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MECHANICAL PROPERTIES OF METALS AND ALLOYS

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

NATIONAL BUREAU OF STANDARDS • Lyman J. Briggs, Director

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MECHANICAL PROPERTIES OF METALS AND ALLOYS

by

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

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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.*

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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

[1]Figures 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].

[2] Not 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 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.

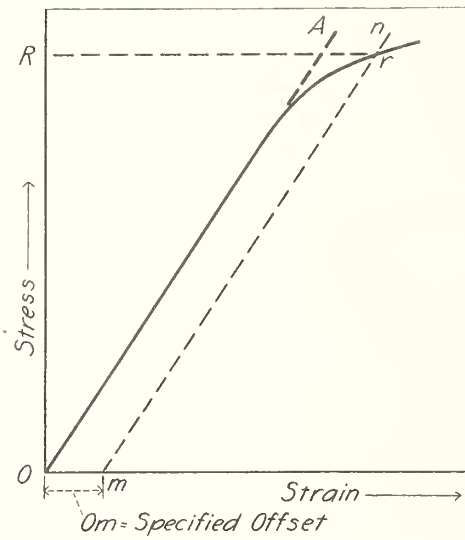


Figure 1.—*Stress-strain diagram.*

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

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

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 tandard round tensile specimen used in the United States has a diameter of 0.500 ± .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.

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

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: (10^8) 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:

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

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,

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

for values of R_E 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

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

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 nonmetallic 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

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 spec	ASTM alloy	SAE	Alcoa	Cu	Si	Mn	Mg	Other	
						WROUGHT ALLOYS—BAR, ROD, WIRE, AND SHAPES						
QQ-A-411	Federal	46A3	...	...	25	2S	...	...	...	...	Al 99 (minimum)	10 to 13, inclusive; 285, 411; figures 4, 18, 19.
QQ-A-356	...do	46A6	...	...	29	3S	...	...	1.2	...	...	179 to 185, inclusive; figure 26.
...	...	...	...	...	...	11S	5.5	...	...	...	Pb 0.5, Bi 0.5	39, 40.
QQ-A-351	Federal	46A4	B89-41T	...	26	17S	4.0	...	0.5	0.5	...	58 to 61, inclusive; 70, 74, 277, 292, 295; figures 8, 9, 21, 22.
...	25526[b]	43R5	...	...	...	A17S	2.5	...	...	.3	...	54.
QQ-A-354	Federal	46A9	...	...	24	24S	4.5	...	.6	1.5	...	75, 76, 80, 81; figure 21.
...	...	46A9	...	...	201	52S	...	...	...	2.5	Cr 0.25	149, 150, 151.
QQ-A-331	Federal	46A10	...	...	...	53S	...	0.7	...	1.3	Cr 0.25	134 to 138, inclusive; figure 25.
						WROUGHT ALLOYS—SHEET AND PLATE						
QQ-A-561	57-151-1	47A2	B25-41T	...	25	2S	...	...	...	...	Al 99 (minimum)	4 to 9, inclusive; 14, 329; figure 3.
QQ-A-359	Federal	47A4	{B79-41T, B126-40T}	...	29	3S	...	...	1.2	...	...	178, 319, 320, 367.
QQ-A-353	...do	47A3	B78-41T	...	26	17S	4.0	...	0.5	0.5	...	63. 64, 65, 287, 288, 290, 291.
QQ-A-355	...do	47A10	...	...	24	24S	4.5	...	.6	1.5	...	82, 83, 85, 86, 302, 303.
QQ-A-318	...do	47A11	B109-41T	...	201	52S	...	...	...	2.5	Cr 0.25	147, 311, 312.
QQ-A-334	...do	47A12	...	...	...	53S	...	0.7	...	1.3	Cr 0.25	Properties similar to 53S above.
...	11326[b]	...	...	...	...	61S	0.25	.6	...	1.0	Cr 0.25	131, 132, 133.
						FORGING ALLOYS						
QQ-A-367	Federal	46A7	...	...	...	14S	4.4	0.8	0.8	0.4	...	78, 79; figure 23.
QQ-A-367	...do	46A7	...	...	26	17S	4.0	...	.5	.5	...	62, 73.
QQ-A-367	...do	46A7	...	...	...	18S	4.0	...	...	.5	Ni 2.0	98, 276.
QQ-A-367	...do	46A7	...	...	27	25S	4.5	.8	.8	...	...	90, 92, 305, 423, 424.
QQ-A-367	...do	46A7	...	...	...	32S	0.9	12.5	...	1.0	Ni 0.9	244, 282, 477, 478.
QQ-A-367	...do	46A7	...	...	280	A51S	...	1.0	...	0.6	Cr 0.25	237, 453, 454.
...	...	...	...	...	...	70S	1.0	...	.7	.4	Zn 10.0	266.
						SAND-CASTING ALLOYS						
QQ-A-601	AN-QQ-A-405	AN-QQ-A-405	B26-41T	JJ	35	43	...	5.0	...	...	...	203, 378, 457, 458.
...	...	...	...	...	...	45	...	10.0	...	...	...	206, 383, 475.
...	...	...	B26-41T	K	37	47	...	12.5	...	...	...	208, 209, 387, 479.
...	...	...	...	...	...	108	4.0	3.0	...	...	...	108, 109, 110, 345, 418, 419.
...	...	...	...	...	33	112	7.0	...	...	...	Zn 1.7, Fe 1.2	128, 431 to 434, inclusive.
QQ-A-601	Federal	M212	B26-41T	F	34	122	10.0	...	...	0.2	Fe 1.2	46, 47, 48, 279.
QQ-A-601	AN-QQ-A-379	AN-QQ-A-379	B26-41T	H	39	142	4.0	...	...	1.5	Ni 2.0	99, 100, 101, 106, 274, 296, 344.
QQ-A-601	AN-QQ-A-390	AN-QQ-A-390	B26-41T	G	38	195	4.5	...	...	...	...	24 to 30, inclusive; 304, 415, 416.
...	...	...	B26-41T	CC	36	212	8.0	1.2	...	...	Fe 1.0	120, 121, 122.
QQ-A-601	AN-QQ-A-402	AN-QQ-A-402	B26-41T	I	320	214	...	...	...	3.8	...	154, 448.
...	AN-QQ-A-392	AN-QQ-A-392	...	...	324	220	...	...	...	10.0	...	171, 176, 318, 450, 451.
...	...	...	...	...	...	A334	3.0	4.0	...	0.3	...	215, 456.
QQ-A-601	AN-QQ-A-376	AN-QQ-A-376	B26-41T	N	322	355	1.3	5.0	...	.5	...	219 to 223, inclusive; 322, 323, 461 to 464, inclusive.
QQ-A-601	Federal	M212	...	...	...	A355	1.4	5.0	0.8	.5	Ni 0.8	227, 228.

[a] Revisions not indicated.

[b] Air 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 spec	ASTM alloy	SAE	Alcoa	Cu	Si	Mn	Mg	Other	
SAND-CASTING ALLOYS—Continued												
QQ-A-601	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.[illegible]	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	....	B195	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	....	0.5	.....	224, 225, 226.
QQ-A-596	.....	46A15	.....	.....	323	356	.....	7.0	....	.3	.....	243, 472, 473, 474.
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	.....	5.0	....	....	.....	205.
.....	.....	.....	B85-39T	XII	312	81	7.0	3.0	....	....	.....	117, 428.
.....	.....	.....	.....	.....	....	82	14.0	5.0	....	....	.....	126.
.....	.....	.....	B85-39T	VI	....	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.
QQ-A-591	AN-QQ-A-366	AN-QQ-A-366	.....	.....	....	218	.....	....	....	8.0	.....	169, 449.

[a]Revisions 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
		Percent
O	Soft or annealed	0
1/4H	1/4 hard	21
1/2H	1/2 hard	37
3/4H	3/4 hard	60
H	Hard	80

Alloy	Solution heat-treatment			Precipitation heat-treatment		
	Tempera-ture	Quench	Temper desig-nation	Tempera-ture	Time of aging	Temper desig-nation
	°F			°F		
17S	930 to 950	Cold water	....	Room	[a]4 days	17S-T
A17S	930 to 950	...do	....	...do	[a]4 days	A17S-T
24S	910 to 930	...do	....	...do	[a]4 days	24S-T
53S	960 to 980	...do	53S-W	315 to 325 or	18 hr	53S-T
				345 to 355	8 hr	53S-T
61S[b]	960 to 980	...do	61S-W	315 to 325 or	18 hr	61S-T
				345 to 355	8 hr	61S-T

[a] More than 90 percent of the maximum properties are obtained during the first day of aging.
[b] Precipitation 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_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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	PURE AND COMMERCIAL ALUMINUM (SEE ALSO FIGS. 2, 3, AND 4)												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
1.....	Si 0.0020, Cu 0.0010, Ca 0.0003, Mg 0.0003, Na 0.0003, Fe 0.0001.	Sheet, 0.064 in., ann 4 hr at 390°F.	....	....	1.8 (0.2% perm)	6.9	49 (2 in.)	......	....	17	....	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 (2S-H).	9,100	12.4	....	25.8	3.3 (2 in.)	......	9.5 (10^8)	......	....	....	[20]
15....	Al 99.0-99.5........	Cast.................	10,000	....	4-6	13-17	18-25 (10 diam)	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+..............	Extruded (2S).........	....	....	13 (0.2% perm)	15	25 (2 in.)	......	6 (5×10^8)	28	....	Shear str.................10 kips/in.².....	[22]
17[a]...	...do...............	Wrought; ann (2S-O)....	10,300	....	5 (0.2% perm)	13	[b]45 (2 in.)	......	5 (5×10^8)	23	....	Comp yld str (0.2%).......5 kips/in.²..... Shear str.................9.5 kips/in.² Specific gravity..........2.71.	[11]
18[a]...	...do...............	Wrought; hard (2S-H)...	10,300	....	21 (0.2% perm)	24	[b]15 (2 in.)	......	8.5 (5×10^8)	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.............	Chill-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-T4).	....	....	24.5	33.5	4.5	6.5	....	R_E 82	[c]4	....	[25]
25[a]...	Cu 4.5..............	Sand-cast; h-t (195-T4).	10,300	....	16 (0.2% perm)	31	8.5 (2 in.)	......	6 (5×10^8)	65	......	Comp yld str (0.2%)........16 kips/in.^{2}..... Shear str..................24 kips/in.^{2} Specific gravity...........2.77.	[11]
26[a]...	...do................	Sand-cast; h-t and aged (195-T6).	10,300	....	22 (0.2% perm)	36	5 (2 in.)	......	6.5 (5×10^8)	80	......	Comp yld str (0.2%)........25 kips/in.^{2}..... Shear str..................30 kips/in.^{2}	[11]
27[a]...	...do................	Sand-cast; h-t and aged (195-T62).	10,300	....	31 (0.2% perm)	40	2 (2 in.)	......	7 (5×10^8)	95	......	Comp yld str (0.2%)........38 kips/in.^{2}..... Shear str..................31 kips/in.^{2}	[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 (5×10^8)	50-70	0.7	Comp yld str (0.2%)........14 kips/in.^{2}..... Compressive str............64 kips/in.^{2} Shear str..................20 kips/in.^{2} Specific gravity...........2.83. Melting range.............1,005°-1,175°F.	[46]
37....	Cu 10.0, Mg 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 (5×10^8)	75	......	Compressive str............45 kips/in.^{2}..... Specific gravity...........2.89. Melting range.............1,004°-1,160°F.	[36]

[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] Charpy specimen with Izod notch.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
ALUMINUM-COPPER-BISMUTH-LEAD ALLOY													
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
39[a]...	Cu 5.5, Bi 0.5, Pb 0.5.	Wrought; h-t and aged (11S-T3).	10,300	....	42 (0.2% perm)	49	[b]14 (2 in.)	......	12.5 (5×10^8)	95	....	Comp yld str (0.2%)........42 kips/in.²..... Shear str..................30 kips/in.² Specific gravity...........2.82.	[11]
40[a]...	...do................	Forged; h-t and aged (11S-T).	10,300	....	36 (0.2% perm)	57	15 (2 in.)	......	13 (5×10^8)	110	....	Comp yld str (0.2%)........36 kips/in.²..... Shear str..................31 kips/in.²	[11]
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)	26	0.5 (2 in.)	......	9.5 (5×10^8)	85	0.6	Shear str..................25 kips/in.²..... Specific gravity...........2.85. Melting range..............1,005°-1,160°F.	[10]
47[a]...	...do................	Sand-cast; ann (122-T2).	10,300	....	20 (0.2% perm)	25	1 (2 in.)	......	9.5 (5×10^8)	75	....	Comp yld str (0.2%)........20 kips/in.²..... Shear str..................21 kips/in.²	[11]
48[a]...	...do................	Sand-cast; h-t and aged (122-T61).	10,300	....	30 (0.2% perm)	36	1 (2 in.)	......	....	100	....	Comp yld str (0.2%)........43 kips/in.²..... Shear str..................29 kips/in.²	[11]
49[a]...	...do................	Chill-cast; aged (122-T52).	10,300	....	31 (0.2% perm)	35	0.5 (2 in.)	......	....	105	....	Comp yld str (0.2%)........31 kips/in.²..... Shear str..................25 kips/in.² Specific gravity...........2.89.	[11]
50[a]...	...do................	Chill-cast; h-t and aged (122-T65).	10,300	....	36 (0.2% perm)	48	0	......	8 (5×10^8)	140	....	Comp yld str (0.2%)........36 kips/in.²..... Shear str..................30 kips/in.²	[11]
51[a]...	...do................	Chill-cast; h-t and aged (122-T551).	10,300	....	35	37	0	......	8.5 (5×10^8)	115	....	Comp yld str (0.2%)........40 kips/in.²..... Shear str..................27 kips/in.²	[11]
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 (A17S-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 3.74, Mg 0.91, Mn 0.84, Fe 0.47, Si 0.42, Ti 0.01.	Rod, 19/32 in. diam, extruded.	....	....	49.2 (0.2%)	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).	....	....	52.5	64.5	21	29	....	R_E 74	....	....	[25]
59[a]...	Cu 4.0, Mg 0.5, Mn 0.5.	Wrought; ann (17S-O)...	10,300	....	10 (0.2% perm)	26	[b]22 (2 in.)	......	11 (5×10^8)	45	....	Comp yld str (0.2%)........10 kips/in.^{2}..... Shear str..................18 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) [d]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-O).	9,800	10.8	....	31.3	12 (2 in.)	......	12.0 (10^8)	R_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)	R_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)	R_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.	Chill-cast............	....	....	20.6 (0.1%)	24.0	<1.0 (2 in.)	<1	....	V 97	Iz <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. [d] Reversed torsion.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	ALUMINUM-COPPER-MAGNESIUM-MANGANESE ALLOYS—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
72....	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.	....	....	29.6 (0.1%)	41.2	1.8 (2 in.)	3.9	....	V 103	Iz 3.6	....	[43]
73....	...do........	Forged; 70 hr at 915°F, w-q, aged 4 days at r-t.	....	....	29.6 (0.1%)	56.9	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	16.5	......	......	....	[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 ($4\sqrt{\text{area}}$)	......	....	......	......	....	[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.)	......	16 (5×10^8)	135	......	Comp yld str (0.2%)........55 kips/in.² Shear str........45 kips/in.² Specific gravity........2.80.	[11]
79....	...do........	Forged, 5×5 in., h-t and aged (14S-T).	....	....	60.0	70.3	12 (2 in.)	24	18.0 (10^7)	......	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; ann (24S-O)...	10,300	....	10 (0.2% perm)	26	[b]22 (2 in.)	......	12 (5×10^8)	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.)	......	18 (5×10^8)	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	18.7 (10^7)	......	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 pnt)	65.7	20 (2 in.)	......	20.5 (5×10^7)	R_F 97	......	....	[41]
87....	...do........	Sheet, 0.032 in., h-t aged (Alclad 24S-T).	....	....	43.0 (yld pnt)	64.3	20 (2 in.)	......	13.0 (5×10^7)	......	......	....	[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 290°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 (5×10^8)	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 290°F, cold-rolled 5 1/2% red. (25S-RT).	....	....	45.0	57.0	16	29	....	R_E 68	....	....	[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 (5×10^8)	110	....	Comp yld str (0.2%)........35 kips/in.^{2}..... Shear str..................35 kips/in.^{2} Specific gravity...........2.79.	[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 (5×10^8)	75	Iz 0.2	Comp yld str (0.2%)........26 kips/in.^{2}..... Compressive str...........49 kips/in.^{2} Shear str..................21 kips/in.^{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 ($11.3\sqrt{\text{area}}$)	......	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.	....	....	47-54 (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 1.68, 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 (5×10^8)	115	....	Comp yld str (0.2%)........47 kips/in.^{2}..... Specific gravity...........2.80.	[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 (5×10^8)	80	0.6	Shear str..................24 kips/in.^{2}..... Specific gravity...........2.73. Melting range.............995°-1,165°F.	[10]
100[a]..	...do...............	Sand-cast; h-t and aged (142-T61).	10,300	....	32 (0.2% perm)	37	0.5 (2 in.)	......	8 (5×10^8)	100	....	Comp yld str (0.2%)........47 kips/in.^{2}..... Shear str..................32 kips/in.^{2}	[11]
101[a]..	...do...............	Sand-cast; aged (142-T571).	10,300	....	28 (0.2% perm)	32	0.5 (2 in.)	......	8 (5×10^8)	85	....	Comp yld str (0.2%)........34 kips/in.^{2}..... Shear str..................27 kips/in.^{2}	[11]
102[a]..	...do...............	Chill-cast (142).......	10,300	....	24 (0.2% perm)	34	1 (2 in.)	......	....	105	....	Comp yld str (0.2%)........24 kips/in.^{2}..... Shear str..................26 kips/in.^{2} Specific gravity...........2.77.	[10]
103[a]..	...do...............	Chill-cast; h-t and aged (142-T61).	10,300	....	42 (0.2% perm)	47	0.5 (2 in.)	......	9.5 (5×10^8)	110	....	Comp yld str (0.2%)........46 kips/in.^{2}..... Shear str..................31 kips/in.^{2}	[11]
104[a]..	...do...............	Chill-cast; aged (142-T571).	10,300	....	34 (0.2% perm)	40	0 (2 in.)	......	10.5 (5×10^8)	105	....	Comp yld str (0.2%)........34 kips/in.^{2}..... Shear str..................26 kips/in.^{2}	[11]
105...	Cu 4, Ni 4, Si 1.75..	Die-cast, 1/4 in. diam (93).	....	....	....	31	1.5 (2 in.)	......	....	......	2	Specific gravity...........2.87.............	[34]

[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.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	ALUMINUM-COPPER-NICKEL ALLOYS—Continued												
	Percent		*Kips/in.*²	*Kips/in.*²	*Kips/in.*²	*Kips/in.*²	*Percent*	*Percent*	*Kips/in.*²		*ft-lb*		
106...	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.	....	....	....	39.5	1.0	......	8.0 (10^8)	121	....	....	[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 (5×10^8)	55	0.6	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 (5×10^8)	80	....	....	[104]
112[a]..	Cu 4.5, Si 2.5.......	Chill-cast; h-t (B195-T4).	10,300	....	22 (0.2% perm)	40	10 (2 in.)	......	9.5 (5×10^8)	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 (5×10^8)	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 (5×10^8)	70-90	3	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 (5×10^8)	55-80	0.6	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 (81).	....	....	24 (0.2% perm)	32	1.3 (2 in.)	......	16 (5×10^8)	......	3	....	[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 (5×10^8)	80	....	Comp yld str (0.2%)........24 kips/in.²..... Shear str..................22 kips/in.² Specific gravity...........2.86. Melting range..............975°-1,165°F.	[10]
119...	...do................	Chill-cast; ann (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 (5×10^8)	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	....	Comp yld str (0.2%)........32 kips/in.^{2}..... Shear str..................22 kips/in.^{2} Specific gravity...........2.91.	[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	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.	[11]
						ALUMINUM-MAGNESIUM ALLOYS (SEE ALSO FIGS. 10, 11, AND 12)							
129...	Mg 0.55, Fe 0.54, 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 ($4\sqrt{\text{area}}$)	......	12.8 (5×10^7)	......	....	....	[48]
131[a]..	Mg 1.0, Si 0.6, Cr 0.25, Cu 0.25.	Wrought; ann (61S-O)...	10,300	....	8 (0.2% perm)	18	[b]22 (2 in.)	......	8 (5×10^8)	30	....	Comp yld str (0.2%)........8 kips/in.^{2}...... Shear str..................12.5 kips/in.^{2} Specific gravity...........2.70.	[11]
132[a]..	...do...............	Wrought; quenched (61S-W).	10,300	....	21 (0.2% perm)	35	[b]22 (2 in.)	......	12.5 (5×10^8)	65	....	Comp yld str (0.2%)........21 kips/in.^{2}..... Shear str..................24 kips/in.^{2}	[11]
133[a]..	...do...............	Wrought; h-t and aged (61S-T).	10,300	....	39 (0.2% perm)	45	12 (2 in.)	......	12.5 (5×10^8)	95	....	Comp yld str (0.2%)........39 kips/in.^{2}..... Shear str..................30 kips/in.^{2}	[11]
134...	Mg 1.2, Si 0.7, Cr 0.25.	Wrought; 1/2 hard (53S-1/2 H).	10,000	....	21 (0.2% offset)	22	8 (2 in.)	......	....	40	....	Specific gravity...........2.69............	[49]
135...	...do...............	Wrought; hard (53S-H)..	10,000	....	26 (0.2% offset)	28	6 (2 in.)	......	....	48	....	....	[49]

[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.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					ALUMINUM-MAGNESIUM ALLOYS—Continued								
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
136[a]	Mg 1.3, Si 0.7, Cr 0.25.	Wrought; ann (53S-O)	10,300	....	7 (0.2% perm)	16	[b]35 (2 in.)	......	7.5 (5×10^8)	26	....	Comp yld str (0.2%) ....7 kips/in.^{2} Shear str ....11 kips/in.^{2}	[11]
137[a]	...do	Wrought; quenched (53S-W).	10,300	....	20 (0.2% perm)	33	[b]30 (2 in.)	......	10 (5×10^8)	65	....	Comp yld str (0.2%) ....20 kips/in.^{2} Shear str ....20 kips/in.^{2}	[11]
138[a]	...do	Wrought; h-t and aged (53S-T).	10,300	....	33 (0.2% perm)	39	[b]20 (2 in.)	......	11 (5×10^8)	80	....	Comp yld str (0.2%) ....33 kips/in.^{2} Shear str ....24 kips/in.^{2}	[11]
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	....	....	[18]
140	...do	Sand-cast; h-t	....	....	....	23-33	0.5-5 (2 in.)	......	....	70-120	....	....	[18]
141	...do	Chill-cast	....	....	....	21-26	3-8 (2 in.)	......	....	40-60	....	....	[18]
142	...do	Chill-cast; h-t	....	....	21-28 (0.2%)	26-36	0.5-5 (2 in.)	......	....	70-120	....	....	[18]
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	....	....	[18]
144	...do	Sheet, h-t and cold-rolled.	....	....	47-51 (0.2%)	50-57	2-10 (2 in.)	......	....	100-120	....	....	[18]
145	Mg 2.2, Mn 1.4	Sheet, soft	....	....	14-21 (0.2%)	31-36	16-20 (2 in.)	......	....	50-65	....	....	[18]
146	...do	Sheet, hard-rolled	....	....	47-57 (0.2%)	51-60	2-5 (2 in.)	......	....	85-100	....	....	[18]
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	....	....	[25]
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 ($4\sqrt{\text{area}}$)	......	17.0 (5×10^7)	......	....	....	[48]
149[a]	Mg 2.5, Cr 0.25	Wrought; annealed (52S-O).	10,300	....	14 (0.2% perm)	29	[b]30 (2 in.)	......	17 (5×10^8)	45	....	Comp yld str (0.2%) ....14 kips/in.^{2} Shear str ....18 kips/in.^{2} Specific gravity ....2.67.	[11]
150[a]	...do	Wrought; 1/2 hard (52S-1/2 H).	10,300	....	29 (0.2% perm)	37	[b]14 (2 in.)	......	19 (5×10^8)	67	....	Shear str ....21 kips/in.^{2}	[11]
151[a]	...do	Wrought; hard (52S-H)	10,300	....	36 (0.2% perm)	41	[b]8 (2 in.)	......	20.5 (5×10^8)	85	....	Comp yld str (0.2%) ....36 kips/in.^{2} Shear str ....24 kips/in.^{2}	[11]
152	Mg 3.4, Mn 0.15	Sheet, soft	....	....	10-14 (0.2%)	28-36	15-20 (2 in.)	......	....	50-60	....	....	[18]
153	...do	Sheet, hard	....	....	36-43 (0.2%)	43-50	2-6 (2 in.)	......	....	85-100	....	....	[18]
154	Mg 3.8	Sand-cast (214)	10,300	....	12 (0.2% perm)	25	9 (2 in.)	......	5.5 (5×10^8)	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.	[10]

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.)	......	....	60	......	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 (2×10^7)	......	......	....	[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	......	....	......	[c]1.7	....	[26]
161	Mg 5.96, Ni 1.49, Mn 1.00, Cu 0.37, Fe 0.28, Si 0.19.	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 (2×10^7)	......	......	....	[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	......	....	......	[c]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 0.18, Si 0.16, Cu 0.04, Ti 0.003.	Sheet, 7/16 in.	....	....	23.5 (0.2%)	53.2	27	......	....	......	[c]1.9	....	[26]
169[a]	Mg 8.0	Die-cast (218)	10,300	....	23 (0.2% perm)	38	5 (2 in.)	......	18 (5×10^8)	......	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 (2×10^7)	......	......	....	[26]
171[a]	Mg 10.0	Sand-cast; h-t (220-T4)	10,300	....	25 (0.2% perm)	45	14 (2 in.)	......	7 (5×10^8)	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]

[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] Notch impact value in m-kg/cm.^{2}

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
						ALUMINUM-MAGNESIUM ALLOYS—Continued							
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
174...	Mg 10...	Mixed powders; compacted at 56 tons/in.²; 24 hr at 800°F in air, w-q.	...	...	...	24.9	...	...	...	...	...	Density...2.52 g/cm³... 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	[c] 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 (10^8)	...	...	...	[20]
179[a]..	Mn 1.2...	Wrought; ann (3S-0)...	10,300	...	6 (0.2% perm)	16	[b]40 (2 in.)	...	7 (5×10^8)	28	...	Comp yld str (0.2%)...6 kips/in.²... Shear str...11 kips/in.² Specific gravity...2.73.	[11]
180[a]..	...do...	Wrought; 1/2 hard (3S-1/2 H).	10,300	...	18 (0.2% perm)	21	[b]16 (2 in.)	...	9 (5×10^8)	40	...	Shear str...14 kips/in.²...	[11]
181[a]..	...do...	Wrought; hard (3S-H)...	10,300	...	25 (0.2% perm)	29	[b]10 (2 in.)	...	10 (5×10^8)	55	...	Comp yld str (0.2%)...25 kips/in.²... Shear str...16 kips/in.²	[11]
182...	...do...	Extruded (3S)...	...	...	15 (0.2% perm)	18	20 (2 in.)	...	8 (5×10^8)	35	...	Shear str...12 kips/in.²...	[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	...	Shear str...16 kips/in.²... Specific gravity...2.72.	[54]
187...	...do...	1/2 hard...	...	...	27	34	9 (2 in.)	...	15	63	...	Shear str...18 kips/in.²...	[54]
188...	...do...	Hard...	...	...	34	40	5 (2 in.)	...	16	77	...	Shear str...21 kips/in.²...	[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 ($4\sqrt{\text{area}}$)	...	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 x 10⁸)	35	4	Comp yld str (0.2%)........9 kips/in.^{2}...... Shear str..................14 kips/in.^{2} Specific gravity...........2.73. Melting range.............1,215°-1,255°F.	[10]
						ALUMINUM-NICKEL ALLOYS							
195...	Ni 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...	Ni 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...	Ni 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 x 10⁸)	45	....	....	[31]
203...	Si 5.0..............	Sand-cast (43).........	10,300	....	9 (0.2% perm)	19	6 (2 in.)	......	6.5 (5 x 10⁸)	40	1	Comp yld str (0.2%)........10 kips/in.^{2}..... Shear str..................14 kips/in.^{2} Specific gravity...........2.66. Melting range.............1,070°-1,165°F.	[10]
204...	...do...............	Chill-cast (43)........	10,300	....	9 (0.2% perm)	24	6 (2 in.)	......	....	40	2.1	Comp yld str (0.2%)........9 kips/in.^{2}...... Shear str..................18 kips/in.^{2} Specific gravity...........2.68.	[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...........2.70.............	[10]
206[a]..	Si 10.0.............	Sand-cast (45).........	10,300	....	10 (0.2% perm)	21	4.5 (2 in.)	......	6 (5 x 10⁸)	45	0.8	Comp yld str (0.2%)........11 kips/in.^{2}..... Shear str..................16 kips/in.^{2} Specific gravity...........2.65. Melting range.............1,070°-1,155°F.	[10]
207[a]..	Si 12................	Die-cast, 1/4 in. diam (13).	10,300	....	18 (0.2% perm)	33	1.8 (2 in.)	......	15 (5 x 10⁸)	......	2	Specific gravity...........2.66............. Melting range.............1,070°-1,150°F.	[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 x 10⁸)	50	3	Comp yld str (0.2%)........11 kips/in.^{2}..... Shear str..................18 kips/in.^{2} Specific gravity...........2.65. Melting range.............1,070°-1,150°F.	[10]
210...	Si 12.64, Mg 0.96, Ni 0.91, Cu 0.90, Fe 0.78, 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]

[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] Charpy specimen with Izod notch.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	ALUMINUM-SILICON ALLOYS—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
212...	Si 13................	Die-cast..............	10,300	....	18 (0.2% offset)	33	2 (2 in.)	......	15 (5 x 10⁸)	80	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.)	......	14.5 (5 x 10⁸)	......	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.)	......	8.5 (5 x 10⁸)	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	....	10.3 (0.02%) 15.8 (0.2%)	24.2	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	....	......	8.0 (10⁸)	......	....	....	[25]
220...	Si 5.0, Cu 1.3, Mg 0.5.	Sand-cast; h-t (355-T4).	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-T61).	10,300	....	33 (0.2% offset)	38	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-T6).	10,300	....	25 (0.2% perm)	35	3.5 (2 in.)	......	8.5 (5 x 10⁸)	80	....	Comp yld str (0.2%)........29 kips/in.²..... Shear str..................30 kips/in.²	[11]
223[a]..	...do................	Sand-cast; aged (355-T51).	10,300	....	23 (0.2% perm)	28	1.5 (2 in.)	......	7 (5 x 10⁸)	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-T4).	10,300	....	23 (0.2% perm)	38	6 (2 in.)	......	....	......	....	....	[11]
225[a]..	...do................	Chill-cast; h-t and aged (355-T6).	10,300	....	26 (0.2% perm)	43	4 (2 in.)	......	9 (5 x 10⁸)	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-T51).	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 (A355-T51).	10,300	....	24 (0.2% perm)	28	1.5 (2 in.)	......	8.5 (5 x 10⁸)	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 (5×10^8)	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 (5×10^8)	......	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 (5×10^8)	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 (5×10^8)	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 (A51S-T).	10,300	....	40 (0.2% perm)	47	20 (2 in.)	......	10.5 (5×10^8)	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 0.65, Fe 0.31, Mn 0.02, Cu 0.01.	Rod, 1 in. diam, extruded, h-t.	....	....	41.0 (0.1%)	44.8	12 ($4\sqrt{\text{area}}$)	......	14.6 (5×10^7)	......	....	....	[48]
239...	Si 6.71, Fe 0.26, Mg 0.25, Cu 0.08.	Rod, 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 (5×10^8)	70	....	Comp yld str (0.2%)........22 kips/in.^{2}..... 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 (5×10^8)	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 (32S-T).	10,300	....	46 (0.2% perm)	56	8 (2 in.)	......	14 (5×10^8)	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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					ALUMINUM-SILICON-NICKEL ALLOYS								
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
246...	Si 10, Ni 2.4, Mn 1.4, Cu 1.2.	Chill-cast, aged......	11,700	....	24.6 (0.02%)	29.6	....	......	....	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	Specific gravity..........2.70............ Melting range.............1,000°-1,095°F.	[56]
248...	...do...............	Forged, solution h-t, and aged.	10,300	....	43 (0.2% offset)	53	8 (2 in.)	......	14 (5×10^8)	118	1.3	Comp yld str (0.2%)........43 kips/in.²..... Compressive str...........54 kips/in.² Shear str.................38 kips/in.²	[56]
249[a]..	Si 12, Ni 2.5, Mg 1.0, Cu 0.8, Fe 0.8.	Chill-cast; h-t (A132-T4).	10,300	....	30 (0.2% perm)	38	1.5 (2 in.)	......	....	100	....	Comp yld str (0.2%)........30 kips/in.²..... Shear str.................29 kips/in.² Specific gravity..........2.69.	[11]
250[a]..	...do...............	Chill-cast; aged (A132-T551).	10,300	....	28 (0.2% perm)	36	0.5 (2 in.)	......	....	105	....	Comp yld str (0.2%)........30 kips/in.²..... Shear str.................24 kips/in.²	[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	....	Specific gravity..........2.95-3.00........	[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	60.0	16	......	....	......	....	....	[60]
256...	Zn 4.38, Mg 3.47, Mn 0.32, Fe 0.30, Si 0.16, 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	....	Comp yld str (0.1%)........9-18 kips/in.²... Specific gravity..........2.8.	[61]
259...	...do...............	Wrought; h-t and aged at r-t.	10,000	....	40-47 (0.1%)	65-72	16-21	......	....	130-140	....	Comp yld str (0.1%)........38-47 kips/in.²..	[61]

260...	...do	Wrought; h-t and artificially aged.	10,000	....	63-74 (0.1%)	72-85	10-16	......	28-29 (2×10^7)	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-T)	....	....	40 (0.2% perm)	50	16 (2 in.)	......	21 (5×10^8)	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 (5×10^8)	70	2	Comp yld str (0.2%)........20 kips/in.^{2}..... Shear str..................22 kips/in.^{2} Specific gravity...........2.94. Melting range..............980°-1,165°F.	[10]
268...	Zn 12.0, Cu 3.0, Mn 0.6, Fe 0.27, Si 0.25, Li 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	Iz 2-3	Specific gravity...........3.00............. Melting point..............1,140°F.	[62]
270...	...do	Chill-cast	....	....	13-20 (yld pnt)	25-34	4-8	......	7.8 (2×10^7)	65-70	Iz 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., ann...	10,000	....	36.0 (yld pnt)	52.4	18 (2 in.)	......	....	......	....	....	[23]

[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.

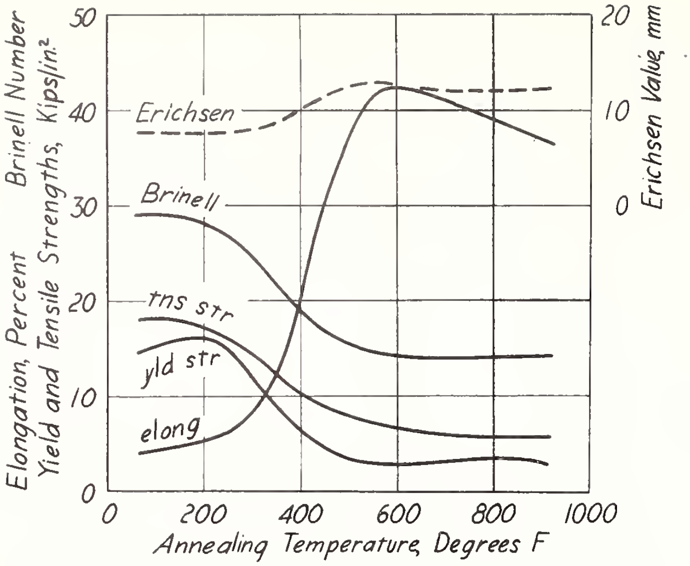


FIGURE 2.—*Effect of annealing on the tensile properties, hardness, and Erichsen value of cold-rolled, high-purity aluminum sheet (Wolf and Tuxhorn [628]).*

(Yield strength, 0.2%)

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

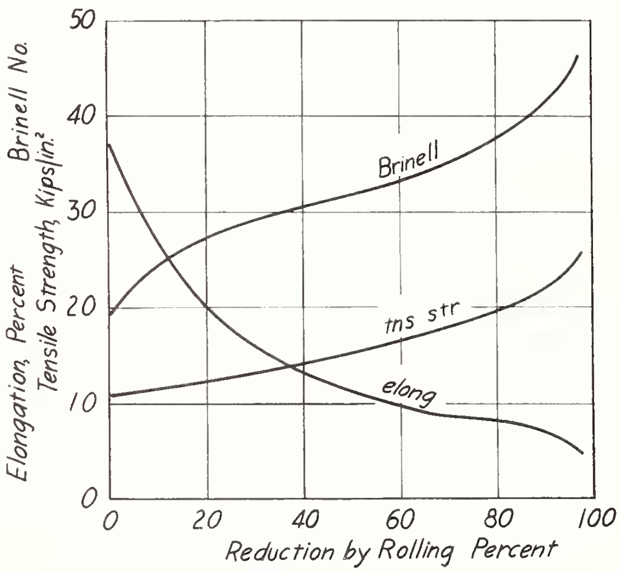


FIGURE 3.—*Effect of cold-rolling on the tensile properties and hardness of aluminum sheet (Weiss [629]).*

Al 99.7%

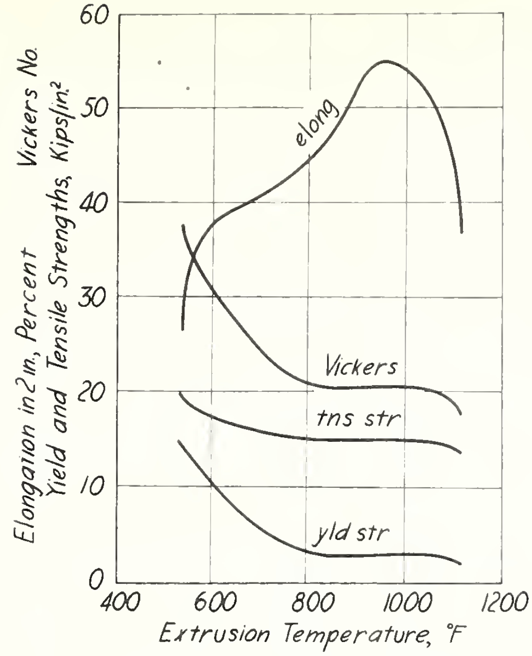


FIGURE 4.—*Effect of extrusion temperature on the tensile properties and hardness of aluminum (Pearson [630]).*

(Yield strength, 0.1%)

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

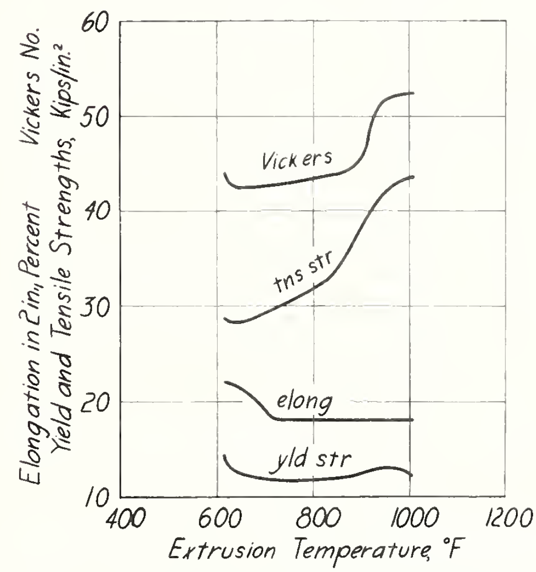


FIGURE 5.—*Effect of extrusion temperature on the tensile properties and hardness of an aluminum-copper alloy (Pearson [630]).*

(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.

