142	7160	7178	7196	7214									
1700	3092	3110	3128	3146	3164	3182	3200	3218	3236	3254	.....																				
1800	3272	3290	3308	3326	3344	3362	3380	3398	3416	3434	.....																				
1900	3452	3470	3488	3506	3524	3542	3560	3578	3596	3614	.....																				
°C	0	10	20	30	40	50	60	70	80	90		°C	0	10	20	30	40	50	60	70	80	90									

EXAMPLES: $134^{\circ}\text{C} = 244^{\circ}\text{F}$; $12.6^{\circ}\text{C} = 245.6^{\circ}\text{F}$; $336.7^{\circ}\text{F} = 185.0^{\circ}\text{C}$; $2.75^{\circ}\text{C} = 1852.75^{\circ}\text{F}$.

TABLE 68.—Temperature interconversion (°C ↔ °F) [678]—Continued

[Single boldface figures indicate recurring decimals]

b.—Conversion table: degrees Fahrenheit to degrees centigrade.

°F	0	10	20	30	40	50	60	70	80	90	°F	0	10	20	30	40	50	60	70	80	90
-400	-240.0	-245.5	-251.1	-256.6	-262.2	-267.7	.....	.....	.....	.....	4000	2204.4	2210.0	2215.5	2221.1	2226.6	2232.2	2237.7	2243.3	2248.8	2254.4
-300	-184.4	-190.0	-195.5	-201.1	-206.6	-212.2	-217.7	-223.3	-228.8	-234.4	4100	2280.0	2285.5	2291.1	2296.6	2302.2	2307.7	2313.3	2318.8	2324.4	2330.0
-200	-128.8	-134.4	-140.0	-145.5	-151.1	-156.6	-162.2	-167.7	-173.3	-178.8	4200	2315.5	2321.1	2326.6	2332.2	2337.7	2343.3	2348.8	2354.4	2360.0	2365.5
-100	-73.3	-78.8	-84.4	-90.0	-95.5	-101.1	-106.6	-112.2	-117.7	-123.3	4300	2351.1	2356.6	2362.2	2367.7	2373.3	2378.8	2384.4	2390.0	2395.5	2401.1
0	-17.7	-23.3	-28.8	-34.4	-40.0	-45.5	-51.1	-56.6	-62.2	-67.7	4400	2386.6	2392.2	2397.7	2403.3	2408.8	2414.4	2420.0	2425.5	2431.1	2436.6
0	17.7	23.3	28.8	34.4	40.0	45.5	51.1	56.6	62.2	67.7	4500	2422.2	2427.7	2433.3	2438.8	2444.4	2450.0	2455.5	2461.1	2466.6	2472.2
100	37.7	43.3	48.8	54.4	60.0	65.5	71.1	76.6	82.2	87.7	4600	2457.7	2463.3	2468.8	2474.4	2480.0	2485.5	2491.1	2496.6	2502.2	2507.7
200	93.3	98.8	104.4	110.0	115.5	121.1	126.6	132.2	137.7	143.3	4700	2493.3	2498.8	2504.4	2510.0	2515.5	2521.1	2526.6	2532.2	2537.7	2543.3
300	148.8	154.4	160.0	165.5	171.1	176.6	182.2	187.7	193.3	198.8	4800	2528.8	2534.4	2540.0	2545.5	2551.1	2556.6	2562.2	2567.7	2573.3	2578.8
400	204.4	210.0	215.5	221.1	226.6	232.2	237.7	243.3	248.8	254.4	4900	2564.4	2570.0	2575.5	2581.1	2586.6	2592.2	2597.7	2603.3	2608.8	2614.4
500	260.0	265.5	271.1	276.6	282.2	287.7	293.3	298.8	304.4	310.0	5000	2600.0	2605.5	2611.1	2616.6	2622.2	2627.7	2633.3	2638.8	2644.4	2650.0
600	315.5	321.1	326.6	332.2	337.7	343.3	348.8	354.4	360.0	365.5	5100	2635.5	2641.1	2646.6	2652.2	2657.7	2663.3	2668.8	2674.4	2680.0	2685.5
700	371.1	376.6	382.2	387.7	393.3	398.8	404.4	410.0	415.5	421.1	5200	2671.1	2676.6	2682.2	2687.7	2693.3	2698.8	2704.4	2710.0	2715.5	2721.1
800	426.6	432.2	437.7	443.3	448.8	454.4	460.0	465.5	471.1	476.6	5300	2706.6	2712.2	2717.7	2723.3	2728.8	2734.4	2739.9	2745.5	2751.1	2756.6
900	482.2	487.7	493.3	498.8	504.4	510.0	515.5	521.1	526.6	532.2	5400	2742.2	2747.7	2753.3	2758.8	2764.4	2769.9	2775.5	2781.1	2786.6	2792.2
1000	537.7	543.3	548.8	554.4	560.0	565.5	571.1	576.6	582.2	587.7	5500	2777.7	2783.3	2788.8	2794.4	2800.0	2805.5	2811.1	2816.6	2822.2	2827.7
1100	593.3	598.8	604.4	610.0	615.5	621.1	626.6	632.2	637.7	643.3	5600	2813.3	2818.8	2824.4	2830.0	2835.5	2841.1	2846.6	2852.2	2857.7	2863.3
1200	648.8	654.4	660.0	665.5	671.1	676.6	682.2	687.7	693.3	698.8	5700	2848.8	2854.4	2860.0	2865.5	2871.1	2876.6	2882.2	2887.7	2893.3	2898.8
1300	704.4	710.0	715.5	721.1	726.6	732.2	737.7	743.3	748.8	754.4	5800	2884.4	2890.0	2895.5	2901.1	2906.6	2912.2	2917.7	2923.3	2928.8	2934.4
1400	760.0	765.5	771.1	776.6	782.2	787.7	793.3	798.8	804.4	810.0	5900	2920.0	2925.5	2931.1	2936.6	2942.2	2947.7	2953.3	2958.8	2964.4	2970.0
1500	815.5	821.1	826.6	832.2	837.7	843.3	848.8	854.4	860.0	865.5	6000	2955.5	2961.1	2966.6	2972.2	2977.7	2983.3	2988.8	2994.4	3000.0	3005.5
1600	871.1	876.6	882.2	887.7	893.3	898.8	904.4	910.0	915.5	921.1	6100	2991.1	2996.6	3002.2	3007.7	3013.3	3018.8	3024.4	3030.0	3035.5	3041.1
1700	926.6	932.2	937.7	943.3	948.8	954.4	960.0	965.5	971.1	976.6	6200	3026.6	3032.2	3037.7	3043.3	3048.8	3054.4	3060.0	3065.5	3071.1	3076.6
1800	982.2	987.7	993.3	998.8	1004.4	1010.0	1015.5	1021.1	1026.6	1032.2	6300	3062.2	3067.7	3073.3	3078.8	3084.4	3090.0	3095.5	3101.1	3106.6	3112.2
1900	1037.7	1043.3	1048.8	1054.4	1060.0	1065.5	1071.1	1076.6	1082.2	1087.7	6400	3097.7	3103.3	3108.8	3114.4	3120.0	3125.5	3131.1	3136.6	3142.2	3147.7
2000	1093.3	1098.8	1104.4	1110.0	1115.5	1121.1	1126.6	1132.2	1137.7	1143.3	6500	3133.3	3138.8	3144.4	3150.0	3155.5	3161.1	3166.6	3172.2	3177.7	3183.3
2100	1148.8	1154.4	1160.0	1165.5	1171.1	1176.6	1182.2	1187.7	1193.3	1198.8	6600	3168.8	3174.4	3180.0	3185.5	3191.1	3196.6	3202.2	3207.7	3213.3	3218.8
2200	1204.4	1210.0	1215.5	1221.1	1226.6	1232.2	1237.7	1243.3	1248.8	1254.4	6700	3204.4	3210.0	3215.5	3221.1	3226.6	3232.2	3237.7	3243.3	3248.8	3254.4
2300	1260.0	1265.5	1271.1	1276.6	1282.2	1287.7	1293.3	1298.8	1304.4	1310.0	6800	3240.0	3245.5	3251.1	3256.6	3262.2	3267.7	3273.3	3278.8	3284.4	3290.0
2400	1315.5	1321.1	1326.6	1332.2	1337.7	1343.3	1348.8	1354.4	1360.0	1365.5	6900	3275.5	3281.1	3286.6	3292.2	3297.7	3303.3	3308.8	3314.4	3320.0	3325.5
2500	1371.1	1376.6	1382.2	1387.7	1393.3	1398.8	1404.4	1410.0	1415.5	1421.1	7000	3311.1	3316.6	3322.2	3327.7	3333.3	3338.8	3344.4	3350.0	3355.5	3361.1
2600	1426.6	1432.2	1437.7	1443.3	1448.8	1454.4	1460.0	1465.5	1471.1	1476.6	7100	3346.6	3352.2	3357.7	3363.3	3368.8	3374.4	3380.0	3385.5	3391.1	3396.6
2700	1482.2	1487.7	1493.3	1498.8	1504.4	1510.0	1515.5	1521.1	1526.6	1532.2	7200	3382.2	3387.7	3393.3	3398.8	3404.4	3410.0	3415.5	3421.1	3426.6	3432.2
2800	1537.7	1543.3	1548.8	1554.4	1560.0	1565.5	1571.1	1576.6	1582.2	1587.7	7300	3417.7	3423.3	3428.8	3434.4	3440.0	3445.5	3451.1	3456.6	3462.2	3467.7
2900	1593.3	1598.8	1604.4	1610.0	1615.5	1621.1	1626.6	1632.2	1637.7	1643.3	7400	3453.3	3458.8	3464.4	3470.0	3475.5	3481.1	3486.6	3492.2	3497.7	3503.3
3000	1648.8	1654.4	1660.0	1665.5	1671.1	1676.6	1682.2	1687.7	1693.3	1698.8	7500	3488.8	3494.4	3500.0	3505.5	3511.1	3516.6	3522.2	3527.7	3533.3	3538.8
3100	1704.4	1710.0	1715.5	1721.1	1726.6	1732.2	1737.7	1743.3	1748.8	1754.4	7600	3524.4	3530.0	3535.5	3541.1	3546.6	3552.2	3557.7	3563.3	3568.8	3574.4
3200	1760.0	1765.5	1771.1	1776.6	1782.2	1787.7	1793.3	1798.8	1804.4	1810.0	7700	3560.0	3565.5	3571.1	3576.6	3582.2	3587.7	3593.3	3598.8	3604.4	3610.0
3300	1815.5	1821.1	1826.6	1832.2	1837.7	1843.3	1848.8	1854.4	1860.0	1865.5	7800	3595.5	3601.1	3606.6	3612.2	3617.7	3623.3	3628.8	3634.4	3640.0	3645.5
3400	1871.1	1876.6	1882.2	1887.7	1893.3	1898.8	1904.4	1910.0	1915.5	1921.1	7900	3631.1	3636.6	3642.2	3647.7	3653.3	3658.8	3664.4	3670.0	3675.5	3681.1
3500	1926.6	1932.2	1937.7	1943.3	1948.8	1954.4	1960.0	1965.5	1971.1	1976.6	8000	3666.6	3672.2	3677.7	3683.3	3688.8	3694.4	3700.0	3705.5	3711.1	3716.6
3600	1982.2	1987.7	1993.3	1998.8	2004.4	2010.0	2015.5	2021.1	2026.6	2032.2	8100	3702.2	3707.7	3713.3	3718.8	3724.4	3730.0	3735.5	3741.1	3746.6	3752.2
3700	2037.7	2043.3	2048.8	2054.4	2060.0	2065.5	2071.1	2076.6	2082.2	2087.7	8200	3737.7	3743.3	3748.8	3754.4	3760.0	3765.5	3771.1	3776.6	3782.2	3787.7
3800	2093.3	2098.8	2104.4	2110.0	2115.5	2121.1	2126.6	2132.2	2137.7	2143.3	8300	3773.3	3778.8	3784.4	3790.0	3795.5	3801.1	3806.6	3812.2	3817.7	3823.3
3900	2148.8	2154.4	2160.0	2165.5	2171.1	2176.6	2182.2	2187.7	2193.3	2198.8	8400	3808.8	3814.4	3820.0	3825.5	3831.1	3836.6	3842.2	3847.7	3853.3	3858.8

EXAMPLES: -246.0°F = -151.1°C - 3.33°C = -154.44°C. 3762°F = 2071.1°C + 1.1°C = 2072.2°C. 2423.5°F = 1326.6°C + 1.66°C = 1328.26°C.