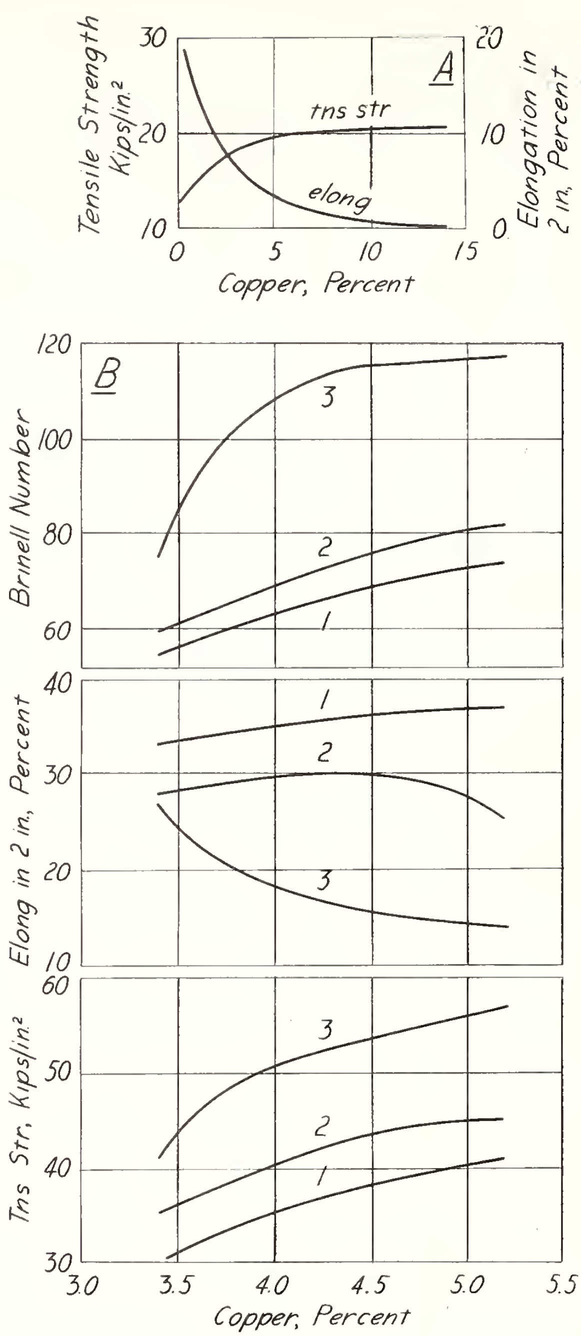


FIGURE 6.—*Tensile properties and hardness of sand-cast and wrought aluminum-copper alloys (Dix and Bowman [631]).*

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.

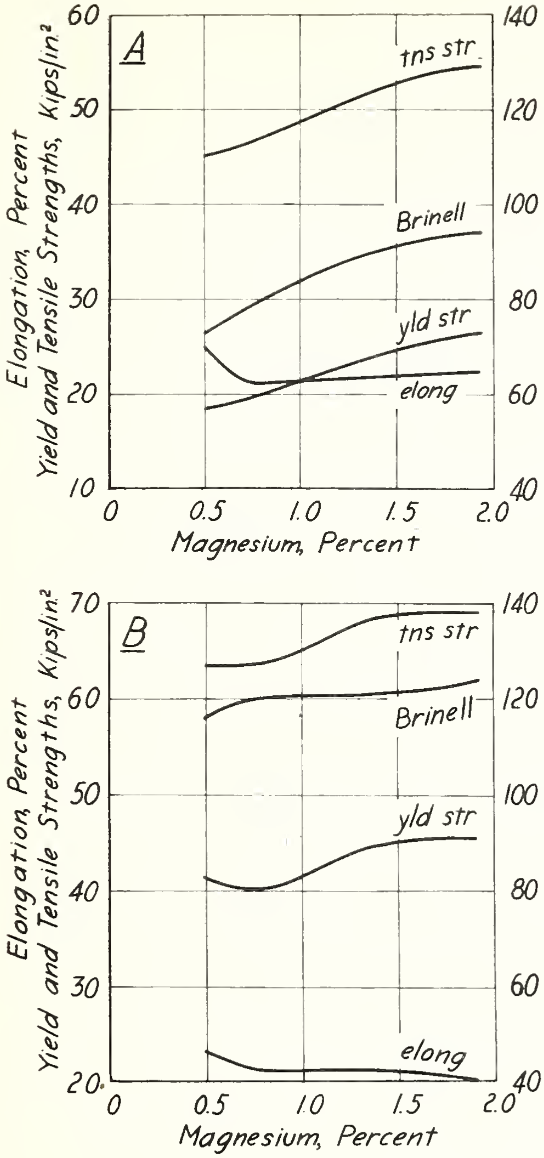


FIGURE 7.—*Effect of magnesium on the tensile properties and hardness of an aluminum-copper alloy containing 4 percent of copper (Hansen and Dreyer [632]).*

(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.

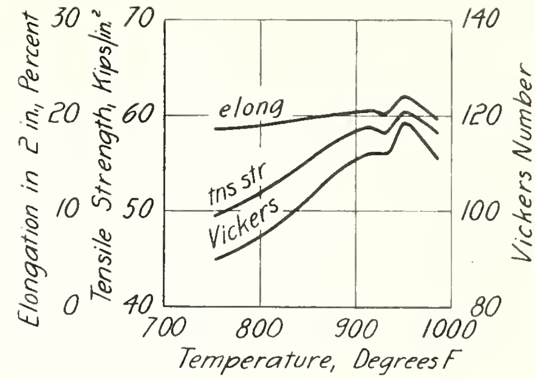


FIGURE 8.—*Effect of temperature of solution heat-treatment on the tensile properties and hardness of Duralumin (Carpenter and Robertson [43]).*

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

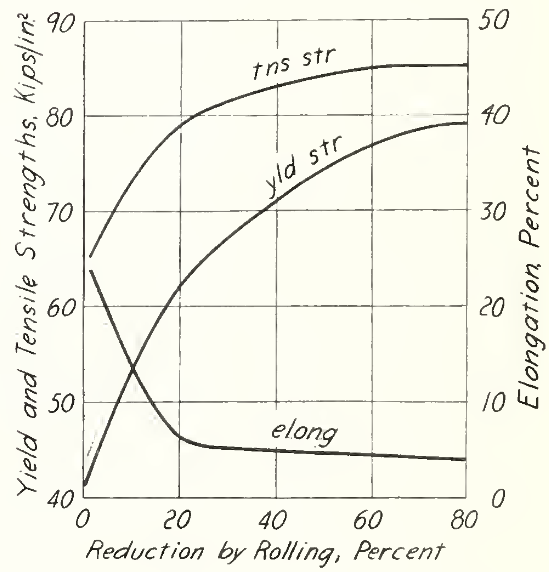
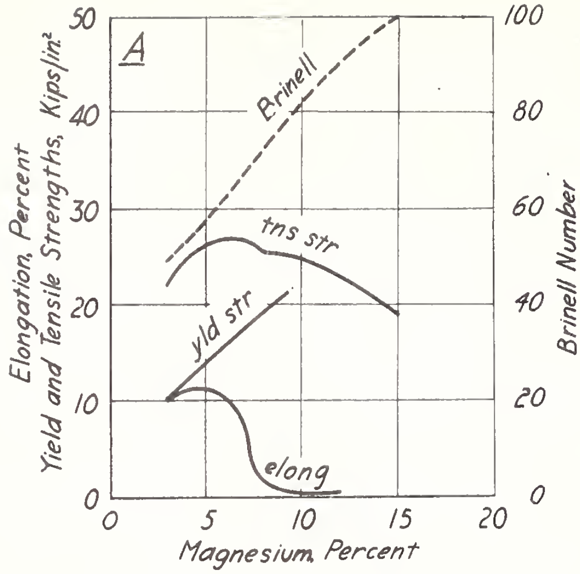


FIGURE 9.—*Effect of cold-rolling on the tensile properties of aged Duralumin (Zeerleder [18]).*

(Yield strength, 0.2%)

Aged 6 days at room temperature before rolling.



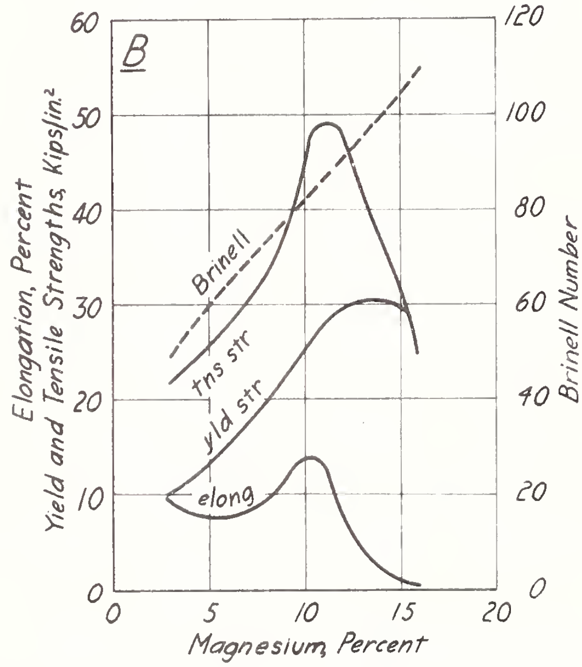


FIGURE 10.—*Tensile properties and hardness of cast aluminum-magnesium alloys (Kempf and Keller [633]).*

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.

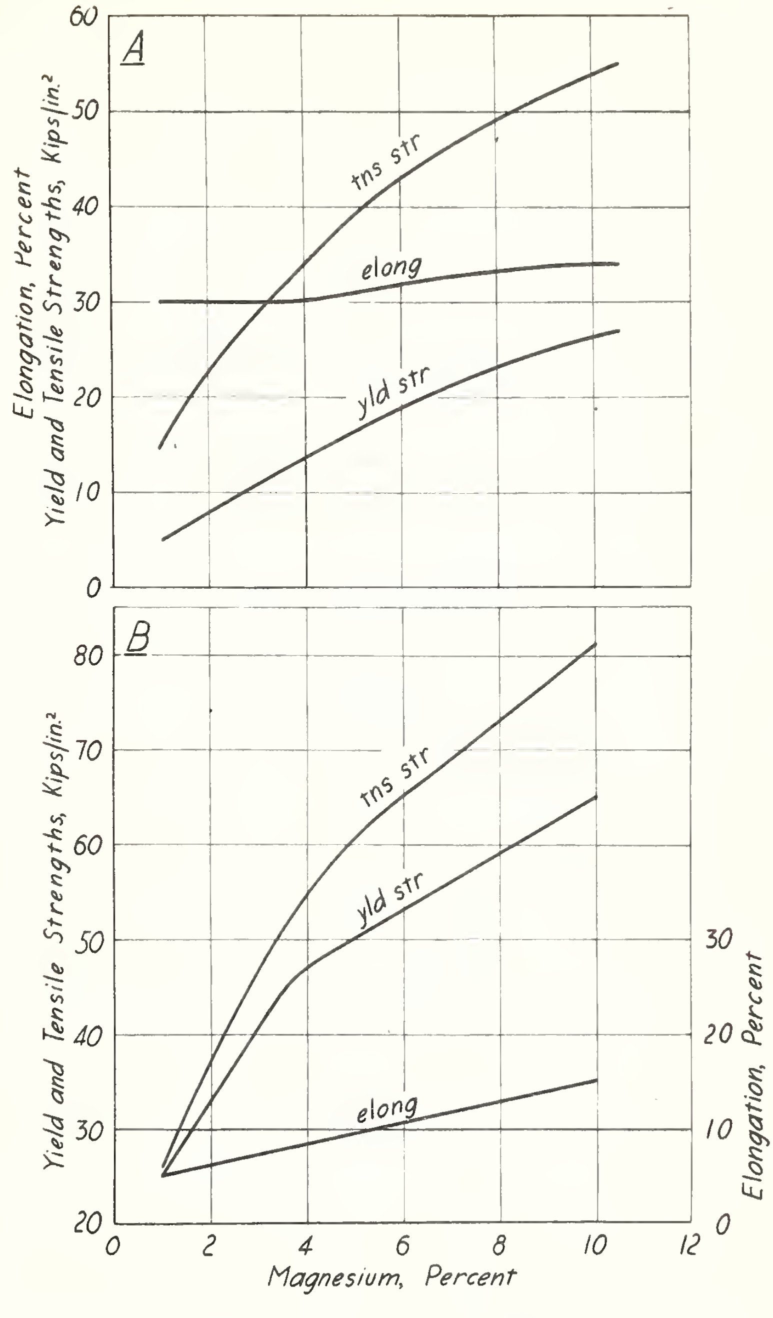


FIGURE 11.—*Tensile properties of aluminum-magnesium alloy sheet (Kempf and Keller [633]).*

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

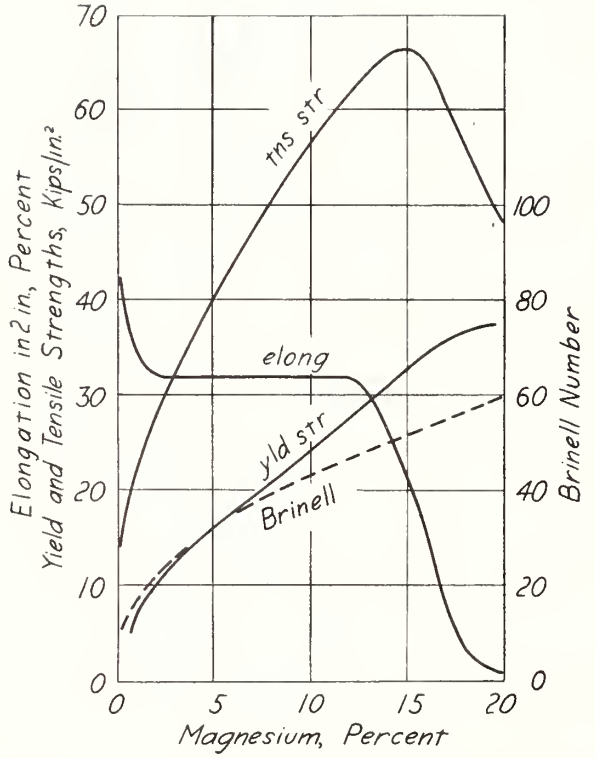


FIGURE 12.—*Tensile properties and hardness of forged or extruded aluminum-magnesium alloys (Kempf and Keller [633]).*

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

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

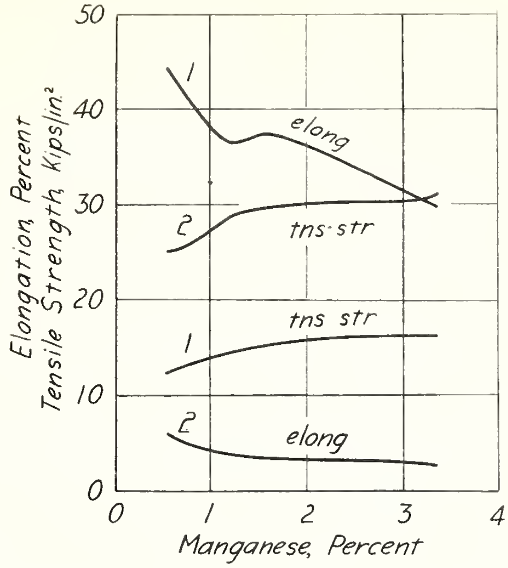


FIGURE 13.—*Tensile properties of aluminum-manganese alloys (Bosshard [634]).*

(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.).

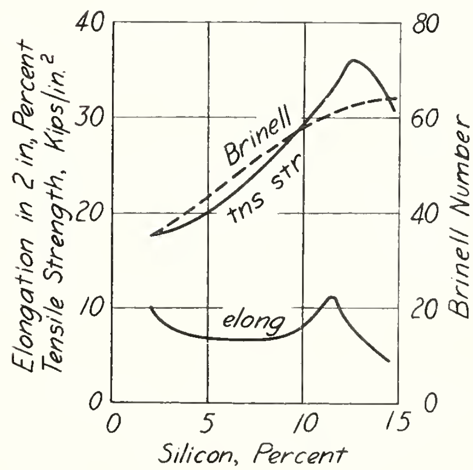


FIGURE 14.—*Tensile properties and hardness of chill-cast aluminum-silicon alloys (Carpenter and Robertson [43]).*

Fe 0.35%, Cu 0.15%

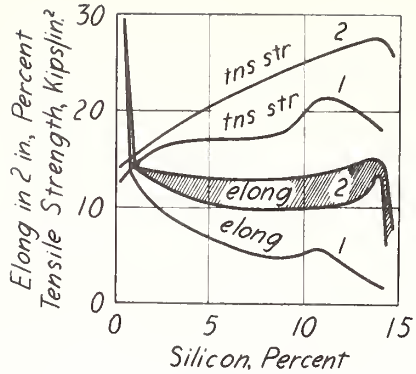
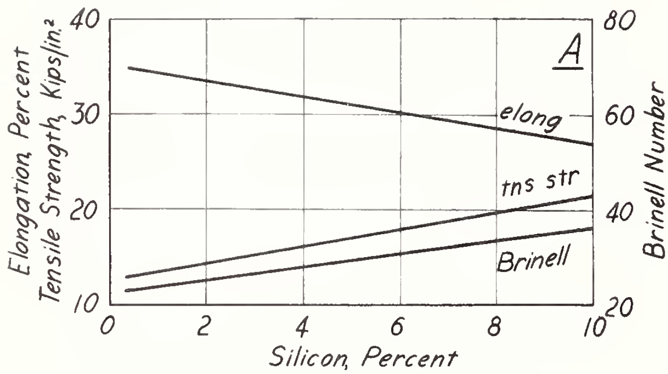


FIGURE 15.—*Tensile properties of sand-cast aluminum-silicon alloys (Kempf [74]).*

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



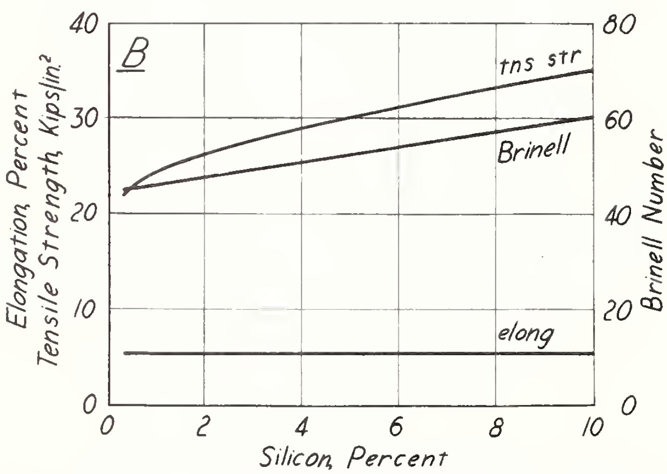


FIGURE 16.—*Tensile properties and hardness of aluminum-silicon alloys (Kempf [74]).*

Sheet, 0.08 in.

A, Annealed; B, hard-rolled.

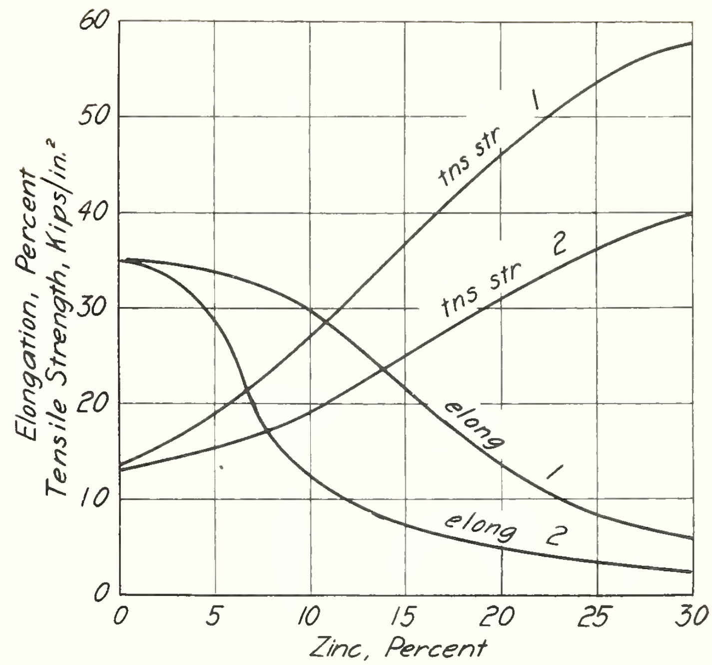


FIGURE 17.—*Tensile properties of wrought and chill-cast aluminum-zinc alloys (Kempf [635]).*

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_B, R_C, etc. (Rockwell B, Rockwell C, etc.); S (Scleroscope); V (Vickers).]

Serial number	Composition	Condition	Temperature	Short-time properties: "Proportional limit"	Short-time properties: Yield strength[a]	Short-time properties: Tensile strength	Short-time properties: Elongation[b]	Short-time properties: Reduction of area	Short-time properties: Hardness number	Creep properties: Stress (kips/in.^{2}) for designated creep rate per 1,000 hours: 0.01%	0.1%	1.0%	Creep properties: Duration	Reference
	FOR PURE AND COMMERCIAL ALUMINUM, SEE FIGURES 18 AND 19													
	ALUMINUM-COPPER ALLOYS (SEE ALSO FIGS. 20 TO 24, INCLUSIVE)													
	Percent		°F	*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Percent*	*Percent*					*Hours*	
274...	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..	Room	26.0	....	39.1	1.0	......	108	....	....	....	.....	[45]
			[c]400	13.5	....	31.5	1.2	......	......	5.0	....	....	312	
			[d]600	4.9	....	13.4	6.0	......	......	....	2.5 (0.28%)	....	293	
275...	Cu 3.91, Ni 2.22, Mg 1.68, Fe 0.35, Si 0.13.	Wrought; 5 hr at 950°F, w-q, aged 5 hr at 375°F.	Room	....	52.8	68.5	13	......	138	....	....	....	.....	[45]
			[e]400	22.0	37.2	43.3	11	......	......	....	15.0 (0.11%)	....	556	
			[f]600	....	....	6.4	59	......	......	....	....	2.5 (0.69%)	317	
276...	Cu 4.06, Ni 2.12, Fe 0.62, Mg 0.47, Si 0.21, Mn 0.01.	Wrought, h-t................................	Room	....	....	51.2	19	......	87	....	....	....	.....	[45]
			[g]400	....	....	17.5	37	......	......	....	5.0 (0.09%)	....	576	
			[g]600	....	....	5.5	73	......	......	....	1.3 (0.4%)	....	308	
277...	Cu 4.25, Mn 0.63, Mg 0.44, Fe 0.52, Si 0.25.	Rod, 5/8 in. diam, wrought, aged.............	63	28.4	[h]39.0	55.6	23	32	110	....	....	....	.....	[63]
			302	23.3	31.8	48.4	22	34	......	....	22.0	....	500	
			482	7.2	19.7	23.5	24	67	......	....	5.7	....	500	
			662	....	4.7	7.4	80	90	......	....	1.5	....	500	
278...	Cu 4.29, Si 0.66, Fe 0.50..	Cast; 24 hr at 960°F, w-q, aged 2 hr at 300°F..	Room	11.2	23.8	34.0	3.5	......	87	....	....	....	.....	[45]
			[c]400	7.5	....	22.8	6.0	......	......	....	5.0 (0.09%)	....	535	
			[d]600	3.8	....	8.0	26	......	......	....	1.3 (0.13%)	....	308	
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..	Room	34.0	....	42.3	0.5	......	130	....	....	....	.....	[45]
			[c]400	12.0	....	28.6	1.5	......	......	5.0	....	....	511	
			[d]600	2.8	....	11.0	12	......	......	....	1.3	....	383	
	ALUMINUM-MAGNESIUM ALLOY (SEE ALSO FIG. 25)													
280...	Mg 5.96, Ni 1.49, Mn 1.00, Cu 0.37, Fe 0.28, Si 0.19.	Cast..	Room	9.0	18.2	27.3	2.5	......	74	....	....	....	.....	[45]
			[a]400	10.0	17.2	24.0	3.0	......	......	....	2.5 (0.15%)	....	600	
			600	....	....	....	......	......	......	....	....	1.3 (0.86%)	313	

FOR ALUMINUM-MANGANESE ALLOYS, SEE FIGURE 26

ALUMINUM-SILICON ALLOYS

281...	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..	Room	9.0	33.5	36.3	1.5	....	86	....	....	....	.....	[45]
			[c]400	10.0	....	26.3	2.0	....	......	....	10.0 (0.12%)	....	554	
			[d]600	3.8	....	7.4	13	....	......	....	1.3 (0.15%)	....	245	
282...	Si 12.64, Mg 0.96, Ni 0.91, Cu 0.90, Fe 0.78, Mn 0.02.	Wrought, h-t....................................	Room	28.0	44.4	52.8	6.0	....	126	....	....	....	.....	[45]
			[e]400	16.0	29.2	35.2	4.0	....	......	....	7.5 (0.09%)	....	578	
			[e]600	3.0	6.1	8.7	35	....	......	....	....	....	.....	
283...	Si 13.18, Ni 3.08, Cu 2.96, Mg 1.04, Fe 0.53.	...do..	Room	30.0	49.3	59.3	4.0	....	139	....	....	....	.....	[45]
			[f]400	....	....	21.7	12	....	......	....	7.5 (0.07%)	....	574	
			[f]600	....	....	7.9	45	....	......	....	1.3 (0.22%)	....	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.

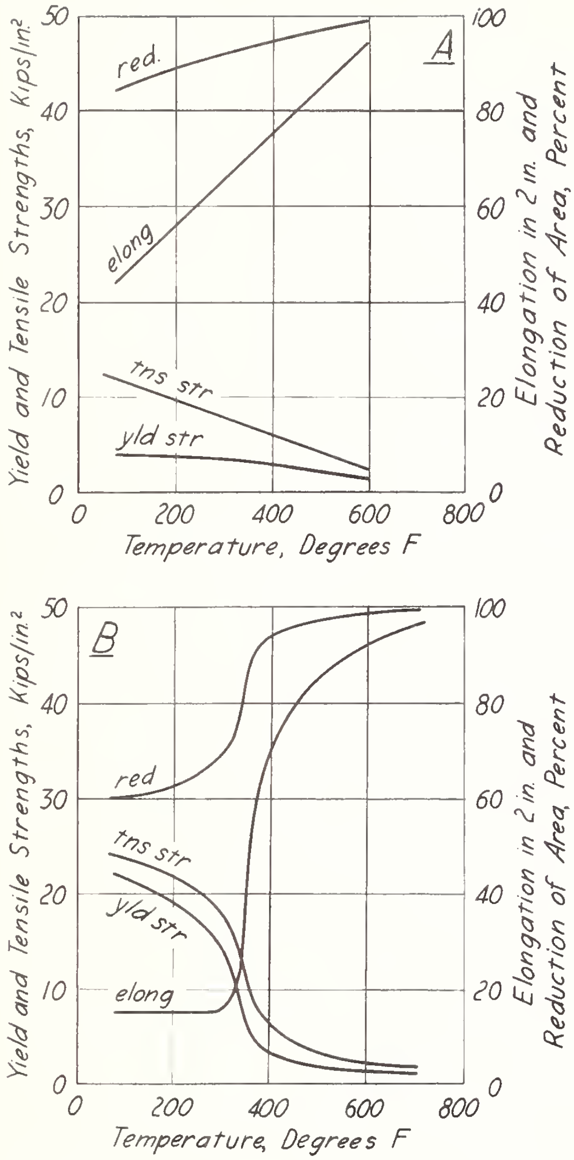


FIGURE 18.—*Short-time tensile properties of wrought aluminum at high temperatures (Howell and Paul [636]).*

(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).

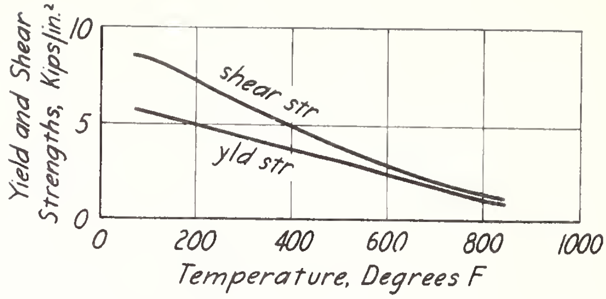


FIGURE 19.—*Shear strength of aluminum at high temperatures (Irmann [637]).*

Al 99.3%

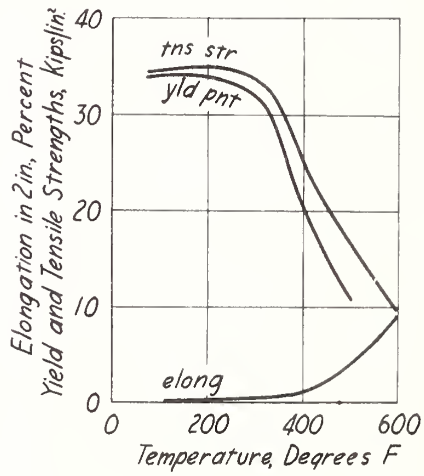


FIGURE 20.—*Short-time tensile properties of an aluminum-copper-iron-magnesium alloy at high temperatures (Heil [77]).*

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

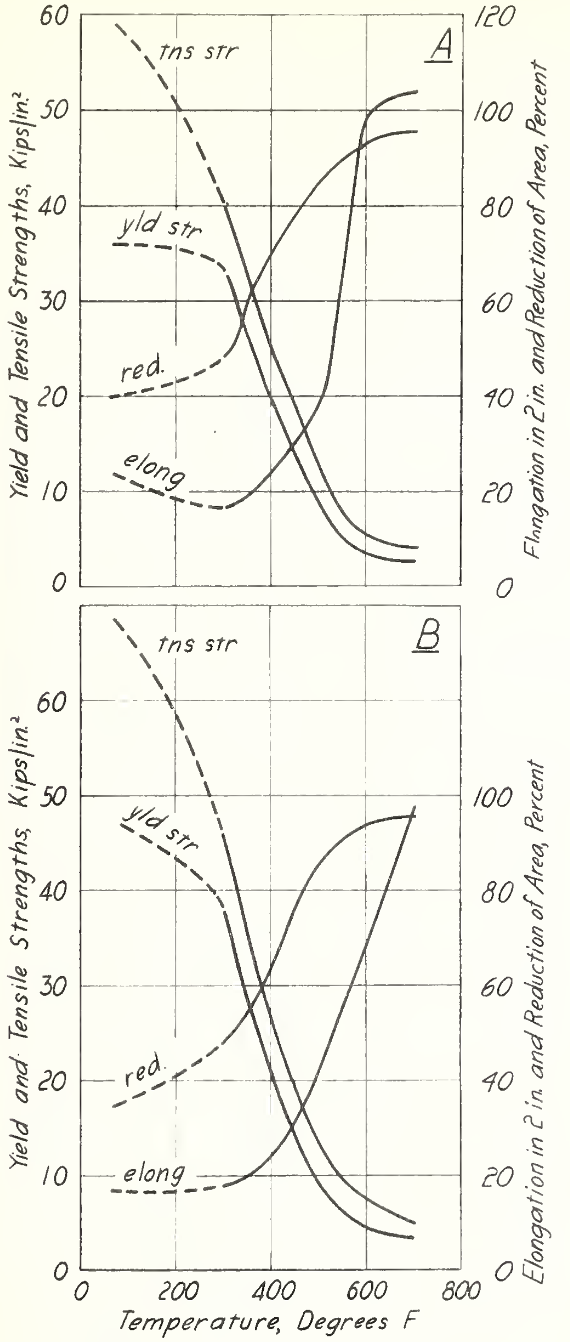


FIGURE 21.—*Short-time tensile properties of wrought aluminum-copper-magnesium-manganese alloys at high temperatures (Howell and Paul [638]).*

(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).

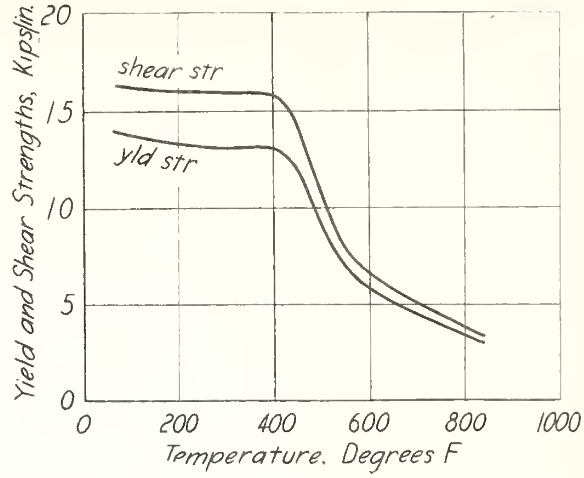


FIGURE 22.—*Shear strength of an aluminum-copper-magnesium-manganese alloy at high temperatures (Irmann [637]).*

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

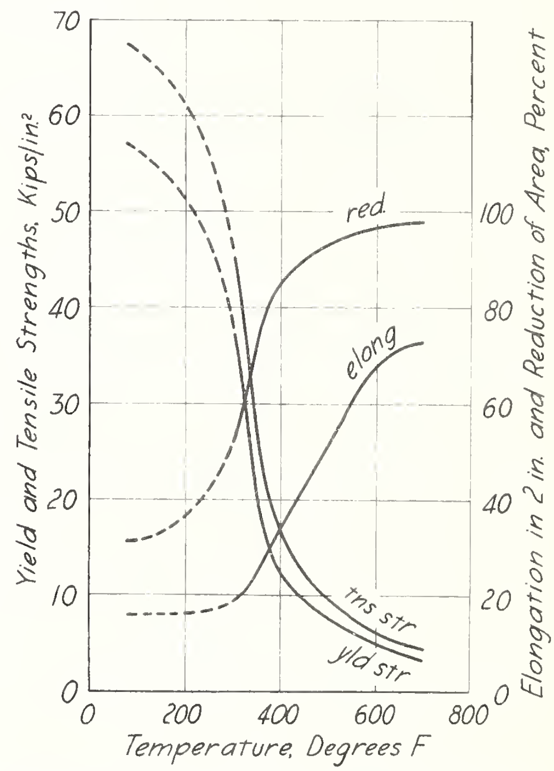


FIGURE 23.—*Short-time tensile properties of a wrought aluminum-copper-magnesium-manganese alloy at high temperatures (Howell and Paul [638]).*

(Yield strength, 0.2%)

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

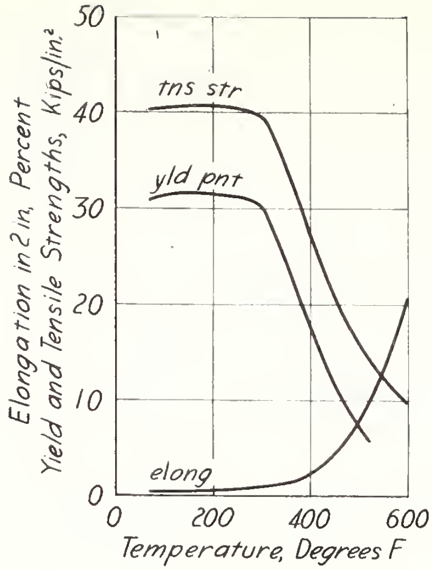


FIGURE 24.—*Short-time tensile properties of an aluminum-copper-nickel-magnesium alloy at high temperatures (Heil [76]).*

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

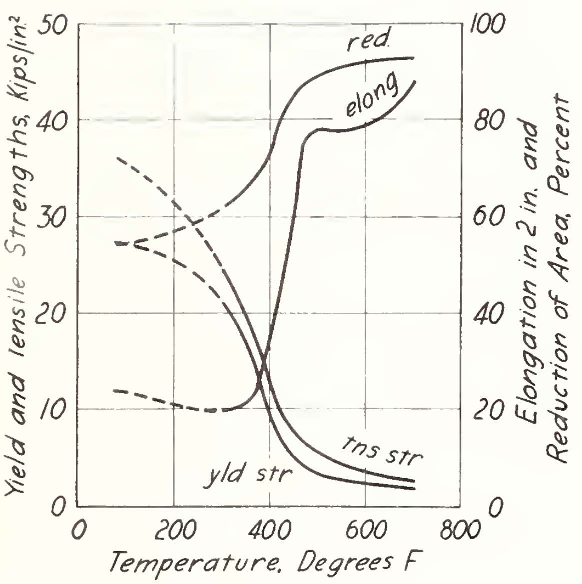


FIGURE 25.—*Short-time tensile properties of a wrought aluminum-magnesium-silicon-chromium alloy at high temperatures (Howell and Paul [638]).*

(Yield strength, 0.2%)

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

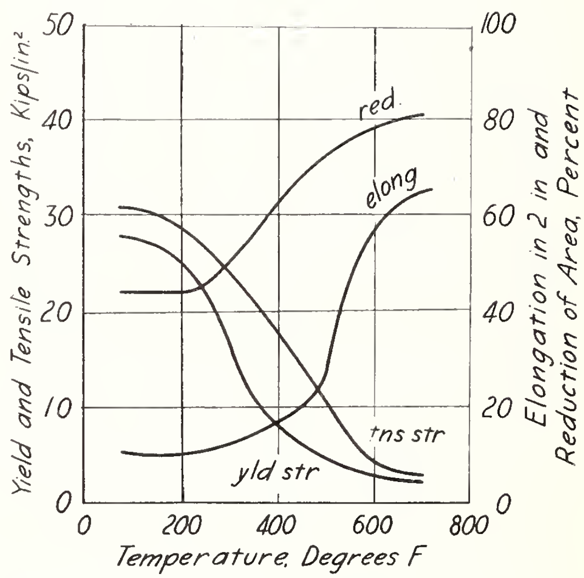


FIGURE 26.—*Short-time tensile properties of a wrought aluminum-manganese alloy at high temperatures (Howell and Paul [636]).*

(Yield strength, 0.2%)

Mn 1.2%, Fe 0.45%, Si 0.22%, Cu 0.1%, Hard-drawn, 80% 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: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Remarks	Reference
						PURE AND COMMERCIAL ALUMINUM						
	Percent		*°F*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
284...	Fe 0.07, Si 0.054	Rod, 1 in. diam; rolled, ann.	Room	4.4 (0.1% perm)	9.8	36 (2 in.)	90	....	......	Iz 19	Tensile specimens 0.25 in. diam.	[64]
			14	3.8 (0.1% perm)	11.4	36 (2 in.)	90	....	......	....		
			-40	4.0 (0.1% perm)	11.6	40 (2 in.)	92	....	......	Iz 19		
			-112	4.3 (0.1% perm)	11.9	38 (2 in.)	92	....	......	Iz 20		
			-184	3.5 (0.1% perm)	14.1	40 (2 in.)	90	....	......	Iz 21		
			-292	4.5 (0.1% perm)	20.8	44 (2 in.)	87	....	......	Iz 27		
285...	Al (commercial)	Hard-drawn (93% red.)	77	....	49.0	2 (2 in.)	32	....	......	....	....	[65]
			-301	....	63.0	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	25.4 (0.1% perm)	47.9	22 (2 in.)	34	....	......	Iz 7.0	Tensile specimens 0.25 in. diam.	[64]
			-40	25.4 (0.1% perm)	49.3	22 (2 in.)	33	....	......	Iz 7.5		
			-112	25.9 (0.1% perm)	50.4	23 (2 in.)	31	....	......	Iz 7.5		
			-184	27.3 (0.1% perm)	55.3	22 (2 in.)	25	....	......	Iz 8.0		
			-292	27.5 (0.1% perm)	62.3	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 (17S-T).	Room	41.5	59.5	22	30	....	R_E 66	15	Long. sample; Charpy impact bar with Izod notch.	[25]
			-105	43.0	61.0	21	23	....	R_E 70	18		
288...	...do	...do	Room	37.0	58.0	16	20	....	R_E 66	8.5	Trans sample; Charpy impact bar with Izod notch.	[25]
			-105	38.5	59.0	19	20	....	R_E 70	10		
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	19 (10 diam)	....	21.8 (2×10^7)	......	....	....	[26]
			-31	....	....	....	....	22.2 (2×10^7)	......	....		
			-85	....	....	....	....	25.6 (2×10^7)	......	....		
290...	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).	Room	52.5	64.5	21	29	....	R_E 74	12	Long. sample; Charpy impact bar with Izod notch.	[25]
			-105	54.5	67.0	18	23	....	R_E 77	14		
291...	...do	...do	Room	48.0	64.0	18	22	....	R_E 74	7.5	Trans sample; Charpy impact bar with Izod notch.	[25]
			-105	50.5	67.5	15	19	....	R_E 77	8		
292...	Cu 3.90, Si 1.23, Mg 0.58, Mn 0.39, Fe 0.32.	Bar, 9/16 in., extruded; h-t (17S-T).	Room	59.0	67.0	14	51	....	139	....	....	[25]
			-40	58.0	69.0	13	52	....	......	....		
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	48.5	61.0	13	25	....	R_E 72	6	Long. sample; Charpy impact bar with Izod notch.	[25]
			-105	49.0	63.0	13	26	....	R_E 77	7.5		

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

Serial number	Composition	Condition	Temperature	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Remarks	Reference
					ALUMINUM-COPPER ALLOYS—Continued							
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
294...	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	47.0	62.0	11	16	....	R_E 72	4.5	Trans sample; Charpy impact bar with Izod notch.	[25]
			-105	47.0	63.0	12	19	....	R_E 77	5		
295...	Cu 4.01, Mn 0.73, Mg 0.57, Fe 0.46, Si 0.23.	Bar, 9/16 in., extruded; 1 1/2 hr at 950°F (17S-T).	Room	12.0	58.0	23	42	....	112	....	....	[25]
			-40	14.5	60.5	24	42	....	......	....		
296...	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.	Room	....	39.5	1.0	....	8.0 (10^8)	121	....	....	[25]
			-40	....	39.5	1.0	....	9.0 (10^8)	115	....		
297...	Cu 4.1, Mn 0.75, Mg 0.57, Fe 0.42.	Rolled............................	Room	50.2	67.2	18 (10 diam)	34	....	135	....	....	[66]
			-422	78.6	103	17 (10 diam)	20	....	......	....		
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 290°F (25S-T).	Room	36.0	56.0	20	32	....	R_E 65	13	Long. sample; Charpy impact bar with Izod notch.	[25]
			-105	37.0	58.0	22	31	....	R_E 70	16		
299...	...do.........................	...do..............................	Room	34.0	56.0	17	22	....	R_E 65	10	Trans sample; Charpy impact bar with Izod notch.	[25]
			-105	34.5	57.5	18	22	....	R_E 70	12		
300...	Cu 4.26, Si 1.29, Fe 1.02.....	Rod, 3/8 in. diam, sand-cast; 12 hr at 955°F, aged 2 hr at 300°F.	Room	....	33.0	....	....	10.0 (5×10^8)	75	....	....	[25]
			-40	....	33.5	....	....	11.0 (5×10^8)	74	....		
301...	Cu 4.27, Mg 1.22, Mn 1.21, Si 0.42, Fe 0.37.	Sheet, 7/16 in....................	68	44.4 (0.2%)	67.4	13	....	....	......	[a]1.0	....	[26]
			-31	....	....	....	....	....	......	[a]1.3		
			-85	....	....	....	....	....	......	[a]1.3		
302...	Cu 4.32, Mg 1.44, Mn 0.18, Fe 0.16, Si 0.14.	Plate, 1/2 in.; w-q from 920°F (24S-T).	Room	48.5	65.5	20	26	....	R_E 74	12	Long. sample; Charpy impact bar with Izod notch.	[25]
			-105	50.0	67.0	21	27	....	R_E 77	12		
303...	...do.........................	...do..............................	Room	42.5	64.5	17	20	....	R_E 74	7.5	Trans sample; Charpy impact bar with Izod notch.	[25]
			-105	45.0	66.5	17	20	....	R_E 77	7		
304...	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-T4).	Room	24.5	33.5	4.5	6.5	....	R_E 82	4	Charpy impact bar with Izod notch....	[25]
			-105	25.5	34.0	5.0	5.5	....	R_E 84	5		
305...	Cu 4.36, Si 0.84, Mn 0.83, Fe 0.34.	Forged propeller blade; w-q from 980°F, aged 12 hr at 300°F (25S).	Room	33.8	58.0	18	24	13.0 (5×10^8)	107	Iz 13	....	[25]
			-40	35.8	62.2	15	26	16.0 (5×10^8)	108	Iz 13		
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	50.5 (0.2%)	68.1	17 (10 diam)	....	23.2 (2×10^7)	......	....	....	[26]
			-31	....	....	....	....	29.5 (2×10^7)	......	....		
			-85	....	....	....	....	26.7 (2×10^7)	......	....		
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 230°F, cold-rolled 5 1/2% red. (25S-RT).	Room	45.0	57.0	16	29	....	R_E 68	10	Long. sample; Charpy impact bar with Izod notch.	[25]
			-105	46.0	58.5	16	28	....	R_E 74	12		
308...	...do.........................	...do..............................	Room	43.0	57.0	10	16	....	R_E 68	7	Trans sample; Charpy impact bar with Izod notch.	[25]
			-105	43.5	58.0	12	19	....	R_E 74	8		

309...	Cu 7.76, Fe 0.18, Si 0.10.....	Rod, 1/2 in. diam, sand-cast.......	Room	....	21.5	3.0	......	7.0 (5×10^8)	65	......	....	[25]
			-40	....	21.5	3.0	......	8.0 (5×10^8)	72	......		
310...	Cu 7.98, Si 0.98, Fe 0.59.....	...do..............................	Room	....	24.5	2.2	......	7.0 (10^8)	82	......	....	[25]
			-40	....	26.5	1.7	......	9.0 (10^8)	89	......		
					ALUMINUM-MAGNESIUM ALLOYS							
311...	Mg 2.35, Cr 0.27, Fe 0.14, Si 0.12, Cu 0.05.	Plate, 1/2 in., rolled (52S).......	Room	21.0	31.5	22	62	....	R_E 68	58	Long. sample; Charpy impact bar with Izod notch.	[25]
			-105	22.0	34.0	29	65	....	R_E 74	58		
312...	...do..........................	...do..............................	Room	21.5	30.5	21	60	....	R_E 68	25	Trans sample; Charpy impact bar with Izod notch.	[25]
			-105	22.0	32.5	25	64	....	R_E 74	26		
313...	Mg 3.66, Mn 0.50, Fe 0.15, Si 0.12, Cu 0.02.	Rod, 1/2 in. diam, sand-cast.......	Room	....	25.0	12	......	6.0 (2×10^8)	58	......	....	[25]
			-40	....	24.5	8.5	......	7.0 (2×10^8)	59	......		
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	14.5 (0.2%)	36.7	24 (10 diam)	......	19.2 (2×10^7)	.....	......	....	[26]
			-31	....	....	....	......	23.9 (2×10^7)	.....	......		
			-85	....	....	....	......	26.7 (2×10^7)	.....	......		
315...	Mg 6.57, Fe 0.70, Mn 0.18, Si 0.11, Ti 0.007.	...do..............................	68	37.3 (0.2%)	51.9	13 (10 diam)	......	25.2 (2×10^7)	.....	......	....	[26]
			-31	....	....	....	......	25.7 (2×10^7)	.....	......		
			-85	....	....	....	......	26.3 (2×10^7)	.....	......		
316...	Mg 7.14, Fe 0.32, Mn 0.22, Si 0.15, Cu 0.01, Ti 0.003.	Sheet, 7/16 in.....................	68	46.4 (0.2%)	59.6	11	......	....	.....	[a]1.3	....	[26]
			-31	....	....	....	......	....	.....	[a]1.5		
			-85	....	....	....	......	....	.....	[a]1.6		
317...	Mg 8.93. Fe 0.44, Mn 0.28, Si 0.12, Cu 0.04, Ti 0.01.	Rod, 19/32 in. diam, extruded......	68	23.6 (0.2%)	50.3	15 (10 diam)	......	20.3 (2×10^7)	.....	......	....	[26]
			-31	....	....	....	......	19.6 (2×10^7)	.....	......		
			-85	....	....	....	......	20.8 (2×10^7)	.....	......		
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-T4).	Room	24.0	35.0	7.5	10	....	R_E 86	6.2	Charpy impact bar with Izod notch....	[25]
			-105	24.0	37.5	8	9	....	R_E 85	2.8		
					ALUMINUM-MANGANESE ALLOY							
319...	Mn 1.04, Fe 0.45, Si 0.14, Cu 0.12.	Plate, 1/2 in., rolled (3S)........	Room	15.5	19.5	30	64	....	R_E 40	36	Long. sample; Charpy impact bar with Izod notch.	[25]
			-105	17.0	23.0	34	66	....	R_E 56	36		
320...	...do..........................	...do..............................	Room	15.0	19.0	30	66	....	R_E 40	33	Trans sample; Charpy impact bar with Izod notch.	[25]
			-105	16.5	23.0	33	66	....	R_E 56	36		

[a]Notch impact value, m-kg/cm.^{2}

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

Serial number	Composition	Condition	Temperature	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Remarks	Reference
	ALUMINUM-SILICON ALLOYS											
	Percent		°F	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
321...	Si 4.71, Fe 0.29, Cu 0.02.....	Rod, 1/2 in. diam, sand-cast.......	Room	....	18.5	11	....	6.0 (2 × 10^8)	45	....	....	[25]
			-40	....	18.5	8.5	....	7.0 (2 × 10^8)	44	....		
322...	Si 4.76, Cu 1.25, Mn 0.49, Fe 0.26.	Rod, 3/4 in. diam, cast; 16 hr at 980°F, w-q to 210°F (355-T4).	Room	25.0	29.0	1.5	1.5	....	R_E 84	1.5	Charpy impact bar with Izod notch....	[25]
			-105	26.5	31.0	2.0	1.5	....	R_E 88	1.8		
323...	Si 5.0, Cu 1.2, Mg 0.5........	Rod, 3/8 in. diam, sand-cast; 16 hr at 980°F, aged 8 hr at 440°F.	Room	....	43.5	....	....	8.0 (10^8)	......	....	....	[25]
			-40	....	43.0	....	....	10.0 (10^8)	......	....		
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	....	....	....	....	....	......	5.7	....	[67]
			32	....	....	....	....	....	......	4.9		
			0	....	....	....	....	....	......	4.8		
325...	Si 6.71, Fe 0.26, Mg 0.25, Cu 0.08.	Rod, 3/4 in. diam, cast; 16 hr at 1,000°F, w-q to 210°F (356-T4).	Room	15.5	24.0	4	4.5	....	R_E 66	2	Charpy impact bar with Izod notch....	[25]
			-105	16.0	24.5	3.5	5	....	R_E 70	2		
326...	Si 11.58, Fe 1.25, Zn 0.28, Cu 0.12, Mn 0.08, Mg 0.03.	Die-cast..........................	70	....	....	....	....	....	......	3.8	....	[67]
			32	....	....	....	....	....	......	3.7		
			0	....	....	....	....	....	......	3.5		

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

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade: 20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 500°C	20° to 600°C	Reference
	PURE AND COMMERCIAL ALUMINUM								
	Percent		$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	
327[a]	Al 99.997	Bar, full anneal	23.9	24.3	25.3	26.5	...	...	[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	...	[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	...	[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	...	[70]
333	Be 27.5, Fe 0.58, Si 0.10, Cu 0.08, Mn 0.05	...do	19.0	20.0	21.1	21.9	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	...	[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	...	[707]
338	Cu 2.47	Cast; stabilized at 225°C, a-c	22.8	23.6	24.2	...	...	...	[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	...	...	...	[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	...	[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	...	[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	...	[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	...	[707]
344	Cu 4.0, Ni 2.0, Mg 1.5	Cast	22.5	...	24.4	...	...	...	[69]
345	Cu 4.41, Si 3.75, Fe 0.57	Sand-cast, f-c from 400°C	22.4	23.4	24.1	...	...	...	[707]
346	Cu 4.5, Mn 0.8, Mg 0.35	...	22	23.5	25	...	...	...	[71]
347	Cu 4.82, Fe 0.41, Mn 0.14, Zn 0.096	Sand-cast	22.9	23.7	25.5	25.7	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	...	...	...	[71]
349	Cu 5.81, Fe 0.42, Si 0.36	Sand-cast	23.8	24.9	27.8	27.8	28.0	...	[707]
350	Cu 6.58, Fe 0.79, Sn 0.52, Zn 0.39, Si 0.25, Mn 0.22	...do	23.1	24.0	25.8	26.4	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	...	...	...	[707]
352	Cu 7.75, Si 1.25, Fe 1.00	Sand-cast	23.5	...	28.0	...	...	...	[69]
353	Cu 7.87, Fe 0.45, Si 0.33, Mn 0.22	...do	23.4	26.8	28.0	26.6	27.2	...	[707]
354	Cu 7.88, Ni 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	...	...	...	[71]
355	Cu 9.77, Fe 5.04, Si 0.06	Cast; stabilized at 225°C, a-c	19.9	20.8	21.5	...	...	...	[71]
356	Cu 9.78, Ni 5.04	...do	20.5	21.5	22.2	...	...	...	[71]
357	Cu 9.86, Si 0.04, Fe 0.03	...do	22.0	23.0	23.8	...	...	...	[71]
358	Cu 9.88, Fe 1.06, Si 0.07	...do	21.2	21.9	22.7	...	...	...	[71]
359	Cu 11.88, Fe 0.43, Si 0.39	Sand-cast	22.4	24.1	28.6	27.5	27.6	...	[707]
360	Cu 14.14, Si 8.31, Fe 0.81	Cast; 1 hr at 400°C, a-c	19.6	20.1	21.0	...	...	...	[71]
361	Cu 20	Cast; stabilized at 225°C, a-c	21.2	21.7	22.3	...	...	...	[71]
362	Cu 33.20	...do	19.7	20.2	20.8	...	...	...	[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).

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

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade: 20° to 100°C	20° to 200°C	20° to 300°C	20° to 400°C	20° to 500°C	20° to 600°C	Ref-er-ence
	ALUMINUM-IRON ALLOYS								
	Percent		$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	
363	Fe 0.70, Cu 0.05, Si 0.03	Cast; stabilized at 225°C, a-c	22.6	23.1	24.4	...	...	...	[71]
364	Fe 3.59, Ni 3.26, Cu 0.064, Si 0.063	...do	20.7	21.6	22.5	...	...	...	[71]
365	Fe 8.45, Ni 3.09, Si 0.084, Cu 0.036	...do	19.5	20.3	21.2	...	...	...	[71]
	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	Mn 1.05, Fe 0.57, Si 0.41, Cu 0.19	Sheet, 1/4 in., rolled	23.8	25.7	25.9	26.5	27.5	28.6	[707]
368	Mn 1.80, Fe 0.84, Si 0.40, Cu 0.23	Sand-cast	23.1	24.2	25.5	25.9	27.0	27.9	[707]
369	Mn 3.66, Fe 0.18, Si 0.10	Cast; 20 hr at 225°C, a-c	20.7	22.2	23.1	...	...	...	[71]
	ALUMINUM-NICKEL ALLOYS								
370	Ni 1.5, Cr 1.5, Cu 1.0, Mn 0.5	Cast	23.2	24.2	25.8	...	...	...	[707]
371	Ni 3.36, Cu 0.11, Fe 0.08, Si 0.06	Cast; stabilized at 225°C, a-c	21.9	22.7	23.7	...	...	...	[71]
372	Ni 7.46, Mg 1.33, Fe 0.15, Si 0.1, Cu 0.02	...do	21.5	22.3	23.5	...	...	...	[71]
373	Ni 9.86, Cu 4.51	...do	19.9	20.9	21.6	...	...	...	[71]
374	Ni 19.53, Fe 0.08, Cu 0.07, Si 0.05	...do	18.2	18.9	19.5	...	...	...	[71]
	ALUMINUM-SILICON ALLOYS								
375	Si 3.12, Cu 2.4, Mn 0.93, Fe 0.55	Sand-cast; f-c from 400°C	22.2	23.4	23.8	...	...	...	[707]
376	Si 3.33, Cu 2.2, Fe 0.55, Mn 0.01	...do	23.4	23.9	24.4	...	...	...	[707]
377	Si 4.15, Fe 0.52, Cu 0.33	...do	22.2	23.2	24.1	...	...	...	[707]
378	Si 4.71, Fe 0.06, Cu 0.035	Cast; stabilized at 225°C, a-c	21.8	22.4	23.5	...	...	...	[71]
379	Si 6.61, Cu 4.53, Fe 0.57	Sand-cast; f-c from 400°C	21.5	22.3	23.1	...	...	...	[707]
380	Si 7.28, Fe 0.47, Cu 0.27	...do	21.8	22.8	23.5	...	...	...	[707]
381	Si 7.42, Cu 2.43, Fe 0.53	...do	21.7	22.5	23.4	...	...	...	[707]
382	Si 9.45, Cu 6.29, Fe 0.53	...do	20.6	21.6	22.2	...	...	...	[707]
383	Si 9.81, Fe 0.50, Cu 0.22	...do	21.1	21.9	22.9	...	...	...	[707]
384	Si 10.18, Cu 2.47, Mn 1.17, Fe 0.70	...do	20.4	21.5	22.3	...	...	...	[707]
385	Si 10.23, Cu 9.78, Ni 3.91, Fe 0.42	Cast; 1 hr at 400°C, a-c	18.8	19.1	20.2	...	...	...	[708]
386	Si 10.28, Cu 4.58, Fe 0.54	Sand-cast; f-c from 400°C	20.4	21.3	22.1	...	...	...	[707]
387	Si 12.55, Fe 0.56, Cu 0.08	...do	19.4	21.5	24.8	24.8	24.7	...	[707]
388	Si 13.19, Cu 8.02, Ni 4.10, Fe 0.80	Cast; 1 hr at 400°C, a-c	18.0	18.7	19.3	...	...	...	[708]
389	Si 13.22, Ni 4.12, Cu 4.05, Fe 0.78	...do	18.5	18.9	19.8	...	...	...	[708]
390	Si 13.34, Cu 4.03, Fe 0.82	...do	19.8	20.6	21.4	...	...	...	[708]
391	Si 13.35, Cu 7.91, Fe 0.74	...do	19.4	20.1	20.9	...	...	...	[708]
392	Si 13.51, Ni 1.93, Mg 0.99, Cu 0.85, Fe 0.5	Cast; 20 hr at 225°C, a-c	19.0	20.2	21.0	...	...	...	[71]
393	Si 14.0, Ni 4.12, Cu 2.08, Mg 1.32, Fe 0.5	...do	18.3	19.0	19.7	...	...	...	[71]
394	Si 14.83, Fe 0.12, Cu 0.09	Cast; stabilized at 225°C, a-c	19.3	19.9	20.6	...	...	...	[71]
395	Si 19.30, Ni 4.18, Cu 3.14, Mn 1.08, Fe 0.84	Cast; 1 hr at 400°C, a-c	16.6	17.0	17.8	...	...	...	[708]
396	Si 19.70, Fe 0.16, Cu 0.10	Cast; stabilized at 225°C, a-c	18.5	18.7	19.0	...	...	...	[71]
397	Si 20.29, Cu 3.18, Mn 1.07, Fe 0.96	Cast; 1 hr at 400°C, a-c	17.4	18.0	18.8	...	...	...	[708]
398	Si 40	Cast; stabilized at 225°C, a-c	14.7	16.0	17.1	...	...	...	[71]

ALUMINUM-ZINC ALLOYS

399....	Zn 12.17, Cu 1.47, Fe 0.31, Si 0.21, Mn 0.01..........	Rolled and drawn..........................	24.3	28.1	27.9	27.6	28.6	....	[707]
400....	Zn 13.50, Cu 2.75....................................	Cast......................................	24.0	....	28.0	....	....	....	[69]
401....	Zn 25..	....	26.1	27.0	28.0	29.1	....	....	[72]
402....	Zn 37.5..	....	26.6	27.5	30.3	....	....	....	[72]
403....	Zn 50..	....	26.5	27.6	33.7	....	....	....	[72]

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

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Thermal properties: Conductivity	Thermal properties: Temperature coefficient of conductivity	Reference
	PURE AND COMMERCIAL ALUMINUM (SEE ALSO FIG. 27)						
	Percent		*Percent IACS*	*Microhm cm*	*Watts cm^{-1} °C^{-1}*	*per °C × 10^{-4}*	
404[a]..	Si 0.0020, Cu 0.0010, Ca 0.0003, Mg 0.0003, Na 0.0003, Fe 0.0001.	Sheet, 0.064 in., 4 hr at 200°C	64.94 (20°C)	2.6548 (20°C)	...	...	[12]
405...	(Fe + Cu) <0.05, Si 0.02	Sand-cast; 2 days at 495°C, cold w-q, 100 days at 200°C	64.3	2.68	...	...	[74]
406...	Si 0.14, (Fe + Cu) <0.05	Sand-cast; 2 days at 495°C, cold w-q	60.56	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	60.97 (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)	[c]1.38 (25°C)	...	[75]
416...	...do	Sand-cast; h-t (195-T4, ann)	50.7 (20°C)	3.40 (20°C)	[c]1.93 (25°C)	...	[75]
417...	Cu 4, Ni 2, Mg 1.5	Chill-cast; soln h-t, quenched, aged (142-T61)	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)	[c]1.21 (25°C)	...	[75]
419...	...do	Sand-cast; ann (108)	37.7 (20°C)	4.57 (20°C)	[c]1.46 (25°C)	...	[75]
420...	Cu 4, Ni 1, Si 2	Die-cast (93)	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°–200°C)	[75]
423...	Cu 4.5, Mn 0.8, Si 0.8	Forged; h-t (25S-T)	38.6 (20°C)	4.47 (20°C)	[c]1.5 (25°C)	...	[75]
424...	...do	Forged; h-t (25S-T, ann)	52.2 (20°C)	3.30 (20°C)	[c]2.01 (25°C)	...	[75]
425...	Cu 7.0, Si 1.5, Fe 1.2	Chill-cast (B113)	28.9 (20°C)	5.96 (20°C)	[c]1.17 (25°C)	...	[75]
426...	...do	Chill-cast; ann (B113)	36.4 (20°C)	4.74 (20°C)	[c]1.42 (25°C)	...	[75]
427...	...do	Chill-cast; h-t (B113-T4)	29.5 (20°C)	5.84 (20°C)	[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 (C113)	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)	[c]1.21 (25°C)	...	[75]
432...	...do	Sand-cast; ann (112)	37.9 (20°C)	4.55 (20°C)	[c]1.46 (25°C)	...	[75]
433...	...do	Sand-cast; soln h-t, quenched, (112-T4)	27.2 (20°C)	6.35 (20°C)	[c]1.09 (25°C)	...	[75]
434...	...do	Sand-cast; h-t (112-T6)	28.7 (20°C)	6.00 (20°C)	[c]1.17 (25°C)	...	[75]
435...	...do	Chill-cast (112)	32.1 (20°C)	5.37 (20°C)	[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]

439...	Cu 12.0	Sand-cast	35.8 (20°C)	1.81 (20°C)	[c]1.42 (25°C)	...	[75]
440...	...do	Sand-cast; ann	44.9 (20°C)	3.84 (20°C)	[c]1.72 (25°C)	...	[75]
441...	Cu 15.46	Chill-cast	...	...	1.51 (30°-100°C) 1.57 (60°-270°C)	...	[78]
442...	...do	Chill-cast; 24 hr at 500°C, f-c	...	...	1.83 (30°-100°C) 1.76 (60°-270°C)	...	[78]
443...	Cu 20.08	...do	...	...	1.75 (30°-100°C) 1.77 (60°-270°C)	...	[78]
444...	Cu 25.6	...do	...	...	1.65 (30°-100°C) 1.69 (60°-270°C)	...	[78]
445...	Cu 30.46	...do	...	...	1.62 (30°-100°C) 1.59 (60°-270°C)	...	[78]
		ALUMINUM-MAGNESIUM ALLOYS					
446...	Mg 2.5, Cr 0.25	Forged (52S)	47.2 (20°C)	3.65 (20°C)	[c]1.80 (25°C)	...	[75]
447...	...do	Forged; ann (52S)	57.3 (20°C)	3.01 (20°C)	[c]2.18 (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)	[c]0.88 (25°C)	...	[75]
451...	...do	Sand-cast; h-t (220-T4)	20.3 (20°C)	8.49 (20°C)	[c].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) 2.14 (200°C)	1.2 (25°-200°C)...	[75]
453...	Si 1.0, Mg 0.6, Cr 0.25	Forged; h-t (A51S-T)	46.7 (20°C)	3.69 (20°C)	[c]1.80 (25°C)	...	[75]
454...	...do	Forged; h-t (A51S-T, ann)	55.6 (20°C)	3.10 (20°C)	[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 (A334)	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)	[c]1.42 (25°C)	...	[75]
458...	...do	Sand-cast; ann (43)	41.7 (20°C)	4.13 (20°C)	[c]1.63 (25°C)	...	[75]
459...	...do	Chill-cast (43)	40.9 (20°C)	4.22 (20°C)	[c]1.59 (25°C)	...	[75]
460...	...do	Chill-cast; ann (43)	48.3 (20°C)	3.57 (20°C)	[c]1.84 (25°C)	...	[75]
461...	Si 5.0, Cu 1.25, Mg 0.5	Sand-cast; h-t (355-T4)	34.9 (20°C)	4.91 (20°C)	[c]1.38 (25°C)	...	[75]
462...	...do	Sand-cast; h-t (355-T4, ann)	45.4 (20°C)	3.80 (20°C)	[c]1.76 (25°C)	...	[75]
463...	...do	Sand-cast; h-t (355-T6)	35.5 (20°C)	4.85 (20°C)	[c]1.38 (25°C)	...	[75]
464...	...do	Sand-cast; h-t (355-T61)	37.2 (20°C)	4.64 (20°C)	[c]1.46 (25°C)	...	[75]
465...	Si 5, Cu 4	Die-cast (85)	28 (20°C)	6.2 (20°C)	1.13 (20°C)	...	[10]
466...	Si 5.04, Cu 0.95, Fe 0.36, Mg 0.31	Sand-cast; soln h-t, quenched, aged at r-t, 2 hr at 370°C, slowly cooled.	47.0 (20°C)	3.67 (20°C)	1.90 (25°C) 1.95 (200°C)	1.3 (25°-200°C)...	[75]
467...	Si 5.5, Cu 4.5	Chill-cast (A108)	37 (20°C)	4.7 (20°C)	1.42 (20°C)	...	[10]
468...	Si 7.0, Mg 0.3	Sand-cast; h-t (356-T4)	38.3 (20°C)	4.50 (20°C)	[c]1.51 (25°C)	...	[75]
469...	...do	Sand-cast; h-t (356-T4, ann)	48.8 (20°C)	3.53 (20°C)	[c]1.88 (25°C)	...	[75]
470...	...do	Sand-cast; h-t (356-T6)	38.8 (20°C)	4.44 (20°C)	[c]1.51 (25°C)	...	[75]
471...	...do	Sand-cast; h-t (356-T51)	42.4 (20°C)	4.07 (20°C)	[c]1.68 (25°C)	...	[75]
472...	...do	Chill-cast; h-t (356-T4)	39.0 (20°C)	4.42 (20°C)	[c]1.51 (25°C)	...	[75]
473...	...do	Chill-cast; h-t (356-T4, ann)	49.1 (20°C)	3.51 (20°C)	[c]1.88 (25°C)	...	[75]
474...	...do	Chill-cast; h-t (356-T6)	40.5 (20°C)	4.26 (20°C)	[c]1.59 (25°C)	...	[75]
475...	Si 10.0	Sand-cast (45)	30.7 (20°C)	5.62 (20°C)	[c]1.21 (25°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.	42.8 (20°C)	4.03 (20°C)	1.78 (25°C) 1.75 (200°C)	-0.9 (25°-200°C)...	[75]
477...	Si 12.0, Mg 1.0, Cu 0.8, Ni 0.8	Forged; h-t (32S-T)	35.8 (20°C)	4.82 (20°C)	[c]1.42 (25°C)	...	[75]
478...	...do	Forged; h-t (32S-T, ann)	42.6 (20°C)	4.05 (20°C)	[c]1.63 (25°C)	...	[75]
479...	Si 13	Sand-cast (47)	40 (20°C)	4.3 (20°C)	1.55 (25°C)	...	[409]
480...	...do	Die-cast (13)	36 (20°C)	4.8 (20°C)	1.38 (25°C)	...	[409]

[a] Constant mass temperature coefficient of electrical resistivity at 20°C is 42.9×10^{-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 40.3×10^{-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		Reference
			Volume conductivity	Resistivity	Conductivity	Temperature coefficient of conductivity	
	ALUMINUM-SILICON ALLOYS—Continued						
	Percent		*Percent IACS*	*Microhm cm*	*Watts* cm^{-1} $°C^{-1}$	*per* $°C \times 10^{-4}$	
481...	Si 13.80, Ni 2.45, Mg 1.18, Fe 1.09, Cu 0.75..........	Chill-cast; 2 hr at 370°C, slowly cooled...............	27.2 (20°C)	6.35 (20°C)	1.36 (25°C) 1.39 (200°C)	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]

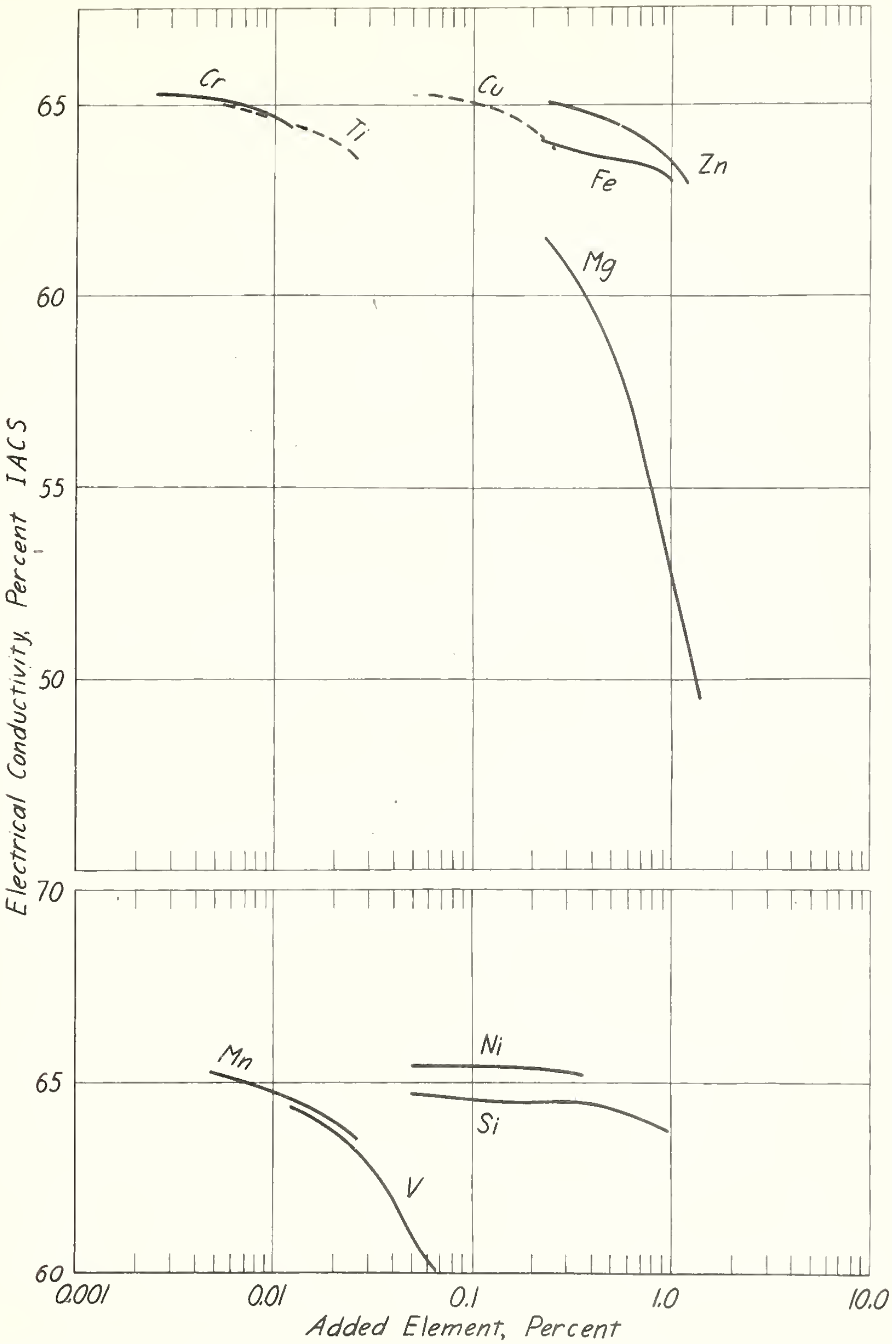


FIGURE 27.—*Effect of various elements on the electrical conductivity of high-purity aluminum (Gauthier [639]).*

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

VI. COPPER AND COPPER ALLOYS

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 lead 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*[a]

[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		
QQ-C-521a			Copper[b]	Not over 2 percent total of other elements	490, 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.
QQ-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, 1097, 1100, 1110, 1148, 1228, 1376, 1377, 1378.
QQ-B-601		44	Semi-red brass	8 to 17 percent zinc; tin less than 6 percent; lead less than 0.5 percent.	1229.
QQ-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.
QQ-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.
QQ-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.
QQ-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.	992, 993, 995, 997, 999, 1001, 1007, 1008, 1025, 1026, 1028, 1077, 1078, 1125, 1233, 1238.
	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		
QQ-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, 892, 896 to 899, inclusive; 925 to 928, inclusive; 1104 to 1107, inclusive; 1147, 1206, 1209, 1217, 1222, 1225, 1226, 1361, 1364.
QQ-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.
QQ-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, 689, 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.
QQ-B-671a, QQ-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, 1264, 1265, 1266, 1268.