XV. REFERENCES

- [1] J. M. Lessells, *Proc. Am. Soc. Testing Materials* 40, 501 (1940).
- [2] N. E. Woldman and A. J. Dornblatt, *Engineering Alloys* (Am. Soc. Metals, Cleveland, Ohio, 1936).
- [3] A.S.T.M. Standards, part 1 (Am. Soc. Testing Materials, Philadelphia, Pa., 1942).
- [4] R. L. Templin, *Proc. Am. Soc. Testing Materials* 29, part 2, 523 (1929).
- [5] C. S. Smith, *Proc. Am. Soc. Testing Materials* 40, 864 (1940).
- [6] H. F. Moore and J. B. Kommers, *The Fatigue of Metals* (McGraw-Hill Book Co., Inc., New York, N. Y., 1927).
- [7] S. N. Petrenko, *BS J. Research* 5, 19 (1930) RP185.
- [8] A.S.T.M. Standards, part I, p. 1592 (Am. Soc. Testing Materials, Philadelphia, Pa., 1942).
- [9] *Metal Progress* 41, 44 (1942).
- [10] *Aluminum Casting Alloys and Alloys for Other Purposes* (Aluminum Company of America, Pittsburgh, Pa., 1941), supplemented by data from the Aluminum Company of America.
- [11] *Alcoa Aluminum and Its Alloys* (Aluminum Company of America, Pittsburgh, Pa., 1941), supplemented by data from the Aluminum Company of America.
- [12] C. S. Taylor, L. A. Willey, D. W. Smith, and J. D. Edwards, *Metals & Alloys* 9, 189 (1938).
- [13] J. D. Edwards, F. C. Frary, and Z. Jeffries, *The Aluminum Industry* (McGraw-Hill Book Co., New York, N. Y., 1930).
- [14] H. Schick, *Aluminium* 20, 75 (1938).
- [15] W. Müller, *Ntl. Adv. Comm. Aeron., Tech. Mem.* 960 (1940).
- [16] W. G. Brombacher and E. R. Melton, *Ntl. Adv. Comm. Aeron., Preprint Report* 358 (1930).
- [17] D. J. McAdam, Jr., and R. W. Clyne, *J. Research NBS* 13, 527 (1934) RP725.
- [18] A. von Zeerleder, *Technology of Aluminum and Its Light Alloys* (English edition by A. J. Field; Nordemann Publishing Co., Amsterdam, Holland, 1936).
- [19] R. R. Moore, *Proc. Am. Soc. Testing Materials* 25, part 2, 66 (1925).
- [20] C. H. Greenall and G. R. Gohn, *Proc. Am. Soc. Testing Materials* 37, part 2, 160 (1937).
- [21] H. Röhrig, *Werkstoffhandbuch Nichteisenmetalle, Section G Aluminum* (Beuth-Verlag GMBH, Berlin, Germany, 1936).
- [22] D. K. Crampton, *Trans. Am. Soc. Metals* 25, 55 (1937).
- [23] *NBS Cir. C346* (1927).
- [24] J. McKeown and E. D. Ward, *Elastic Properties of Non-Ferrous Metals and Alloys* (Brit. Non-Ferrous Metals Research Assn., London, England, Research Report, Association Series, No. 473, 1938).
- [25] H. W. Gillett, *Impact Resistance and Tensile Properties of Metals at Subatmospheric Temperatures* (Am. Soc. Mech. Engrs. and Am. Soc. Testing Materials, Project 13, 1941).
- [26] K. Bungardt, *Z. Metallkunde* 30, 235 (1938).
- [27] H. F. Moore and R. E. Lewis, *Proc. Am. Soc. Testing Materials* 31, part 2, 236 (1931).
- [28] R. J. Anderson, *Proc. Am. Soc. Testing Materials* 26, part 2, 349 (1926).
- [29] E. H. Dix, Jr. and J. J. Bowman, *Symposium on High-Strength Constructional Metals*, p. 109 (Am. Soc. Testing Materials, Philadelphia, Pa., 1936).
- [30] R. H. Greaves, *Metallurgist* 11, 72 (1937).
- [31] J. B. Johnson and T. Oberg, *Metals & Alloys* 4, 25 (1933).
- [32] H. J. Rowe, *Metals Handbook*, p. 1265 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [33] R. L. Templin and S. Tour, *Proc. Am. Soc. Testing Materials* 37, part 1, 258 (1937).
- [34] G. M. Rollason and S. Tour, *Metals Handbook*, p. 1302 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [35] M. Prever, *Ind. meccan.* 17, 1041 (1935).
- [36] *Trans. Am. Foundrymen's Assn.* 43, 1 (1935).
- [37] *Light Metals* 1, 283 (1938).
- [38] H. F. Moore and T. M. Jasper, *Univ. Illinois Eng. Exp. Sta. Bul.* 152, Urbana, Ill. (1925).
- [39] W. B. Mechling and S. S. Jack, *Proc. Am. Soc. Testing Materials* 39, 769 (1939).
- [40] J. R. Fischel, *J. Aeron. Sci.* 8, 373 (1941).
- [41] R. M. Brick and A. Phillips, *Heat Treating Forging* 26, 551 (1940).
- [42] M. Prever, *Ind. meccan.* 18, 485 (1936).
- [43] H. C. H. Carpenter and J. M. Robertson, *Metals* 2 (Oxford University Press, London, England, 1939).
- [44] J. O. Hitchcock, *Metal Ind. (London)* 50, 710 (1937).
- [45] R. R. Kennedy, *Proc. Am. Soc. Testing Materials* 35, part 2, 218 (1935).
- [46] H. J. Rowe, *Metals Handbook*, p. 1250 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [47] T. T. Oberg and J. B. Johnson, *Proc. Am. Soc. Testing Materials* 37, part 2, 195 (1937).
- [48] G. Forrest, *Metallurgia* 22, 51 (1940).
- [49] F. Keller and T. W. Bossert, *Metals Handbook*, p. 1276 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [50] W. E. Martin, *Trans. Am. Foundrymen's Assn.* 50, 766 (1943).
- [51] *Nickel Rev.* 11, 33 (1938).
- [52] J. Wulff (editor) *Powder Metallurgy* (Am. Soc. Metals, Cleveland, Ohio, 1942).
- [53] *Dowmetal Magnesium Alloys* (Dow Chemical Co., Midland, Mich., 1942).
- [54] T. W. Bossert and J. A. Nock, Jr., *Metals Handbook*, p. 1277 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [55] *Landolt-Börnstein, Physikalisch-Chemische Tabellen* (Julius Springer, Berlin, Germany, 1935).
- [56] L. W. Kempf and O. H. Heil, *Metals Handbook*, p. 1282 (Am. Soc. Metals, Cleveland, Ohio, 1939).

- [57] L. W. Kempf and J. H. Alden, *Metals Handbook*, p. 1284 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [58] J. L. Burns, T. L. Moore, and R. S. Archer, *Trans. Am. Soc. Metals* **26**, 1 (1938).
- [59] M. Melhuish, *Proc. Inst. Automobile Engrs.* **35**, 1 (1940).
- [60] W. Bungardt and G. Schaitberger, *Luftfahrt-Forschung* **18**, 26 (1941).
- [61] *Aircraft Eng.* **10**, 10 (1938).
- [62] J. Laing and R. T. Rolfe, *Metal Ind.* (London) **54**, 463 (1939).
- [63] *Compilation of Available High-Temperature Creep Characteristics of Metals and Alloys* (Am. Soc. Mech. Engrs. and Am. Soc. Testing Materials, 1938).
- [64] E. W. Colbeck and W. E. MacGillivray, *Trans. Inst. Chem. Engrs.* (London) **11**, 107 (1933).
- [65] H. W. Russell, *Symposium on Effect of Temperature on the Properties of Metals*, p. 658 (Am. Soc. Mech. Engrs. and Am. Soc. Testing Materials, 1931).
- [66] W. J. De Haas and R. Hadfield, *Phil. Trans. Roy. Soc. (London)* [A] **232**, 297 (1934).
- [67] B. E. Sandell, *Trans. Am. Inst. Mining Met. Engrs.* **99**, 359 (1932).
- [68] F. C. Nix and D. MacNair, *Phys. Rev.* **60**, 597 (1941).
- [69] N. L. Mochel, *Symposium on Effect of Temperature on the Properties of Metals*, p. 683 (Am. Soc. Mech. Engrs. and Am. Soc. Testing Materials, 1931).
- [70] P. Hidnert and W. T. Sweeney, *BS Sci. Pap.* **22**, 533 (1927) S565.
- [71] L. W. Kempf, *Trans. Am. Inst. Mining Met. Engrs.* **104**, 308 (1933).
- [72] *International Critical Tables II*, (Published for the National Research Council by the McGraw-Hill Book Co., Inc., New York, N. Y., 1927).
- [73] J. D. Edwards, *Metals Handbook*, p. 1240 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [74] L. W. Kempf, *Metals Handbook*, p. 1261 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [75] L. W. Kempf, C. S. Smith, and C. S. Taylor, *Trans. Am. Inst. Mining Met. Engrs.* **124**, 287 (1937); resistivity data at 20°C supplied by the Aluminum Company of America, through private communication from J. D. Edwards, March 1943.
- [76] O. H. Heil, *Metals Handbook*, p. 1274 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [77] O. H. Heil, *Metals Handbook*, p. 1268 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [78] D. Hanson and C. E. Rodgers, *J. Inst. Metals* **48**, 37 (1932).
- [79] A. S. T. M. Standards, part I, p. 1319, B119-40T (Am. Soc. Testing Materials, Philadelphia, Pa., 1942).
- [80] A. S. T. M. Standards, Supplement, part I, p. 431, 462, and 456, B134-41T, B36-41T, and B152-41T (Am. Soc. Testing Materials, Philadelphia, Pa., 1941).
- [81] J. S. Smart, Jr., A. A. Smith, and A. J. Phillips, *Trans. Am. Inst. Mining Met. Engrs.* **143**, 272 (1941).
- [82] A. R. Anderson and C. S. Smith, *Proc. Am. Soc. Testing Materials* **41**, 849 (1941).
- [83] C. S. Smith and R. W. Van Wagner, *Proc. Am. Soc. Testing Materials* **41**, 825 (1941).
- [84] C. G. Goetzel, *Trans. Am. Soc. Metals* **27**, 458 (1939).
- [85] J. R. Townsend, *Am. Soc. Testing Materials, Bul.* No. 115, p. 35 (March 1942).
- [86] D. J. McAdam, Jr., *Trans. Am. Soc. Steel Treating* **8**, 782 (1925).
- [87] C. G. Goetzel and R. P. Seelig, *Proc. Am. Soc. Testing Materials* **40**, 746 (1940).
- [88] *Smithsonian Physical Tables* (Smithsonian Institution, Washington, D. C., 1934).
- [89] H. Osborg, *Metals Handbook*, p. 1562 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [90] E. M. Wise and J. T. Eash, *Trans. Am. Inst. Mining Met. Engrs.* **111**, 218 (1934).
- [91] J. Strauss, *Trans. Am. Soc. Steel Treating* **12**, 69 (1927).
- [92] J. Strauss, *Trans. Am. Soc. Steel Treating* **12**, 239 (1927).
- [93] D. J. McAdam, Jr., *Trans. Am. Soc. Steel Treating* **7**, 54 (1925).
- [94] C. H. Davis, *Symposium on High-Strength Constructional Metals*, p. 79 (Am. Soc. Testing Materials, Philadelphia, Pa., 1936).
- [95] R. Genders, R. C. Reader, and V. T. S. Foster, *J. Inst. Metals* **40**, 187 (1928).
- [96] R. R. Moore, *Proc. Am. Soc. Testing Materials* **24**, part 2, 547 (1924).
- [97] J. Strauss and L. H. Fawcett, *Metals Handbook*, p. 1425 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [98] J. Strauss and L. H. Fawcett, *Metals Handbook*, p. 1408 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [99] F. Hudson, *Metal Ind.* (London) **42**, 297 (1933).
- [100] W. W. Edens, *Metal Progress* **38**, 797 (1940).
- [101] R. Cazaud, *Rev. mét.* **33**, 164 (1936).
- [102] H. J. Miller, *Metal Ind.* (London) **53**, 461 (1938).
- [103] *Aluminium Bronze* (Copper Development Association, London, England, 1938).
- [104] J. B. Johnson, *J. Soc. Automotive Engrs.* **40**, 153 (1937).
- [105] L. J. Brice, *J. Inst. Metals* **45**, 209 (1931).
- [106] *Metallurgist* **11**, 148 (1938).
- [107] M. Dérivé, *Mécanique* **20**, 259 (1936).
- [108] H. C. Jennison and H. F. Silliman, *Metals Handbook*, p. 1411 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [109] F. Hudson, *Metallurgia* **16**, 195 (1937).
- [110] L. L. Stott, *Soc. Aeron. Weight Engrs.*, Paper No. 6 (1941).
- [111] L. L. Stott, *Steel* **109**, 62 (Oct. 27, 1941).
- [112] G. W. Preston, *Elec. Rev.* **116**, 372 (1935).
- [113] H. J. Miller, *Metal Ind.* (London) **54**, 642 (1939).