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

[b] Includes alloys such as cadmium 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	Class	Addition elements	
			BRONZES—Continued		
QQ-C-593.....	....	....	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 Spec	Federal Alloy	ASTM Spec	ASTM Alloy	SAE Spec	SAE Alloy	Cu	Zn	Sn	Pb	Fe	Mn	Ni	Al	Other	Serial numbers of corresponding alloys in the tables
						Nominal composition—percent									
						BARS, RODS, WIRE, AND SHAPES									
QQ-C-501	.....	B5-27	.....	....	.....	99.9	.....	.....	.....	.....	.....	.....	.....	....	484 to 489, inclusive; 491, 492, 496, 497, 498, 501 to 505, inclusive; 510, 511, 1082, 1083, 1127, 1163, 1164, 1243, 1244; 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]Cd 1.5, [b]Si 3.0	645, 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; 900 to 903, inclusive; 1095, 1145, 1204, 1250 to 1254, inclusive; 1288 to 1294, inclusive; 1346, 1347, 1349, 1351, 1352.
QQ-B-666	B	B150-41T	.....	701	.....	78-93	.....	[b]0.6	.....	[b]4.0	[b]2.0	[b c]5.5	6.5-11	[b c]Si 2.25	535 to 538, inclusive; 542, 543, 546, 552, 555, 557, 558, 559, 573, 574, 584, 587, 1129, 1130, 1166, 1167, 1260, 1263; figures 37 and 38.
....	.....	B120-41T	.....	....	.....	rem	.....	.....	.....	.....	.....	.....	.....	[d]Be 2.0	636 to 640, inclusive; 1131 to 1135, inclusive; 1170, 1282 to 1285, inclusive.
QQ-N-321	A	B151-41T	A	....	.....	65	17	.....	.....	.....	.....	18	.....	....	776, 777, 1326; figure 61.
QQ-C-591a	B	B98-41	B	....	.....	96	[b]1.5	[b]1.6	.....	[b]0.8	[b]0.75	.....	.....	Si 1.5	813 to 817, inclusive; 917, 918, 1340.
....	.....	B98-41	A	....	.....	94.8	[b]1.5	[b]0.75	.....	1.6	[b]1.5	.....	.....	Si 3.0	806, 807, 821, 822, 1092, 1093, 1094, 1113.
QQ-C-591a	D	B98-41	D	....	.....	94.0	[b]1.5	.....	0.5	.....	[b]1.5	.....	.....	Si 3.0	....
QQ-C-591a	A	B98-41	C	....	.....	91.0	[b]4.5	.....	.....	[a]0.8	[b]1.25	.....	.....	Si 2.5	....
QQ-B-746	A	B139-41T	A	81	.....	rem	.....	5.0	.....	.....	.....	.....	.....	[b]P 0.35	881, 1096, 1098, 1099, 1116, 1355 to 1358, inclusive; figures 48, 49, 66.
....	.....	B139-41T	B1	....	.....	rem	.....	5.0	1.0	.....	.....	.....	.....	[b]P 0.35	....
....	.....	B139-41T	B2	....	.....	rem	3.75	4.0	4.0	.....	.....	.....	.....	[b]P 0.5	904, 1374.
QQ-B-746	A	B139-41T	C	....	.....	rem	.....	8.0	.....	.....	.....	.....	.....	[b]P 0.5	887 to 890, inclusive; 1359, 1360.
QQ-B-746	B	B139-41T	D	....	.....	rem	.....	10.0	.....	.....	.....	.....	.....	[b]P 0.5	893, 894, 1362, 1363; figure 48.
....	.....	B134-41T	1	....	.....	95	5	.....	.....	.....	.....	.....	.....	....	1375.
....	.....	B134-41T	2	....	.....	90	10	.....	.....	.....	.....	.....	.....	....	939, 940; figure 67.
....	.....	B134-41T	3	....	.....	85	15	.....	.....	.....	.....	.....	.....	....	944, 947, 1108, 1109.
....	.....	B140-41T	B	....	.....	89	rem	.....	1.75	.....	.....	.....	.....	....	1010, 1379, 1380.
....	.....	B140-41T	A	....	.....	85	rem	.....	2.0	.....	.....	.....	.....	....	1011, 1381.
....	.....	B134-41T	4	....	.....	80	20	.....	.....	.....	.....	.....	.....	....	948, 951, 952; figures 56 and 67.
QQ-W-321	C	B134-41T	5	80	A	72	28	.....	.....	.....	.....	.....	.....	....	955, 1236.
QQ-W-321	C	B134-41T	6	....	.....	70	30	.....	.....	.....	.....	.....	.....	....	962, 963, 1113 to 1118, inclusive; 1151; figures 57 and 68.
QQ-B-611 / QQ-W-321	C / A&B	B134-41T	7	80	B	65	35	.....	.....	.....	.....	.....	.....	....	970, 971, 975, 1237, 1393, 1394; figure 68.
....	.....	B134-41T	8	....	.....	62	38	.....	.....	.....	.....	.....	.....	....	979, 986, 981; figure 68.
QQ-B-721a	B	B138-41T	B	....	.....	65.5	23.3	.....	.....	3.0	3.7	.....	4.3	....	....
QQ-N-321	B	B151-41T	C	....	.....	62	19	.....	1.0	.....	.....	18	.....	....	775.
QQ-B-636	.....	B21-40T	.....	73	.....	60	rem	0.75	.....	.....	.....	.....	.....	....	1074, 1075, 1076, 1119, 1120, 1123, 1158, 1239.
QQ-B-611a	B	B16-41	.....	72	.....	60	rem	.....	3.0	.....	.....	.....	.....	....	1017, 1021, 1022, 1122, 1124.
....	.....	B138-41T	A	....	.....	58.5	39	1.0	.....	1.4	.....	.....	.....	....	1006, 1080, 1156, 1397.
....	.....	B151-41T	B	....	.....	55	27	.....	.....	.....	.....	18	.....	....	776, 777.
						SHEET, STRIP, AND PLATE									
QQ-C-501	.....	B152-41T	A	71	.....	99.9	.....	.....	.....	.....	.....	.....	.....	....	493, 494, 495.
QQ-C-501	.....	B152-41T	B	71	.....	99.9	.....	.....	.....	.....	.....	.....	.....	[b]P 0.04	....
QQ-C-501	.....	B152-41T	C	71	.....	99.9	.....	.....	.....	.....	.....	.....	.....	....	....
....	.....	B152-41T	E	....	.....	99.45	.....	.....	.....	.....	.....	.....	.....	[b]As 0.5	....
....	.....	B120-41T	.....	....	.....	rem	.....	.....	.....	.....	.....	.....	.....	[d]Be 2.0	618 to 621, inclusive; 624, 641 to 644, inclusive.
QQ-C-591a	B	B97-41	B	....	.....	96.0	[b]1.5	[b]1.6	.....	[b]0.8	[b]0.75	.....	.....	Si 1.5	....
....	.....	B97-41	A	....	.....	94.8	[b]1.5	[b]0.75	.....	[b]1.6	[b]1.5	[b]0.6	.....	Si 3.0	803, 808, 809, 818, 819, 820, 824, 830.
QQ-C-591a	A	B97-41	C	....	.....	91.0	[b]4.5	.....	.....	[b]0.8	[b]1.25	[b]0.6	.....	Si 2.5	....
QQ-B-716	A	....	.....	77	A	rem	.....	5.0	.....	.....	.....	.....	.....	[b]P 0.35	877, 882.
....	.....	....	.....	77	C	rem	.....	8.0	.....	.....	.....	.....	.....	[b]P 0.25	884, 885.
....	.....	B36-41T	1	....	.....	95	5	.....	.....	.....	.....	.....	.....	....	935 to 938, inclusive.
....	.....	B36-41T	2	....	.....	90	10	.....	.....	.....	.....	.....	.....	....	943.
....	.....	B36-41T	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 9.—*Classification of some wrought copper-base alloys (1942)*—Continued

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	
SHEET, STRIP, AND PLATE—Continued															
....	.....	B36-41T	4	79	B	80	20	.....	.....	.....	.....	.....	......	....	949.
QQ-B-611a......	E	B36-41T	5	....	.....	72	28	.....	.....	.....	.....	.....	......	....	956, 957.
QQ-B-611a......	E	B36-41T	6	70	A	70	30	.....	.....	.....	.....	.....	......	....	958 to 961, inclusive.
QQ-B-611a......	C	B36-41T	7	70	B	67	33	.....	.....	.....	.....	.....	......	....	968, 969.
QQ-B-611a......	C	B36-41T	8	70	C	65	35	.....	.....	.....	.....	.....	......	....	972, 973, 976, 977.
....	.....	B121-41T	1	....	.....	90	9.5	.....	0.5	.....	.....	.....	......	....	....
QQ-B-611a[e].....	D	B121-41T	7	....	.....	67	29.0	.....	4.0	.....	.....	.....	......	....	....
QQ-B-611a......	C	B121-41T	2	....	.....	65	34.55	.....	0.45	.....	.....	.....	......	....	....
....	.....	B121-41T	3	....	.....	65	34.1	.....	0.9	.....	.....	.....	......	....	....
QQ-B-611a[e].....	D	B121-41T	6	....	.....	64	33.5	.....	2.5	.....	.....	.....	......	....	....
QQ-B-611a[e].....	D	B121-41T	4	....	.....	63	35.25	.....	1.75	.....	.....	.....	......	....	1018.
QQ-B-611a[e].....	D	B121-41T	5	....	.....	63	35.0	.....	2.0	.....	.....	.....	......	....	....

[e] Tin also specified as 1.50 percent maximum.

TABLE 10.—*Temper designations for copper alloys*[1]

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)
		Percent	*Percent*			*Percent*	*Percent*
1/8 hard	1/2	5.5	10.9	Hard	4	37.1	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

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

TABLE 11.—*Hardness conversion table for cartridge brass* (Cu 70%, Zn 30%) [85]

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	500-kg load, 10-mm ball		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	500-kg load, 10-mm 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	...	62.5	43.0	110
48	...	47.0	53.5	...	...	45	126	70.0	97.0	83.5	63.0	44.0	112
49	...	49.0	54.5	...	...	46	128	71.0	97.5	...	63.5	45.0	113
50	...	50.5	55.5	...	...	47	130	72.0	98.0	84.0	64.5	45.5	114
52	...	53.5	57.0	...	...	48	132	73.0	98.5	84.5	65.0	46.5	116
54	...	56.5	58.5	12.0	...	50	134	73.5	99.0	...	65.5	47.5	118
56	...	58.8	60.0	15.0	...	52	136	74.5	99.5	85.0	66.0	48.0	120
58	...	61.0	61.0	18.0	...	53	138	75.0	100.0	...	66.5	49.0	121
60	10.0	63.0	62.5	20.5	...	55	140	76.0	100.5	85.5	67.0	50.0	122
62	12.5	65.0	63.5	23.0	...	57	142	77.0	101.0	...	67.5	51.0	124
64	15.5	66.8	65.0	25.5	...	59	144	77.5	101.5	86.0	68.0	51.5	126
66	18.5	68.5	66.0	28.0	...	61	146	78.0	102.0	...	68.5	52.5	128
68	21.5	70.0	67.0	30.0	...	62	148	79.0	102.5	...	69.0	53.0	129
70	24.5	71.8	68.0	32.0	...	63	150	80.0	...	86.5	69.5	53.5	131
72	27.5	73.2	69.0	34.0	...	64	152	80.5	103.0	...	...	54.0	133
74	30.0	74.8	70.0	36.0	1.0	66	154	81.5	103.5	...	70.0	54.5	135
76	32.5	76.0	70.5	38.0	4.5	68	156	82.0	104.0	87.0	70.5	55.5	136
78	35.0	77.4	71.5	39.5	7.5	70	158	83.0	104.5	...	71.0	56.0	138
80	37.5	78.6	72.0	41.0	10.0	72	160	83.5	...	...	71.5	56.5	139
82	40.0	80.0	73.0	43.0	12.5	74	162	84.0	105.0	87.5	...	57.5	141
84	42.0	81.2	73.5	44.0	14.5	76	164	85.0	105.5	...	72.0	58.0	142
86	44.0	82.3	74.5	45.5	17.0	77	166	85.5	...	...	72.5	58.5	144
88	46.0	83.5	75.0	47.0	19.0	79	168	86.0	106.0	88.0	73.0	59.0	146
90	47.5	84.4	75.5	48.0	21.0	80	170	87.0	...	...	...	59.5	147
92	49.5	85.4	76.5	49.0	23.0	82	172	87.5	106.5	...	73.5	60.0	149
94	51.0	86.3	77.0	50.5	24.5	83	174	88.0	...	88.5	74.0	60.5	150
96	53.0	87.2	77.5	51.5	26.6	85	176	88.5	107.0	...	...	61.0	152
98	54.0	88.0	78.0	52.5	28.0	86	178	89.0	...	...	74.5	61.5	154
100	56.0	89.0	78.5	53.5	29.5	88	180	90.0	107.5	...	75.0	62.0	156
102	57.0	89.8	79.0	54.5	30.5	90	182	90.5	108.0	89.0	...	62.5	157
104	58.0	90.5	79.5	55.0	32.0	92	184	91.0	...	...	75.5	63.0	159
106	59.5	91.2	80.0	56.0	33.0	94	186	91.5	108.5	...	76.0	63.5	161
108	61.0	92.0	...	57.0	34.5	95	188	92.0	...	89.5	...	64.0	162
110	62.0	92.6	80.5	58.0	35.5	97	190	92.5	109.0	...	76.5	64.5	164
112	63.0	93.0	81.0	58.5	37.0	99	192	93.0	...	...	77.0	65.0	166
114	64.0	94.0	81.5	59.5	38.0	101	194	...	109.5	...	...	65.5	167
116	65.0	94.5	82.0	60.0	39.0	103	196	93.5	110.0	90.0	77.5	66.0	169
118	66.6	95.0	82.5	60.5	40.0	105							

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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	PURE AND COMMERCIAL COPPER (SEE ALSO FIGS. 28 TO 33, INCLUSIVE)												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
483...	[1] Cu 99.999 minimum..	Wire, 0.24 in. diam; ann 1/2 hr at 1,110°F.	....	....	....	32	75 (2 in.)	......	....	....	....	Density (68°F)..................8.9592 g/cm³...	[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 (3×10^8)	R_B 37	....	....	[82]
485...	Oxygen-free copper (OFHC): Cu 99.996, S 0.002, Fe 0.002.	Rod, 3/4 in. diam, ann 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, Ni 0.0005.	Rod, hard-drawn.......	18,300	4.9	18.1 (0.01%)	11.4	29 ($4\sqrt{\text{area}}$)	......	....	....	....	....	[24]
488...	...do.............	Rod, ann 1 hr at 390°F.	18,700	7.6	20.2 (0.01%)	10.8	28 ($4\sqrt{\text{area}}$)	......	....	....	....	....	[24]
489...	...do.............	Rod, ann 1 hr at 930°F.	17,300	0.8	3.4 (0.01%)	30.7	62 ($4\sqrt{\text{area}}$)	......	....	....	....	....	[24]
490...	Oxygen-free copper (OFHC).	Bar, 2 1/2 in. diam, cast from 2,075°F.	....	....	14	23	45 (2 in.)	57	....	, 38	Iz 31	Comp str (65%)..................323 kips/in.².. Specific gravity................8.90.	[84]
491...	Tough-pitch copper: Cu 99.950, O_2 0.043, Fe 0.002, S 0.002.	Rod, 3/4 in. diam, ann 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 (10^8)	....	....	....	[20]
494...	...do.............	Sheet, 0.020 in., cold-worked (21% red.).	....	15.9	....	44.4	7.8 (2 in.)	......	13.0 (10^8)	R_B 33	....	....	[20]
495...	...do.............	Sheet, 0.020 in., cold-worked (50% red.).	....	14.7	....	52.6	2.2 (2 in.)	......	14.0 (10^8)	R_B 55	....	....	[20]
496...	Tough-pitch copper: Cu 99.948, O_2 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 (3×10^8)	R_B 47	....	....	[82]

[1] Determination 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: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	PURE AND COMMERCIAL COPPER—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
497...	Cu 99.94, O_2 0.030, Pb 0.014, Fe 0.003.	Rod, ann 1/2 hr at 1,200°F.	......	<0.9	......	31.1	60 $(4\sqrt{\text{area}})$	......	......	......	......	......	[24]
498...	...do......	Rod, drawn (37% red.)..	17,200	4.9	14.3 (0.01%)	37.0	32 $(4\sqrt{\text{area}})$	......	......	......	......	......	[24]
499...	Cu 99.895......	Rod, 3/4 in. diam, ann 1/2 hr at 1,290°F.	......	3.2	......	32.4	56 (2 in.)	72	10.0 (10^8)	47	30	......	[38]
500...	...do......	Rod, 1/2 in. diam, cold-drawn (56% red.).	......	38.4	......	56.2	6.5 (2 in.)	52	10.0 (10^8)	104	16	......	[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 0.0058, Pb <0.002.	Rod, 1 in. diam, hot-rolled.	13,300	......	6.5 (0.01% perm)	31.4	59 (2 in.)	72	[b]4.0	41	......	Torsion str......29.9 kips/in.²... Shear str......33.9 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	45	......	......	[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; recompacted 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)......6,000-6,800 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 (10^8) [b]10.0 (10^8) [c]19.0 (10^8)	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 saltpeter.	....	....	....	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 ($4\sqrt{area}$)	......	....	......	....	....	[24]
514...	...do............	Rod, 1 in. diam, cold-drawn (10% red.), ann 2 hr at 570°F.	19,200	7.2	....	35.2	51 ($4\sqrt{area}$)	......	....	......	....	....	[24]
515...	...do............	Rod, 1 in. diam, cold-drawn (50% red.).	19,400	8.1	....	52.9	24 ($4\sqrt{area}$)	......	....	......	....	....	[24]
516...	...do............	Rod, 1 in. diam, cold-drawn (50% red.), ann 2 hr at 570°F.	20,100	12.5	....	49.7	26 ($4\sqrt{area}$)	......	....	......	....	....	[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	......	....	....	[93]
522...	...do............	Rod, 1 in. diam, rolled.	16,600	....	26.8 (0.01% perm)	71.9	43 (2 in.)	66	19.0 (10^8)	......	....	Shear str...............53.2 kips/in.^{2}......... Torsion str.............52.5 kips/ in.^{2}	[93]
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_B 30	....	Specific gravity........7.78..................	[94]
528...	...do............	Sheet or plate, hard..	15,000	....	60 (0.5% extn)	120	4 (2 in.)	......	....	R_B 99	....	....	[94]
529...	Al 8.5............	Rolled; 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..	Rolled...............	15,000	....	30.5 (0.01% perm)	86.8	34 (2 in.)	54	24.5 (7×10^7) [b]10.0 (8×10^7)	......	....	Shear str...............54.8 kips/in.^{2}......... Torsion str.............59.8 kips/in.^{2}	[93]
531...	Al 9.7............	Round bar, die-cast at 2,120°F.	....	....	28.0 (0.15% perm)	58.9	9 (2 in.)	19	....	129	....	Specific gravity........7.43..................	[95]
532...	Al 9.78...........	Cast.................	15,300	5.1	....	59.3	20 (8 in.)	28	22.0 (5×10^7)	96	6.3	Compressive str.........82.1 kips/in.^{2}......... Shear str...............40.8 kips/in.^{2} Mod-el (shear)..........6,000 kips/in.^{2} Specific gravity........7.57.	[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: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	COPPER-ALUMINUM ALLOYS—Continued												
	Percent		*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Percent*	*Percent*	*Kips/in.^{2}*		*ft-lb*		
533...	Al 9.78	Cast; w-q from 1,650°F, 1/2 hr at 1,200°F, f-c.	19,400	24.9	....	77.8	14 (8 in.)	19	26.0 (7×10^7)	142	13	Compressive str..............94.3 kips/in.^{2}... Shear str....................43.6 kips/in.^{2} Mod-el (shear)...............6,100 kips/in.^{2}	[96]
534...	Al 10..........	Cast..........	12,000-15,000	10-11	20-25 (0.5% perm)	60-75	15-25 (2 in.)	15-25	....	90-100	Iz 20-30	Comp yld str (0.001 in.)......6-19 kips/in.^{2}... Specific gravity.............7.5.	[97]
535...	...do..........	Rolled; 1 hr at 1,200°F, a-c.	......	....	21.8 (0.01% perm)	62.3	24 (2 in.)	23	20.0	......	....	....	[92]
536...	...do..........	Rolled; 1 hr at 1,200°F, f-c.	......	....	39.8 (0.01% perm)	89.0	37 (2 in.)	43	31.5	......	....	....	[92]
537...	Al 10.00, 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.	20,000	16.9	....	77.5	36 (8 in.)	34	34.0 (6×10^7)	128	14	Compressive str..............83.3 kips/in.^{2}... Shear str....................51.5 kips/in.^{2} Mod-el (shear)...............6,300 kips/in.^{2} Specific gravity.............7.57.	[96]
	COPPER-ALUMINUM-IRON ALLOYS												
539...	Al 5.39, Fe 5.14...	Forged..........	......	....	48.1 (yld pnt)	86.5	32 (2 in.)	49	....	119	Iz 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 8, Fe 2.5......	Rod, soft..........	......	....	29 (0.5% extn)	72	50 (2 in.)	......	....	R_B 52	....	Specific gravity.............7.75..........	[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	Compressive str..............119 kips/in.^{2}....	[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	[d] 3.7	....	[101]
547...	Al 9, Fe 3.......	Die-cast..........	......	24.6	33.6 (0.5% extn)	85.1	40 (2 in.)	......	....	130	....	....	[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	Iz 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	Iz 30	....	[103]
551...	...do..........	Wrought..........	......	....	40.0	80.0	15 (2 in.)	......	25.0 (5×10^8)	160	....	....	[104]

552...	Al 9.5, Fe 0.5.....	Rod, hard............	15,000	....	40 (0.5% extn)	88	35 (2 in.)	......	....	......	....	Specific gravity.............7.58............	[94]
553...	Al 9.5, Fe 1.0.....	Sand-cast............	....	12	25-32	70-75	30-40 (2 in.)	30-40	....	115-126	26-30	....	[100]
554...	...do.............	Centrifugally cast....	....	14	27-34	77-82	25-30 (2 in.)	25-30	....	121-134	....	....	[100]
555...	Al 9.83, Fe 0.60...	Rod, 1/2 in., hard-drawn.	17,500	....	50.0	84.0	20 (2 in.)	16	....	143	Iz 20	....	[25]
556...	Al 10.32, Fe 3.19..	Rod, 1 in. diam, forged; w-q from 1,650°F, a-c from 1,000°F.	....	49.7	....	103	13 (2 in.)	17	....	......	Iz 13	....	[98]
557...	Al 10.40, Fe 2.92..	Rod, 1 in. diam, rolled, 1 hr at 1,200°F, f-c.	....	....	39.8 (0.01% perm)	89.0	37 (2 in.)	43	31.5	......	....	....	[93]
558...	...do.............	Rod, 1 in. diam, rolled.	17,100	....	41.8 (0.01% perm)	99.0	31 (2 in.)	40	35.0 (5×10^7)	......	....	Shear str....................58.2 kips/in.^{2}... Torsion str.................30.5 kips/in.^{2}	[93]
559...	Al 10.5, Fe 2.64...	Rod, 1 in. diam, 3 hr at 600°F, f-c.	....	32.9	42.8 (0.01% perm)	102	17 (2 in.)	......	....	......	....	....	[24]
560...	Al 11, Fe 3.7......	Sand-cast............	....	18.5	35-42	77-85	10-14 (2 in.)	6-10	25 (10^8)	159-183	17	Compressive str.............136 kips/in.^{2}.... Specific gravity.............7.56.	[100]
561...	...do.............	Centrifugally cast....	....	19	38-44	82-90	8-12 (2 in.)	6-10	....	166-187	....	....	[100]
562...	Al 14.1, Fe 4.5....	Sand-cast............	....	....	>45	75-85	0-2 (2 in.)	0-2	....	321-352	4	Compressive str.............171 kips/in.^{2}.... Specific gravity.............7.11.	[100]
					COPPER-ALUMINUM-IRON-MANGANESE ALLOYS								
563...	Al 7.18, Fe 0.62, Mn 0.58.	Sand-cast............	....	....	17.5 (yld pnt)	55.8	52 (2 in.)	......	....	69	....	....	[99]
564...	...do.............	Bar, 2 1/2 in. diam, chill-cast.	....	....	19.9 (yld pnt)	58.2	56 (2 in.)	......	....	67	....	....	[99]
565...	...do.............	Forged from 2 1/2 in. to 1 in. diam.	....	....	36.3 (yld pnt)	72.6	42 (2 in.)	......	....	86	....	....	[99]
566...	Al 9.58, Fe 5.49, Mn 0.96.	Rod, 1 1/4 in. diam, forged.	....	....	43.9 (yld pnt)	103	24 (2 in.)	......	....	143	....	....	[99]
567...	...do.............	Rod, 1 1/4 in. diam, forged, w-q from 1,560°F, reheated to 1,110°F, f-c.	....	....	64.1 (yld pnt)	97.7	30 (2 in.)	......	....	201	....	....	[99]
568...	Al 9.9, Fe 3.2, Mn 2.9.	Round bar, die-cast at 2,155°F.	....	....	32.0 (0.15% perm)	90.0	10 (2 in.)	12	....	......	....	Specific gravity.............7.42............	[95]
569...	Al 10, Fe 3, Mn 3..	Chill-cast...........	....	....	31.8 (0.15%)	98.8	11 (2 in.)	17	....	159	....	....	[103]
570...	Al 10.39, Fe 3.64, Mn 0.60.	Rod, 1 1/4 in. diam, forged.	....	....	43.0 (yld pnt)	94.1	8.0 (2 in.)	......	....	185	....	....	[99]
571...	...do.............	Rod, 1 1/4 in. diam, forged, w-q from 1,560°F.	....	....	43.0 (yld pnt)	78.0	4.0 (2 in.)	......	....	209	....	....	[99]
					COPPER-ALUMINUM-IRON-NICKEL ALLOYS								
572...	Al 5.00, Fe 3.07, Ni 1.91, Mn 0.33.	Rod, 1 1/4 in. diam, forged (75% red.).	....	....	35.8 (yld pnt)	73.0	34 (2 in.)	38	....	130	Iz 67	....	[99]
573...	Cu 88.67, Fe 2.89, Ni 0.81, Mn 0.14, Al rem.	Rod, 1 in. diam, rolled.	....	24.2	45.2 (0.01% perm)	90.3	35 (2 in.)	......	....	......	....	....	[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: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
COPPER-ALUMINUM-IRON-NICKEL ALLOYS—Continued													
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
574...	Al 9.73, Fe 5.42, Ni 4.97.	Rod, 3/4 in. diam, forged.	18,800	5.4	73.5 (0.1%)	116	11 ($4\sqrt{\text{area}}$)	......	....	....	....	....	[24]
575...	Al 10, Fe 5, Ni 5..	Sand-cast............	....	26.9	56.0 (0.5% extn)	108	10 (2 in.)	......	....	170	....	....	[102]
576...	Al 10.7, Fe 4, Ni 4.	Forged, h-t..........	....	30	55-60	96-102	10-15 (2 in.)	10-15	....	190-217	25-30	Specific gravity..........7.75..	[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.)	......	....	300	....	....	[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.)	2	....	247	....	Specific gravity..........7.39..	[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.)	15	....	137	....	Specific gravity..........7.46..	[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.)	60	....	55	....	Specific gravity..........8.53..	[95]
581...	Al 7, Mn 1........	Sheet, 0.2 in., cold-rolled (50% red.).	....	76.9	....	106	12 (2 in.)	49	....	......	....	....	[92]
582...	...do.............	Sheet, 0.2 in., cold-rolled (50% red.), 1/2 hr at 600°F, a-c.	....	84.1	....	112	8.5 (2 in.)	47	....	......	....	....	[92]
583...	...do.............	Sheet, 0.2 in., cold-rolled (50% red.), 1/2 hr at 1,200°F, a-c.	....	17.4	....	66.4	61 (2 in.)	57	....	......	....	....	[92]
584...	Al 8.91, Mn 2.98...	Rod, 13/16 in., hot-rolled.	....	....	44.8 (yld pnt)	89.6	39 (2 in.)	44	....	......	....	....	[98]
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	......	27.0	158	[d] 4.2	....	[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.)	33	....	......	....	....	[92]
589...	...do.............	Sheet, 0.2 in., cold-rolled (50% red.), 1/2 hr at 500°F, a-c.	....	97.8	....	124	4.5 (2 in.)	22	....	......	....	....	[92]
590...	...do.............	Sheet, 0.2 in., cold-rolled (50% red.), 1/2 hr at 1,200°F, a-c.	....	19.2	....	66.2	62 (2 in.)	52	....	......	....	....	[92]

591...	Al 10, Ni 5........	Chill-cast............	....	....	55.6 (yld pnt)	81.1	2 (2 in.)	5	....	185	....	....	[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..	[95]
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..	[95]
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..	[95]
						COPPER-ALUMINUM-SILICON ALLOYS							
597...	Al 7.20, Si 1.88, 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 ($4\sqrt{area}$)	......	....	....	....	....	[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 ($4\sqrt{area}$)	......	....	....	....	....	[24]
603...	...do..............	Rod, 7/8 in. diam, drawn (7% red.), ann 2 hr at 390°F.	....	11.2	16.8 (0.01%)	33.4	44 ($4\sqrt{area}$)	......	....	....	....	....	[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 ($4\sqrt{area}$)	......	....	....	....	....	[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 ($4\sqrt{area}$)	......	....	....	....	....	[24]
606...	...do..............	Rod, 7/8 in. diam, drawn (7% red.), ann 100 hr at 390°F.	....	14.8	....	35.2	46 ($4\sqrt{area}$)	......	....	....	....	....	[24]
607...	As 0.47, Fe 0.005, Sn 0.005.	Rod, 1 in. diam, drawn (10% red.).	....	2.7	....	34.9	47 ($4\sqrt{area}$)	......	....	....	....	....	[24]
608...	...do..............	Rod, 1 in. diam, drawn (10% red.), ann 100 hr at 570°F.	18,600	5.4	....	34.0	47 ($4\sqrt{area}$)	......	....	....	....	....	[24]

[d] Notch impact value, m-kg/cm.^{2}

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
						COPPER-ARSENIC ALLOYS—Continued							
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
609...	As 0.47, Fe 0.005, Sn 0.005.	Rod, 1 in. diam, drawn (50% red.).	....	9.9	....	52.9	10 ($4\sqrt{\text{area}}$)	......	....	....	....	....	[24]
610...	...do.............	Rod, 1 in. diam, drawn (50% red.), 100 hr at 570°F.	19,400	1.8	....	34.0	58 ($4\sqrt{\text{area}}$)	......	....	....	....	....	[24]
						COPPER-BERYLLIUM ALLOYS							
611...	Be 1.0............	Quenched............	....	....	21 (yld pnt)	43-50	50-55 (10 diam)	85-90	....	65-70	d 13	Specific gravity..............8.6..............	[106]
612...	...do.............	Quenched and h-t......	13,700	....	57 (yld pnt)	64-71	30-35 (10 diam)	80-85	....	125-130	d 18	....	[106]
613...	...do.............	Quenched and work-hardened.	....	....	102 (yld pnt)	107	6 (10 diam)	70	....	200	d 15	....	[106]
614...	...do.............	Quenched, work-hardened and h-t.	15,700	....	93 (yld pnt)	121	12 (10 diam)	55	....	230-240	d 10-12	....	[106]
615...	Be 1.5............	Cold-worked, 1 hr at 1,470°F, o-q.	16,800	....	....	55.4	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	d 18	....	[101]
618...	Be 2.0-2.25.......	Sheet, 0.050 in., soft..	18,000	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 645°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)	R_B 111	....	....	[20]
625...	Be 2.4............	Quenched............	16,800	....	47 (yld pnt)	81-88	30-35 (10 diam)	35-40	....	110-130	d 10-11	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	d 1.3	....	[106]
627...	...do.............	Quenched and work-hardened.	17,000	....	129 (yld pnt)	135	3 (10 diam)	25	....	230	d 3.5	....	[106]

628...	...do...	Quenched, work-hardened, and h-t.	18,500	...	159 (yld pnt)	192	4 (10 diam)	45	...	375	[d]1.3	...	[106]
629...	Be 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	3.0 (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 33	...	Specific gravity... 8.35...	[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...	18,000	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 (21% 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 (3×10^8)	R_B 98	...	...	[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 (10^8)	R_B 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 (10^8)	R_B 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 (10^8)	R_B 84	...	...	[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 (10^8)	R_B 104	...	...	[20]

[b] Alternating torsion.

[d] Notch impact value, m-kg/cm.^{2}

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	COPPER-CADMIUM ALLOYS												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
645...	Cd 0.8	Wire, cold-drawn	18,000	...	...	101	...	...	...	...	...	...	[112]
646...	Cd 0.9, P 0.005	Cast	...	...	4.5 (0.15%)	21.6	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, 0.032 in., cold-rolled (37% red.).	...	26.5	...	55.4	6.0	...	...	R_B 64	...	...	[115]
649...	...do	Strip, 0.032 in., cold-rolled (60% red.).	...	28.0	...	61.2	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	...	35-40 (0.01% perm) 60-65 (0.2% perm)	75-80	20-25 (2 in.)	55-65	18-20 (10^8)	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, 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.).	19,800	...	66.1 (0.5% extn)	72.8	7.5 (2 in.)	54	25.8 (3×10^8)	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 (3×10^8)	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 930°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	...	...	80	...	...	[118]
657...	...do	Rod, 1 in. diam; quenched from 1,650°F, cold-worked (36% 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 (36% 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	30-35 (10 diam)	65-80	....	75-80	[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	42 ($4\sqrt{area}$)	......	....	......	....	....	[24]
666...	...do.............	Rod, 1 in. diam, drawn (6% red.), ann 100 hr at 570°F.	19,800	14.3	....	38.5	49 ($4\sqrt{area}$)	......	....	......	....	....	[24]
667...	...do.............	Rod, 1 in. diam, drawn (29% red.).	....	9.0	....	45.7	26 ($4\sqrt{area}$)	......	....	......	....	....	[24]
668...	...do.............	Rod, 1 in. diam, drawn (29% red.), ann 100 hr at 570°F.	19,800	19.7	....	44.8	35 ($4\sqrt{area}$)	......	....	......	....	....	[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 0.46, 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 0.16, P 0.064.	Sand-cast from 2,100°F.	....	....	8.5 (yld pnt)	9.6	1.8 (2 in.)	5.3	....	23	....	....	[122]

[d] Notch impact value, m-kg/cm.^{2}

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					COPPER-LEAD-TIN ALLOYS								
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
680...	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.....	10,900	....	14.7 (0.1% offset)	30.4	17 (2 in.)	20	....	52	....	Comp yld str (0.12%).........14.5 kips/in.².... Comp str (12%)..............34.5 kips/in.² Specific gravity............8.83.	[123]
681...	Pb 9.81, Sn 9.91, Zn 0.29, 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 kips/in.².... Comp str (12%)..............42.0 kips/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 kips/in.².. Comp str (10%)..............45-47 kips/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 kips/in.².... Comp str (10%)..............38-40 kips/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.	Chill-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 kips/in.².... Comp str (10%)..............33-35 kips/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 kips/in.².... Comp str (12%)..............41.0 kips/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 kips/in.².... Comp str (12%)..............26.0 kips/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 (4 $\sqrt{\text{area}}$)	......	....	......	....	....	[24]
695...	...do.............	Rod, 1 in. diam, drawn (10% red.), 2 hr at 570°F.	19,700	8.1	....	36.7	53 (4 $\sqrt{\text{area}}$)	......	....	......	....	....	[24]
696...	...do.............	Rod, 1 in. diam, drawn (50% red.).	19,300	6.3	....	54.4	19 (4 $\sqrt{\text{area}}$)	......	....	......	....	....	[24]
697...	...do.............	Rod, 1 in. diam, drawn (50% red.), 2 hr at 570°F.	20,600	12.5	....	51.5	23 (4 $\sqrt{\text{area}}$)	......	....	......	....	....	[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.)	21	....	70	....	....	[127]
699...	Mn 3.0, Be 1.5.....	Cold-worked, 1 hr at 1,470°F, o-q.	17,500	....	....	76.8	25	......	....	121	....	....	[107]
700...	...do.............	Cold-worked, 1 hr at 1,470°F, o-q, aged 4 hr at 610°F.	19,100	....	....	149	4.5	......	....	300	....	....	[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.)	21	....	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.)	35	....	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.)	31	....	....	....	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.)	44	....	92	....	Specific gravity............8.36..............	[95]
705...	Mn 5..............	Soft ann.............	....	....	....	46-51	35-39	......	....	71	....	Specific gravity............8.6.............. Melting point...............1,910°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...	Manganin: 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..........	....	....	....	107	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, ann 1/2 hr at 1,290°F.	....	3.6	....	33.4	64 (4 $\sqrt{\text{area}}$)	......	....	......	....	....	[24]
712...	...do.............	Rod, cold-drawn (14% red.).	....	19.7	....	51.7	26 (4 $\sqrt{\text{area}}$)	......	....	......	....	....	[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.)	71	16.0	61	....	....	[93]
715...	...do.............	Rod, 1 in. diam, cold-rolled.	22,000	....	30.0 (0.01% perm)	49.9	36 (2 in.)	68	18.0 (5×10^7)	86	....	Shear str...................35.3 kips/in.^{2}.... Torsion str.................41.7 kips/in.^{2}	[93]
716...	Ni 20.24...........	Sheet, 0.058 in., cold-rolled; 5 hr at 1,110°F.	....	....	18.9 (0.2% offset)	15.3	27 (2 in.)	......	....	V 70	....	....	[129]

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					COPPER-NICKEL ALLOYS—Continued								
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
717...	Ni 20.55, Ag 0.11..	Sheet, 0.058 in., cold-rolled; 6 hr at 1,110°F.	....	....	30.2 (0.2% offset)	51.0	25 (2 in.)	......	....	V 107	....	....	[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	17.8 (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	25.5 (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, ann 4 hr at 1,400°F.	24,800	20.2	27.1 (yld pnt)	66.6	46 (2 in.)	78	....	R_B 54	Iz 84	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	Iz 96	Torsion str....................48.8 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	34.5	100	....	Shear str......................19.4 kips/in.^{2}.. Torsion str....................66.1 kips/in.^{2}	[93]
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	28.0	96	....	Shear str......................19.9 kips/in.^{2}.. Torsion str....................55.7 kips/in.^{2}	[93]
727...	...do..............	Rod, cold-rolled......	....	....	54.7 (0.01% perm)	103	15 (2 in.)	70	43.0 (4×10^7)	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	40.5 (10^8)	......	....	....	[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 1,560°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 (56% red.).	....	....	....	66.6	4.3 (2 in.)	......	....	......	....	....	[135]
747...	...do..............	Quenched from 1,650°F, 1/2 hr at 930°F, cold-drawn (56% red.).	....	....	....	122	2.5 (2 in.)	......	....	......	....	....	[135]
748...	Ni 2.0, P 0.3, Be 0.2.	Quenched from 1,470°F, cold-drawn (56% 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, 1 hr at 1,500°F, f-c.	....	29.5	43.0 (0.01% perm)	100	27 (2 in.)	44	35.0	......	....	....	[93]
751...	...do..............	Rod, 1 in. diam, forged.	25,000	31.0	54.0 (0.01% perm)	97.1	22 (2 in.)	47	34.0	......	....	Shear str......................61.7 kips/in.^{2}.. Torsion str....................69.7 kips/in.^{2}	[93]

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
COPPER-NICKEL-IRON ALLOYS													
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
752...	Ni 28.66, Fe 2.82, Mn 1.35, C 0.40, Si 0.002.	Rod, cold-rolled; 1 hr at 1,450°F, f-c.	....	12.5	24.5 (0.01% perm)	70.4	44 (2 in.)	70	26.5 (4×10^7)	......	....	....	[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	36.0 (10^8)	......	....	....	[17]
754...	Ni 30, Fe 1, Mn 1, Si 0.5.	Bar, cast............	....	18-22	32-35 (0.5% extn)	63-66	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	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	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	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., soft.	16,400	53.2	....	103	4.0 (2 in.)	......	14.0 (10^8)	......	....	....	[20]
763...	...do..............	Sheet, 0.020 in., cold-worked (69% red.).	15,900	38.6	....	133	1.0 (2 in.)	......	24.0 (10^8)	......	....	....	[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-q, 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-q, 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-q, 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}..	[93]
772...	...do...	Rod, 1 in. diam, 1 hr at 1,500°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}	[93]
773...	Ni 29.58, 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_B 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	18	...	...	...	...	...	[139]
775...	Cu 65.60, Ni 17.77, Pb 1.08, Fe 0.24, Mn 0.06, Zn rem.	Rolled (53% red.)...	...	...	...	94.2	2.2 (2 in.)	27	...	S 37	...	Erichsen...3.5 mm...	[140]
776...	Cu 65.44, Ni 17.83, Fe 0.34, Mn 0.08, Zn rem.	Rolled (53% red.)...	...	...	...	95.0	2.3 (2 in.)	31	...	S 38	...	Erichsen...5.2 mm...	[140]
777...	...do...	Annealed at 1,200°F...	...	...	29.4 (0.05% perm)	61.0	37 (2 in.)	45	...	S 14	...	Erichsen...9.9 mm...	[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	...	136	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...43.9 kips/in.^{2}	[93]
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...45.3 kips/in.^{2}	[93]
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_B 25	...	Specific gravity...8.86...	[94]
784...	...do...	Sheet or plate, hard..	19,000	...	43 (0.5% extn)	85	5 (2 in.)	...	...	R_B 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 0.08, Mg 0.06.	Rod, 3/4 in. diam, ann to 0.060-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 0.060-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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	COPPER-NICKEL-ZINC ALLOYS—Continued												
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
790...	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.	20,800	....	45.6 (0.5% extn)	58.3	32 (2 in.)	78	....	....	....	....	[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 (29% red.).	....	9.0	....	48.8	29 (4√area)	......	....	....	....	....	[24]
800...	...do.............	Rod, 1 in. diam, drawn (29% 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	[d] 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 (50% 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 ($11.3\sqrt{area}$)	......	....	77	....	....	[190]
						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 (3×10^8)	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 0.40-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 0.140-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	....	Melting point........................1,865°F.. Specific gravity......................8.53.	[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..	16,600	9.4	....	59.3	63 (2 in.)	......	16.0 (10^8)	R_B 41	....	....	[20]
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 (3×10^8)	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 (3×10^8)	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 (10^8)	R_B 91	....	....	[20]
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 (10^8)	......	....	....	[146]
826...	...do.............	Tubing, 3/8 in. o-d by 0.05 in. wall, cold-worked.	....	....	....	67.0	49 (2 in.)	......	18.0 (10^8)	......	....	....	[146]
827...	Si 4, Mn 1........	Sand-cast............	15,000	....	20 (0.75% extn)	50	20 (2 in.)	25	....	80	....	Melting point........................1,832°F.. Specific gravity......................8.15.	[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]

[d] Notch impact value, m-kg/cm.^{2}

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	COPPER-SILICON-ZINC ALLOYS												
	Percent		*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Percent*	*Percent*	*Kips/in.^{2}*		*ft-lb*		
830...	Si 3.12, Zn 0.22, Fe 0.16, Ni 0.03.	Sheet, 0.025 in., rolled (50% red.).	......	......	......	104	5.0 (2 in.)	......	29.0 (5×10^7)	R_B 93	......	......	[149]
831...	Cu 95.70, Si 3.13, Zn 0.92, Te rem.	Rod, 1/2 in. diam, ann..	......	......	23.0 (0.5% extn)	62.0	53 (2 in.)	63	......	R_F 86	Iz 99	......	[148]
832...	...do......	Rod, 1/2 in. diam, drawn (36% red.).	......	......	61.5 (0.5% extn)	101	12 (2 in.)	40	......	R_L 110	Iz 24	......	[148]
833...	Cu 96.12, Si 3.11, Zn rem.	Rod, 1/2 in. diam, ann..	......	......	24.0 (0.5% extn)	62.5	54 (2 in.)	71	......	R_F 89	Iz 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	Iz 71	......	[148]
835...	Si 3.25, Zn 1.50, Sn 0.50.	Cast......	......	......	......	55.0	70	......	......	......	......	Specific gravity......8.54.... 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	$\frac{51}{(4\sqrt{\text{area}})}$	......	......	......	......	......	[24]
837...	...do......	Rod, 1 in. diam, drawn (10% red.), 2 hr at 570°F.	19,900	8.1	......	34.3	$\frac{51}{(4\sqrt{\text{area}})}$	......	......	......	......	......	[24]
838...	...do......	Rod, 1 in. diam, drawn (50% red.).	......	4.5	......	50.6	$\frac{22}{(4\sqrt{\text{area}})}$	......	......	......	......	......	[24]
839...	...do......	Rod, 1 in. diam, drawn (50% red.), 2 hr at 570°F.	20,100	8.1	......	49.1	$\frac{22}{(4\sqrt{\text{area}})}$	......	......	......	......	......	[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 ($4\sqrt{\text{area}}$)	......	....	....	....	....	[24]
858...	...do.............	Rod, 1 in. diam, drawn, (10% red.), 2 hr at 570°F.	19,600	28.7	....	45.0	37 ($4\sqrt{\text{area}}$)	......	....	....	....	....	[24]
859...	...do.............	Rod, 1 in. diam, drawn (50% red.).	19,600	9.0	....	58.9	20 ($4\sqrt{\text{area}}$)	......	....	....	....	....	[24]
860...	...do.............	Rod, 1 in. diam, drawn, (50% red.), 2 hr at 570°F.	20,100	36.7	....	56.4	25 ($4\sqrt{\text{area}}$)	......	....	....	....	....	[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 (3×10^8)	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 1.59, 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 (3×10^8)	R_B 71	....	....	[82]
866...	Sn 2.99, P 0.48....	Sheet, 0.04 in., rolled (30% red.).	16,900	30.2	....	64.7	14	......	....	....	....	....	[151]
867...	3.19, Fe 1.12, Si 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 0.09, P 0.068, Fe 0.04.	Sheet, 0.020 in., soft..	12,800	13.3	....	55.1	52 (2 in.)	......	13.8 (10^8)	R_B 14	....	....	[20]

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
						COPPER-TIN ALLOYS—Continued							
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
869...	Sn 3.86, Zn 0.09, P 0.068, Fe 0.04.	Sheet, 0.020 in., cold-worked (60% red.).	14,800	54.4	...	90.2	1.8 (2 in.)	...	22.0 (10^8)	R_G 57	...	...	[20]
870...	Sn 3.99, P 0.40...	Rod, 1/2 in., hard-drawn.	16,500	...	82.5	87.0	20 (2 in.)	70	...	178	Iz 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 ($4\sqrt{\text{area}}$)	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 kips/in.²...	[153]
873...	Sn 4.28, P 0.29, Fe 0.02, Pb 0.003.	Rod, 3/4 in. diam, ann to 0.040-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 0.090-mm grain size.	16,400	...	60.0 (0.5% extn)	69.8	23 (2 in.)	79	29.0 (3×10^8)	R_B 92	...	...	[82]
875...	Sn 4.56, P 0.11, Fe 0.03.	Wire, 0.104 in. diam, cold-drawn.	...	...	...	...	...	...	...	...	...	Mod-el (shear)...6,200 kips/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	[b] 12.0 (7×10^7)	...	...	Shear str...37.0 kips/in.²... Torsion str...52.6 kips/in.²	[93]
877...	Sn 4.66, P 0.032...	Sheet, 0.025 in., rolled (50% red.).	...	...	...	97.9	2.5 (2 in.)	...	36.0 (5×10^7)	R_B 91	...	...	[149]
878...	Sn 5, P 0.05...	Sand-cast from 2,245°F...	...	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 1,290°F.	...	...	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°F.	...	...	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 kips/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°F.	...	...	26.9 (yld pnt)	52.6	75	...	...	...	...	...	[154]
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 (10^8)	R_B 34	...	...	[20]
885...	...do...	Sheet, 0.020 in., cold-worked (60% red.).	15,100	56.1	...	113	1.5 (2 in.)	...	27.0 (10^8)	R_G 80	...	...	[20]

886...	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	....	....	....	....	[83]
888...	Sn 8.10, P 0.08, Fe 0.043, 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 (3×10^8)	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 (3×10^8)	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 (3×10^8)	R_B 98	....	....	[82]
891...	Sn 9..............	Mixed powders; cold-compacted at 9 tons/in.^{2}, hot-compacted 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, Sb 0.10, Zn rem.	Cast from 2,200°F.....	12,600	....	20.7 (0.5%)	17.3	42	21	....	62	....	Specific gravity..............8.65.............	[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 (3×10^8)	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)	63.8	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)	63.5	76 (2 in.)	72	20.5 (10^8)	....	....	....	[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.................	....	....	....	....	....	......	....	....	....	Mod-el (shear)...............5,800 kips/in.^{2}..	[88]
899...	Sn 15.29, Zn 0.09, P 0.08, Pb 0.02, Fe 0.016.	Bar, 1 1/4 in. diam, sand-cast from 2,115°F.	....	....	28.2 (yld pnt)	32.3	1.5 (2 in.)	......	....	88	Iz 26	....	[138]

COPPER-TIN-CADMIUM ALLOY

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

COPPER-TIN-LEAD ALLOYS

904...	Sn 4, Pb 4, Zn 4, P 0.45.	Rod, 1 in., hard......	15,000	....	45 (0.5% extn)	60	20 (2 in.)	......	....	R_B 75	....	Melting point.................1,830°F.......... Specific gravity..............8.86.	[145]
905...	Sn 5.0, Pb 1.0, P 0.10.	Sheet, 0.040 in., ann..	15,000	....	20 (0.5% extn)	50	45 (2 in.)	......	....	R_B 25	....	Melting point.................1,920°F.......... Specific gravity..............8.91.	[145]

Alternating torsion.

545875 O - 43 - 7

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	COPPER-TIN-LEAD ALLOYS—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
906...	Sn 5.0, Pb 1.0, P 0.10.	Sheet, 0.010 in., hard..	15,000	....	60 (0.5% extn)	82	8 (2 in.)	......	....	R_B 90	....	....	[145]
907...	Sn 6.94, 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	....	[157]
909...	Sn 10, Pb 5, Zn 1.5..	...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 930°F.	17,500	37.9	....	73.0	22 (2 in.)	......	....	R_B 80	....	....	[158]
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 0.59, P 0.40.	Sheet, cold-rolled; quenched from 1,470°F, aged 1 hr at 930°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, Te 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	....	93	....	....	[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 $(4\sqrt{\text{area}})$	......	....	....	....	....	[24]
933...	...do.............	Rod, 1 in. diam, drawn (10% red.), 2 hr at 570°F.	19,100	11.6	....	34.5	52 $(4\sqrt{\text{area}})$	......	....	....	....	....	[24]
934...	...do.............	Rod, 1 in. diam, drawn (29% red.).	19,600	6.3	....	42.3	28 $(4\sqrt{\text{area}})$	......	....	....	....	....	[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]

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
			COPPER-ZINC ALLOYS—Continued										
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
941...	Zn 10	Annealed	17,000			40.3			15.7 (5 x 10^7)			Specific gravity 8.80; Melting range 1,870°-1,920°F.	[166]
942...	...do	Mixed powders; cold-compacted at 9 tons/in.², hot-compacted at 5 tons/in.² and 1,650°F.			19.0 (yld pnt)	34.2	22						[154]
943...	Zn 10.12, P 0.04	Sheet, 0.032 in., rolled (60% red.).				71.5	4						[146]
944...	Zn 11.23, Fe 0.02, Pb 0.01.	Rod, 3/4 in. diam, ann to 0.125-mm grain size.	17,500		8.6 (0.5% extn)	37.9	58 (2 in.)	87					[83]
945...	Zn 15	Sheet, 0.040 in., cold-drawn (37% red.).				71	5 (2 in.)			R_B 78			[164]
946...	...do	Sheet, 0.040 in., cold-drawn (60% red.).				83	3 (2 in.)			R_B 85			[164]
947...	Zn 15.44, Fe 0.02, Pb 0.01.	Rod, 1/2 in. diam, cold-worked (4% red.) from 0.025-mm grain size.	17,200		29.3 (0.5% extn)	44.7	40 (2 in.)	80	20.0 (3 x 10^8)	R_B 50			[82]
948...	Zn 20	Wire, 0.125 in. diam, cold-drawn.	13,000		52.0 (0.1% offset)	72.0	7.2 (10 in.)	51	15.0 (10^8)				[167]
949...	...do	Sheet, hard				85	4 (2 in.)			150		Specific gravity 8.67; Melting point 1,830°F.	[168]
950...	...do	Mixed powders; cold-compacted at 9 tons/in.², hot-compacted at 5 tons/in.² and 1,650°F.			20.2 (yld pnt)	41.4	34						[154]
951...	Zn 20.38, Pb 0.09, Fe 0.02.	Rod, 3/4 in. diam, 1 hr at 1,100°F, w-q.	15,900	10.1		45.3	51 (8 in.)	73	22.4 (5 x 10^7)	R_B 17			[169]
952...	...do	Rod, 3/4 in. diam, cold-drawn (27% red.).	14,700	14.0		72.7	18 (2 in.)	61	21.5 (5 x 10^7)	R_B 81			[169]
953...	Zn 26.61, Pb 0.026, Fe 0.135.	Rod, cold-drawn	17,500	9.5	21.5 (0.01% perm)	50.4	57 (2 in.)	73	17.0 (2 x 10^7)				[93]
954...	Zn 27	Cold-worked										Mod-el (shear) 5,300 kips/in.²	[55]
955...	Zn 28.24, Fe 0.13, Pb 0.017.	Rod, cold-drawn	16,600	15.0	20.0 (0.01% perm)	47.8	64 (2 in.)	74	[b]9.0			Shear str 34.4 kips/in.²; Torsion str 42.1 kips/in.²	[93]
956...	Cu 71.68, Fe 0.02, Pb 0.01, Zn rem.	Sheet, 0.020 in., soft.	15,600	11.8		49.4	54 (2 in.)		16.5 (10^8)	R_B 24			[20]
957...	...do	Sheet, 0.020 in., cold-worked (37% red.).	15,900	23.1		75.2	7.5 (2 in.)		19.0 (10^8)	R_B 82			[20]
958...	Cu 70.5, Pb 0.01, Fe 0.009, Ni 0.006, P 0.001, Zn rem.	Strip, rolled; ann 2 hr at 1,155°F.		5.8	11.4 (0.1%)	46.1	74 (2 in.)	73		58			[170]
959...	...do	Strip, cold-rolled (11% red.).		16.4	31.8 (0.1%)	51.7	54 (2 in.)	66		89			[170]

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 (90% 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 (5×10^7)	R_B 11	...	...	[169]
963...	...do...	Rod, 3/4 in., cold-drawn (27% red.).	15,500	17.8	...	74.1	20 (2 in.)	58	22.0 (5×10^7)	R_B 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	Iz 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	Iz 28	...	[141]
968...	Zn 33...	Sheet, hard...	...	...	...	85	4 (2 in.)	...	...	153	...	Specific gravity...8.48... Melting point...1,720°F.	[168]
969...	Cu 66.12, Zn rem...	Sheet, 0.025 in. (grain size 0.035 mm).	...	...	...	50.8	62 (2 in.)	...	...	...	...	Erichsen...11.0 mm...	[172]
970...	Zn 34.23, Fe 0.15..	Wire, 0.064 in. diam, cold-drawn.	...	...	...	...	...	...	...	...	...	Mod-el (shear)...4,800 kips/in.^{2}..	[153]
971...	Zn 34.6, Fe <0.1...	Rod, rolled...	...	...	41.6 (yld pnt)	52.5	40 (2 in.)	51	...	101	Iz 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 (10^8)	...	...	...	[146]
973...	...do...	Sheet, 0.020 in., rolled (69% red.).	...	...	...	95.5	2	...	21.5 (10^8)	...	...	...	[146]
974...	Zn 34-38...	Cold-worked...	...	...	...	...	...	...	...	...	...	Mod-el (shear)...4,800 kips/in.^{2}..	[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 (10^8)	R_B 14	...	...	[20]
977...	...do...	Sheet, 0.020 in., cold-worked (37% red.).	15,600	31.9	...	73.7	6.5 (2 in.)	...	17.5 (10^8)	R_B 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 (3×10^8)	R_B 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.	...	...	...	...	...	...	...	...	...	Mod-el (shear)...4,800 kips/in.^{2}..	[153]
982...	Zn 40...	Die-cast...	...	...	...	56	45 (2 in.)	...	...	85	Iz 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 (5×10^7)	R_B 54	...	...	[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								
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
984...	Zn 40.03, Pb 0.09, Fe 0.03, Sn 0.01.	Rod, drawn (25% red.)..	15,300	17.7	....	77.6	24 (2 in.)	52	27.7 (5×10^7)	R_B 82	....	....	[169]
985...	Muntz metal: Zn 40.11, Pb 0.20, Fe 0.164, Sn 0.10.	Rod, hot-rolled, cooled in iced brine, reheated to 480°F.	17,800	26.0	49.5 (0.01% perm)	76.6	2.2 (2 in.)	5.2	16.0 (10^8) [b]5.5 (5×10^6)	......	....	Shear str....................55.3 kips/in.^{2}... Torsion.str...................54.8 kips/in.^{2}	[93]
986...	...do.............	Rod, hot-rolled, cooled in iced brine, reheated to 840°F.	16,000	20.0	27.4 (0.01% perm)	65.6	34 (2 in.)	42	18.0 (10^8) [b]8.5 (5×10^7)	......	....	Shear str....................41.0 kips/in.^{2}... Torsion str...................45.3 kips/in.^{2}	[93]
987...	Zn 41.04..........	Cast..................	....	....	19.7 (yld pnt)	55.8	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	28 (2 in.)	33	....	......	....	....	[174]
990...	...do.............	Chill-cast...........	....	30.6	....	97.0	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	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	12 (2 in.)	15	....	159	Iz 11	....	[175]
994...	...do.............	Bar, 1 in. square, forged.	....	....	54.4 (0.5% perm)	103	16 (2 in.)	18	....	185	Iz 19	....	[175]
995...	Zn 33.57, Al 3.95, Ni 3.13.	Bar, 2 1/2 in. square, cast.	....	....	58.2 (0.5% perm)	95.2	6.0 (2 in.)	8.4	....	185	Iz 7	....	[175]
996...	...do.............	Bar, 1 in. square, forged.	....	....	61.4 (0.5% perm)	105	11 (2 in.)	12	....	200	Iz 7	....	[175]
997...	Zn 34.68, 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	4.5 (2 in.)	8.4	....	154	Iz 9	....	[175]
998...	...do.............	Bar, 1 in. square, forged.	....	....	55.6 (0.5% perm)	98.1	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	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 57.06, Al 0.97, Fe 0.95, Mn 0.82, Sn 0.46, Zn rem.	Bar, chill-cast from 1,795°-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; ann..........	....	....	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 38.48, 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 (2.5×10^8)	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_B 58	....	Melting point..........1,900°F.......... Specific gravity..........8.83.	[178]
1011..	Zn 13.25, Pb 1.75..	...do..............	....	....	....	60	10 (2 in.)	......	....	....	....	Melting point..........1,877°F.......... Specific gravity..........8.77.	[178]
1012..	Zn 24.5, Pb 3, Sn 1.5.	Cast..............	....	....	15-20 (yld pnt)	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..........	....	....	....	32.7	37	......	....	R_B 14	....	....	[179]
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 1.89, 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 2.8, Zn rem.	Rod, 3/4 in. diam.....	....	32.0	....	60.4	23 (2 in.)	47	18.0 (10^8) [b] 14.0 (10^8) [c] 26.0 (10^8)	124	....	Torsion str..........42.2 kips/in.^{2}...	[27]

[b] Alternating torsion.

[c] Zero to maximum torsion.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	COPPER-ZINC-LEAD ALLOYS—Continued												
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
1018..	Zn 37, Pb 1.5......	Sheet, hard..........	....	....	....	80	4 (2 in.)	......	....	142	....	....	[168]
1019..	Zn 37.66, Pb 1.53, Fe 0.12, Al 0.06.	Chill-cast...........	....	....	19.3 (0.2%)	47.2	20 (2 in.)	......	....	76	....	....	[180]
1020..	Zn 40, Pb 2........	Drawn................	....	....	....	59.4	5	......	23.5	141	d 8	....	[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, ann 1/2 hr at 1,020°F.	....	15.6	16.8 (yld pnt)	54.2	56 (2 in.)	51	22.0 (10^8)	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 (10^8)	179	19	....	[38]
	COPPER-ZINC-MANGANESE ALLOYS												
1025..	Zn 33.1, Mn 4.2, Al 3.5.	Round bar, die-cast from 1,930°F.	....	....	62.5 (0.15% perm)	93.6	7 (2 in.)	16	....	187	....	Specific gravity.............7.79	[95]
1026..	Cu 56.62, Mn 2.20, Fe 1.76, Al 1.72, Zn rem.	Bar, chill-cast from 1,795°-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	......	....	....	Iz 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	....	....	[158]
1030..	Zn 9.89, Ni 2.32, Si 0.57.	Sheet, 0.020 in., quenched from 1,470°F, aged 1 hr at 930°F.	19,800	44.5	....	90.0	14 (2 in.)	......	18.5 (10^8)	R_B 86	....	....	[20]
1031..	Zn 10.3, Ni 3.97, Sn 2.51.	Mixed powders; cold-compacted at 9 tons/in.^{2}, hot-compacted 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 0.57.	Sheet, 0.020 in., quenched from 1,470°F, aged 1 hr at 930°F.	17,200	37.2	....	85.8	22 (2 in.)	......	16.0 (10^8)	R_B 85	....	....	[20]

1034..	Zn 20.0, Ni 6.0, Al 1.5.	Sheet, 1/8 in., cold-rolled (50% red.).		24.9	69.0 (0.1%)	88.9	6 (2 in.)			V 198			[132]
1035..	...do	Sheet, 1/8 in., cold-rolled (50% red.), aged 2 hr at 930°F.		56.0	69.4 (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		Erichsen 11.6 mm	[140]
1037..	...do	Rolled (50% red.)				95.1	4.0 (2 in.)	28		S 40		Erichsen 2.4 mm	[140]
1038..	Zn 26.2, Ni 15.5, Mn 0.17, Fe 0.15.	Annealed at 1,200°F										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., ann.				60.5	48 (2 in.)		16.5 (10^8)	R_B 53			[20]
1040..	...do	Sheet, 0.020 in., rolled (37% red.).				95.4	1.5 (2 in.)		20.5 (10^8)	R_G 66			[20]
1041..	...do	Sheet, 0.020 in., rolled (69% red.).				118	1.2 (2 in.)		25.0 (10^8)	R_G 79			[20]
1042..	Cu 64.68, Ni 6.73, Fe 0.19, Mn 0.06, Zn rem.	Sheet, 0.050 in., ann at 1,200°F.			22.6 (yld pnt)	53.8	62 (2 in.)	56		S 12		Erichsen 12.5 mm	[182]
1043..	...do	Sheet, 0.050 in., hard-rolled.				99.2	3.5 (2 in.)	30		S 42		Erichsen 3.3 mm	[182]
1044..	Zn 30.12, Ni 2.36, Si 0.66.	Sheet, 0.040 in., hard-rolled.	14,000	48.0		114	2.5 (2 in.)			R_B 98			[158]
1045..	...do	Sheet, 0.020 in., quenched from 1,470°F, aged 1 hr at 930°F.	16,500	38.0		85.4	28 (2 in.)		20.5 (10^8)	R_B 79			[20]
1046..	Zn 31.1, Ni 19.5	Rod, 1 in. diam, chill-cast.			26.4 (0.15% perm)	51.3	31 (2 in.)	34		91		Specific gravity 8.52	[95]
1047..	Zn 32.7, Ni 18.0, Al 1.1.	...do			67.2 (0.15% perm)	76.6	4 (2 in.)	13				Specific gravity 8.37	[95]
1048..	Zn 39.74, Ni 3.35	Cast; ann 2 hr at 1,380°F.				67.2	43	52		97			[175]
1049..	...do	Rod, cold-drawn				75.9	33	51		144			[175]
1050..	Zn 44.4, Ni 9.4, Pb 1.55.	Rod, extruded				90.5	17-27 (2 in.)			V 150	Iz 20-28		[183]

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]

[d] Notch impact value, m-kg/cm.^{2}

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	COPPER-ZINC-SILVER ALLOYS												
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
1056..	Zn 22.5, Ag 25.0...	Chill-cast..........	....	....	....	....	....	......	....	......	....	Specific gravity.............8.94	[184]
1057..	Zn 30, Ag 20, Cd 5..	...do...............	....	....	....	53.0	12 (2 in.)	......	....	......	....	Specific gravity.............8.80 Melting range................1,400°-1,485°F.	[184]
1058..	Zn 35, Ag 20.......	....	....	....	....	....	....	......	....	......	....	Melting range................1,400°-1,510°F...	[184]
1059..	Zn 40, Ag 9........	Chill-cast..........	....	....	....	18.8	16 (2 in.)	......	....	......	....	Specific gravity.............8.55	[184]
	COPPER-ZINC-TELLURIUM ALLOYS												
1060..	Cu 90.87, 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.).	....	....	49.5 (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°F.....	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	......	....	50-65	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)	65.2	12 (2 in.)	77	29.3 (3 x 10^8)	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°F.	....	....	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	....	62.9 (0.5% extn)	78.8	13 (2 in.)	64	28.3 (3 x 10^8)	R_B 89	....	....	[82]
1071..	Admiralty brass: Zn 27.95, Sn 0.97.	Rod, 5/8 in. diam, cold-drawn (31% red.).	....	31.8	....	68.5	35 (2 in.)	64	....	......	....	....	[189]

1072..	Admiralty brass: Zn 28, Sn 1.	Sheet, ann...........	15,000	....	....	45	60 (2 in.)	......	....	....	....	Melting point.................1,720°F......... Specific gravity.............8.53.	[178]
1073..	Cu 60, Sn 12, Zn rem.	Cast..................	....	....	....	....	....	......	....	....	....	Mod-el (shear)...............5,300 kips/in.^{2}..	[88]
1074..	Naval brass: Zn 35.95, Sn 0.31, Pb 0.08.	Rod, 1/2 in., hard-drawn.	15,000	....	54.0	72.0	24 (2 in.)	65	....	138	Iz 38	....	[25]
1075..	Naval brass: Cu 61.20, Sn 0.13, Pb 0.10, Zn rem.	Rod, 3/4 in. diam, rolled.	15,300	33.4	....	68.2	27	53	21.0 (10^8)	....	25	Compressive str..............72.8 kips/in.^{2}... Shear str.....................45.5 kips/in.^{2} Mod-el (shear)...............5,400 kips/in.^{2} Specific gravity.............8.42.	[19]
1076..	Naval brass: Zn 38.32, Sn 0.85, Fe 0.002, Pb 0.002.	Rod, hot-rolled.......	14,300	14.7	18.3 (0.01% perm)	59.3	48 (2 in.)	56	18.5 (5×10^7)	....	....	Shear str.....................40.8 kips/in.^{2}... Torsion str..................43.0 kips/in.^{2}	[93]
1077..	Cu 57.12, Sn 1.56, Al 0.99, Fe 0.79, Mn 0.76, Zn rem.	Bar, chill-cast from 1,795°-1,870°F.	....	28.0	48.0 (yld pnt)	94.4	22 (2 in.)	23	....	R_E 76	....	....	[176]
1078..	Zn 39.0, Sn 0.79, Al 0.71, Fe 0.68, Mn 0.38, Pb 0.03.	Cast..................	13,800	11.2	25.8 (0.2%)	60.5	20	......	....	....	....	....	[24]
1079..	Zn 39.08, Sn 0.89, Fe 0.03, Pb 0.03.	Rod, 1 in. diam, cold-worked (12% red.).	14,100	....	49.0 (0.5% extn)	69.6	25 (2 in.)	51	23.7 (3×10^8)	R_B 77	....	....	[82]
1080..	Zn 40.10, Sn 1.04, Fe 0.65, Pb 0.02.	Rod, hot-rolled.......	15,600	....	32.3 (0.01% perm)	75.5	34 (2 in.)	44	18.5 (2×10^7)	....	....	Shear str.....................49.4 kips/in.^{2}... Torsion str..................50.7 kips/in.^{2}	[93]
1081..	Zn 41, Sn 1........	Die-cast..............	....	....	30-35 (yld pnt)	55-60	15-20 (2 in.)	15-20	....	120-130	....	Specific gravity.............8.47.............	[186]

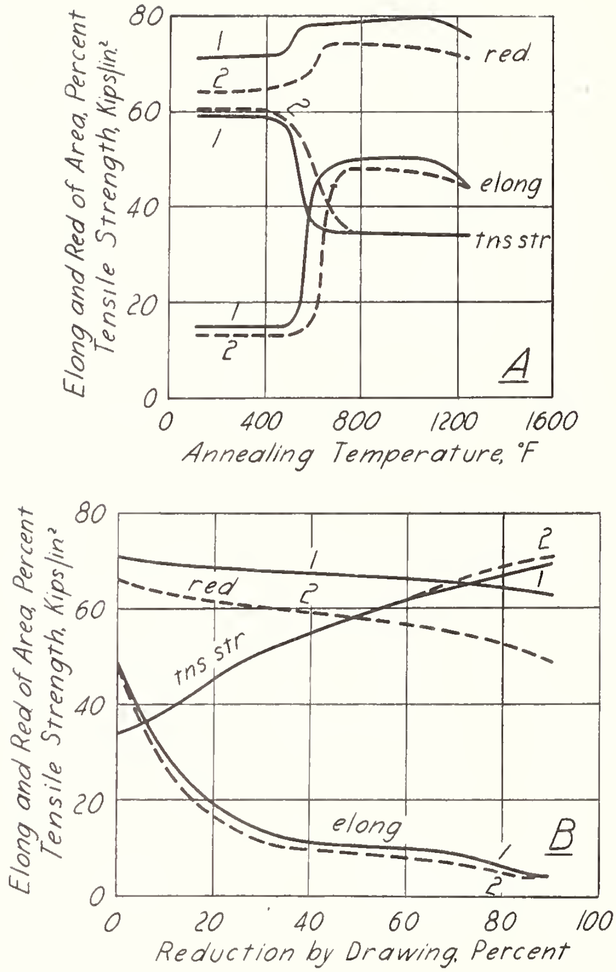


FIGURE 28.—*Effect of annealing and cold-drawing on the tensile properties of oxygen-free and phosphorized copper (Rolle and Schleicher [640]).*

(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%.

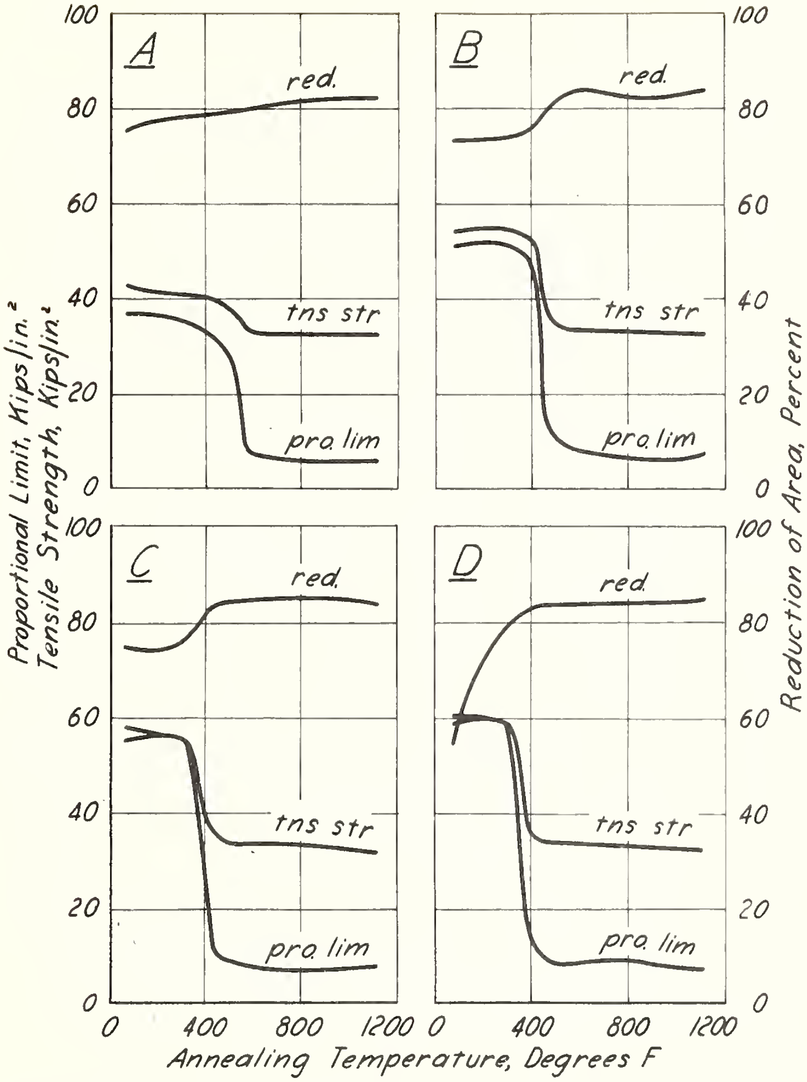


FIGURE 29.—*Effect of annealing on the tensile properties of copper cold-worked various amounts (Krupkowski and Balicki [641]).*

Annealed 1/2 hour after cold-working:

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

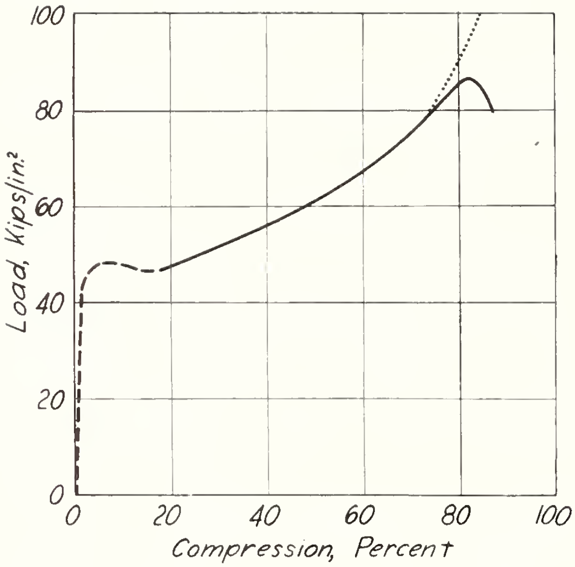


FIGURE 30.—*Compressive strength of cold-drawn copper (Crane [642]).*

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.

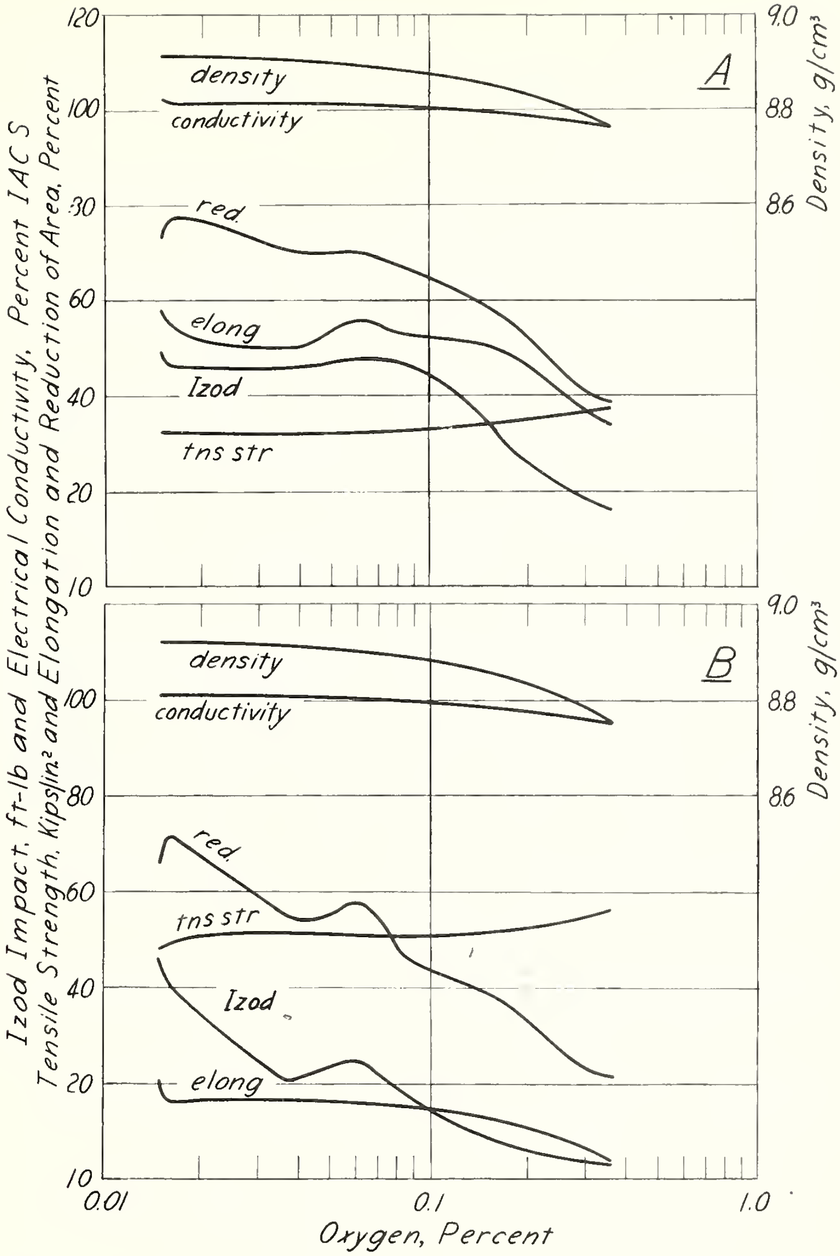


FIGURE 31.— *Effect of oxygen on the tensile properties, impact value, density, and electrical conductivity of copper (Hanson, Marryat and Ford [643]).*

(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.).