- [114] F. R. Hensel, E. I. Larsen, and A. S. Doty, *Metals & Alloys* 10, 372 (1939).
- [115] R. H. Harrington and L. E. Cole, *Trans. Am. Soc. Metals*, Preprint 33 (1942).
- [116] P. H. Brace, *Metals & Alloys* 9, 311 (1938).
- [117] C. H. Davis, *Wire and Wire Products* 13, 565 (1938).
- [118] T. S. Fuller, *Metal Progress* 32, 51 (1937).
- [119] R. H. Harrington, *Trans. Am. Inst. Mining Met. Engrs.* 124, 172 (1937).
- [120] E. E. Schumacher and A. G. Souden, *Metals & Alloys*, 7, 95 (1936).
- [121] K. M. Simpson and R. T. Banister, *Metals & Alloys* 7, 88 (1936).
- [122] F. R. Hensel and L. M. Tichvinsky, *Trans. Am. Soc. Mech. Engrs. (Iron and Steel)* 54, 11 (1932).
- [123] O. E. Harder and C. S. Cole, *Trans. Am. Foundrymen's Assn.* 41, 314 (1933).
- [124] *Trans. Am. Foundrymen's Assn.* 47, 195 (1939).
- [125] R. G. N. Evans, *Metal Progress* 34, 43 (1938).
- [126] W. R. D. Jones, *J. Inst. Metals* 58, 143 (1936).
- [127] E. Voce, *J. Inst. Metals* 44, 331 (1930).
- [128] F. Heusler, *Werkstoffhandbuch Nichteisenmetalle*, Section F, 9 and 10. (Beuth-Verlag GMBH, Berlin, Germany, 1936).
- [129] L. Addicks (editor) *Silver in Industry* (Reinhold Publishing Corporation, New York, N. Y., 1940).
- [130] W. A. Graham, *Metals Handbook*, p. 1418 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [131] W. A. Mudge and L. W. Luff, *Proc. Am. Soc. Testing Materials* 28, part 2, 278 (1928).
- [132] H. W. Brownsdon, M. Cook, and H. J. Miller, *J. Inst. Metals* 52, 153 (1933).
- [133] D. G. Jones, L. B. Pfeil, and W. T. Griffiths, *J. Inst. Metals* 52, 139 (1933).
- [134] W. A. Mudge and P. D. Merica, *Trans. Am. Inst. Mining Met. Engrs.* 117, 265 (1935).
- [135] M. Okamoto, *Japan Nickel Rev.* 9, 168 (1941).
- [136] T. E. Kihlgren, *Metals Handbook*, p. 1419 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [137] H. J. Miller, *Proc. Inst. Brit. Foundrymen* 32, 237 (1938).
- [138] F. W. Rowe, *J. Inst. Metals* 32, 73 (1924).
- [139] J. Laing and R. T. Rolfe, *Metal Ind. (London)* 54, 349 (1939).
- [140] W. B. Price and P. Davidson, *Chem. & Met. Eng.* 25, 141 (1921).
- [141] S. N. Petrenko, *Trans. Am. Soc. Steel Treating* 8, 519 (1925).
- [142] C. S. Smith, *Trans. Am. Inst. Mining Met. Engrs.* 128, 325 (1938).
- [143] W. Ballay and R. Chavy, *Metal Ind. (London)* 48, 347 (1936).
- [144] J. A. Duma, *Trans. Am. Soc. Metals*, 25, 788 (1937).
- [145] *Am. Machinist* 83, 643 (1939).
- [146] H. W. Gillett, *Metals & Alloys* 3, 200 (1932).
- [147] H. A. Redworth and V. P. Weaver, *Metal Ind. (London)* 49, 139 (1936).
- [148] H. L. Burghoff and D. E. Lawson, *Trans. Am. Inst. Mining Met. Engrs.* 128, 315 (1938).
- [149] W. B. Price and R. W. Bailey, *Trans. Am. Inst. Mining Met. Engrs.* 124, 271 (1937).
- [150] W. Hessenbruch, *Z. Metallkunde* 28, 320 (1936).
- [151] T. Tanabe and G. Koiso, *Inst. Metals (Japan)* 3, No. 4, 153 (1939).
- [152] H. J. Gough and D. G. Sopwith, *J. Inst. Metals* 60, 143 (1937).
- [153] W. P. Wood, *Trans. Am. Soc. Steel Treating* 15, 971 (1929).
- [154] W. D. Jones, *Metal Ind. (London)* 56, 225 (1940).
- [155] W. B. George, *Trans. Am. Foundrymen's Assn.* 48, 141 (1940).
- [156] F. Hudson, *Metal Ind. (London)* 52, 101 (1938).
- [157] H. J. Miller, *Foundry Trade J.* 61, 117 (1939).
- [158] W. C. Ellis and E. E. Schumacher, *Trans. Am. Inst. Mining Met. Engrs.* 83, 535 (1929).
- [159] W. C. Stewart, *J. Am. Soc. Naval Engrs.* 50, 107 (1938).
- [160] L. H. Fawcett, *Metals Handbook*, p. 1452 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [161] F. W. Rowe, *J. Inst. Metals* 32, 327 (1924).
- [162] W. H. Bassett, *Symposium on Effect of Temperature on the Properties of Metals*, p. 351 (Am. Soc. Mech. Engrs. and Am. Soc. Testing Materials, 1931).
- [163] F. R. Hensel and E. I. Larsen, *Trans. Am. Inst. Mining Met. Engrs.* 99, 55 (1932).
- [164] D. K. Crampton, *Metals Handbook*, p. 1396 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [165] R. A. Wilkins and E. S. Bunn, *Product Eng.* 12, 432 (1941).
- [166] *Brass Pressings (Copper Development Association, London, England, 1937).*
- [167] C. P. Wampler and N. J. Alleman, *Am. Soc. Testing Materials*, Bul. No. 101, p. 13 (Dec. 1939).
- [168] *S.A.E. Handbook (Society of Automotive Engineers, Inc., New York, N. Y., 1940).*
- [169] J. B. Kommers, *Proc. Am. Soc. Testing Materials* 31, part 2, 243 (1931).
- [170] M. Cook, *J. Inst. Metals* 60, 159 (1937).
- [171] J. L. Gregg, *Arsenical and Argentiferous Copper (Am. Chem. Soc. Monograph Series No. 67, The Chemical Catalog Co., Inc., New York, N. Y., 1934).*
- [172] W. B. Price and R. W. Bailey, *Trans. Am. Inst. Mining Met. Engrs.* 147, 136 (1942).
- [173] W. B. Price, *Symposium on Effect of Temperature on the Properties of Metals*, p. 340 (Am. Soc. Mech. Engrs. and Am. Soc. Testing Materials, 1931).
- [174] L. H. Fawcett, *Trans. Am. Inst. Mining Met. Engrs.* 83, 532 (1929).
- [175] O. Smalley, *Trans. Am. Inst. Mining Met. Engrs.* 73, 799 (1926).
- [176] O. W. Ellis, *Trans. Am. Inst. Mining Met. Engrs.* 83, 508 (1929).
- [177] *Cast Metals Handbook (Am. Foundrymen's Assn., Chicago, Ill., 1940).*

- [178] *Am. Machinist* 82, 1101 (1938).
- [179] J. Laing and R. T. Rolfe, *Metal Ind.* (London) 53, 509 (1938).
- [180] W. Claus, *Z Metallkunde* 31, 335 (1939).
- [181] F. Hudson, *Metallurgia* 17, 61 (1937).
- [182] W. B. Price and C. G. Grant, *Trans. Am. Inst. Mining Met. Engrs.* 70, 328 (1924).
- [183] J. O. Hitchcock, *Metal Ind.* (London) 57, 382 (1940).
- [184] R. H. Leach, *Proc. Am. Soc. Testing Materials* 30, part 2, 493 (1930).
- [185] A. U. Seybolt and B. W. Gonser, *Trans. Am. Inst. Mining Met. Engrs.* 137, 414 (1940).
- [186] J. C. Fox, *Proc. Am. Soc. Testing Materials* 37, part 1, 215 (1937).
- [187] H. L. Burghoff, *Metal Ind.* (London) 56, 29 (1940).
- [188] J. Laing and R. T. Rolfe, *Metal Ind.* (London) 52, 307 (1938).
- [189] C. L. Clark and A. E. White, *Metal Ind.* (London) 37, 601 (1930).
- [190] J. Laing and R. T. Rolfe, *Metal Ind.* (London) 54, 315 (1939).
- [191] H. L. Burghoff, A. I. Blank, and S. E. Maddigan, *Am. Soc. Testing Materials*, Preprint 37 (1942).
- [192] A. Krupkowski, *Rev. mét.* 28, 641 (1931) and 29, 74 (1932).
- [193] C. S. Smith, *Proc. Am. Soc. Testing Materials* 33, 642 (1939).
- [194] W. Broniewski and K. Wesolowski, *Rev. mét.* 30, 396, 453 (1933).
- [195] W. D. Boone and H. B. Wishart, *Proc. Am. Soc. Testing Materials* 35, part 2, 147 (1935).
- [196] H. Esser and H. Eusterbrock, *Arch. Eisenhüttenw.* 14, 341 (1941).
- [197] P. Hidnert, *J. Research NBS* 16, 529 (1936) RP664.
- [198] *Tables Annuelles des Constantes et Données Numérique* 11, part 1 (Gauthier-Villars, publishers, Paris, France, 1937 and McGraw-Hill Book Co., Inc., New York, N. Y.).
- [199] P. Hidnert, *BS J. Research* 12, 391 (1934) RP665.
- [200] *Tables Annuelles de Constantes et Données Numérique* 10, part 1 (Gauthier-Villars, publishers, Paris, France, 1934 and McGraw-Hill Book Co., Inc., New York, N. Y.).
- [201] S. Aoyama and T. Itô, *Sci. Rep. Tôhoku Imperial Univ. First Series* 27, 348 (1938).
- [202] W. Souder, P. Hidnert, and J. F. Fox, *J. Research NBS* 13, 497 (1934) RP722.
- [203] M. Cook, *J. Inst. Metals* 58, 151 (1936).
- [204] H. von Steinwehr and A. Schulze, *Physik. Z.* 35, 385 (1934).
- [205] C. S. Smith and E. W. Palmer, *Trans. Am. Inst. Mining Met. Engrs.* 117, 225 (1935).
- [206] C. S. Smith, *Trans. Am. Inst. Mining Met. Engrs.* 93, 176 (1931).
- [207] J. S. Smart and A. A. Smith, Jr., *Trans. Am. Inst. Mining Met. Engrs.* 147, 48 (1942).
- [208] C. H. Davis and I. T. Hook, *Wire and Wire Products* 13, 665 (1938).
- [209] J. L. Thomas, *J. Research NBS* 16, 149 (1936) RP863.
- [210] J. W. Donaldson, *J. Inst. Metals* 65, 139 (1939).
- [211] G. F. Comstock and R. E. Bannon, *Metals & Alloys* 8, 106 (1937).
- [212] J. Delmonte, *Metals & Alloys* 7, 175 (1936).
- [213] C. Blazey, *J. Inst. Metals* 58, 123 (1936).
- [214] F. R. Hensel, U. S. Patent No. 2,033,709 (March 10, 1936).
- [215] *Metallurgia* 25, 104 (1942).
- [216] H. C. Jennison and W. S. Girvin, *Metals Handbook* p. 1415 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [217] *Nickel Bul.* 10, 213 (1937).
- [218] G. C. Stauffer, *Metals Handbook*, p. 1417 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [219] *Metals Handbook*, p. 1420 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [220] G. G. Andrewartha and E. J. Evans, *Phil. Mag.* [7] 31, 265 (1941).
- [221] C. S. Smith, *Trans. Am. Inst. Mining Met. Engrs.* 89, 84 (1930).
- [222] H. B. Gardner and C. M. Saeger, *J. Research NBS* 22, 707 (1939) RP1215.
- [223] *Metal Progress* 42, 523B (1942).
- [224] *Contributions to the Metallurgy of Steel—No. 8* (Am. Iron Steel Inst., New York, N. Y. 1942).
- [225] *Metals Handbook*, p. 127 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [226] H. E. Cleaves and J. M. Hiegel, *J. Research NBS* 28, 643 (1942) RP1472.
- [227] F. Adcock and C. A. Bristow, *Proc. Roy. Soc.* (London) [A] 153, 172 (1935-6).
- [228] W. F. Roeser and H. T. Wensel, *J. Research NBS* 26, 273 (1941) RP1375.
- [229] R. L. Kenyon, *Metals Handbook*, p. 424 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [230] C. H. N. Jenkins and G. A. Mellor, *J. Iron Steel Inst.* (London) 132, 179 (1935).
- [231] J. B. Kommers, *Proc. Am. Soc. Testing Materials* 30, part 2, 368 (1930).
- [232] A. H. Allen, *Steel* 104, 43 (April 10, 1939).
- [233] H. W. Russell and W. A. Welcker, Jr., *Proc. Am. Soc. Testing Materials* 36, part 2, 118 (1936).
- [234] B. B. Wescott and C. N. Bowers, *Trans. Am. Inst. Mining Met. Engrs.* 114, 177 (1935).
- [235] G. M. Yocom, *Trans. Am. Inst. Mining Met. Engrs.* 145, 160 (1941).
- [236] H. W. Swift, *J. Inst. Automobile Engrs.* 8, 361 (1939-40).
- [237] Landolt-Börnstein, *Physikalisch-Chemische Tabellen* (Julius Springer, Berlin, Germany, 1931).
- [238] W. H. Hatfield, *Metallurgia* 20, 107 (1939).
- [239] F. T. Sisco, *Alloys of Iron and Carbon*, II (published for the Engineering Foundation by the McGraw-Hill Book Co., Inc.; New York, N. Y., 1937).