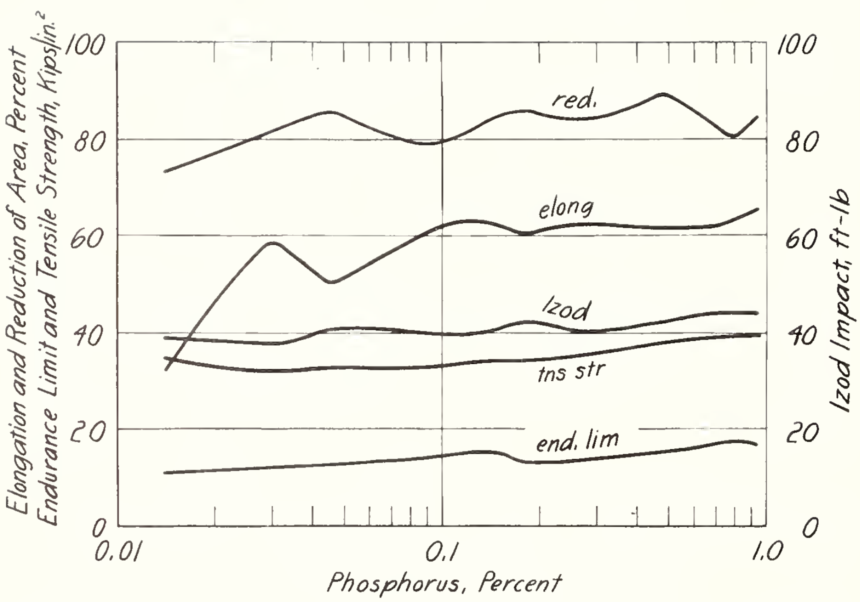


FIGURE 32.—*Effect of phosphorus on the tensile properties, endurance limit, and impact value of copper (Hanson, Archbutt, and Ford [644]).*

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

Rod, 5/8 in. diameter, annealed 1/2 hour at 1,290°F, air-cooled.

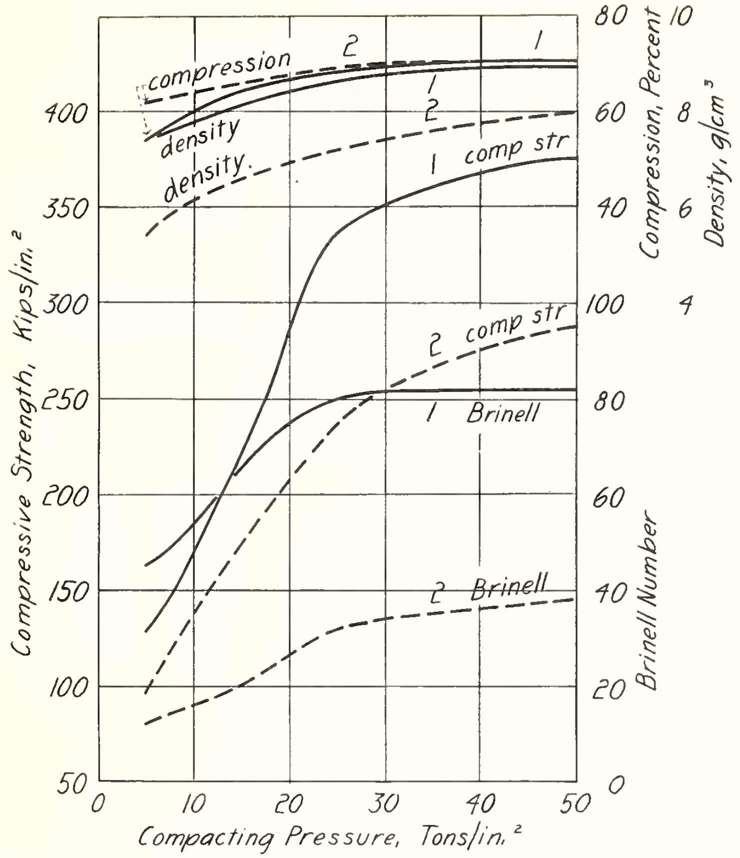


FIGURE 33.—*Compressive properties, hardness, and density of copper powder compacts (Goetzel [52]).*

(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.

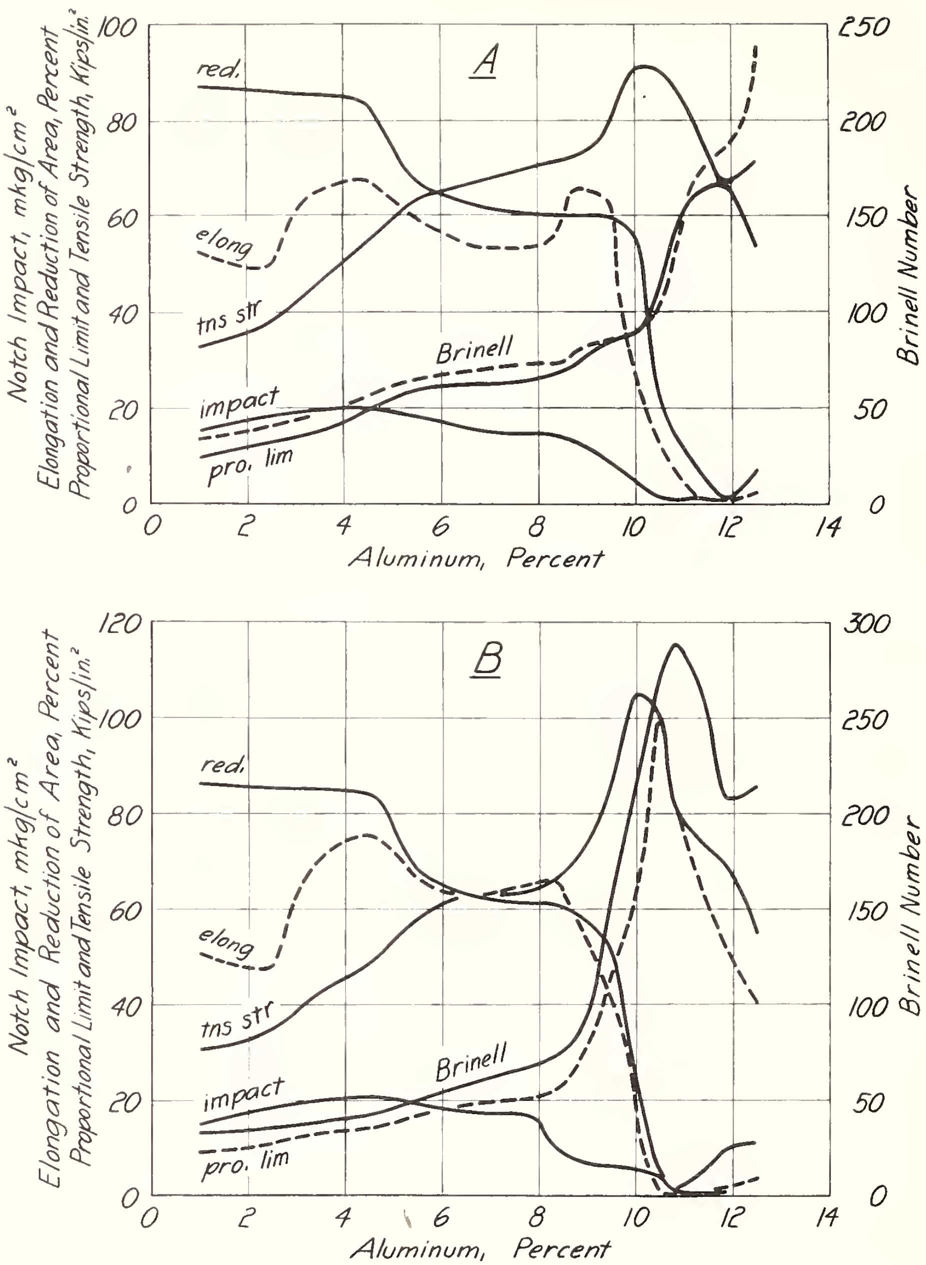


FIGURE 34.—*Tensile properties, impact value, and hardness of wrought copper-aluminum alloys (Broniewski [645]).*

(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.

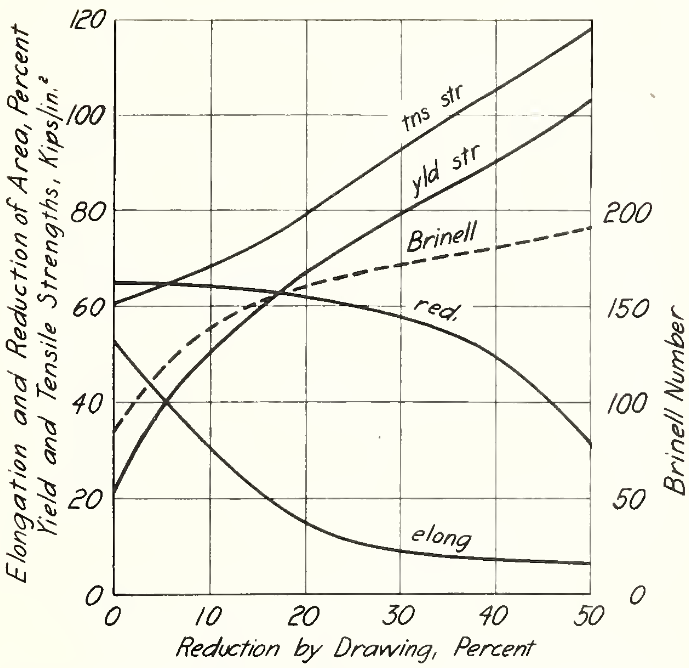


FIGURE 35.—*Effect of cold-drawing on the tensile properties and hardness of a copper-aluminum alloy containing 4 percent of aluminum (Lay [646]).*

(Yield strength, 0.2%)

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

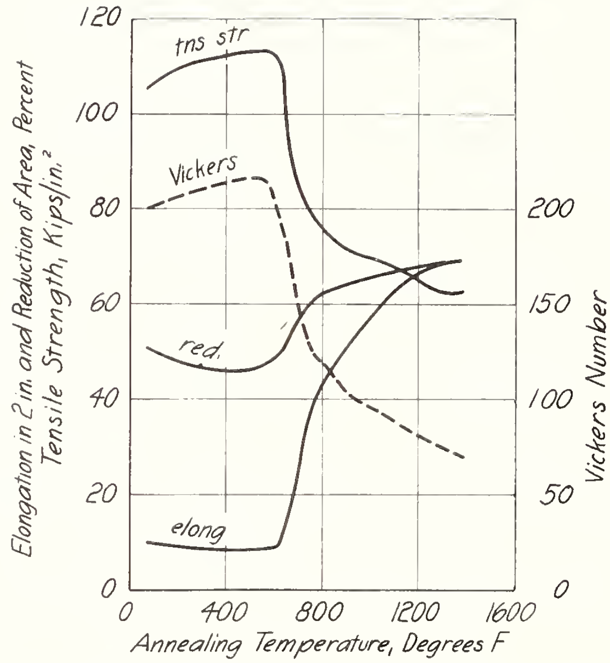


FIGURE 36.—*Effect of annealing on the tensile properties and hardness of a cold-worked copper-aluminum alloy containing 7 percent of aluminum* [103].

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

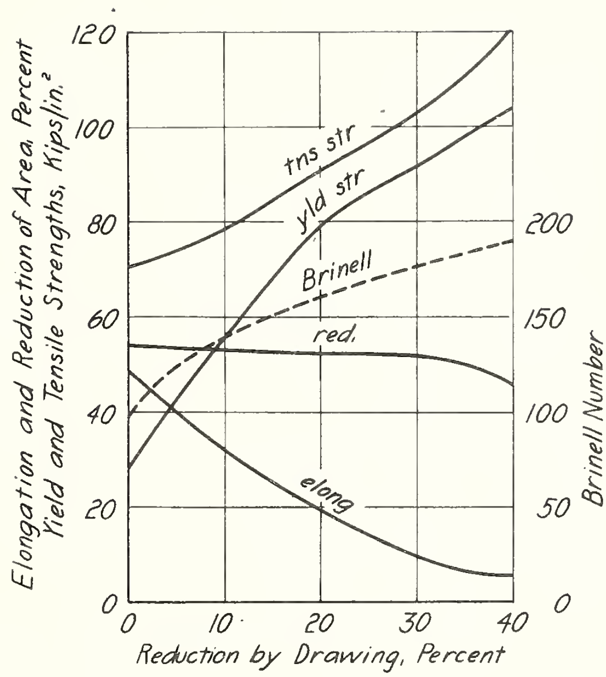


FIGURE 37.—*Effect of cold-drawing on the tensile properties and hardness of a copper-aluminum alloy containing 8 percent of aluminum (Lay [646]).*

(Yield strength, 0.2%)

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

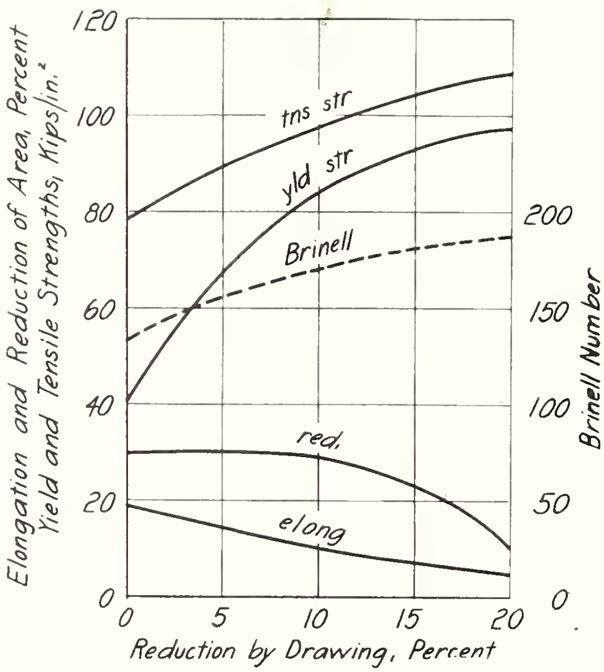


FIGURE 38.—*Effect of cold-drawing on the tensile properties and hardness of a copper-aluminum alloy containing 10 percent of aluminum (Lay [646]).*

(Yield strength, 0.2%)

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

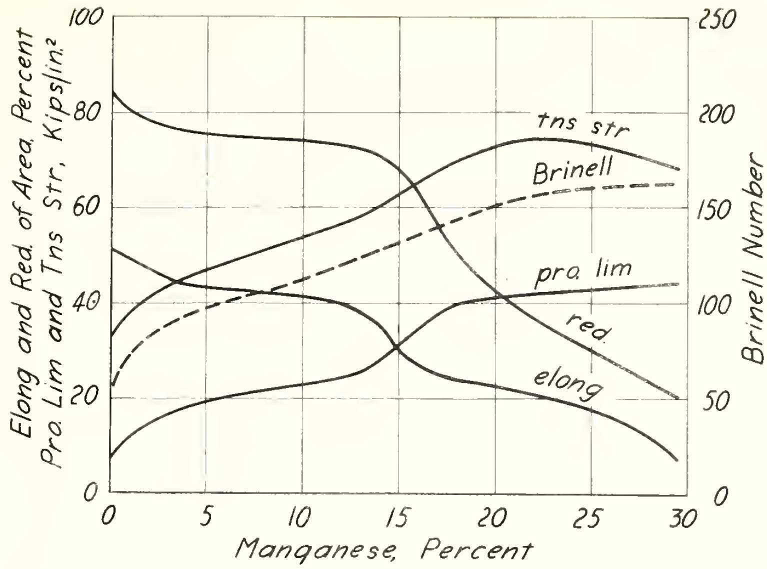


FIGURE 39.—*Tensile properties and hardness of wrought copper-manganese alloys (Broniewski and Jaslan [647]).*

(Elongation in 10 diam)

Annealed 1 hour at 930°F.

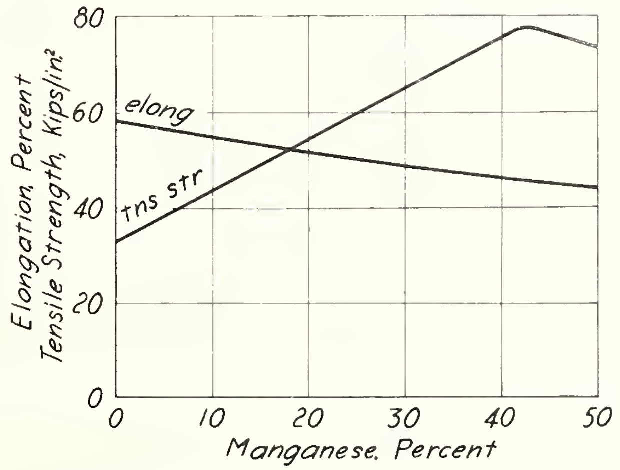


FIGURE 40.—*Tensile properties of forged copper-manganese alloys (Hesse and Myskowski [572]).*

(Elongation in 4 diam)

Alloys made with electrolytic manganese.
Annealed 2 hours at 1,380°F, quenched.

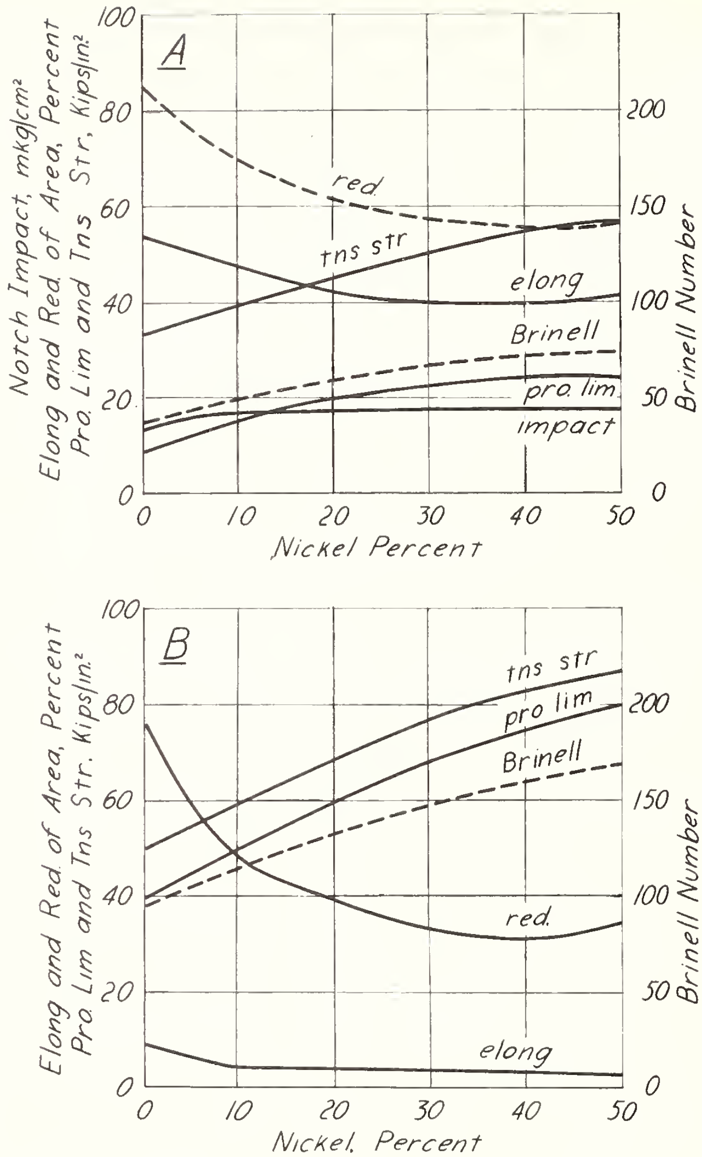


FIGURE 41.—*Tensile properties, impact value, and hardness of wrought copper-nickel alloys (Broniewski and Kulesza [648]).*

(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.

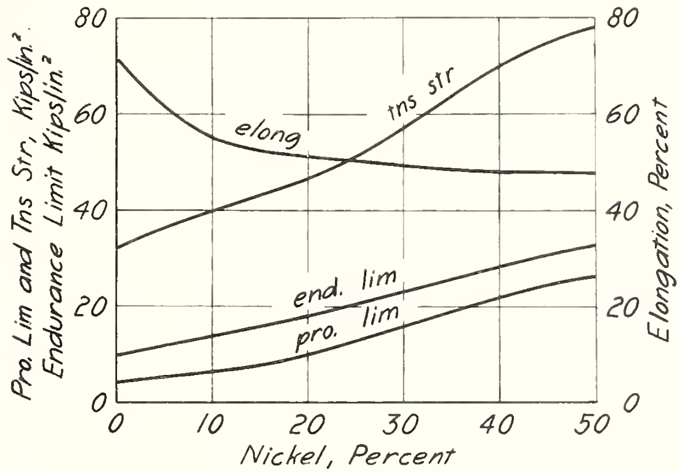


FIGURE 42.—*Tensile properties and endurance limit of wrought, annealed commercial copper-nickel alloys (Wise [649]).*

(Endurance limit at 10^8 cycles)

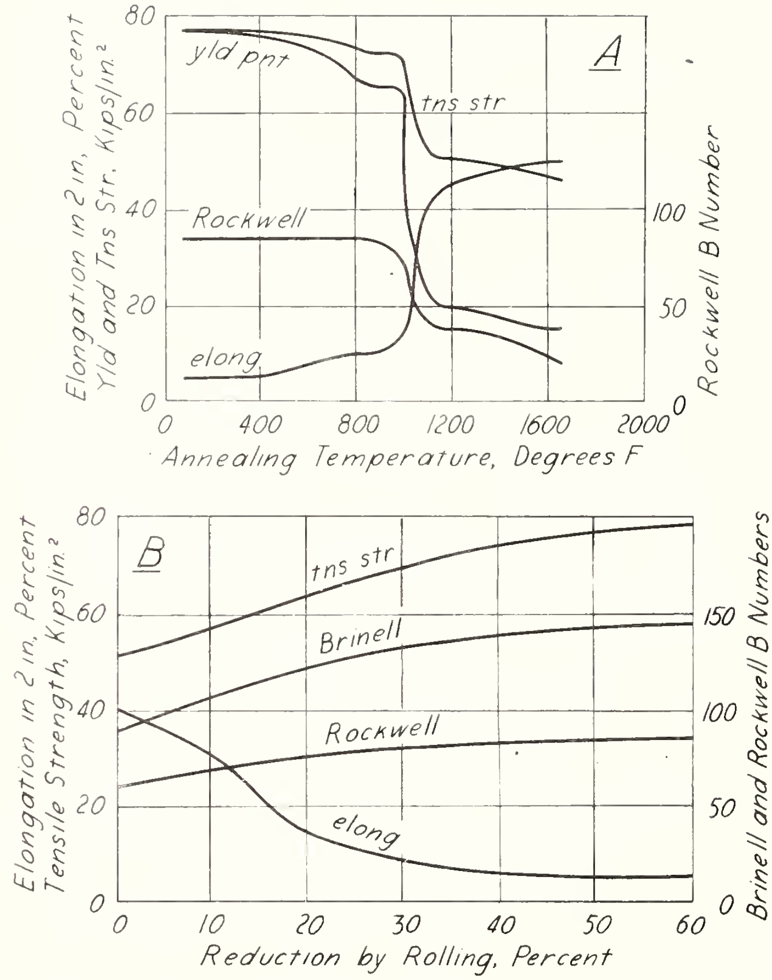
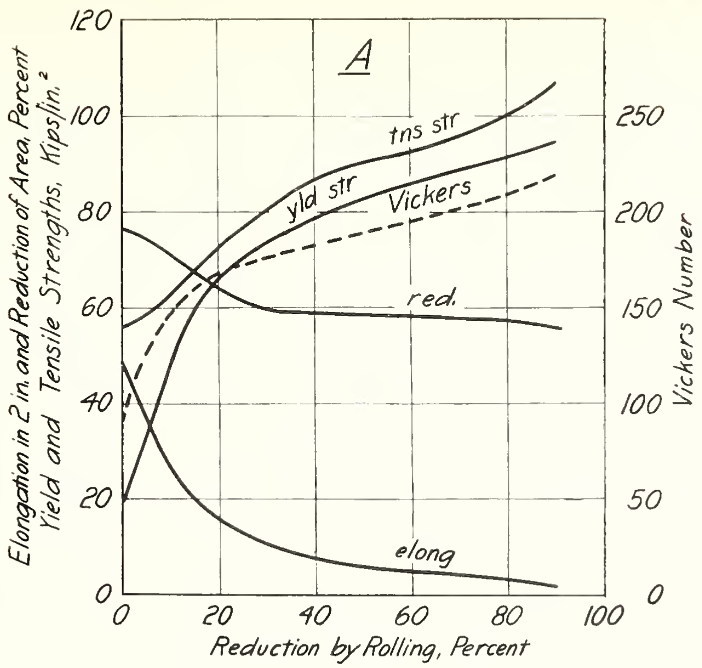


FIGURE 43.—*Effect of annealing and cold-rolling on the tensile properties and hardness of a copper-nickel alloy containing 30 percent of nickel (Jennison and Girvin [216]).*

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



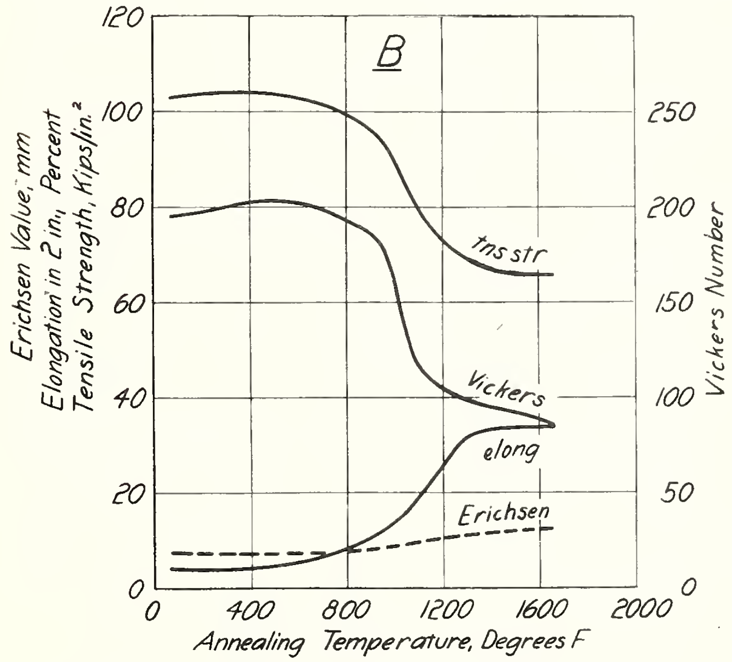


FIGURE 44.—*Effect of annealing and cold-rolling on the tensile properties, hardness, and Erichsen value of a copper-nickel-zinc alloy (Cook [203]).*

(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.

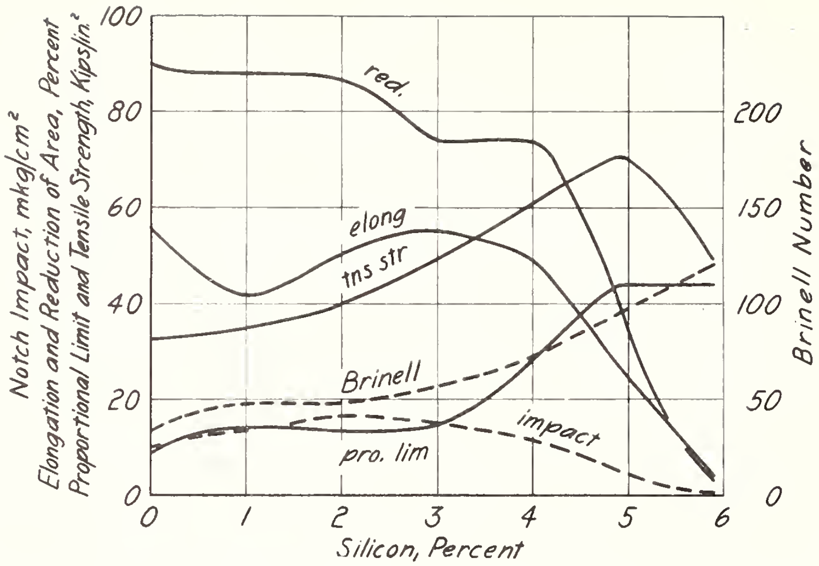


FIGURE 45.--*Tensile properties, impact value, and hardness of wrought copper-silicon alloys (Broniewski [645]).*

(Elongation in 10 diam)

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

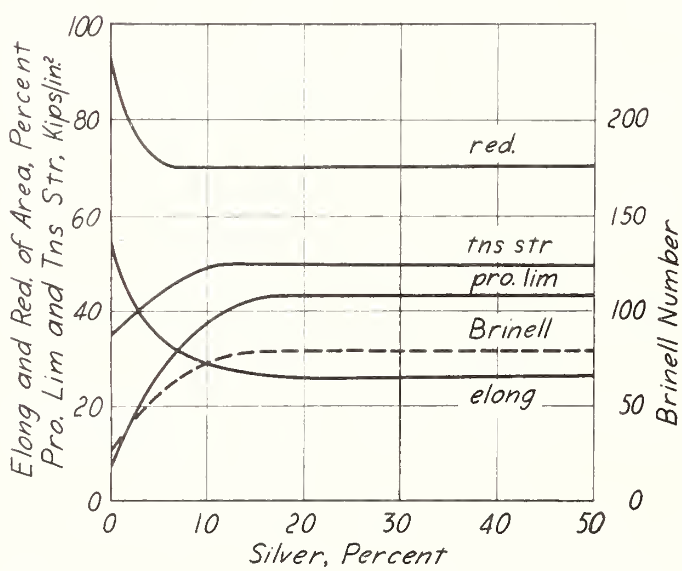


FIGURE 46 --*Tensile properties and hardness of wrought copper-silver alloys (Broniewski [651]).*

(Elongation in 10 diam)

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

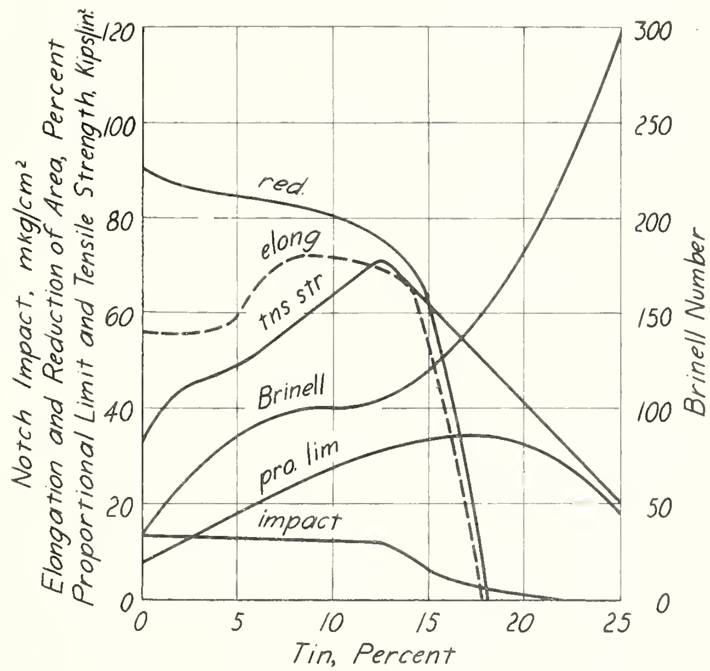


FIGURE 47.—*Tensile properties, impact value, and hardness of wrought copper-tin alloys (Broniewski and Wawrzynkiewicz [652]).*

(Elongation in 10 diam)

Annealed at 840°F.

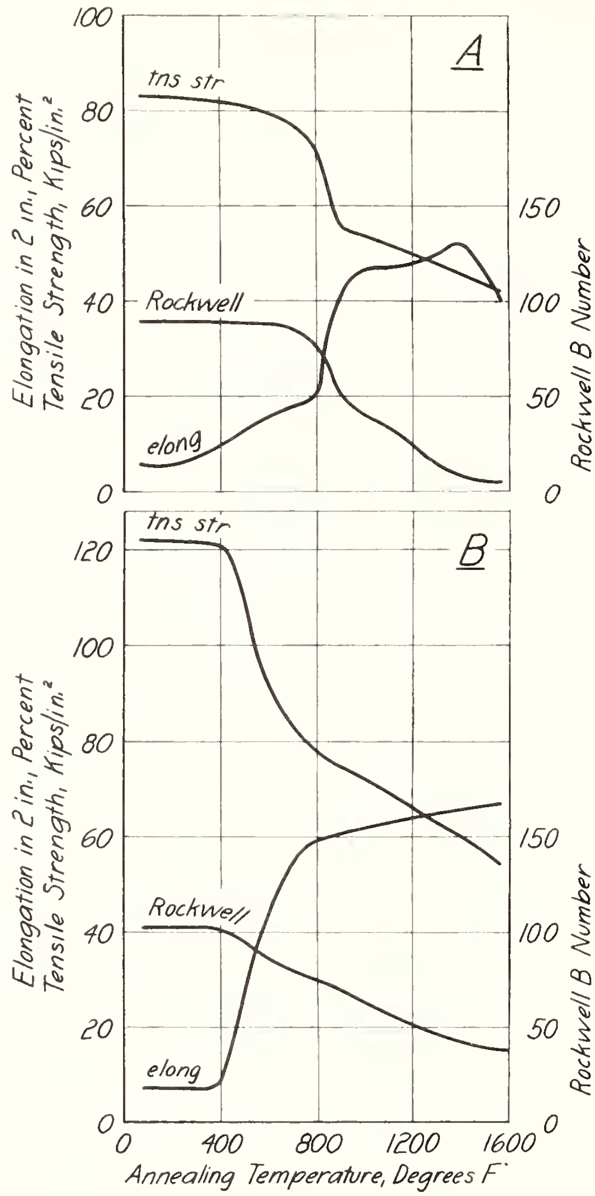


FIGURE 48.—*Effect of annealing on the tensile properties and hardness of cold-rolled copper-tin alloys (Jennison and Girvin [650]).*

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%.

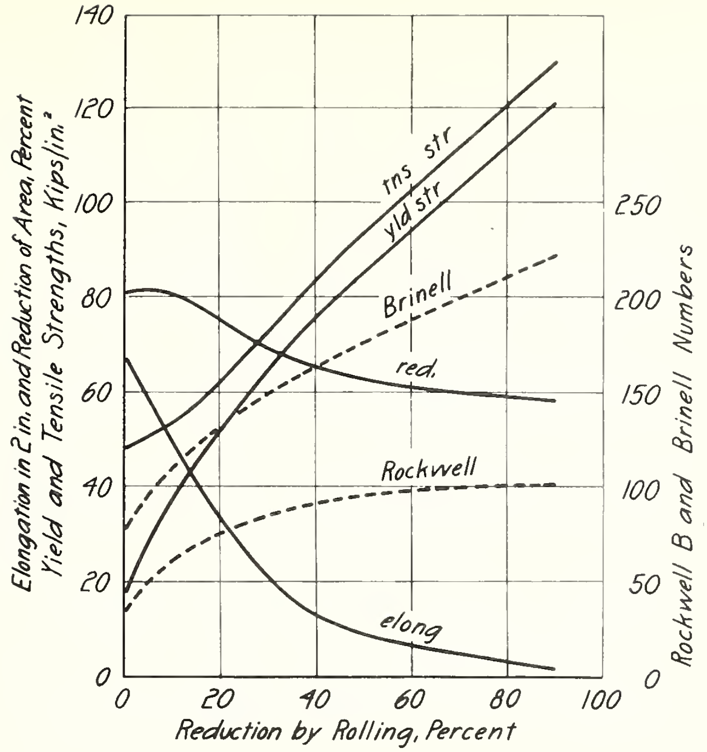


FIGURE 49.—*Effect of cold-rolling on the tensile properties and hardness of a copper-tin alloy (Cook and Tallis [653]).*

(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.

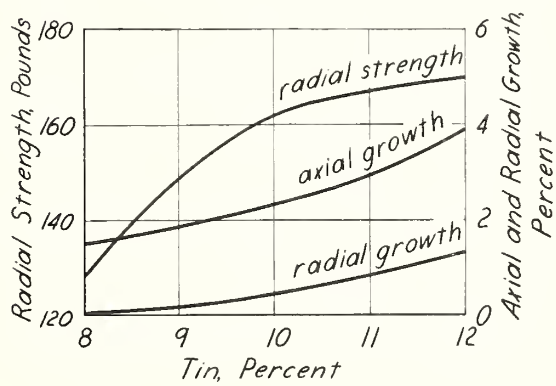


FIGURE 50.—*Effect of tin content on the properties of sintered copper-tin-graphite compacts (Koehring [52]).*

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

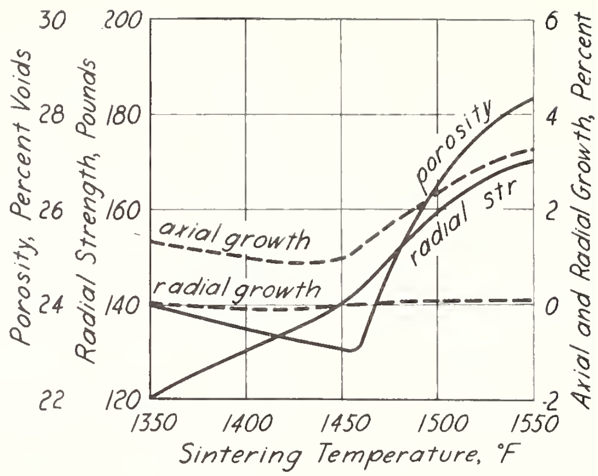


FIGURE 51.—*Effect of sintering temperature on the properties of sintered copper-tin-graphite compacts (Koehring [52]).*

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

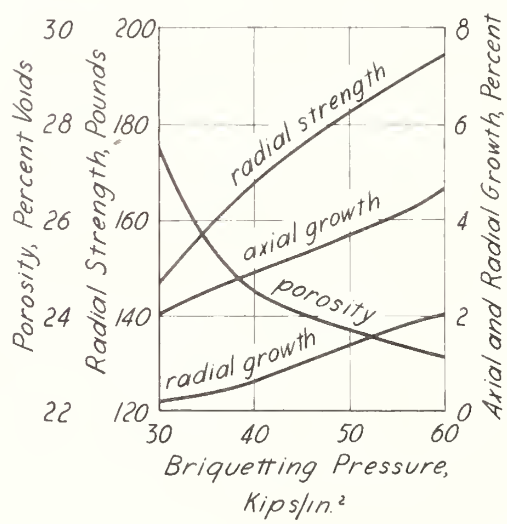


FIGURE 52.—*Effect of briquetting pressure on the properties of sintered copper-tin-graphite compacts (Koehring [52]).*

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

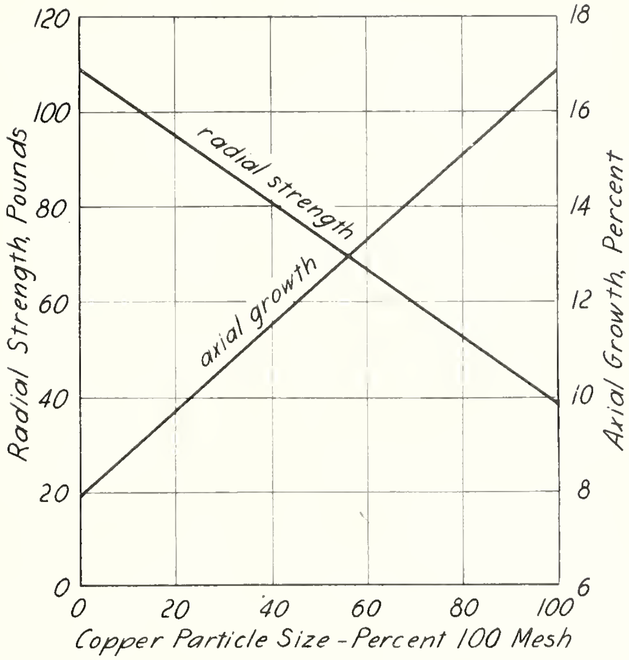


FIGURE 53.—*Effect of particle size on the properties of sintered copper-tin-graphite compacts (Koehring [52]).*

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

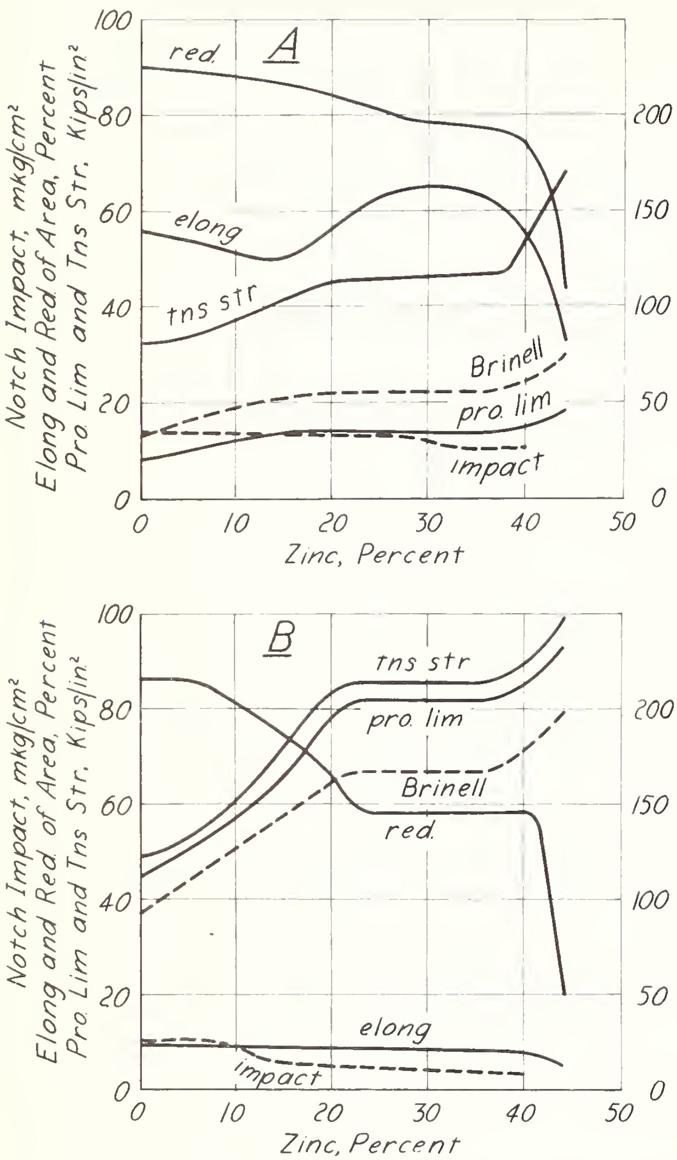


FIGURE 54.—*Tensile properties, impact value, and hardness of wrought copper-zinc alloys (Broniewski and Trzebski [654]).*

(Elongation in 10 diam)

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

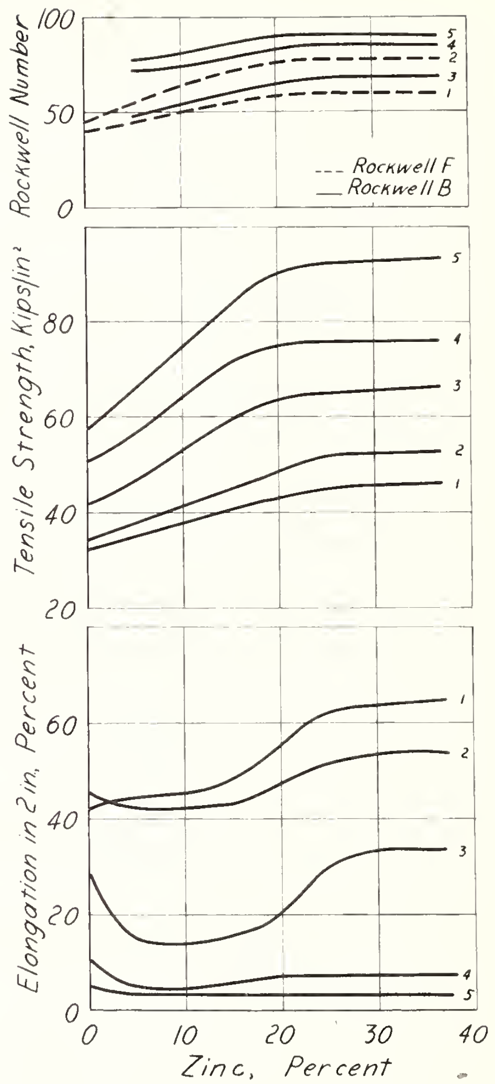


FIGURE 55.—*Tensile properties and hardness of copper-zinc alloys (Crampton [164]).*

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

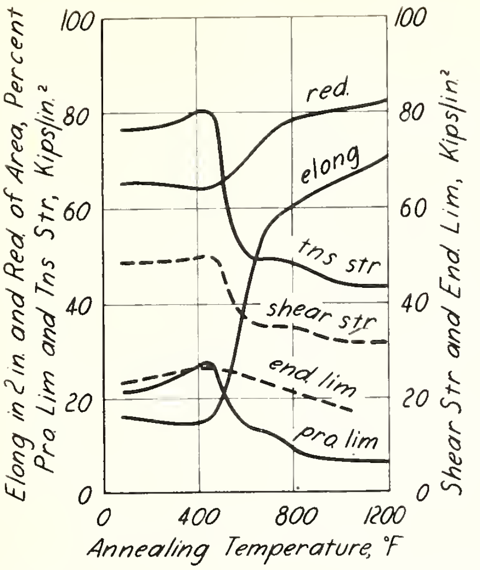


FIGURE 56.—*Effect of annealing on the tensile properties, endurance limit, and shear strength of a cold-drawn copper-zinc alloy (McAdam [86]).*

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

Annealed 1 hour.

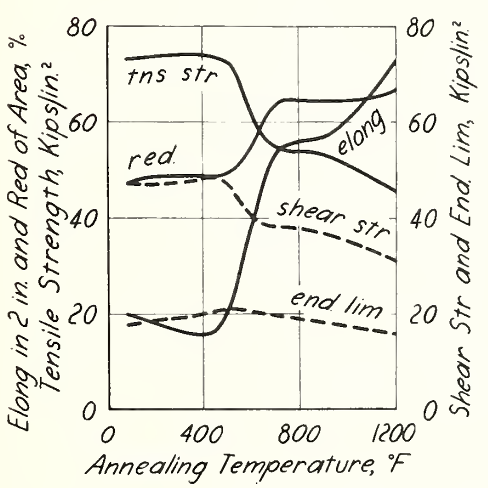


FIGURE 57.—*Effect of annealing on the tensile properties, endurance limit, and shear strength of a cold-drawn copper-zinc alloy (McAdam [86]).*

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

Annealed 1 to 1 1/2 hours.

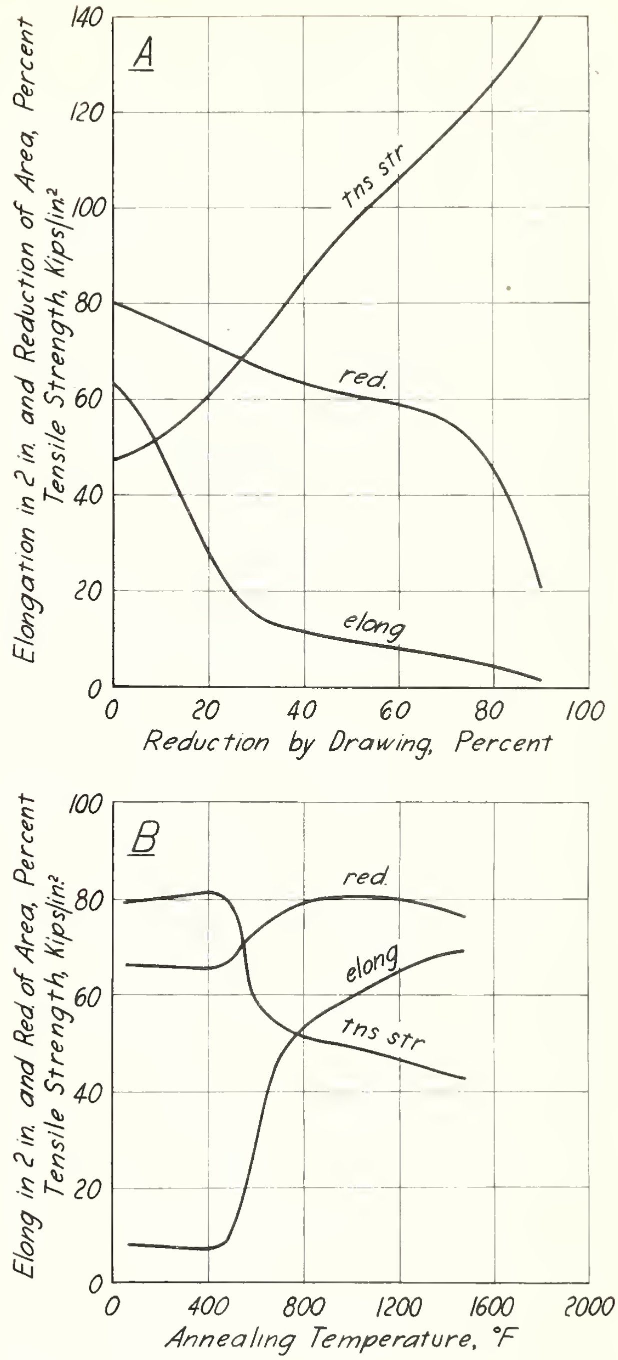


FIGURE 58.—*Effect of annealing and cold-drawing on the tensile properties of a copper-zinc alloy containing 34 percent of zinc (Pratt [655]).*

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

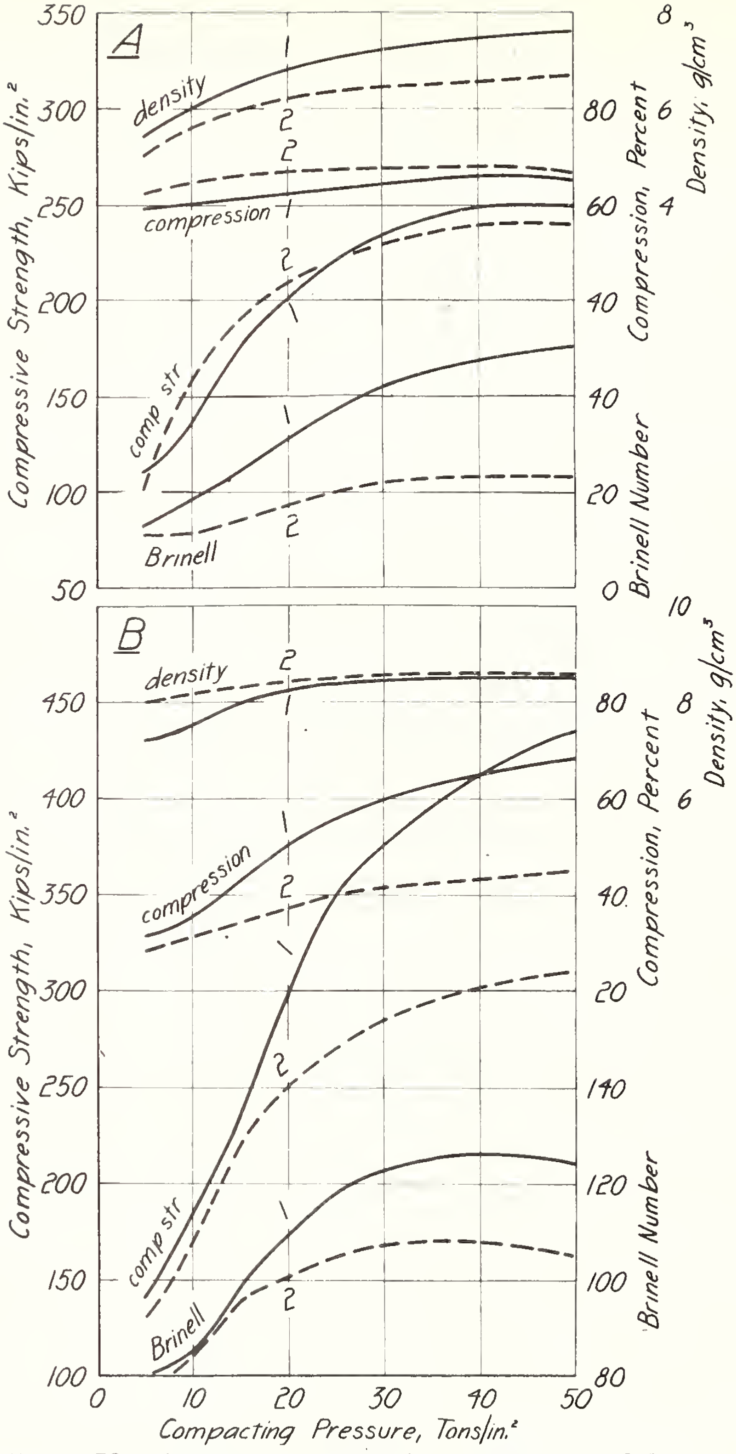


FIGURE 59.—*Compressive properties, hardness, and density of copper-zinc powder compacts containing 25 percent of zinc (Goetzel [52]).*

(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.

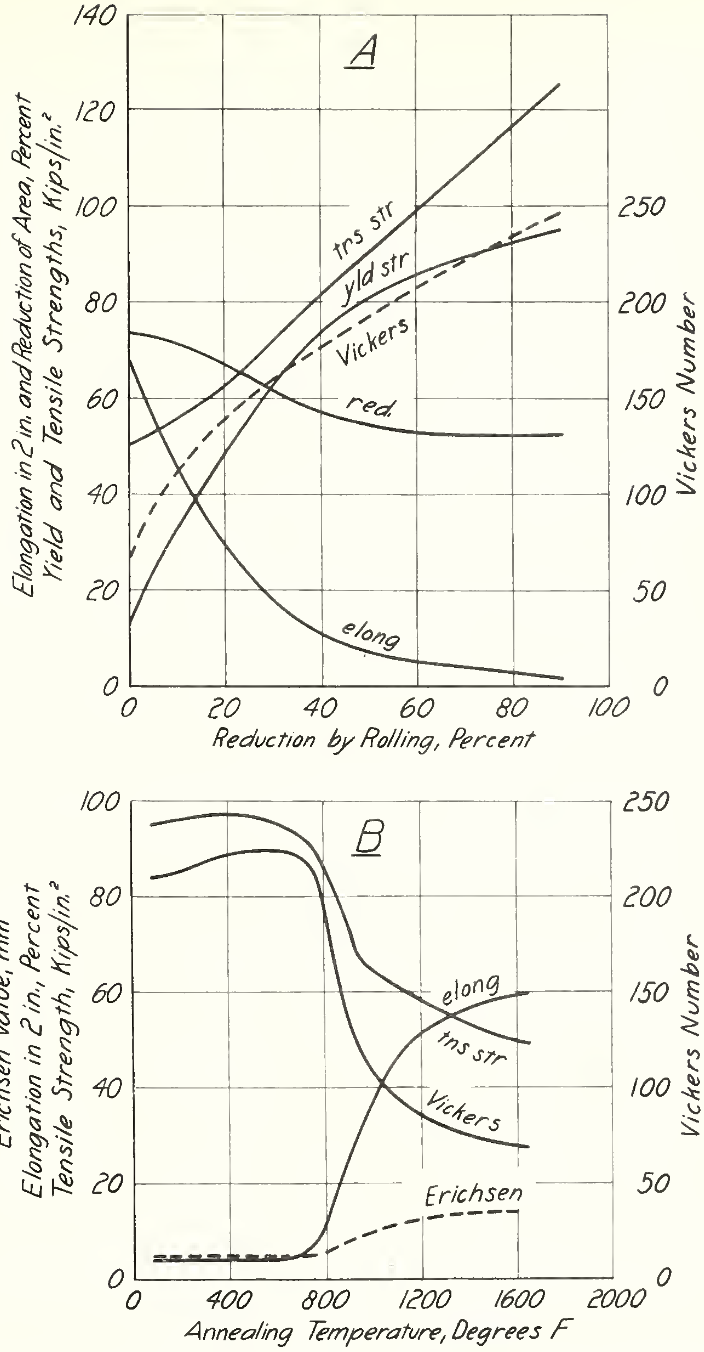


FIGURE 60.—*Effect of annealing and cold-rolling on the tensile properties, hardness, and Erichsen value of a copper-zinc-nickel alloy (Cook [203]).*

(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.

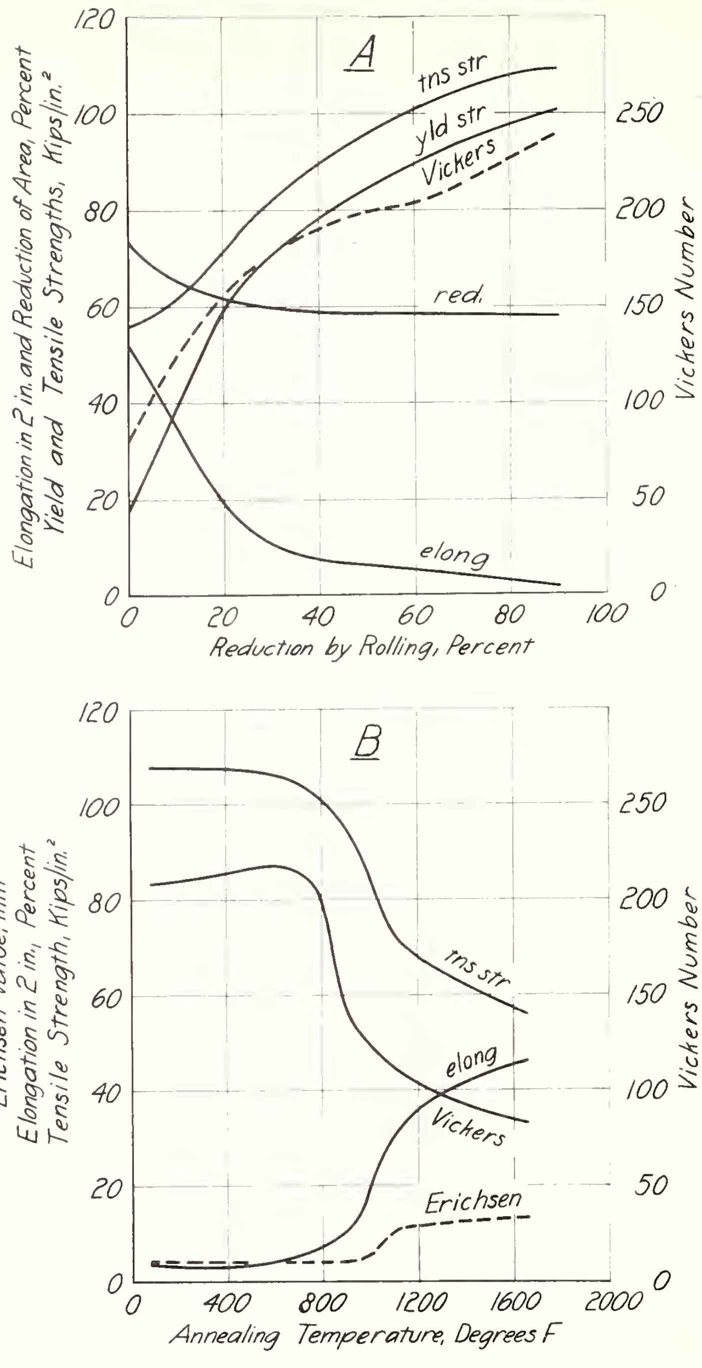


FIGURE 61.—*Effect of annealing and cold-rolling on the tensile properties, hardness, and Erichsen value of a copper-zinc-nickel alloy (Cook [203]).*

(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 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).]

Serial number	Composition	Condition	Temperature	Short-time properties: "Proportional limit"	Short-time properties: Yield strength	Short-time properties: Tensile strength	Short-time properties: Elongation	Short-time properties: Reduction of area	Short-time properties: Hardness number	Creep properties: Stress (kips/in.^{2}) for designated creep rate per 1,000 hours: 0.001%	0.01%	0.1%	1.0%	Creep properties: Duration	Reference
PURE AND COMMERCIAL COPPER (SEE ALSO FIGS. 62, 63, AND 64)															
	Percent		°F	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*		0.001%	0.01%	0.1%	1.0%	*Hours*	
1082....	Electro copper..................	Wrought, full anneal...........	400	....	....	....	....	....	......	......	3.1	6.7	....	1,135	[63]
1083....	Deoxidized copper: Cu 99.97, P 0.015.	Rod, 3/4 in., cold-drawn, ann...	85	18.4	42.0 (0.5%)	43.3	31 (2 in.)	81	88	......	....	....	....	.....	[63]
			400	12.5	....	36.8	21 (2 in.)	83	......	......	9.4	20.5	....	1,000	
COPPER-ALUMINUM ALLOY															
1084....	Al 7.68, Fe 0.66, Sn 0.08, P 0.01.	Die-cast......................	70	9.0	19.2 (yld pnt)	55.8	72 (2 in.)	60	R_B 24	......	....	....	....	.....	[63]
			200	....	13.6 (yld pnt)	52.6	71 (2 in.)	58	......	......	....	....	....	.....	
			400	14.0	16.2 (yld pnt)	48.3	63 (2 in.)	46	......	......	....	....	....	.....	
			600	10.6	14.4 (yld pnt)	37.7	33 (2 in.)	32	......	......	....	....	10.0 (0.54%)	500	
			700	6.5	15.9 (yld pnt)	26.9	17 (2 in.)	18	......	......	....	....	....	.....	
			800	....	16.1 (yld pnt)	26.4	8.5 (2 in.)	14	......	......	3.0 (0.04%)	....	....	250	
			900	....	16.1 (yld pnt)	22.2	5.0 (2 in.)	7.7	......	......	....	3.0 (0.35%)	....	250	
			1,000	....	10.1 (yld pnt)	15.4	4.8 (2 in.)	7.0	......	......	....	....	....	.....	
COPPER-NICKEL ALLOYS (SEE ALSO FIG. 65)															
1085....	Ni 20.0, Zn 5.08, Mn 0.69.......	Rod, 3/4 in., cold-drawn, ann at 1,200°F.	85	11.0	18.2 (0.5%)	50.4	51 (2 in.)	75	74	......	....	....	....	.....	[63]
			600	12.5	....	45.0	28 (2 in.)	72	......	......	13.8	27.8	....	1,000	
1086....	Ni 30.06, Mn 0.80, Fe 0.03, Pb 0.005.	Wire, 0.125 in. diam, ann to 0.020-mm grain size.	Room	....	21.0 (0.5% extn)	59.0	40 (2 in.)	....	......	......	....	....	....	.....	[191]
			300	....	....	....	....	....	......	24.0	35.0	....	....	5,000	
			500	....	....	....	....	....	......	16.0	30.0	....	....	5,000	
1087....	...do..........................	Wire, 0.125 in. diam, drawn (84% red.).	Room	....	80.0 (0.5% extn)	90.5	9 (2 in.)	....	......	......	....	....	....	.....	[191]
			500	....	....	....	....	....	......	8.0	....	....	....	5,000	
1088....	Ni 30.32, Mn 0.65, Zn 0.15......	Rod, 3/4 in., cold-drawn, ann at 1,020°F.	85	37.5	48.3 (0.5%)	64.7	37 (2 in.)	65	127	......	....	....	....	.....	[63]
			750	17.5	....	17.6	22 (2 in.)	48	......	......	9.1	18.8	....	1,000	
COPPER-SILICON ALLOYS															
1089....	Cu 96.34, Si 2.80, Fe 0.06, Pb 0.005, Zn rem.	Wire, 0.125 in. diam, ann to 0.100-mm grain size.	Room	....	8.0 (0.5% extn)	49.5	65 (2 in.)	....	......	......	....	....	....	.....	[191]
			400	....	....	....	....	....	......	......	8.5	....	....	5,000	
			500	....	....	....	....	....	......	3.5	5.3	8.0	....	5,000	

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

Serial number	Composition	Condition	Temperature	Short-time properties: "Proportional limit"	Short-time properties: Yield strength	Short-time properties: Tensile strength	Short-time properties: Elongation	Short-time properties: Reduction of area	Short-time properties: Hardness number	Creep properties: Stress (kips/in.^{2}) for designated creep rate per 1,000 hours: 0.001%	0.01%	0.1%	1.0%	Creep properties: Duration	Reference
					COPPER-SILICON ALLOYS—Continued										
	Percent		°F	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*		0.001%	0.01%	0.1%	1.0%	*Hours*	
1090....	Cu 96.34, Si 2.80, Fe 0.06, Pb 0.005, Zn rem.	Wire, 0.125 in. diam, ann to 0.008-mm grain size.	Room	....	25.0 (0.5% extn)	61.5	61 (2 in.)	....	......	......	....	....	....	.....	[191]
			300	....	....	....	....	....	......	10.0	20.0	....	....	5,000	
			400	....	....	....	....	....	......	1.6	5.0	15.0	....	5,000	
			500	....	....	....	....	....	......	0.7	1.7	4.2	....	5,000	
1091....	...do...........................	Wire, 0.125 in. diam, drawn (84% red.).	Room	....	68.5 (0.5% extn)	143	5.5 (2 in.)	....	......	......	....	....	....	.....	[191]
			300	....	....	....	....	....	......	......	16.0	....	....	5,000	
			400	....	....	....	....	....	......	4.0	24.0	....	....	5,000	
			500	....	....	....	....	....	......	0.65	1.5	3.2	....	5,000	
1092....	Si 2.81, Mn 1.25, Zn 0.20, Fe 0.15.	Wrought, fully ann..............	400	....	....	....	....	....	......	......	10.5	22.5	....	1,120	[63]
1093....	...do...........................	Rod, 3/4 in., cold-drawn, ann at 840°F.	85	22.0	38.7 (0.5%)	70.3	53 (2 in.)	64	119	......	....	....	....	.....	[63]
			550	10.0	....	48.4	60 (2 in.)	80	......	......	3.75	6.4	....	1,000	
1094....	Si 3.40, Mn 1.21, Fe 0.10.......	Rod, 3/4 in., hot-rolled........	70	38.0	86.5 (yld pnt)	102	15 (2 in.)	55	182	......	....	....	....	.....	[63]
			550	13.8	71.6 (yld pnt)	82.9	8.5 (2 in.)	27	......	......	....	....	....	.....	
			700	....	....	....	....	....	......	......	....	10.0 (0.5%)	....	750	
			800	11.9	28.9 (yld pnt)	48.5	13 (2 in.)	20	......	......	....	1.05	2.15	250	
					COPPER-TIN ALLOYS (SEE ALSO FIG. 66)										
1095....	Sn 3.78, P 0.23, Fe 0.22.........	Rod, 3/4 in., hot-rolled, ann at 1,250°F.	70	12.4	21.4 (yld pnt)	47.8	74 (2 in.)	84	63	......	....	....	....	.....	[63]
			450	12.0	17.0 (yld pnt)	47.9	70 (2 in.)	68	......	......	....	10.0 (0.2%)	....	250	
			500	....	....	....	....	....	......	......	....	10.0 (0.3%)	....	250	
			550	11.9	16.7 (yld pnt)	41.3	32 (2 in.)	36	......	......	....	....	10.0 (0.7%)	500	
			600	....	....	....	....	....	......	......	....	3.0	....	500	
			650	9.5	14.0 (yld pnt)	34.8	18 (2 in.)	23	......	......	....	1.6	....	500	
			800	8.5	10.8 (yld pnt)	27.4	34 (2 in.)	34	......	......	....	....	....	.....	
1096....	Sn 5.49, P 0.24.................	Rod, 5/8 in., wrought...........	63	8.3	....	48.8	84 ($4\sqrt{area}$)	84	......	......	....	....	....	.....	[63]
			482	....	....	....	....	....	......	......	....	12.8	21.0	500	
			500	5.8	14.6 (0.2%)	40.3	34 ($4\sqrt{area}$)	41	......	......	....	....	....	.....	
			662	4.5	13.4 (0.2%)	30.0	25 ($4\sqrt{area}$)	28	......	......	....	2.4	....	500	
			932	....	9.4 (0.2%)	20.4	6 ($4\sqrt{area}$)	10	......	......	....	....	6.2	500	
1097....	Sn 5.55, Zn 4.42, Pb 4.15, Ni 0.30, Fe 0.05.	Cast............................	500	....	....	....	....	....	......	......	3.3 (0.02%)	11.5	....	1,000	[63]

1098....	Sn 5.56, P 0.24, Fe 0.01	Wire, 0.125 in. diam, ann to 0.050-mm grain size.	Room	...	20.0 (0.5% extn)	52.0	66 (2 in.)	...	...	...	...	...	...	...	[191]
			300	...	...	...	...	...	...	11.0	...	...	...	5,000	
1099....	...do	Wire, 0.125 in. diam, drawn (84% red.).	Room	...	77.5 (0.5% extn)	144	3.5 (2 in.)	...	...	...	...	...	...	...	[191]
			300	...	...	...	...	...	...	5.0	32.0	...	...	5,000	
			400	...	...	...	...	...	...	...	7.5	...	...	5,000	
			500	...	...	...	...	...	...	...	2.7	...	...	5,000	
1100....	Sn 5.85, Zn 5.77, Pb 2.06, Fe 0.03.	Cast	70	...	16.4 (yld pnt)	37.6	36 (2 in.)	36	R_B 25	...	...	...	...	...	[63]
			400	...	14.2 (yld pnt)	32.2	26 (2 in.)	29	...	...	10.0 (0.015%)	...	...	250	
			600	...	13.0 (yld pnt)	16.2	2.5 (2 in.)	6.2	...	...	...	...	...	...	
			800	...	...	8.9	0 (2 in.)	0.8	...	...	...	...	...	...	
			1,000	...	...	7.6	0 (2 in.)	0	...	...	...	...	...	...	
1101....	Sn 5.99, Zn 5.10, Pb 2.33, Ni 0.23, Fe 0.06.	...do	70	9.0	16.0 (yld pnt)	31.0	20 (2 in.)	22	R_B 19	...	...	...	...	...	[63]
			500	...	...	...	...	...	...	...	...	10.0	...	250	
			600	5.6	12.4 (yld pnt)	25.6	16 (2 in.)	24	...	...	1.0 (0.04%)	3.0	...	250	
			700	6.5	12.4 (yld pnt)	15.4	1.5 (2 in.)	2.6	...	...	...	3.0 (0.065%)	...	500	
			800	6.2	11.9 (yld pnt)	11.4	2.0 (2 in.)	4.3	...	...	...	...	...	...	
1102[a]...	Sn 6.22, Zn 4.61, Pb 1.83	...do	75	...	16.5 (yld pnt)	39.4	31 (2 in.)	...	...	...	...	...	...	...	[63]
			500	...	13.1 (yld pnt)	32.7	20 (2 in.)	...	...	...	5.0 (0.03%)	...	...	1,000	
			600	...	12.5 (yld pnt)	29.5	16 (2 in.)	...	...	...	...	3.5	...	1,000	
			700	...	11.3 (yld pnt)	18.5	4.0 (2 in.)	...	...	...	...	...	...	...	
1103....	Sn 6.50, Zn 3.42, Pb 1.83	...do	550	...	...	...	...	...	...	...	4.0	...	...	1,000	[63]
1104....	Sn 10.18, Zn 2.02	Bar, 1/2 in. diam, sand-cast	Room	...	20.4 (yld pnt)	49.1	35 (2 in.)	...	...	...	...	...	...	...	[63]
			500	...	...	...	...	...	...	...	6.0 (0.03%)	8.0 (0.07%)	...	1,000	
			550	...	...	...	...	...	...	...	4.0 (0.027%)	...	...	1,500	
1105....	Sn 10.3, Zn 2.2	Cast	Room	...	20.4 (yld pnt)	49.1	35 (2 in.)	...	...	...	...	...	...	...	[63]
			500	...	...	...	...	...	...	...	6.0 (0.015%)	...	...	1,000	
			550	...	...	...	...	...	...	...	4.0	...	...	1,000	
			600	...	...	...	...	...	...	...	3.0 (0.02%)	...	...	1,500	
1106....	Sn 11.86, Zn 1.29, Pb 0.17, Ni 0.09, Fe 0.01.	...do	70	15.2	21.8 (yld pnt)	42.4	17 (2 in.)	20	90	...	...	...	...	...	[63]
			150	10.5	17.5 (yld pnt)	40.8	15 (2 in.)	...	...	...	10.0 (0.035%)	...	...	250	
			500	...	...	...	...	...	...	...	...	10.0 (0.2%)	...	250	
			550	13.0	16.8 (yld pnt)	34.8	12 (2 in.)	21	...	...	...	...	10.0 (4.5%)	250	
			650	10.0	16.8 (yld pnt)	26.2	4.0 (2 in.)	6.6	...	...	...	3.0 (0.3%)	...	250	
			800	8.5	16.0 (yld pnt)	20.4	2.0 (2 in.)	2.8	...	...	...	...	...	...	

[a]Charpy impact value (ft-lb) at 75°F, 20; 400°F, 20; 500°F, 15; 600°F, 2.2.