- [240] H. L. Whittemore, G. W. Nusbaum, and E. O. Seaquist, J. Research NBS 14, 139 (1935) RP763.
- [241] S. M. Shelton and W. H. Swanger, J. Research NBS 14, 17 (1935) RP754.
- [242] J. H. Nead, C. E. Sims, and O. E. Harder, Metals & Alloys 10, 68 (1939).
- [243] B. Johnston and F. Opila, Proc. Am. Soc. Testing Materials 41, 552 (1941).
- [244] E. G. Holley, Proc. Inst. Mech. Engrs. (London) 143, 237 (1940).
- [245] J. F. McDowell, Metals & Alloys 11, 27 (1940).
- [246] E. C. Wright, Trans. Am. Soc. Metals 30, 356 (1942).
- [247] I. Lyse and H. J. Godfrey, Proc. Am. Soc. Testing Materials 33, part 2, 274 (1933).
- [248] O. W. Boston and W. W. Gilbert, Trans. Am. Soc. Metals 28, 186 (1940).
- [249] J. G. Magrath, Am. Machinist 85, 645 (1941).
- [250] T. J. Dolan and B. R. Price, Metals & Alloys 11, 20 (1940).
- [251] W. H. Swanger and P. D. France, BS J. Research 9, 9 (1932) RP454.
- [252] O. J. Horger, Trans. Am. Soc. Mech. Engrs. (J. Applied Mechanics) 57, A128 (1935).
- [253] S. H. Rees, J. Iron Steel Inst. (London) 108, 273 (1923).
- [254] J. B. Johnson, Iron Age 133, 12 (March 15, 1904).
- [255] Am. Machinist 85, 875 (1941).
- [256] R. S. Sergeson and M. M. Clark, Trans. Am. Soc. Mech. Engrs. (Machine-Shop Practice) 53, No. 2, 9 (1931).
- [257] D. J. McAdam, Jr., Trans. Am. Inst. Mining Met. Engrs. 99, 282 (1932).
- [258] A. E. Gibson, Steel 93, 27 (Oct. 2, 1933).
- [259] B. Kinzel and W. Crafts, Alloys of Iron and Chromium, I (Published for the Engineering Foundation by the McGraw-Hill Book Co., Inc., New York, N. Y., 1937).
- [260] W. L. Collins and T. J. Dolan, Proc. Am. Soc. Testing Materials 38, part 2, 157 (1938).
- [261] R. Franks, Trans. Am. Soc. Metals 27, 78 (1939).
- [262] E. C. Wright and P. F. Mumma, Trans. Am. Inst. Mining Met. Engrs. 105, 77 (1933).
- [263] H. D. Newell, Metal Progress 29, 51 (Feb. 1936).
- [264] A. B. Kinzel and R. Franks, Alloys of Iron and Chromium, II (Published for the Engineering Foundation by the McGraw-Hill Book Co., Inc., New York, N. Y. 1940).
- [265] W. H. Wills, Trans. Am. Soc. Metals 23, 469 (1935).
- [266] Metals Handbook, p. 544 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [267] D. J. McAdam, Jr., Proc. Am. Soc. Testing Materials 24, part 2, 273 (1924).
- [268] F. N. Speller, I. B. McCorkle, and P. F. Mumma, Proc. Am. Soc. Testing Materials 29, part 2, 238 (1929).
- [269] O. Hengstenberg and R. Mailänder, Z. Ver. deut. Ing. 74, 1126 (1930).
- [270] J. B. Johnson and T. T. Oberg, Metals & Alloys 5, 129 (1934).
- [271] N. L. Mochel, Proc. Am. Soc. Testing Materials 30, part 2, 406 (1936).
- [272] H. Sutton, Metal Treatment 2, 89 (Summer 1936).
- [273] F. B. Lounsberry and W. R. Breeler, Trans. Am. Soc. Steel Treating 15, 733 (1929).
- [274] J. S. Marsh, Alloys of Iron and Nickel, I (Published for the Engineering Foundation by McGraw-Hill Book Co., Inc., New York, N. Y. (1938).
- [275] A. Krisch, Arch. Eisenhüttenw. 14, 325 (1941).
- [276] F. M. Becket and R. Franks, Trans. Am. Inst. Mining Met. Engrs. 113, 126 (1934).
- [277] W. Crafts, Trans. Am. Inst. Mining Met. Engrs. 135, 473 (1939).
- [278] R. Franks, Trans. Am. Soc. Metals 23, 968 (1935).
- [279] Foundry Trade J. 64, 259 (1941).
- [280] H. H. Burton and T. F. Russell, J. Iron Steel Inst. 138, 57P (1938).
- [281] A. Pomp and V. Hempel, Mitt. Kaiser-Wilhelm Inst. Eisenforsch. Düsseldorf 19, 221 (1937).
- [282] H. D. Newell, Trans. Am. Inst. Mining Met. Engrs. 131, 419 (1938).
- [283] T. Swinden, Trans. North-East Coast Inst. Engrs. Shipbuilders 54, 177 (1937-8).
- [284] F. B. Riggan, Metals & Alloys 12, 615 (1940).
- [285] S. P. Watkins, Metal Progress 39, 452 (1941).
- [286] J. L. Gregg, The Alloys of Iron and Molybdenum (Published for the Engineering Foundation by McGraw-Hill Book Co., Inc., New York, N. Y., 1932).
- [287] C. Thompson, Trans. Manchester Assn. Engrs., p. 311 (1937-8).
- [288] E. E. Thum (editor), The Book of Stainless Steels (Am. Soc. Metals, Cleveland, Ohio, 1933).
- [289] F. C. Kelley, Can. Metals and Met. Ind. 4, 322 (1941).
- [290] R. M. Brick and A. Phillips, Trans. Am. Soc. Metals 29, 435 (1941).
- [291] N. B. Pilling, Proc. Am. Soc. Testing Materials 30, part 2, 278 (1930).
- [292] R. Franks and W. O. Binder, Trans. Am. Inst. Mining Met. Engrs. 140, 433 (1940).
- [293] H. Pray, R. S. Peoples, and F. W. Fink, Proc. Am. Soc. Testing Materials 41, 646 (1941).
- [294] K. W. Ostrom and R. D. Thomas, Jr., Welding J. 20, 317S (1941).
- [295] J. A. Dums, Trans. Am. Soc. Metals 27, 149 (1939).
- [296] W. Tofaute and H. Schottky, Forschungsberichte Tech. Mitt. Krupp 3, 103 (1940).
- [297] W. H. Hatfield, J. Roy. Aeron. Soc. 39, 552 (1935).

- [298] G. C. Kiefer, *Metal Progress* 40, 59 (1941).
- [299] J. L. Gregg, *The Alloys of Iron and Tungsten* (Published for the Engineering Foundation by the McGraw-Hill Book Co., Inc., New York, N. Y., 1934).
- [300] W. Crafts and J. L. Lamont, *Trans. Am. Soc. Metals* 27, 258 (1939).
- [301] J. S. Vanick, W. W. de Sveshnikoff, and J. M. Thompson, *Tech. Pap. BS* 22, 199 (1927) T361.
- [302] *Product Eng.* 12, 607 (1941).
- [303] NBS Cir. C101 [ed 2] (1924).
- [304] C. R. Austin and G. P. Halliwell, *Trans. Am. Inst. Mining Met. Engrs.* 99, 78 (1932).
- [305] S. Epstein, J. H. Nead, and J. W. Halley, *Trans. Am. Inst. Mining Met. Engrs.* 120, 369 (1936).
- [306] H. W. Gillett, *Metals Handbook*, p. 479 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [307] G. F. Comstock, *Trans. Am. Soc. Metals* 30, 337 (1942).
- [308] J. W. Halley, *Trans. Am. Soc. Metals* 30, 358 (1942).
- [309] D. J. McAdam, Jr., *Proc. Am. Soc. Testing Materials* 29, part 2, 250 (1929).
- [310] J. I. Gregg and B. N. Daniloff, *Alloys of Iron and Copper* (Published for the Engineering Foundation by the McGraw-Hill Book Co., Inc., New York, N. Y., 1934).
- [311] W. Alexander, *Iron Steel Inst. (London) Special Report* 23, 61 (1938).
- [312] W. B. Sallitt, *Foundry Trade J.* 58, 385 (1938).
- [313] *Steel Castings Handbook* (Steel Founders' Society of America, Cleveland, Ohio, 1941).
- [314] *Metallurgist* 12, 93 (1940).
- [315] H. W. McQuaid, *Metal Progress* 40, 451 (1941).
- [316] H. F. Moore, *Univ. Illinois Eng. Exp. Sta., Bul.* 156, Urbana, Ill. (1926).
- [317] *Am. Machinist* 85, 1039 (1941).
- [318] J. H. Hall, *Metals Handbook*, p. 567 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [319] G. Riedrich, *Stahl u. Eisen* 60, 815 (1940).
- [320] R. H. Aborn and E. C. Bain, *Symposium on Effect of Temperature on the Properties of Metals*, p. 466 (Am. Soc. Mech. Engrs. and Am. Soc. Testing Materials 1931).
- [321] E. Houdremont, H. Bennek, and H. Neumeister, *Forschungsberichte Tech. Mitt. Krupp* 2, 99 (1939).
- [322] *Proc. Am. Soc. Civil Engrs.* 62, 361 (1936).
- [323] R. F. Miller, R. F. Campbell, R. H. Aborn, and E. C. Wright, *Trans. Am. Soc. Metals* 26, 81 (1938).
- [324] R. H. Greaves, *J. Iron Steel Inst. (London)* 132, 99 (1935).
- [325] T. H. Wickenden, *Metals Handbook*, p. 577 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [326] T. N. Armstrong, *Mech. Eng.* 63, 585 (1941).
- [327] H. J. French, *Alloy Constructional Steels* (Am. Soc. Metals, Cleveland, Ohio, 1942).
- [328] J. H. Andrew and D. Binnie, *J. Iron Steel Inst.* 119, 309 (1929).
- [329] NBS Cir. 58, [ed. 2] (1923).
- [330] S. G. Eskin and J. R. Fritze, *Trans. Am. Soc. Mech. Engrs.* 62, 433 (1940).
- [331] T. J. Dolan, *Trans. Am. Soc. Mech. Engrs. (J. Applied Mechanics)* 60, A141 (1938).
- [332] H. H. Abram, *J. Iron Steel Inst.* 134, 241R (1936).
- [333] C. L. Clark and A. E. White, *Univ. Mich. Eng. Research Bul. No. 27*, Ann Arbor, Mich. (1936).
- [334] H. J. Gough, *Metal Progress* 31, 516 (1937).
- [335] M. Dérivière, *Mécanique* 21, 189 (1937).
- [336] F. J. Walls and T. N. Armstrong, *Metal Progress* 33, 387 (1938).
- [337] J. W. Sands, *Metals Handbook*, p. 583 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [338] W. T. Griffiths and L. B. Pfeil, *Iron Steel Inst. (London) Special Report* 24, 343 (1939).
- [339] T. N. Armstrong, *Metal Progress* 33, 163 (1938).
- [340] E. S. Greiner, J. S. Marsh, and B. Stoughton, *Alloys of Iron and Silicon* (Published for the Engineering Foundation by the McGraw-Hill Book Co., Inc., New York, N. Y., 1933).
- [341] F. R. Bonte and W. Fleischmann, *Metal Progress* 31, 409 (1937).
- [342] G. A. Stumpf and F. R. Bonte, *Heat Treating Forging* 23, 390 (1937).
- [343] L. S. Marks (editor) *Mechanical Engineer's Handbook*, 4th ed. (McGraw-Hill Book Co., Inc., New York, N. Y., 1941).
- [344] *Proc. Am. Soc. Testing Materials* 33, part 1, 87 (1933).
- [345] E. M. Currie, *Metallurgia* 21, 63 (1940).
- [346] W. L. Collins and J. O. Smith, *Am. Soc. Testing Materials*, Preprint 35 (1942).
- [347] R. Schneidewind and E. C. Hoenicke, *Am. Soc. Testing Materials*, Preprint 34 (1942).
- [348] T. Tyrie, *Foundry Trade J.* 62, 185 (1940).
- [349] J. G. Pearce, *Proc. Inst. Mech. Engrs. (London)* 140, 163 (1938).
- [350] E. R. Young, V. A. Crosby, and A. J. Herzig, *Trans. Am. Foundrymen's Assn.* 46, 891 (1938).
- [351] F. J. Walls, *Foundry* 65, 28 (March 1937).
- [352] W. E. Hirsh, *Metal Progress* 34, 230 (1938).
- [353] J. G. Pearce, *Mech. World Eng. Record* 110, 184 (1941).
- [354] *Product Eng.* 13, 37 (1942).
- [355] G. R. Shotton and H. G. Hall, *Foundry Trade J.* 42, 399 (1930).
- [356] E. G. Mahin and J. W. Hamilton, *Trans. Am. Foundrymen's Assn.* 43, 41 (1935).
- [357] R. Schneidewind and A. E. White, *Trans. Am. Foundrymen's Assn.* 45, 1 (1937).
- [358] C. H. Lorig and C. S. Smith, *Trans. Am. Foundrymen's Assn.* 42, 211 (1934).
- [359] F. C. Lea, *Proc. Inst. Mech. Engrs. (London)* p. 885 (1922).
- [360] W. H. Hatfield, *Trans. Am. Soc. Steel Treating* 16, 121 (1929).

- [361] Joint Research Committee, Proc. Am. Soc. Testing Materials 38, part 1, 112, Project No. 14 (1938) and Trans. Am. Soc. Mech. Engrs. 58, 97 (1936).
- [362] R. F. Miller, W. G. Benz, and W. E. Unversagt, Proc. Am. Soc. Testing Materials 40, 771 (1940).
- [363] C. B. Austin and H. D. Nickol, J. Iron Steel Inst. 137, 177P (1938).
- [364] H. S. Avery, E. Cook, and J. A. Fellows, Trans. Am. Inst. Mining Met. Engrs. 150, 373 (1942).
- [365] S. H. Weaver, Proc. Am. Soc. Testing Materials 41, 608 (1941).
- [366] J. J. Kanter and G. Guarnieri, Am. Soc. Testing Materials, Preprint 36 (1942).
- [367] E. W. Colbeck, W. E. MacGillivray, and W. R. D. Manning, Trans. Inst. Chem. Engrs. (London) 11, 89 (1933).
- [368] H. J. Gough and A. J. Murphy, Proc. Inst. Mech. Engrs. (London), p. 1159 (1930).
- [369] S. J. Rosenberg, J. Research NBS 25, 673 (1940) RP1347.
- [370] A. Krisch and G. Haupt, Arch. Eisenhüttenw. 13, 299 (1940).
- [371] T. N. Armstrong and A. P. Gegnebin, Trans. Am. Soc. Metals 28, 1 (1940).
- [372] N. A. Ziegler and H. W. Northrup, Valve World 39, 11 (Jan. 1942).
- [373] G. Gruschka, Forsch. Gebiete Ingenieurw., Ausgabe B, Forschungsheft 364 (1934).
- [374] C. Pardon and E. Vierheus, Die Glesserei 15, 99 (1928).
- [375] Chem. & Met. Eng. 45, 629 (1938).
- [376] G. G. Sherratt and A. R. Challoner, Iron Steel Inst. (London) Special Report 24, 237 (1939).
- [377] P. Hidnert, Metals Handbook, p. 486 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [378] P. Hidnert, J. Research NBS 24, 25 (1940) RP1269.
- [379] J. B. Austin and R. H. W. Pierce, Jr., Ind. Eng. Chem., Ind. Ed. 25, 776 (1933).
- [380] J. A. Jones and W. C. Heselwood, J. Iron Steel Inst. 137, 361P (1938).
- [381] J. B. Austin and R. H. W. Pierce, Jr., Trans. Am. Inst. Mining Met. Engrs. 116, 289 (1935).
- [382] H. Cornelius and F. Bollenrath, Z. Metallkunde 28, 383 (1936).
- [383] W. H. Hatfield, J. Inst. Fuel 11, 245 (1938).
- [384] P. Hidnert, J. Research NBS 20, 809 (1938) RP1106.
- [385] J. V. Iohr and C. H. Hopkins, Trans. Am. Inst. Mining Met. Engrs. 135, 535 (1939).
- [386] T. J. Wood, Trans. Am. Soc. Metals 23, 455 (1935).
- [387] J. W. Bolton, Foundry 64, 32 (Sept. 1936).
- [388] E. Söhnchen and O. Bornhofen, Arch. Eisenhüttenw. 8, 357 (1935).
- [389] L. W. Eastwood, A. E. Bousu, and C. T. Eddy, Trans. Am. Foundrymen's Assn. 44, 51 (1936).
- [390] Symposium on Malleable Iron Castings (Am. Foundrymen's Assn., and Am. Soc. Testing Materials, 1931).
- [391] W. Souder and P. Hidnert, BS Sci. Pap. 17, 611 (1922) S433.
- [392] Metallurgist 11, 152 (1938).
- [393] R. W. Powell, Proc. Phys. Soc. (London) 46, 659 (1934).
- [394] S. M. Shelton, BS J. Research 12, 441 (1934) RP669.
- [395] E. Maurer, Arch. Eisenhüttenw. 10, 145 (1936).
- [396] T. D. Yensen, Metals Handbook, p. 490 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [397] R. W. Powell and M. J. Hickman, Iron Steel Inst. (London) Special Report 24, 242 (1939).
- [398] F. P. Peters, Metal Progress 28, 63 (Oct. 1935).
- [399] G. Ranque, E. Henry, and M. Chaussain, Rev. mét. 33, 602 (1936).
- [400] J. P. Gill and R. S. Rose, Iron Age 148, 33 (Sept. 25, 1941).
- [401] I. B. Thomas and R. W. Davies, Phil. Mag. [7] 22, 681 (1936).
- [402] M. S. Van Dusen and S. M. Shelton, BS J. Research 12, 429 (1934) RP668.
- [403] C. H. Lorig and V. H. Schee, Trans. Am. Foundrymen's Assn. 48, 425 (1940).
- [404] J. W. Donaldson, Metallurgia 22, 115 (1940).
- [405] J. H. Goss, Metals & Alloys 15, 576 (1942).
- [406] L. W. Kempf and H. J. Rowe, Metals Handbook, p. 1278 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [407] D. M. Scott and A. W. F. Green, Steel 100, 46 (Feb. 1, 1937).
- [408] L. W. Kempf and H. J. Rowe, Metals Handbook, p. 1259 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [409] H. J. Rowe, Metals Handbook, p. 1265 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [410] J. L. Everhart, Wire and Wire Products 8, 363 (1933).
- [411] "Reprinted from the 1942 edition of the SAE Handbook, by permission of the Society of Automotive Engineers, Inc."
- [412] A. S. T. W. Standards, Supplement, part 1, p. 438, B20-40T (Am. Soc. Testing Materials, Philadelphia, Pa., 1940).
- [413] G. O. Hiers, Trans. Am. Inst. Chem. Engrs. 20, 131 (1927).
- [414] J. McKeown, J. Inst. Metals 51, 80 (1933).
- [415] J. R. Townsend and C. H. Greenall, Proc. Am. Soc. Testing Materials 30, part 2, 395 (1930).
- [416] J. C. Chaston, Elec. Communications 13, 31 (1934).
- [417] A. Burkhardt, Metallwirtschaft 14, 445 (1935).
- [418] G. Grime and J. E. Eaton, Phil. Mag. [7] 23, 96 (1937).
- [419] H. Waterhouse, The Fatigue Resistance of Lead and Lead Alloys (Brit. Non-Ferrous Metals Research Assn., London, England, Research No. 18, Association Series No. 440, 1937).
- [420] E. E. Schumacher and G. M. Bouton, Metals & Alloys 1, 405 (1930).
- [421] E. E. Schumacher and G. O. Hiers, Metals Handbook, p. 1533 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [422] C. G. Fink and A. J. Dornblatt, Trans. Electrochem. Soc. 79, 269 (1941).

- [423] J. C. Fox, *Automotive Ind.* (now *Automotive and Aviation Ind.*) 84, 520 (1941).
- [424] *Chem. & Met. Eng.* 47, Supplementary Chart (1940).
- [425] A. S. T. M. Standards, part I, p. 677, B23-26 (Am. Soc. Testing Materials, Philadelphia, Pa., 1939).
- [426] O. W. Ellis, *Trans. Am. Inst. Chem. Engrs.* 20, 167 (1927).
- [427] J. G. Thompson, *BS J. Research* 5, 1085 (1930) RP248.
- [428] T. Takase, *Int. Metals (Japan)* 3, No. 3, 117 (1939).
- [429] A. J. Phillips, A. A. Smith, and P. A. Beck, *Metal Ind. (London)* 59, 258 (1941).
- [430] A. S. Kenneford, H. O'Neill, R. Arrowsmith, and H. Greenwood, *Int. Tin Research Development Council T. P. Series A*, No. 9 (1934).
- [431] J. W. Cuthbertson, *J. Inst. Metals* 64, 209 (1939).
- [432] F. Bollenstein, W. Bungardt, and E. Schmidt, *Luftfahrt-Forsch.* 14, 417 (1937).
- [433] G. T. Brittingham, *Modern Eng.* 12, 91 (1938).
- [434] W. H. Bassett, Jr. and C. J. Snyder, *Proc. Am. Soc. Testing Materials* 40, 910 (1940).
- [435] J. Cournot, *Compt. rend.* 186, 867 (1928).
- [436] E. E. Schumacher and E. J. Basch, *Ind. Eng. Chem., Ind. Ed.* 21, 16 (1929).
- [437] P. M. Heldt, *Automotive Ind.* (now *Automotive and Aviation Ind.*) 78, 412 (1938).
- [438] W. L. Nelson, *Oil & Gas J.* 37, 56 (Feb. 9, 1939).
- [439] S. Turkus and A. A. Smith, Jr., *Metals & Alloys* 15, 412 (1942).
- [440] I. Stewart, *Metal Ind. (London)* 59, 98 (1941).
- [441] W. Singleton and H. Jones, *J. Inst. Metals* 51, 71 (1933).
- [442] K. von Hanff-Bengel and H. Haneemann, *Z. Metallkunde* 30, 11 (1938).
- [443] B. W. Gonser and C. W. Heath, *Trans. Am. Inst. Mining Met. Engrs.* 122, 349 (1936).
- [444] S. Nightingale, *Tin Solders* (Brit. Non-Ferrous Metals Research Assn., London, England, Research Monograph No. 1, 1942).
- [445] D. J. McNaughtan, E. S. Hedges, and W. R. Lewis, *Int. Tin Research Development Council Bul.* No. 2 (1935).
- [446] A. Demmer, *Met. Abst.* 1, 172 (1934).
- [447] H. W. Gillett and R. W. Dayton, *Metals & Alloys* 15, 584 (1942).
- [448] F. N. Rhines and W. A. Anderson, *Metals & Alloys* 14, 704 (1941).
- [449] W. A. Baker, *J. Inst. Metals* 65, 277 (1939).
- [450] S. Aoyama and T. Fukuroi, *Sci. Rep. Tôhoku Imperial Univ. First Series* 28, 423 (1939-40).
- [451] A. Molnar, *Compt. rend.* 190, 1423 (1930).
- [452] P. Hidnert and W. T. Sweeney, *BS J. Research* 9, 703 (1932) RP500.
- [453] P. Hidnert, *J. Research NBS* 17, 697 (1936) RP938.
- [454] H. N. Bassett, *Bearing Metals & Alloys* (E. Arnold & Co., London, England, 1937).
- [455] *The Metal Industry Handbook and Directory No. 31* (The Louis Cassier Co., Ltd., London, England, 1942).
- [456] *Handbook of Chemistry and Physics*, 26th ed. (1942-3) (Chemical Rubber Publishing Co., Cleveland, Ohio, 1942).
- [457] S. Valentiner, *Z. Physik* 115, 11 (1940).
- [458] J. E. Harris, *Metals Handbook*, p. 1527 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [459] *International Critical Tables V* (Published for the National Research Council by the McGraw-Hill Book Co., Inc., New York, N. Y., 1929).
- [460] *International Critical Tables VI* (Published for the National Research Council by the McGraw-Hill Book Co., Inc., New York, N. Y., 1929).
- [461] *Metal Progress* 40, 436 (1941).
- [462] W. R. D. Jones, *J. Inst. Metals* 43, 237 (1930).
- [463] A. Beck, *The Technology of Magnesium and Its Alloys* (F. A. Hughes & Co., London, England, 1940).
- [464] C. S. Taylor and J. D. Edwards, *Metals Handbook*, p. 1576 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [465] L. B. Grant, *Iron Age* 144, 36 (Nov. 2, 1939).
- [466] *Am. Mechanist* 84, 291 (1940).
- [467] I. Musatti, *Metallurgia Italiana* 22, 1052 (1930).
- [468] J. L. Haughton and W. E. Prytherch, *Magnesium and Its Alloys* (His Majesty's Stationery Office, London, England, 1937).
- [469] A. W. Sinston, *Proc. Am. Soc. Testing Materials* 39, 284 (1939).
- [470] J. L. Haughton and A. E. L. Tate, *J. Inst. Metals* 62, 175 (1938).
- [471] W. Walbersdorf, *Metallwirtschaft* 17, 1282 (1938).
- [472] K. Matthes, *Z. Metallkunde* 24, 176 (1932).
- [473] W. T. Cook and W. R. D. Jones, *J. Inst. Metals* 38, 103 (1927).
- [474] W. R. D. Jones and K. J. B. Wolfe, *J. Inst. Metals* 62, 155 (1938).
- [475] *Trans. Am. Foundrymen's Assn.* 44, 33 (1936).
- [476] G. Siebel, *Int. Assn. Testing Materials, London Congress*, p. 126 (1937).
- [477] R. L. Templin and D. A. Paul, *Symposium on Effect of Temperature on the Properties of Metals*, p. 290 (Am. Soc. Mech. Engrs. and Am. Soc. Testing Materials 1931).
- [478] P. Hidnert and W. T. Sweeney, *BS J. Research* 1, 771 (1928) RP29.
- [479] *Tables Annuelles de Constantes et Données Numérique 12* (Gauthier-Villars, publishers, Paris, France, 1937 and McGraw-Hill Book Co., Inc., New York, N. Y.).
- [480] G. Grube and H. Vosskuhler, *Z. Elektrochem.* 40, 566 (1934).
- [481] G. Grube and A. Burkhardt, *Z. Elektrochem.* 35, 315 (1929).
- [482] R. W. Powell, *Phil. Mag* [7] 27, 677 (1939).

- [483] Nickel and Nickel Alloys (International Nickel Co., Inc., New York, N. Y., 1941).
- [484] G. F. Geiger, Metals Handbook, p. 1643 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [485] C. F. Catlin and W. A. Mudge, Proc. Am. Soc. Testing Materials 38, part 2, 269 (1938).
- [486] G. F. Geiger, Metals Handbook, p. 1616 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [487] N. L. Mochel, Proc. Am. Soc. Testing Materials 28, part 2, 292 (1928).
- [488] Metal Progress 33, 277 (1938).
- [489] Sheet Metal Ind. 13, 871 (1939).
- [490] L. L. Stott, Trans. Am. Inst. Mining Met. Engrs. 122, 57 (1936).
- [491] F. L. LaQue, Mech. Eng. 58, 827 (1936).
- [492] W. A. Gatward, Metals Handbook, p. 1654 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [493] C. A. Crawford, Metals Handbook, p. 1663 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [494] Cuivre et laiton 10, 513 (1937).
- [495] C. A. Crawford, Metals Handbook, p. 1670 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [496] W. A. Mudge, Metals Handbook, p. 1664 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [497] B. E. Field, Metals Handbook, p. 1671 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [498] F. T. McCurdy, Proc. Am. Soc. Testing Materials 39, 698 (1939).
- [499] R. F. Vines, The Platinum Metals and Their Alloys (The International Nickel Co., New York, N. Y., 1941).
- [500] C. A. Crawford, Metals Handbook, p. 1652 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [501] J. A. Bennett and D. J. McAdam, Jr., J. Research NBS 28, 417 (1942) RP1462.
- [502] D. E. Ackerman, Metal Progress 30, 56 (Nov. 1938).
- [503] L. J. Jordan and W. H. Swanger, BS J. Research 3, 1291 (1930) RP257.
- [504] H. Masumoto, Sci. Rep. Tôhoku Imperial Univ. First Series 20, 101 (1931).
- [505] C. A. Crawford, Metals Handbook, p. 1666 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [506] W. Souder and P. Hidnert, BS Sci. Pap. 17, 497 (1922) S426.
- [507] R. S. Dean, C. T. Anderson, and E. V. Potter, Trans. Am. Soc. Metals 29, 907 (1941).
- [508] M. A. Hunter, Metals Handbook, p. 465 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [509] Nickel Bul. 4, 195 (1931).
- [510] W. F. Burchfield, Metals Handbook, p. 1655 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [511] L. Walden, J. Sci. Instr. 16, 1 (1939).
- [512] Private communication from W. F. Roeser, National Bureau of Standards (Jan. 1943).
- [513] C. L. Mantell, Metals Handbook, p. 1714 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [514] Iron Age, 148, 42 (Sept. 25, 1941).
- [515] D. W. Guertler and M. Pirani, Int. Tin Research Development Council, T. P. Series A, No. 50 (1937).
- [516] O. W. Ellis, Metals Handbook, p. 1721 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [517] B. Egeberg and H. B. Smith, Trans. Am. Inst. Mining Met. Engrs. 89, 490 (1930).
- [518] P. G. J. Gueterbock and G. N. Nicklin, Metal Ind. (London) 27, 143 (1925).
- [519] D. Hanson and E. J. Sandford, J. Inst. Metals 62, 215 (1938).
- [520] B. S. Barham, Metal Ind. (London) 52, 521 (1938).
- [521] D. Hanson and E. J. Sandford, J. Inst. Metals 59, 159 (1936).
- [522] H. Greenwood, Int. Tin Research Development Council T. P. Series A, No 58 (1937).
- [523] W. G. John and E. J. Evans, Phil. Mag. [7] 23, 1033 (1937).
- [524] P. H. Brace, Metal Progress 41, 354 (1942).
- [525] A.S.T.M. Standards, part I, p. 682, B69-39 (Am. Soc. Testing Materials, Philadelphia, Pa., 1939).
- [526] Cir. BS 395 (1931).
- [527] W. M. Peirce and E. A. Anderson, Trans. Am. Inst. Mining Met. Engrs. 83, 560 (1929).
- [528] J. Ruzicka, Trans. Am. Inst. Mining Met. Engrs. 124, 252 (1937).
- [529] K. Bayer, Z. Metallkunde 31, 264 (1939).
- [530] W. Guertler, F. Klewata, W. Claus, and E. Rickertsen, Z. Metallkunde 28, 107 (1936).
- [531] E. A. Anderson and M. Stern, Metals Handbook, p. 1770 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [532] E. A. Anderson and G. L. Werley, Metals & Alloys 5, 97 (1934).
- [533] E. H. Kelton, Am. Soc. Testing Materials, Preprint 38 (1942).
- [534] K. Löhberg, Z. Metallkunde 31, 133 (1939).
- [535] E. Schmid, Metal Ind. (London) 55, 345 (1939).
- [536] K. Bauer and A. Burkhardt, Z. Metallkunde 31, 131 (1939).
- [537] E. H. Kelton and G. Edmunds, Trans. Am. Inst. Mining Met. Engrs. 11, 245 (1934).
- [538] A. Burkhardt and W. Wolf, Metal Ind. (London) 57, 342 (1940).
- [539] C. H. M. Jenkins, J. Inst. Metals 36, 63 (1926).
- [540] C. T. Anderson, Conference on Metallurgical Research, p. 129 (Bureau of Mines, Metallurgical Division, Salt Lake City, Utah, 1940).
- [541] P. Goerens and R. Mailänder, Forschungsarb. Gebiete Ingenieurw. 295, 18 (1927).
- [542] J. R. Freeman, Jr., F. Sillers, Jr., and P. F. Brandt, BS Sci. Pap. 20, 661 (1925) S522.
- [543] A. Schulze, Physik. Z. 22, 403 (1921).
- [544] E. A. Anderson and J. H. Craig, Metals Handbook, p. 1757 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [545] H. E. Way, Phys. Rev. 50, 1181 (1936).
- [546] Metals Handbook, p. 78 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [547] L. Losana, Alluminio 8, 67 (1939).
- [548] C. B. Sawyer and B. Kjellgren, Metals & Alloys 11, 163 (1940).
- [549] J. B. Johnson, Metals & Alloys 9, 94 (1938).

- [550] C. H. M. Jenkins, *J. Inst. Metals* **45**, 307 (1931).
- [551] C. E. Swartz, *Metals Handbook*, p. 1332 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [552] P. Bastien, *Rev. mét.* **32**, 120 (1935).
- [553] L. Guillet, Jr., *Rev. mét.* **36**, 497 (1939).
- [554] B. S. Hopkins, *Chapters in the Chemistry of the Less Familiar Elements* (Stipes Publishing Co., Champaign, Ill., 1938-39).
- [555] *Physical Constants of Pure Metals* (National Physical Laboratory, Teddington, England, Miscellaneous Publications, 1936).
- [556] W. R. Barclay, *J. Soc. Chem. Ind.* **41**, Review 5, 167R (1922).
- [557] W. A. Wissler, *Metal Progress* **36**, 131 (1939).
- [558] E. Einecke, *Z. anorg. Chem.* **238**, 113 (1938).
- [559] J. McKeown and O. F. Hudson, *J. Inst. Metals* **60**, 109 (1937).
- [560] R. L. Coleman, *BS J. Research* **1**, 867 (1928) RP32.
- [561] W. Spraragen and G. E. Claussen, *Welding J.* **20**, 121-S (1941).
- [562] R. H. Lauderdale, R. L. Dowell, and K. Casselman, *Metals & Alloys* **10**, 24 (1939).
- [563] L. Sterner-Rainer, *Z. Metallkunde* **18**, 143 (1926).
- [564] E. M. Wise, *Trans. Am. Inst. Mining Met. Engrs.* **83**, 384 (1929).
- [565] T. C. Jarrett, *Trans. Am. Inst. Mining Met. Engrs.* **143**, 209 (1941).
- [566] T. C. Jarrett, *Trans. Am. Inst. Mining Met. Engrs.* **137**, 447 (1940).
- [567] W. Souder and G. C. Paffenbarger, *NBS Cir.* **C433** (1942).
- [568] E. M. Wise, W. S. Crowell, and J. T. Eash, *Trans. Am. Inst. Mining Met. Engrs.* **99**, 363 (1932).
- [569] M. T. Ludwick, *Metal Finishing* **40**, 13 (1942).
- [570] F. E. Carter and H. E. Stauss, *Metals Handbook*, p. 1686 and 1691 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [571] R. S. Dean, C. T. Anderson, and E. V. Potter, *Conference on Metallurgical Research*, p. 38 (Bureau of Mines, Metallurgical Division, Salt Lake City, Utah, (1940).
- [572] A. H. Hesse and E. T. Myskowski, *Trans. Am. Inst. Mining Met. Engrs.* **147**, 243 (1942).
- [573] R. S. Dean, *U. S. Patent No. 2,230,236* (Feb. 4, 1941).
- [574] F. T. Sisco, *Mining and Met.* **23**, 34 (1942).
- [575] A. King, *Rev. Sci. Instr.* **11**, 114 (1940).
- [576] R. H. Atkinson and A. R. Raper, *J. Inst. Metals* **59**, 179 (1936).
- [577] E. M. Wise and J. T. Eash, *Trans. Am. Inst. Mining Met. Engrs.* **117**, 313 (1935).
- [578] Y. Yamamoto, *Japan Nickel Rev.* **4**, 29 (1936).
- [579] B. A. Rogers, I. C. Schoonover, and L. Jordan, *NBS Cir.* **C412** (1936).
- [580] L. Jordan, L. H. Grenell, and H. K. Herschman, *Tech. Pap. BS* **21**, 459 (1927) T348.
- [581] A. E. Richards, *Metal Ind. (London)* **59**, 340 (1941).
- [582] R. W. Dayton, *Metals & Alloys* **10**, 306 (1939).
- [583] A. Mackenzie, *Metals Handbook*, p. 909 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [584] J. G. Thompson, *Metals & Alloys* **4**, 114 (1933).
- [585] H. W. Gillett, *Foot-Prints* **13**, No. 1, p. 1 (1940).
- [586] W. Kroll, *Trans. Electrochem. Soc.* **78**, 35 (1940).
- [587] C. J. Smithells, *Tungsten* (Chapman & Hall, Ltd., publishers, London, England, 1927 and D. Van Nostrand Co., Inc. New York, N. Y.).
- [588] Private Communication from L. Robbin, P. R. Mallory & Co.
- [589] G. H. S. Price, C. J. Smithells, and S. V. Williams, *J. Inst. Metals* **62**, 239 (1938).
- [590] J. D. Fast, *Foot-Prints* **13**, No. 1, 22 (1940).
- [591] K. R. Van Horn, *Metals Handbook*, p. 1328 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [592] *Metals Handbook*, p. 1210 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [593] C. R. Austin, *Trans. Am. Soc. Metals* **24**, 451 (1936).
- [594] C. H. Lander and J. V. Howard, *Proc. Roy. Soc. (London)* [A] **156**, 411 (1936).
- [595] P. Hidnert, *J. Research NBS* **14**, 523 (1935) RP784.
- [596] A. Schulze, *Z. tech. Physik* **8**, 365 (1927).
- [597] P. Hidnert and H. S. Krider, *BS J. Research* **11**, 279 (1933) RP 590.
- [598] *Tables Annuelles de Constantes et Données Numérique* **6**, part 1 (Gauthier-Villars, publishers, Paris, France, 1927, and McGraw-Hill Book Co., Inc., New York, N. Y.).
- [599] P. Hidnert, *J. Research NBS* **26**, 81 (1941) RP1361.
- [600] L. W. Schad and P. Hidnert, *BS Sci. Pap.* **15**, 31 (1919) S 332.
- [601] G. F. Taylor, *Phys. Rev.* **26**, 841 (1925).
- [602] W. Klemm, *Z. anorg. Chem.* **198**, 178 (1931).
- [603] H. D. Erfling, *Ann. Physik* **429**, 162 (1940).
- [604] H. Osborg, *Trans. Electrochem. Soc.* **66**, 91 (1934).
- [605] J. Disch, *Z. Physik* **5**, 173 (1921).
- [606] Sample of indium supplied by the Indium Corporation of Am., tested by A. H. Stang and B. L. Wilson, *National Bureau of Standards* (Feb. 1943).
- [607] *Contributions to the Metallurgy of Steel—No. 5* (Am. Iron Steel Inst., New York, N. Y. 1942).
- [608] F. C. Nix and D. MacNair, *Phys. Rev.* **61**, 74 (1942).
- [609] P. Hidnert, *J. Research NBS* **30**, 101 (1943) RP1520.
- [610] H. Ebert, *Physik Z.* **39**, 6 (1938).
- [611] S. Siegel and S. L. Quimby, *Phys. Rev.* **54**, 76 (1938).
- [612] P. Hidnert, *BS J. Research* **2**, 887 (1929) RP62.
- [613] P. Hidnert and W. T. Sweeney, *BS Sci. Pap.* **20**, 483 (1925) S515.
- [614] P. Hidnert, *J. Research NBS* **18**, 47 (1937) RP960.
- [615] W. G. John and E. J. Evans, *Phil. Mag.* [7] **22**, 417 (1936).

- [616] E. J. Lewis, Phys. Rev. **34**, 1575 (1929).
- [617] S. Gabe and E. J. Evans, Phil. Mag. [7] **19**, 773 (1935).
- [618] C. L. Mantell and C. Hardy, Metals Handbook, p. 1334 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [619] J. L. Thomas, J. Research NBS **14**, 589 (1935) RP789.
- [620] J. G. G. Conybeare, Proc. Phys. Soc. (London) **49**, 29 (Jan. 1937).
- [621] R. S. Dean and C. T. Anderson, Trans. Am. Soc. Metals **29**, 899 (1941).
- [622] R. H. Osborn, J. Optical Soc. Am. **31**, 428 (1941).
- [623] J. W. Donaldson, Metallurgia **13**, 159 (1936).
- [624] J. S. Acken, BS J. Research **12**, 249 (1934) RP650.
- [625] B. Brenner, U. S. Patent No. 2,080,110 (May 11, 1937).
- [626] L. Malter and D. V. Langmuir, Phys. Rev. **55**, 743 (1939).
- [627] P. Clausinz and G. Moubis, Physica **7**, 245 (1927).
- [628] H. Wolf and H. Tuxhorn, Aluminium **22**, 14 (1940).
- [629] L. Weiss, Z. Metallkunde **28**, 240 (1936).
- [630] C. E. Pearson, Metal Ind. (London) **54**, 295 (1939).
- [631] E. H. Dix, Jr. and J. J. Bowman, Metals Handbook, p. 1248 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [632] M. Hansen and K. L. Dryer, Z. Metallkunde **31**, 204 (1939).
- [633] L. W. Kempf and F. Keller, Metals Handbook, p. 1254 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [634] M. Bosshard, Aluminium **1**, 361 (1932).
- [635] L. W. Kempf, Metals Handbook, p. 1286 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [636] F. M. Howell and D. A. Paul, Metals & Alloys **5**, 176 (1934).
- [637] R. Irmann, Aluminium **23**, 36 (1941).
- [638] F. M. Howell and D. A. Paul, Metals & Alloys **6**, 284 (1935).
- [639] G. G. Gauthier, J. Inst. Metals **59**, 129 (1936).
- [640] S. Rolle and H. M. Schleicher, Metals & Alloys **11**, 82 (1940).
- [641] A. Krupkowski and M. Balicki, Ann. acad. sci. tech. Varsovie **3**, 90 (1936).
- [642] "Reprinted by permission from 'Plastic Working of Metals and Power Press Operations' by E. V. Crane, published by John Wiley & Sons, Inc., New York, N. Y., 1939."
- [643] D. Hanson, C. Marryat, and G. W. Ford, J. Inst. Metals **30**, 197 (1923).
- [644] D. Hanson, S. L. Archbutt, and G. W. Ford, J. Inst. Metals **43**, 41 (1930).
- [645] W. Broniewski, Rev. mét. **35**, 385 (1938).
- [646] E. Lay, Z. Metallkunde **28**, 64 (1936).
- [647] W. Broniewski and S. Jaslan, Ann. acad. sci. tech. Varsovie **3**, 141 (1936).
- [648] W. Broniewski and S. Kulesza, Métaux et corrosion **12**, 67 (1937).
- [649] E. M. Wise, Metals Handbook, p. 1413 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [650] H. C. Jennison and W. S. Girvin, Metals Handbook, p. 1457 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [651] W. Broniewski, Rev. mét. **35**, 333 (1938).
- [652] W. Broniewski and Z. Wawzynkiewicz, Rev. fonderie moderne **30**, 147 (1936).
- [653] M. Cook and W. G. Tallis, J. Inst. Metals **67**, 49 (1941).
- [654] W. Broniewski and S. Trzebski, Rev. fonderie moderne, **28**, 173 (1934).
- [655] R. S. Pratt, Metals Handbook, p. 1399 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [656] C. H. Lorig, F. B. Dahle, and D. A. Roberts, Metals & Alloys **9**, 63 (1938).
- [657] W. Schwinning and E. Strobels, Z. Metallkunde **26**, 1 (1934).
- [658] W. Broniewski and J. Szreniawski, Rev. mét. **33**, 442 (1936).
- [659] L. L. Wyman, Gen. Elec. Rev. **37**, 120 (1934); private communication from S. Skowronski, Raritan Copper Works (1942).
- [660] W. Broniewski and W. Robowski, Ann. acad. sci. tech. Varsovie **4**, 255 (1937).
- [661] E. C. Bain, Functions of the Alloying Elements in Steel (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [662] H. C. Cross and E. E. Hill, BS Sci. Pap. **22**, 451 (1927) S562.
- [663] E. E. McGinley and L. D. Woodworth, Trans. Am. Inst. Mining Met. Engrs. **145**, 151 (1941).
- [664] H. J. Godfrey, Trans. Am. Soc. Metals **29**, 133 (1941).
- [665] C. T. Eakin, Iron Age **134**, 16 (Aug. 16, 1934).
- [666] G. S. von Heydekampf, Proc. Am. Soc. Testing Materials **31**, part 2, 157 (1931).
- [667] S. P. Watkins, Wire and Wire Products **14**, 527 (1939).
- [668] J. H. Jones, Metal Progress **41**, 793 (1942).
- [669] C. S. Aitchison, W. Ramberg, L. B. Tuckerman, and H. L. Whittemore, J. Research NBS **28**, 499 (1942) RP1467.
- [670] C. H. Lorig, Metals Handbook, p. 554 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [671] C. T. Greenidge and C. H. Lorig, Trans. Am. Foundrymen's Assn. **47**, 229 (1939).
- [672] H. L. Campbell, Proc. Am. Soc. Testing Materials **37**, part 2, 66 (1937).
- [673] H. T. Wensel, Misc. Pub. NBS **126** (1937).
- [674] A. W. F. Green, Metals Handbook, p. 457 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [675] R. G. Batson and H. J. Tapsell, Int. Assn. Testing Materials, Zurich Congress, p. 160 (1931).
- [676] M. Hempel and H. E. Tillmanns, Arch. Eisenhüttenw. **10**, 395 (1937).
- [677] J. S. Kinney, Proc. Am. Soc. Testing Materials **38**, part 2, 197 (1938).

- [678] Metals Handbook, p. 550 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [679] W. L. Collins and J. O. Smith, Proc. Am. Soc. Testing Materials **41**, 797 (1941).
- [680] J. Z. Briggs, Metals & Alloys **9**, 49 (1938).
- [681] W. R. D. Jones and L. Powell, J. Inst. Metals **66**, 331 (1940).
- [682] R. T. Wood, Metals Handbook, p. 1581 (Am. Soc. Metals, Cleveland, Ohio, 1939).
- [683] J. C. McDonald, Trans. Am. Inst. Mining Met. Engrs. **137**, 430 (1940).
- [684] J. C. McDonald, Trans. Am. Inst. Mining Met. Engrs. **143**, 179 (1941).
- [685] L. Aitchison, J. Roy. Aeron. Soc. **38**, 382 (1934).
- [686] H. Vosskübler, Metallwirtschaft **17**, 935 (1938).
- [687] Metal Progress **35**, 65 (1939).
- [688] C. E. Ransley and C. J. Smithells, J. Inst. Metals **49**, 287 (1932).
- [689] C. H. M. Jenkins, H. J. Tapsell, C. R. Austin, and W. P. Rees, J. Iron Steel Inst. **121**, 237 (1930).
- [690] Metal Progress **35**, 375 (1939).
- [691] W. A. Mudge, Proc. Am. Soc. Testing Materials **36**, part 2, 232 (1936).
- [692] K. E. Quier, Metals & Alloys **9**, 40 (1938).
- [693] N. B. Pilling and R. Worthington, Symposium on Effect of Temperature on the Properties of Metals, p. 495 (Am. Soc. Mech. Engrs. and Am. Soc. Testing Materials 1931).
- [694] G. F. Geiger, Symposium on High-Strength Constructional Metals, p. 95 (Am. Soc. Testing Materials, Philadelphia, Pa., 1936).
- [695] Metals & Alloys **6**, 101 (1935).
- [696] D. Hanson and W. T. Pell-Walpole, J. Inst. Metals, **63**, 87 (1938).
- [697] D. Hanson and E. J. Sandford, J. Inst. Metals **56**, 191 (1935).
- [698] D. Hanson and W. T. Pell-Walpole, J. Inst. Metals **56**, 165 (1935).
- [699] D. Hanson, E. J. Sandford, and H. Stevens, J. Inst. Metals **55**, 115 (1934).
- [700] D. J. McNaughtan, J. Inst. Metals **55**, 33 (1934).
- [701] R. Chadwick, J. Inst. Metals **51**, 93 (1933).
- [702] G. Rigg and G. M. Williams, Proc. Am. Soc. Testing Materials **13**, 669 (1913).
- [703] H. A. Anderson, Symposium on Effect of Temperature on the Properties of Metals, p. 271 (Am. Soc. Mech. Engrs. and Am. Soc. Testing Materials, 1931).
- [704] R. H. Leach and J. L. Christie, Mining and Met. **23**, 456 (1942).
- [705] E. M. Wise and J. T. Eash, Trans. Am. Inst. Mining Met. Engrs. **128**, 262 (1938).
- [706] R. H. Leach, Symposium on Effect of Temperature on the Properties of Metals, p. 627 (Am. Soc. Mech. Engrs. and Am. Soc. Testing Materials, 1931).
- [707] P. Hidnert, BS Sci Pap. **19**, 697 (1924) S497.
- [708] Determined by P. Hidnert and W. T. Sweeney of National Bureau of Standards.
- [709] Landolt-Börnstein, Physikalisch-Chemische Tabellen (Julius Springer, Berlin, Germany, 1927).
- [710] P. H. Brace, Metal Progress **41**, 354 (1942).
- [711] A. Schulze, Z. tech. Physik **9**, 338 (1928).
- [712] P. Hidnert and W. T. Sweeney, BS Sci. Pap. **22**, 639 (1927) S570.
- [713] P. Hidnert, BS J. Research **7**, 1031 (1931) RP388.
- [714] L. Baraduc-Muller, Rev. mét. **7**, 657 (1910).
- [715] P. Hidnert, BS Sci Pap. **17**, 91 (1922) S410.
- [716] P. Hidnert, J. Research NBS **30**, 75 (1943) RP1518.
- [717] P. R. Kosting, Rensselaer Polytech. Inst., Eng. Sci. Series **26**, part I, Troy, New York (1930).
- [718] P. Hidnert and W. T. Sweeney, Phys. Rev. **35**, 667 (1930).
- [719] P. Hidnert, Phys. Rev. **39**, 551 (1932).
- [720] E. Grüneisen, Ann. Physik **338**, 33 (1910).
- [721] H. D. Erfiling, Ann. Physik **426**, 136 (1939).
- [722] Z. Metallkunde **12**, 179 (1920).
- [723] Phys. Rev. **36**, 787 (1930).
- [724] A. Schulze, Z. tech. Physik **8**, 365 (1927).

Page

8

	Page
Bend number, definition.....	11
Beryllium.....	410, 450, 459
Beryllium alloys.....	410, 434
Beryllium bronze (see Copper alloys, nomenclature).	
Bismuth.....	410, 416, 450, 459
Bismuth alloys (see also Low-melting alloys and Soft solders).....	410, 450
Boron, physical properties.....	459
Brass (see Copper alloys, nomenclature).	
Brazing materials, melting ranges.....	433
Britannia metal.....	378
Bromine, physical properties.....	459
Bronze (see Copper alloys, nomenclature).	

[477]

	Page
Iron—Continued	
probable hardening effect of elements in pure.....	228
Iron, cast, alloy.....	221,263,281,284,292
effect of various elements on the mechanical properties....	219
high-temperature tensile strengths and endurance limits.....	270
Iron, cast, malleable.....	224,263,281,285,293
relation between hardness and tensile properties.....	249
tensile properties and hardness of copper.....	250
tensile properties of manganese.....	250
tensile properties of molybdenum.....	250
Iron, cast, plain.....	239,263,280,281,292
damping capacity.....	234
effect of section thickness on the compressive strength.....	247
effect of section thickness on the mechanical properties	
of a permanent mold.....	248
effect of section thickness on the tensile strength.....	247
high-temperature compressive strength.....	270
Iron, ingot.....	174,252,271,282,286
effect of annealing and cold-drawing on the mechanical	
properties.....	257
high-temperature endurance limits.....	266
high-temperature mechanical properties.....	265
Iron, wrought.....	175,252,271,282,287
high-temperature tensile properties.....	265

J

Jominy end quench test, definition.....	173
---	-----

K

Krypton, physical properties.....	459
-----------------------------------	-----

L

Lanthanum, physical properties.....	459
Latent heat of fusion (see elements).	
Lead.....	298,308,310,312,313,314,459
Lead alloys (see also Low-melting alloys and Soft solders):	
classification.....	297
electrical properties.....	314
mechanical properties—	
high temperature.....	310
low temperature.....	312
normal temperature.....	298
thermal conductivity.....	314
thermal expansion.....	313
Lead-antimony alloys (see also Babbitts).....	298,307,308,310,313,314
high-temperature tensile properties of a 15% antimony-5%	
tin alloy.....	311
tensile strength and hardness.....	305
Lead-barium alloys.....	300
Lead-bismuth alloys.....	301,309,314
tensile properties and hardness.....	305
Lead-cadmium alloys.....	301,308
Lead-calcium alloys.....	301,310,313
high-temperature compressive strength of a 2% calcium	
alloy.....	311
tensile strength.....	306
Lead-copper alloys.....	302,310
Lead-indium alloys.....	314
Lead-silver alloys.....	302,308,314
Lead-tellurium alloys.....	302
Lead-thallium alloys.....	303,308,314
Lead-tin alloys.....	303,308,310,312,313,314
high-temperature tensile properties of a 40% tin-10%	
antimony-1% copper alloy.....	311
tensile properties and hardness.....	306
Lanthanum metal.....	299
Lipowitz's alloy.....	432
Lithium.....	447,459
Lithium-calcium deoxidized copper.....	75
Low brass (see Copper alloys, nomenclature).	
Low-melting alloys (see also Soft solders).....	432
Lutecium, physical properties.....	459

M

Magnesium.....	320,340,343,344,459
effect of annealing on the tensile properties and hardness..	326
effect of cold-rolling on the tensile properties and	
hardness.....	327
effect of temperature on the tensile properties of	
extruded.....	336
Magnesium alloys:	
classification.....	319
electrical properties.....	344
mechanical properties—	
high temperature.....	335
low temperature.....	340
normal temperature.....	320
thermal conductivity.....	344
thermal expansion.....	343
Magnesium-aluminum alloys.....	320,340,343,344
high-temperature tensile properties of a 4% aluminum-0.3%	
manganese alloy.....	336
tensile properties of rolled.....	329
tensile properties of cast, containing small amounts of	
manganese.....	328

Magnesium-aluminum alloys—Continued	
tensile properties of extruded, containing small amounts	
of manganese.....	329
Magnesium-aluminum-cadmium alloys.....	321,313
Magnesium-aluminum-silicon alloys.....	322
Magnesium-aluminum-silver alloys.....	322
Magnesium-aluminum-zinc alloys.....	322,335,340,343,344
high temperature tensile properties of a 6% aluminum-1%	
zinc alloy.....	337
high temperature tensile properties of a 6% aluminum-3%	
zinc alloy.....	337
high temperature tensile properties of a 8% aluminum-0.5%	
zinc alloy.....	336
low temperature tensile properties of a 6% aluminum-1%	
zinc alloy.....	342
Magnesium-cadmium alloys.....	323,343
tensile properties of rolled.....	330
Magnesium-calcium alloys.....	344
tensile properties of rolled.....	350
Magnesium-cerium alloys.....	323,341
Magnesium-copper alloys.....	323,343,341
tensile properties of rolled.....	331
Magnesium-lead alloys.....	345
Magnesium-manganese alloys.....	324,335,341,343,345
high temperature tensile properties of a 2% manganese	
alloy.....	359
high-temperature tensile properties of a 2% manganese-0.5%	
cerium alloy.....	339
Magnesium-nickel alloys.....	324,343,345
tensile properties of rolled.....	331
Magnesium-silicon alloys.....	321,335,343,345
tensile properties of extruded.....	332
Magnesium-silver alloys.....	325,343,345
tensile properties of rolled.....	332
Magnesium-thallium alloys:	
tensile properties of rolled.....	333
Magnesium-tin alloys.....	325,343,345
tensile properties of rolled.....	333
Magnesium-zinc alloys.....	325,341,343,345
tensile properties of rolled.....	334
Magnesium-zirconium alloys.....	325
Magnetic properties (see Permanent magnet alloys).	
Manganese.....	416,417,459
Manganese alloys.....	416,417,432
Manganese bronze (see Copper alloys, nomenclature).	
Manganin.....	55,149
Masurium, physical properties.....	459
Matrix alloy.....	432
Melting points (see elements).	
Mercury.....	445,459
Misch metal.....	411
Modulus of elasticity, definitions:	
compression.....	7
shear.....	7
tension.....	7
Modulus of rigidity (see Modulus of elasticity, shear).	
Modulus of rupture, definition.....	6
Molybdenum.....	117,445,447,453,459
high-temperature tensile properties of wire.....	437
Monel (see Nickel alloys, classification).	
Mono-type metal.....	300
Muntz metal.....	100
Music wire:	
relationship between tensile strength and diameter.....	233

N

National Emergency steels (see Steels, various).	
Naval brass.....	105,137,146
Neodymium, physical properties.....	459
Neon, physical properties.....	459
Newton's alloy.....	432
Nickel.....	350,363,368,370,372,459
effect of annealing on the tensile properties of cold-	
drawn.....	357
effect of annealing on the tensile properties of hard-	
drawn wire.....	359
effect of cold-drawing on the tensile properties.....	358
high-temperature tensile properties.....	364
relationship between hardness and tensile properties.....	356
Nickel alloys:	
classification.....	349
electrical properties.....	372
mechanical properties—	
high temperature.....	363
low temperature.....	368
normal temperature.....	350
thermal conductivity.....	372
thermal expansion.....	370
Nickel-aluminum alloys.....	351,372
Nickel-beryllium alloys.....	351,370,372
Nickel-chromium alloys.....	351,363,368,370,372
high-temperature mechanical properties of a 19% chromium	
alloy.....	365
high-temperature tensile properties of a 20% chromium-1%	
silicon alloy.....	364
tensile properties of rolled.....	360
Nickel-cobalt alloys.....	352,363,370,373

	Page
Nickel-copper alloys.....	352,363,369,370,373
effect of annealing on the tensile properties of a 30% copper alloy.....	362
high-temperature tensile properties of a 30% copper alloy...	365
high-temperature tensile properties of a 30% copper-2.75% aluminum alloy.....	366
mechanical properties of.....	361
tensile properties and endurance limits of annealed.....	362
Nickel-iron alloys.....	354,369,371,373
high temperature design strength for a 25% iron-15% chromium alloy.....	270
high-temperature tensile properties of a 21% iron-16% chromium alloy.....	367
Nickel-manganese alloys.....	354,371,373
effect of cold-drawing on the tensile properties of a 4.6% manganese alloy.....	358
effect of cold-drawing on the tensile properties of a 15% manganese alloy.....	358
Nickel-molybdenum alloys.....	355,371
high-temperature tensile properties of a 20% molybdenum-20% iron alloy.....	367
high-temperature tensile properties of a 30% molybdenum-5% iron alloy.....	367
Nickel-rhodium alloys.....	355
Nickel-silicon alloys.....	355,373
Nickel-silver (see Copper alloys, nomenclature).	
Nickel-tantalum alloys.....	355
Nickel-zirconium alloys.....	355
Nitrided steels (see Steels, various).	
Nitrogen, physical properties.....	459
O	
Osmium.....	417,453,459
Oxygen, physical properties.....	459
Oxygen-free copper.....	73,151
P	
Palladium.....	417,447,453,459
effect of annealing on the tensile properties of hard-drawn.....	423
high-temperature tensile properties.....	438
Palladium alloys.....	417,453
high-temperature tensile properties of a 4% ruthenium-1% rhodium alloy.....	438
tensile properties and hardness of silver.....	423
Ferritic malleable cast iron (see Iron, cast, malleable).	
Permanent magnet alloys, magnetic properties.....	294
Physical properties (see elements).	
Phosphor bronze (see Copper alloys, nomenclature).	
Phosphorus, physical properties.....	460
Phosphorus-deoxidized copper.....	75,133,143,151
Platinum.....	418,435,448,454,460
high-temperature tensile properties of wire.....	439
Platinum alloys.....	418,448,454
high-temperature tensile properties of a 5% iridium alloy...	439
high-temperature tensile properties of a 5% nickel alloy...	439
high-temperature tensile properties of a 20% palladium-5% rhodium alloy.....	440
high-temperature tensile properties of a 10% rhodium alloy...	440
tensile properties of gold.....	424
tensile strength and hardness of iridium.....	425
tensile strength and hardness of palladium.....	425
tensile strength and hardness of rhodium.....	426
tensile strength and hardness of tungsten.....	426
Poisson's ratio, definition.....	7
Polonium, physical properties.....	460
Potassium, physical properties.....	460
Powder metallurgy, definitions.....	15
Powdered metal compacts:	
aluminum-magnesium.....	31
aluminum-zinc.....	37
copper.....	74,111
copper-tin.....	94,95,96,125,126,127
copper-zinc.....	98,100,102,130
iron.....	175,226
iron-chromium-nickel.....	193
iron-molybdenum-copper.....	206
nickel-molybdenum-iron.....	355
tungsten-copper.....	419
tungsten-nickel-copper.....	422
Praseodymium, physical properties.....	460
Processed cast iron (see Iron, cast).	
"Proportional limit," definition.....	6
Protoactinium, physical properties.....	460
R	
Radium, physical properties.....	460
Radon, physical properties.....	460
Red brass (see Copper alloys, nomenclature).	
Reduction of area, definition.....	7
References, list.....	465
Rhenium, physical properties.....	460
Rhodium.....	419,448,455,460
Rhodium alloys.....	455
Rich low brass (see Copper alloys, nomenclature).	
Rose's alloy.....	432

	Page
Rubidium, physical properties.....	460
Ruthenium.....	419,460
S	
Samarium, physical properties.....	460
Scandium, physical properties.....	460
Selenium.....	448,460
Shear strength, definition.....	6
Signal bronze.....	93
Silicon, physical properties.....	460
Silver.....	419,435,448,455,460
effect of cold-rolling on the tensile strength and hardness.....	427
high-temperature tensile properties.....	441
Silver alloys (see also Hard solders).....	420,433,448,455
classification.....	409
effect of cold-rolling on the tensile strength and hardness of copper.....	427
high-temperature tensile properties of sterling silver and coin silver.....	441
mechanical properties of annealed copper.....	428
mechanical properties of manganese.....	429
mechanical properties of silicon.....	430
Society of Automotive Engineers, classification of constructional steels.....	163
Society of Automotive Engineers, summary charts.....	169
Sodium.....	448,460
Solders:	
hard, melting ranges.....	433
soft.....	377
Specific heat (see elements).	
Steels (see also Steels, various and Permanent magnet alloys):	
combined standard steel lists of the American Iron and Steel Institute and Society of Automotive Engineers.....	163
electrical properties.....	286
freezing point calculation.....	251
hardness conversion table.....	168
hardness-tensile strength relationship.....	168
Jominy end quench test, definition.....	173
maximum hardness obtainable in quenched carbon and alloy...	172
mechanical properties—	
high temperature.....	252
low temperature.....	271
normal temperature.....	174
substitutes for constructional.....	167
summary charts—	
relationship between hardness and tensile strength.....	169
relationship between tensile strength and reduction of area.....	171
relationship between tensile strength and yield point...	170
thermal conductivity.....	286
thermal expansion.....	282
Steels, various:	
aluminum.....	180,273,282
aluminum-chromium.....	180,254
carbon.....	175,252,271,282,287
comparison of Bessemer and open-hearth steels of similar carbon content.....	230
comparison of Bessemer and open-hearth steels of equivalent tensile strength.....	231
compression of cast.....	232
compressive strength of a 0.15%.....	229
damping capacity.....	234
density of hot-rolled and annealed.....	228
effect of cold-rolling on the tensile properties of a 0.45%.....	232
high-temperature endurance limits.....	266
high-temperature tensile properties and endurance limits of a 0.58%.....	266
mechanical properties of hot-worked.....	230
relationship between tensile strength and diameter of wire.....	233
tensile properties of annealed cast.....	232
tensile properties and endurance limits of cold-drawn wire.....	233
chromium.....	181,254,273,282,287,294
effect of cold-drawing on the tensile properties of 12% chromium wire.....	235
effect of tempering on the tensile properties of 12% chromium wire.....	235
high-temperature endurance limits of 12% chromium.....	267
tensile properties of normalized.....	235
chromium-aluminum.....	185,274,283,288
chromium-cobalt.....	187,288
chromium-columbium.....	187,256
chromium-copper.....	187,274
chromium-manganese.....	189
chromium-molybdenum.....	190,254,273
chromium-nickel.....	192,257,274,283,288
damping capacity.....	234
design strength.....	268
effect of cold-drawing on the tensile properties and hardness of an 18% chromium-8% nickel wire.....	240
effect of cold-rolling on the tensile and compressive properties of an 18% chromium-7% nickel sheet.....	239
effect of titanium on the mechanical properties of a 22% chromium-12% nickel.....	240

	Page		Page
Steels, various—Continued		Tin alloys—Continued	
chromium-nickel—continued		thermal conductivity.....	389
high-temperature tensile properties and endurance limits		thermal expansion.....	387
of a 15% chromium-13% nickel-2% tungsten.....	268	Tin-antimony alloys.....	307,309,374,385,386,388
high-temperature tensile properties of a 19% chromium-7% nickel-4% tungsten.....	269	effect of antimony on the properties of white bearing metal.....	384
relationship between tensile strength and diameter of an 18% chromium-8% nickel wire.....	233	high-temperature compressive strength and hardness of an 8% antimony-4% copper alloy.....	311
chromium-nitrogen.....	193,282	tensile properties and hardness.....	382
chromium-silicon.....	196,274	Tin-arsenic alloys.....	379
chromium-titanium.....	197	Tin-beryllium alloys.....	379
chromium-tungsten.....	197,255,256	Tin-bismuth alloys.....	309,379
chromium-vanadium.....	198,273,282	tensile properties.....	382
chromium-zirconium.....	200	Tin-cadmium alloys.....	309,385
cobalt.....	200,276,283,290,294	tensile strength and hardness.....	383
copper.....	201,258,276,283	Tin-copper alloys.....	379,388
mechanical properties of quenched and tempered cast.....	243	effect of antimony on the mechanical properties of a 3.5% copper alloy.....	384
tensile properties and hardness of normalized cast.....	242	tensile properties.....	383
tensile properties of normalized 1% and 2% copper.....	241	Tin-germanium alloys.....	380
tensile properties of quenched and tempered 1% and 2% copper.....	241	Tin-indium alloys.....	388
flame-hardened.....	178,182,191,208,210,215	Tin-iron alloys:	
graphitic.....	219	tensile properties.....	383
manganese.....	203,259,276,283,290	Tin-lead alloys.....	309,312,390,386,387,388
tensile properties of normalized.....	244	Tin-magnesium alloys.....	387
molybdenum.....	205,259,277,283,290,294	Tin-nickel alloys.....	380,385
high-temperature tensile properties of a 0.5%.....	269	tensile properties.....	383
tensile properties of quenched and tempered.....	244	Tin-silver alloys.....	309,380,385,388
National Emergency (see also Steels, Combined standard steel lists and Substitutes for constructional).		Tin-zinc alloys.....	309,381
mechanical properties of NE 8630.....	236	Titanium.....	422,449,456,460
mechanical properties of NE 8739.....	236	Torsional strength, definition.....	8
mechanical properties of NE 8749.....	238	Tough-pitch copper (see Electrolytic tough-pitch copper).	
mechanical properties of NE 8949.....	237	Tungsten.....	422,435,445,449,456,460
nickel.....	207,260,277,283,291	high-temperature tensile properties of wire.....	442
high-temperature endurance limits.....	267	high-temperature tensile properties of wire containing thorium.....	442,443
tensile properties of annealed and hot-rolled.....	246	Tungsten alloys.....	422,449
tensile properties of normalized.....	245	Tungsten carbide (cemented).....	422,449
nickel-beryllium.....	309	effect of cobalt on the mechanical properties.....	431
nickel-chromium.....	209,261,278,283,291	hardness of commercial at elevated temperatures.....	444
damping capacity.....	234		
design strength.....	270	U	
high-temperature tensile properties and endurance limits of a 20% nickel-8% chromium.....	270	Uranium.....	422,460
nickel-chromium-aluminum.....	211	V	
nickel-chromium-molybdenum.....	212,260,277	Vanadium, physical properties.....	460
high-temperature tensile properties and endurance limits of a 2% nickel-0.9% chromium-0.4% molybdenum.....	267	W	
nickel-chromium-silicon.....	213,262,283	Wood's alloy.....	432
nickel-chromium-titanium.....	213	X	
nickel-chromium-tungsten.....	211,261,278	Xenon, physical properties.....	460
nickel-chromium-vanadium.....	214,283	Y	
nickel-copper.....	214	Yellow brass (see Copper alloys, nomenclature).	
nickel-manganese.....	215,279	Yield point, definition.....	4
nickel-molybdenum.....	215,261,278,283	Yield strength, definition.....	5
nickel-silicon.....	216	Young's modulus (see Modulus of elasticity in tension).	
nickel-vanadium.....	216	Ytterbium, physical properties.....	460
nitrided.....	181,186,211	Yttrium, physical properties.....	460
silicon.....	216,262,290,284,291	Z	
titanium.....	218	Zinc.....	393,402,404,405,406,460
tungsten.....	218,262,280,284,292,294	dynamic ductility, definition.....	392
vanadium.....	219	compressive strength of cast.....	399
Stereotype metal.....	300	effect of cold-rolling on the tensile properties of electrolytic.....	399
Strain, definition.....	4	high-temperature tensile properties of rolled.....	403
Straits tin.....	378	temper, definition.....	392
Stress, definition.....	4	Zinc alloys (see also Brazing materials and Soft solders):	
Stress-strain diagram, definition.....	4	classification.....	391
Strontium, physical properties.....	460	creep properties.....	402
Sulfur, physical properties.....	460	electrical properties.....	406
Swedish iron.....	174,175	mechanical properties—	
		low temperature.....	404
T		normal temperature.....	393,402
Tantalum.....	421,448,455,460	thermal conductivity.....	406
Tantalum alloys.....	421,448	thermal expansion.....	405
Tellurium.....	421,460	Zinc-aluminum alloys.....	394,404,405,406
Temper (zinc), definition.....	392	effect of temperature on the impact values of die-cast.....	403
Temper designation (see Aluminum alloys and Copper alloys).		effect of temperature on the tensile properties of a 4% aluminum-3% copper-0.1% magnesium alloy.....	403
Temperature coefficient of electrical resistivity, definition.....	12	tensile properties.....	399
Temperature coefficient of thermal conductivity, definition.....	12	Zinc-cadmium alloys.....	309,396,406
Temperature conversion ($^{\circ}\text{C} \leftrightarrow ^{\circ}\text{F}$).....	463	Zinc-copper alloys.....	397,402,406,433
Tensile strength, definition.....	6	effect of cold-rolling on the mechanical properties of a 1% copper-0.1% magnesium alloy.....	400
Terbium, physical properties.....	460	tensile properties.....	400
Thallium.....	455,460	Zinc-gold alloys.....	406
Thermal conductivity, definition.....	12	Zinc-lead alloys.....	404,406
Thermal expansion, definition.....	11	Zinc-magnesium alloys.....	405
Thorium.....	421,460	Zinc-manganese alloys.....	398
Thulium, physical properties.....	460	Zinc-silver alloys.....	406
Tin.....	378,385,387,388,460	tensile properties and hardness.....	401
effect of various elements on the tensile strength.....	383	Zinc-tin alloys.....	398
Tin alloys (see also Babbitts and Soft solders):		Zirconium.....	422,449,456,460
classification.....	377		
electrical properties.....	388		
mechanical properties—			
high temperature.....	386		
normal temperature.....	378,385		