Serial number	Composition	Condition	Temperature	Short-time properties: "Proportional limit"	Short-time properties: Yield strength	Short-time properties: Tensile strength	Short-time properties: Elongation	Short-time properties: Reduction of area	Short-time properties: Hardness number	Creep properties: Stress (kips/in.²) for designated creep rate per 1,000 hours: 0.001%	0.01%	0.1%	1.0%	Creep properties: Duration	Reference
					COPPER-TIN ALLOYS—Continued										
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*						*Hours*	
1107....	Sn 12.25, Zn 1.46, Pb 0.01, Fe 0.01.	Cast..........	70	14.0	20.0 (yld pnt)	40.4	15 (2 in.)	18	......	......	....	....	....	.....	[63]
			500	10.1	18.2 (yld pnt)	32.4	5.5 (2 in.)	7.8	......	......	10.0 (0.03%)	....	....	250	
			550	....	....	....	......	......	......	......	....	3.0	....	250	
			600	7.5	16.5 (yld pnt)	33.6	9.5 (2 in.)	......	......	......	....	2.0 (0.08%)	....	500	
			800	6.5	15.1 (yld pnt)	22.5	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 0.060-mm grain size.	Room	....	9.0 (0.5% extn)	41.0	47 (2 in.)	......	......	......	....	....	....	.....	[191]
			300	....	....	....	......	......	......	4.9	8.0	....	....	5,000	
			400	....	....	....	......	......	......	......	6.2	....	....	5,000	
1109....	...do..........	Wire, 0.125 in. diam, drawn (84% red.).	Room	....	67.0 (0.5% extn)	96.5	7 (2 in.)	......	......	......	....	....	....	.....	[191]
			300	....	....	....	......	......	......	......	37.0	....	....	5,000	
			400	....	....	....	......	......	......	......	2.6	....	....	5,000	
1110....	Zn 4.86, Pb 5.24, Sn 5.10.......	Cast..........	Room	....	14.3 (yld pnt)	30.2	24 (2 in.)	......	......	......	....	....	....	.....	[63]
			500	....	....	....	......	......	......	......	8.0 (0.02%)	....	....	1,500	
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.	Room	....	15.5 (0.5% extn)	52.0	60 (2 in.)	......	......	......	....	....	....	.....	[191]
			500	....	....	....	......	......	......	......	2.2	5.0	....	5,000	
1112....	...do..........	Wire, 0.125 in. diam, drawn (60% red.).	Room	....	71.0 (0.5% extn)	109	6 (2 in.)	......	......	......	....	....	....	.....	[191]
			500	....	....	....	......	......	......	......	....	0.90	....	5,000	
1113....	Cu 70.45, Pb <0.05, Fe 0.01, Zn rem.	Wire, 0.125 in. diam, ann to 0.200-mm grain size.	Room	....	8.5 (0.5% extn)	42.5	55 (2 in.)	......	......	......	....	....	....	.....	[191]
			400	....	....	....	......	......	......	2.4	....	....	....	5,000	
			500	....	....	....	......	......	......	1.95	2.7	3.7	....	5,000	
1114....	...do..........	Wire, 0.125 in. diam, ann to 0.022-mm grain size.	Room	....	19.0 (0.5% extn)	52.0	49 (2 in.)	......	......	......	....	....	....	.....	[191]
			400	....	....	....	......	......	......	......	3.0	8.5	....	5,000	
			500	....	....	....	......	......	......	......	0.80	2.2	....	5,000	
1115....	...do..........	Wire, 0.125 in. diam, drawn (84% red.); coarse grained.	Room	....	....	124	5.5 (2 in.)	......	......	......	....	....	....	.....	[191]
			400	....	....	....	......	......	......	......	2.0	....	....	5,000	
			500	....	....	....	......	......	......	......	0.30	....	....	5,000	
1116....	Cu 69.43, Pb <0.05, Fe 0.01, Zn rem.	Wire, 0.125 in. diam, ann to 0.085-mm grain size.	Room	....	11.5 (0.5% extn)	48.5	57 (2 in.)	......	......	......	....	....	....	.....	[191]
			300	....	....	....	......	......	......	9.5	16.0	....	....	5,000	
			400	....	....	....	......	......	......	......	7.7	....	....	5,000	
			500	....	....	....	......	......	......	1.0	2.0	4.0	....	5,000	
1117....	...do..........	Wire, 0.125 in. diam, ann to 0.016-mm grain size.	Room	....	22.5 (0.5% extn)	59.5	42 (2 in.)	......	......	......	....	....	....	.....	[191]
			300	....	....	....	......	......	......	......	13.0	....	....	5,000	
			400	....	....	....	......	......	......	......	2.9	....	....	5,000	
			500	....	....	....	......	......	......	......	0.65	1.75	....	5,000	

1118....	...do...	Wire, 0.125 in. diam, drawn (84% red.); fine-grained.	Room	...	65.0 (0.5% extn)	120	4.5 (2 in.)	...	...	...	...	...	...	...	[191]
			300	...	...	...	...	...	...	...	22.0	50.0	...	5,000	
			400	...	...	...	...	...	...	...	1.4	3.5	...	5,000	
			500	...	...	...	...	...	...	...	0.25	0.70	...	5,000	
1119....	Naval brass: Cu 59.98, Sn 0.65, Pb <0.05, Fe 0.015, Zn rem.	Wire, 0.125 in. diam, ann at 1,000°F.	Room	...	30.5 (0.5% extn)	66.0	40 (2 in.)	...	...	...	...	...	...	...	[191]
			300	...	...	...	...	...	...	...	10.5	...	...	5,000	
			400	...	...	...	...	...	...	...	1.9	5.0	...	5,000	
			500	...	...	...	...	...	...	...	0.25	0.80	...	5,000	
1120....	...do...	Wire, 0.125 in. diam, drawn (37% red.).	Room	...	66.0 (0.5% extn)	95.0	10 (2 in.)	...	...	...	...	...	...	...	[191]
			300	...	...	...	...	...	...	...	9.0	...	...	5,000	
			400	...	...	...	...	...	...	...	3.0	9.0	...	5,000	
1121....	Zn 38.67, Pb 0.99, Sn 0.34, Fe 0.20.	Rod, 5/8 in., wrought...	63	...	...	60.7	41 (4√area)	38	...	...	...	...	...	...	[63]
			302	...	30.5 (0.2%)	52.2	55 (4√area)	54	...	...	...	20.7	28.0	500	
			662	...	9.9 (0.2%)	20.2	42 (4√area)	32	...	...	...	...	...	...	
			932	...	2.7 (0.2%)	5.4	30 (4√area)	24	...	...	...	...	...	...	
1122....	Zn 39.00, Pb 2.94, Sn 0.04, Fe 0.04.	Rod, 13/16 in., extruded, ann at 1,500°F.	70	38.6	54.8 (yld pnt)	69.2	22 (2 in.)	38	148	...	...	...	...	...	[63]
			450	6.5	30.7 (yld pnt)	53.6	30 (2 in.)	40	...	...	...	3.0 (0.35%)	...	250	
			550	4.5	21.5 (yld pnt)	45.2	28 (2 in.)	28	...	...	...	...	1.0 (1.9%)	1,000	
			600	3.0	15.5 (yld pnt)	38.8	24 (2 in.)	21	...	...	...	...	...	...	
			800	<1.0	6.0 (yld pnt)	15.2	31 (2 in.)	27	...	...	...	...	...	...	
1123....	Naval brass: Zn 39.20, Sn 0.75, Pb 0.08, Fe 0.05.	Rod, 3/4 in., extruded, ann at 1,500°F.	70	7.0	15.7 (yld pnt)	60.3	42 (2 in.)	45	96	...	...	...	...	...	[63]
			300	8.0	19.7 (yld pnt)	50.4	50 (2 in.)	66	...	...	10.0 (0.013%)	...	...	250	
			400	...	...	...	...	...	...	...	...	2.2	7.1	250	
			450	14.0	21.3 (yld pnt)	40.5	35 (2 in.)	40	...	...	...	...	4.1	250	
			800	...	4.5 (yld pnt)	11.5	38 (2 in.)	45	...	...	...	...	...	...	
1124....	Zn 39.52, Pb 2.78, Fe 0.07...	...do...	70	11.5	17.5 (yld pnt)	55.0	36 (2 in.)	28	65	...	...	...	...	...	[63]
			300	16.0	20.0 (yld pnt)	47.3	41 (2 in.)	36	...	...	...	...	...	...	
			350	...	...	...	...	...	...	...	...	10.0 (0.3%)	...	250	
			400	...	...	...	...	...	...	...	...	...	10.0 (1.8%)	250	
			450	10.0	18.5 (yld pnt)	40.1	31 (2 in.)	29	...	...	...	...	...	...	
1125....	Zn 40.11, Fe 1.72, Pb 0.49, Al 0.44, Sn 0.10.	Cast...	70	11.6	22.2 (yld pnt)	64.9	23 (2 in.)	25	R_B 60	...	...	...	...	...	[63]
			300	17.0	24.2 (yld pnt)	54.1	37 (2 in.)	33	...	...	...	10.0	...	500	
			400	17.0	26.2 (yld pnt)	46.5	52 (2 in.)	19	...	...	...	...	...	...	
			600	4.0	12.3 (yld pnt)	30.2	74 (2 in.)	59	...	...	...	...	...	...	
			800	...	3.7 (yld pnt)	10.9	102 (2 in.)	71	...	...	...	...	...	...	

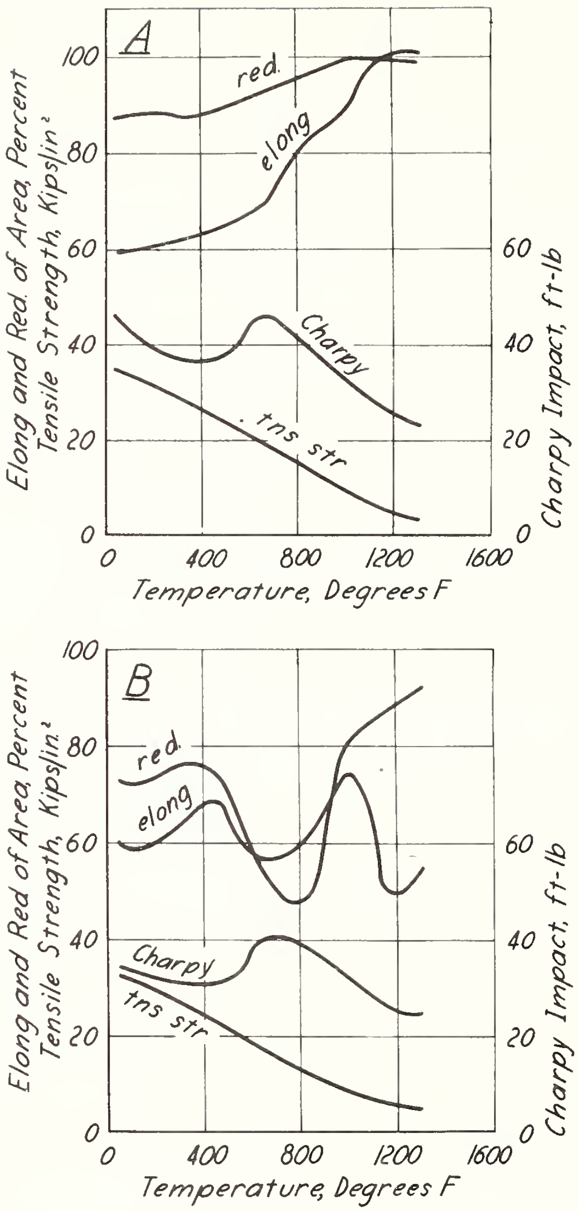


FIGURE 62.—*Short-time tensile properties and impact value of hot-rolled oxygen-free and tough-pitch copper at high temperatures (Lorig, Dahle, and Roberts [656]).*

(Elongation in 2 in.)

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

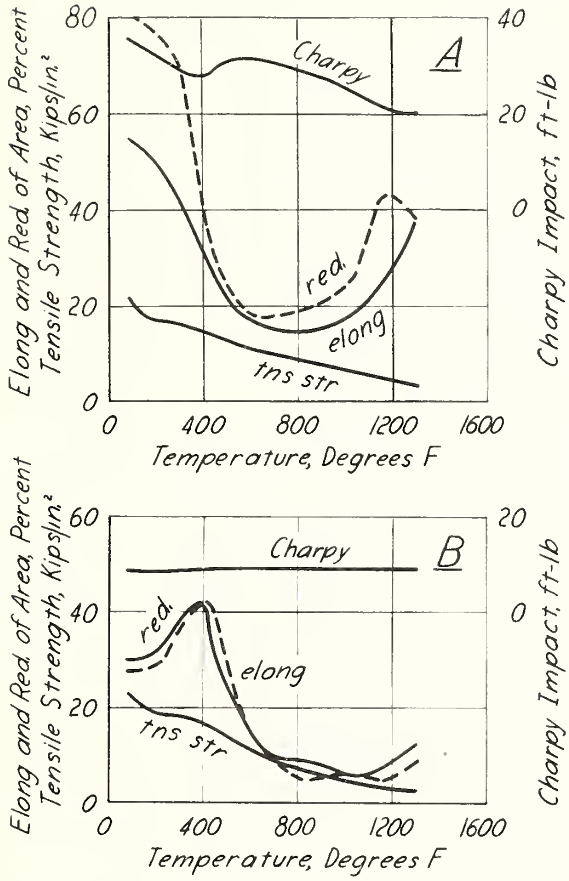


FIGURE 63.—*Short-time tensile properties and impact value of cast oxygen-free and tough-pitch copper at high temperatures (Lorig, Dahle, and Roberts [656]).*

(Elongation in 2 in.)

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

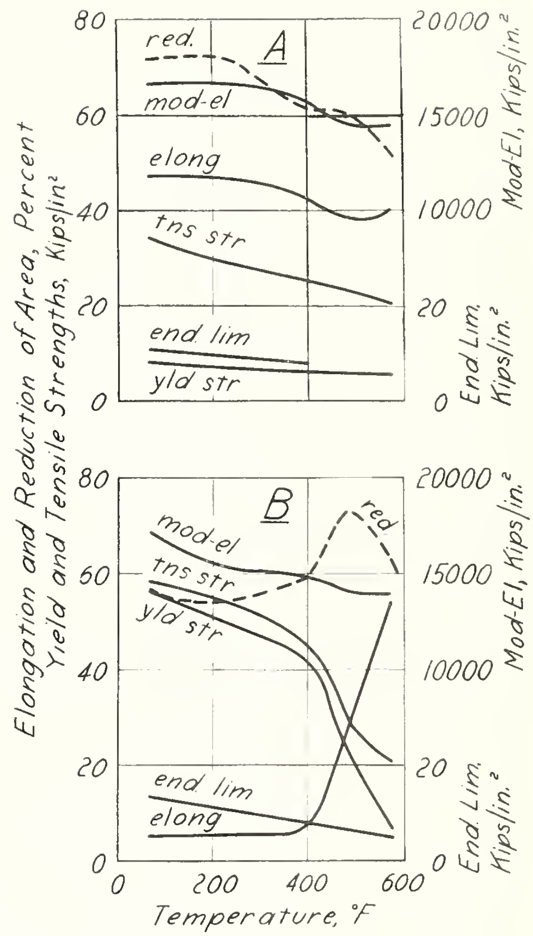


FIGURE 64.—*Short-time tensile properties and endurance limit of copper at high temperatures (Schwinning and Strobel [657]).*

(Yield strength, 0.2%)

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

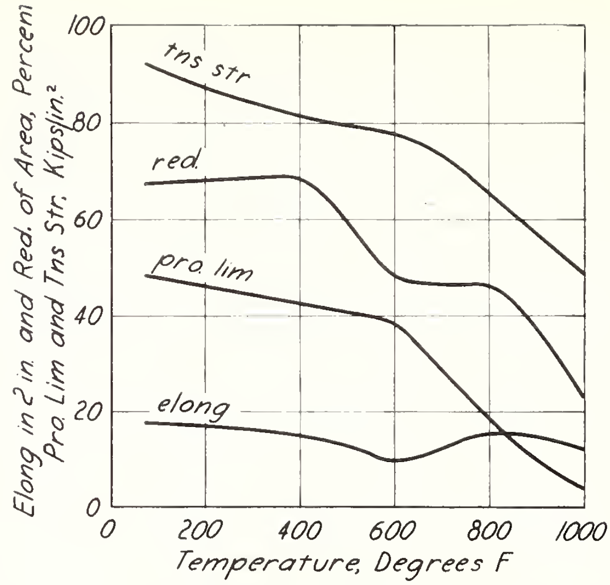


FIGURE 65.—*Short-time tensile properties of a copper-nickel-zinc alloy at high temperatures (Clark and White [189]).*

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

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

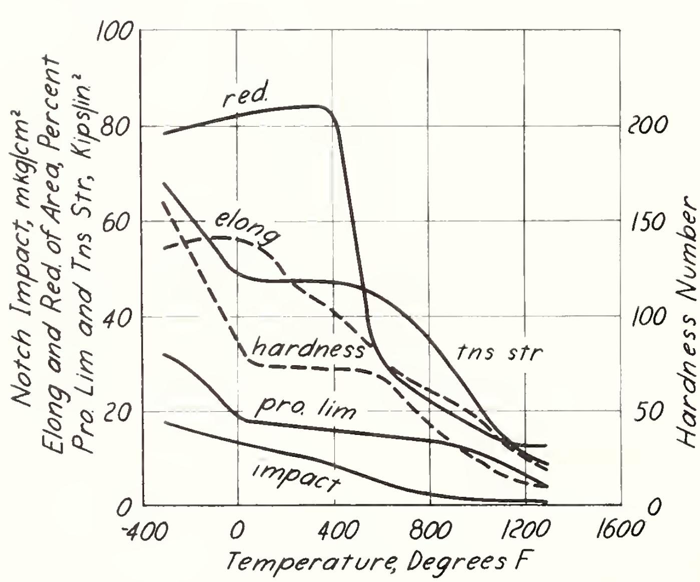


FIGURE 66.—*Short-time tensile properties, impact value, and hardness of a copper-tin alloy containing 5 percent of tin at various temperatures (Broniewski and Szreniawski [658]).*

(Elongation in 10 diam)

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

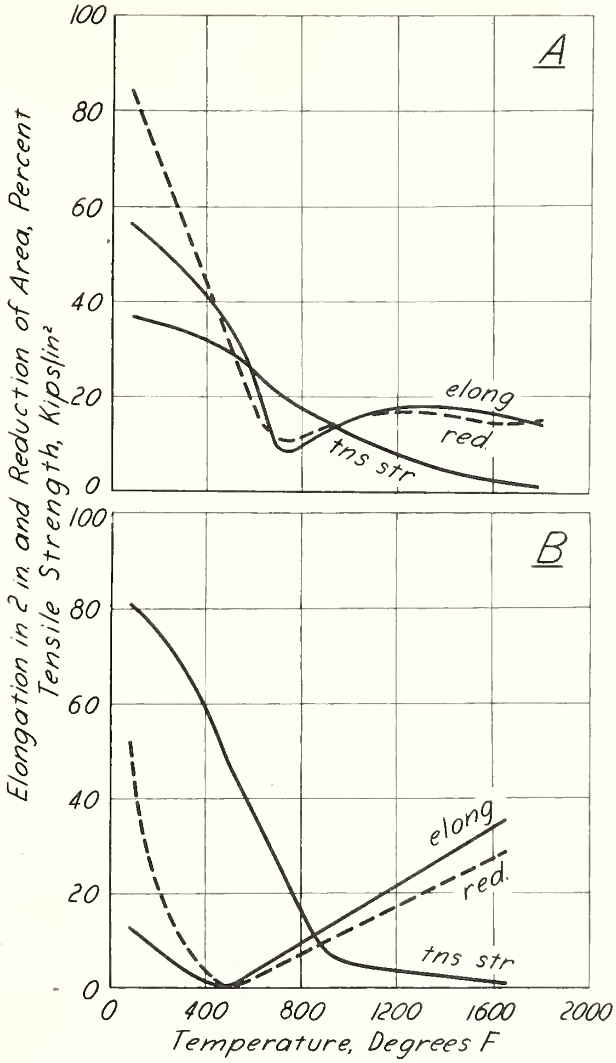


FIGURE 67.—*Short-time tensile properties of copper-zinc alloys at high temperatures (Price [173]).*

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.).

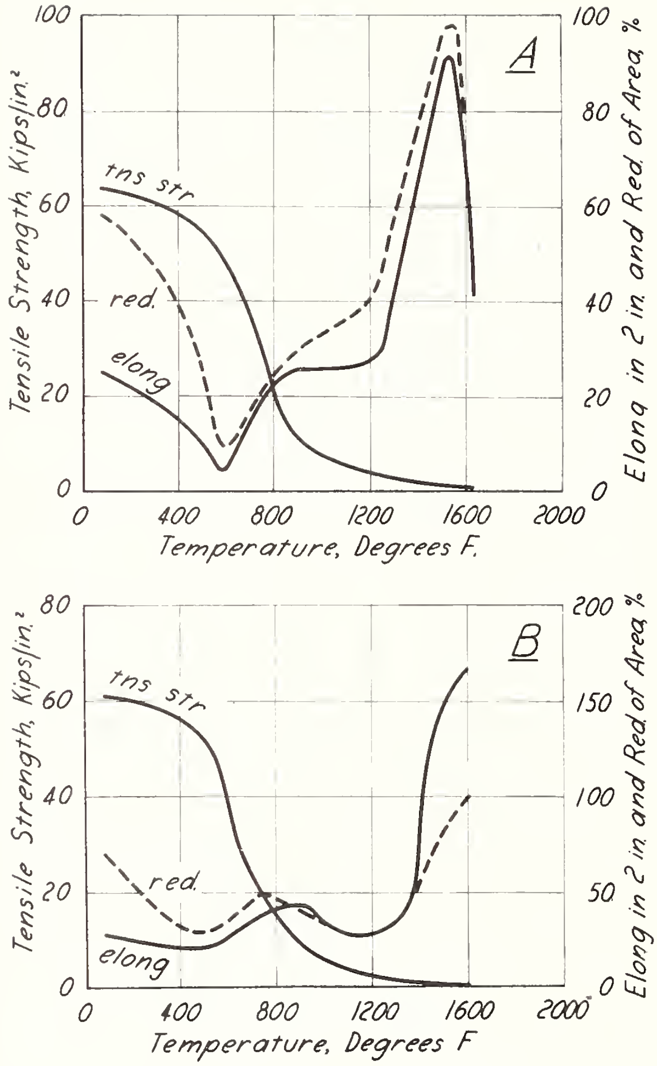


FIGURE 68.—*Short-time tensile properties of copper-zinc alloys at high temperatures (Price [173]).*

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*

[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: Modulus of elasticity	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Hardness number	Impact value	Remarks	Reference
					PURE AND COMMERCIAL COPPER							
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*		*ft-lb*		
1126....	Cu 99.985..................	Rod, 1 in. diam, ann.............	Room	....	8.6 (0.1% perm)	31.4	18 (2 in.)	76	......	Iz 43	Tensile specimens 0.25 in. diam.	[64]
			-40	....	9.2 (0.1% perm)	33.8	47 (2 in.)	77	......	Iz 45		
			-112	....	10.1 (0.1% perm)	38.5	47 (2 in.)	74	......	Iz 44		
			-181	....	10.8 (0.1% perm)	41.2	45 (2 in.)	70	......	Iz 44		
			-292	....	11.5 (0.1% perm)	50.8	58 (2 in.)	77	......	Iz 50		
1127....	Electro copper.............	Cold-worked......................	68	....	....	58.6	8.4 (10 diam)	52	[a] 112	[b] 6.4	....	[192]
			-108	....	....	60.4	12 (10 diam)	57	[a] 127	[b] 6.6		
			-297	....	....	64.7	11 (10 diam)	61	[a] 152	[b] 7.4		
1128....	Cu 99.95, P 0.025..........	Annealed.........................	Room	....	8.3 (0.5% extn)	32.6	58 (2 in.)	....	R_F 43	47	....	[193]
			-25	....	....	....	....	....	......	45		
			-60	....	....	....	....	....	......	44		
			-110	....	....	....	....	....	......	46		
			-175	....	....	....	....	....	......	48		
					COPPER-ALUMINUM ALLOYS							
1129....	Al 7.31, Zn 1.02, Mn 0.44, Fe 0.056, P 0.018.	Rod, 1 in. diam, ann.............	Room	....	26.7 (0.1% perm)	77.3	26 (2 in.)	29	......	Iz 24	Tensile specimens 0.25 in. diam.	[64]
			-40	....	26.9 (0.1% perm)	79.7	35 (2 in.)	36	......	Iz 24		
			-112	....	27.1 (0.1% perm)	82.7	31 (2 in.)	30	......	Iz 24		
			-184	....	27.6 (0.1% perm)	88.0	32 (2 in.)	31	......	Iz 21		
			-292	....	29.2 (0.1% perm)	96.1	28 (2 in.)	30	......	Iz 20		
1130....	Al 9.83, Fe 0.60............	Rod, 1/2 in., hard-drawn.........	Room	17,500	50.0	84.0	20 (2 in.)	16	143	Iz 20	Tensile specimen 0.375 in. diam; square impact specimen.	[25]
			-42	17,500	53.0	88.0	17 (2 in.)	16	......	Iz 24		
					COPPER-BERYLLIUM ALLOYS							
1131....	Be 2.02, Ni 0.26, Fe 0.09...	Rod, 5/8 in., ann................	Room	18,500	39.0	72.5	46 (2 in.)	58	188	Iz 54	Tensile specimen 0.375 in. diam; square impact specimen.	[25]
			-42	18,500	44.5	75.0	46 (2 in.)	59	......	Iz 68		

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

[b] Notch impact value, m-kg/cm.²

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

Serial number	Composition	Condition	Temperature	Tensile properties: Modulus of elasticity	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Hardness number	Impact value	Remarks	Reference
					COPPER-BERYLLIUM ALLOYS—Continued							
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*		*ft-lb*		
1132....	Be 2.02, Ni 0.26, Fe 0.09...	Rod, 5/8 in., ann................	Room	20,000	111	113	11 (2 in.)	42	225	Iz 46	Tensile specimen 0.375 in. diam; square impact specimen.	[25]
			-42	20,000	112	118	12 (2 in.)	42	......	Iz 51		
1133....	...do......................	Rod, 5/8 in.; 2 hr at 575°F......	Room	21,000	170	202	3 (2 in.)	6	375	Iz 2	...do........................	[25]
			-42	21,000	176	215	2.5 (2 in.)	4	......	Iz 4		
1134....	Be 2.56, Fe 0.034...........	Rod, 1 in. diam, w-q from 1,470°F.	Room	17,000	24.9 (0.1% perm)	76.2	36 (2 in.)	50	......	Iz 41	Tensile specimens 0.25 in. diam.	[64]
			-112	21,600	29.1 (0.1% perm)	86.7	38 (2 in.)	54	......	Iz 40		
			-292	21,700	50.0 (0.1% perm)	112	41 (2 in.)	57	......	Iz 40		
1135....	...do......................	Rod, 1 in. diam, w-q from 1,470°F, aged 2 hr at 570°F.	Room	21,400	125 (0.1% perm)	187	2.6 (2 in.)	5.0	......	Iz 2.0	...do........................	[64]
			-112	22,700	147 (0.1% perm)	202	0.4 (2 in.)	5.0	......	Iz 3.0		
			-184	23,400	139 (0.1% perm)	198	0.4 (2 in.)	4.0	......	Iz 2.5		
			-292	20,600	155 (0.1% perm)	214	3.0 (2 in.)	6.0	......	Iz 3.0		
					COPPER-NICKEL ALLOYS							
1136....	Ni 5.86, Al 1.73............	Rod, 1 in. diam, w-q from 1,650°F.	Room	....	11.4 (0.1% perm)	51.5	42 (2 in.)	80	......	Iz 58	Tensile specimens 0.25 in. diam.	[64]
			-40	....	16.1 (0.1% perm)	55.8	42 (2 in.)	80	......	....		
			-112	....	16.4 (0.1% perm)	57.3	42 (2 in.)	79	......	....		
			-184	....	15.0 (0.1% perm)	61.6	44 (2 in.)	82	......	....		
			-292	....	22.8 (0.1% perm)	67.2	49 (2 in.)	82	......	Iz 67		
1137....	...do......................	Rod, 1 in. diam, w-q from 1,650°F, aged 2 hr at 1,020°F.	Room	....	....	90.9	24 (2 in.)	50	......	Iz 40	...do........................	[64]
			-40	....	61.6 (0.1% perm)	104	24 (2 in.)	57	......	....		
			-112	22,400	51.5 (0.1% perm)	101	22 (2 in.)	57	......	....		
			-184	24,300	63.4 (0.1% perm)	108	26 (2 in.)	63	......	....		
			-292	20,800	54.9 (0.1% perm)	107	26 (2 in.)	67	......	Iz 55		
1138....	Ni 19.49, Zn 5.43, Mn 0.80..	Annealed........................	Room	....	35.2 (0.5% extn)	54.7	43 (2 in.)	....	R_B 49	68	....	[193]
			-25	....	....	....	....	....	......	56		
			-60	....	....	....	....	....	......	56		
			-110	....	....	....	....	....	......	56		
			-175	....	....	....	....	....	......	53		

1139....	Ni 20.58, Mn 0.11, Si 0.03..	Rod, 1 in. diam, ann.............	Room	....	27.7 (0.1% perm)	51.5	26 (2 in.)	78	......	Iz 77	Tensile specimens 0.25 in. diam.	[64]
			-40	....	29.0 (0.1% perm)	59.6	29 (2 in.)	77	......	Iz 81		
			-112	....	28.9 (0.1% perm)	61.6	29 (2 in.)	76	......	Iz 79		
			-173	....	29.2 (0.1% perm)	66.1	28 (2 in.)	75	......	Iz 84		
			-292	....	32.5 (0.1% perm)	73.7	36 (2 in.)	72	......	Iz 85		
1140....	Ni 29.54, Zn 0.62, Mn 0.57..	Annealed........................	Room	....	34.2 (0.5% extn)	57.6	54 (2 in.)	....	R_B 55	66	....	[193]
			-25	....	....	....	....	....	......	59		
			-60	....	....	....	....	....	......	59		
			-110	....	....	....	....	....	......	59		
			-175	....	....	....	....	....	......	60		
1141....	Ni 30.50, Zn 14.30..........	Rod, 1 in. diam, ann.............	Room	....	27.9 (0.1% perm)	75.3	33 (2 in.)	52	......	Iz 80	Tensile specimens 0.25 in. diam.	[64]
			-40	....	28.6 (0.1% perm)	78.2	34 (2 in.)	52	......	Iz 87		
			-112	....	27.5 (0.1% perm)	83.1	39 (2 in.)	52	......	Iz 83		
			-184	....	28.8 (0.1% perm)	89.8	38 (2 in.)	52	......	Iz 80		
			-292	....	28.4 (0.1% perm)	104	41 (2 in.)	55	......	Iz 87		
1142....	Ni 45.78, Mn 0.39, Co 0.26, Si 0.15, Fe 0.07.	...do............................	Room	....	19.6 (0.1% perm)	60.0	40 (2 in.)	77	......	Iz 80	...do........................	[64]
			-40	....	21.0 (0.1% perm)	67.6	43 (2 in.)	78	......	Iz 85		
			-112	....	22.1 (0.1% perm)	72.2	48 (2 in.)	75	......	Iz 81		
			-184	....	24.1 (0.1% perm)	77.1	48 (2 in.)	74	......	Iz 83		
			-292	....	26.3 (0.1% perm)	89.6	57 (2 in.)	76	......	Iz 86		
					COPPER-SILICON ALLOYS							
1143....	Si 2.75, Mn 0.97, Fe 0.15...	Rod, 1/2 in. diam, cold-drawn (42% red.).	77	....	....	74.2	40 (2 in.)	75	......	....	....	[193]
			-112	....	....	82.9	32 (2 in.)	72	......	....		
			-310	....	....	100	36 (2 in.)	72	......	....		
1144....	Si 3.05, Mn 0.98, Fe 0.17...	Annealed........................	Room	....	29.9 (0.5% extn)	62.4	66 (2 in.)	....	R_B 54	66	....	[193]
			-25	....	....	....	....	....	......	75		
			-60	....	....	....	....	....	......	73		
			-110	....	....	....	....	....	......	69		
			-175	....	....	....	....	....	......	64		
					COPPER-TIN ALLOYS							
1145....	Sn 3.99, P 0.40............	Rod, 1/2 in., hard-drawn.........	Room	16,500	82.5	87.0	20 (2 in.)	70	178	Iz 46	Tensile specimens 0.375 in. diam; round impact specimens.	[25]
			-42	16,500	85.0	93.0	20 (2 in.)	68	......	Iz 44		
1146....	Sn 5.0, Zn 0.30, Pb 0.10, P 0.02.	Cold-worked......................	Room	....	....	....	....	....	......	Iz 62	....	[25]
			-40	....	....	....	....	....	......	Iz 63		
1147....	Sn 10.0, Zn 1.61...........	Cast............................	Room	....	29.3 (yld pnt)	45.5	30 (10 diam)	36	90	....	Tensile specimens 0.12 in. diam.	[66]
			-423	....	46.4 (yld pnt)	58.0	18 (10 diam)	38	......	....		

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

Serial number	Composition	Condition	Temperature	Tensile properties: Modulus of elasticity	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Hardness number	Impact value	Remarks	Reference
	COPPER-ZINC ALLOYS											
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*		*ft-lb*		
1148....	Zn 5, Sn 5, Pb 5............	Cast..............................	Room	....	....	....	....	......	.....	5.5	....	[25]
			-50	....	....	....	....	......	.....	6		
			-75	....	....	....	....	......	.....	6		
1149....	Cu 71.6, Zn rem.............	....	64	....	9.5 (yld pnt)	41.5	83 (2 in.)	76	.....	85	Impact specimens 10-mm square; sharp notch.	[65]
			-22	....	10.4 (yld pnt)	43.2	76 (2 in.)	80	.....	90		
			-112	....	12.2 (yld pnt)	48.6	74 (2 in.)	80	.....	89		
1150....	Admiralty brass: Zn 28.44, Sn 0.95, Fe 0.03, Pb 0.01.	Annealed..........................	Room	....	13.3 (0.5% extn)	46.5	84 (2 in.)	......	R_F 64	61	....	[193]
			-25	....	....	....	....	......	.....	61		
			-60	....	....	....	....	......	.....	59		
			-110	....	....	....	....	......	.....	62		
			-175	....	....	....	....	......	.....	59		
1151....	Zn 30.50, Fe 0.10..........	Rod, 1 in. diam, ann............	Room	....	28.2 (0.1% perm)	51.1	49 (2 in.)	77	.....	Iz 66	Tensile specimens 0.25 in. diam.	[64]
			-40	....	26.9 (0.1% perm)	54.7	58 (2 in.)	77	.....	Iz 66		
			-112	....	27.3 (0.1% perm)	57.1	60 (2 in.)	79	.....	Iz 69		
			-184	....	28.0 (0.1% perm)	61.2	55 (2 in.)	78	.....	Iz 70		
			-292	....	29.6 (0.1% perm)	73.5	75 (2 in.)	73	.....	Iz 78		
1152....	Zn 33......................	Annealed 2 hr at 1,020°F.........	Room	....	....	56.9	50 (10 diam)	72	[a] 77	[b] 14.4	....	[194]
			-108	....	....	61.2	50 (10 diam)	77	[a] 86	[b] 16.9		
			-297	....	....	76.4	51 (10 diam)	71	[a] 100	[b] 14.2		
1153[c]...	...do......................	Cold-worked......................	Room	....	....	85.3	6.3 (10 diam)	66	[a] 142	[b] 8.1	....	[194]
			-108	....	....	92.4	7.8 (10 diam)	72	[a] 149	[b] 9.2		
			-297	....	....	103	10 (10 diam)	66	[a] 172	[b] 9.4		
1154....	Zn 35, Pb 3................	Annealed 3/4 hr at 650°F, f-c....	80	....	....	....	....	......	.....	....	Endurance limit[d] ....26.0 kips/in.²..	[195]
			-20	....	....	....	....	......	.....	....	Endurance limit[d] ....27.5 kips/in.²..	
			-40	....	....	....	....	......	.....	....	Endurance limit[d] ....27.0 kips/in.²..	
1155....	Naval brass: Zn 36.96, Sn 0.31, Pb 0.08.	Rod, 1/2 in., hard-drawn.........	Room	15,000	54.0	72.0	24 (2 in.)	65	138	Iz 38	Tensile specimens 0.375 in. diam; square impact specimens.	[25]
			-42	15,000	58.0	74.5	26 (2 in.)	65	.....	Iz 37		
1156....	Zn 38.48, Fe 1.21, Sn 0.72, Al 0.10, Pb 0.09.	...do............................	Room	15,500	81.0	88.0	12 (2 in.)	36	178	Iz 10	...do........................	[25]
			-42	15,500	81.5	94.5	14 (2 in.)	38	.....	Iz 14		

1157....	Zn 38.85, Mn 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		
			-181	....	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)	64.6	41 (2 in.)	....	R_B 61	16	....	[193]
			-25	....	....	....	....	....	......	18		
			-60	....	....	....	....	....	......	18		
			-110	....	....	....	....	....	......	18		
			-175	....	....	....	....	....	......	17		
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[e]...	...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/cm.^{2}
[c] Tensile tests on material cold-worked 40% reduction; hardness and impact tests on material cold-worked 12% reduction.
[d] Endurance limit at 5×10^7 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: 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	Reference
PURE AND COMMERCIAL COPPER											
	Percent		$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	
1163[a]	Electro copper	Annealed at 1,020°C	...	[b]16.9	17.0	17.3	17.6	17.9	18.3	18.6 (0° to 600°C) 19.0 (0° to 700°C) 19.1 (0° to 800°C) 19.8 (0° to 900°C) 20.3 (0° to 1,000°C)	[196]
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	Rolled	...	...	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 (27% 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	...	...	...	[69]
COPPER-ANTIMONY ALLOY											
1169	Sb 5	...	...	...	[d]19.2	...	...	...	...	...	[72]
COPPER-BERYLLIUM ALLOYS											
1170	Be 2.14, Fe 0.06, 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	...	...	...	[e]22.0	...	...	...	...	[717]
1173	Fe 33.5, Ni 18.5	...do	...	...	...	[e]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	17.6 (-20° to 20°C)	[f]18.4	...	...	...	...	...	...	[716]
1176	Pb 14, Sn 8	Cast	...	...	18.2	18.6	19.2	...	...	...	[69]
1177	Pb 20.50, Sn 9.72, P 0.02	Sand-cast from 1,165°C	...	18.6	18.6	18.8	...	...	...	...	[199]
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

1180.....	Mn 4.87, Fe 0.03	Rolled	......	......	......	......	......	......	17.8	......	[69]
1181.....	Mn 9.4, Al 5.5, Fe 0.22	Wire, 0.02 in. diam; cold-drawn (50% red.), 18 hr at 140°C.	......	......	18.0	......	......	......	......	......	[209]
1182.....	Manganin: Mn 12, Ni 2	Rod, 3/16 in. diam	......	......	18.1	18.5	18.9	19.3	19.6	......	[198]

COPPER-NICKEL ALLOYS

1183[a]....	Ni 1.03, Fe 0.03	Forged; vacuum ann 3 hr at 750°C	14.1 (-182° to 0°C)	[g]15.9	......	......	......	......	......	......	[201]
1184.....	Ni 3.14, Si 0.86	Quenched from 850°C	......	......	16.6	16.7	17.2	17.3	17.8	......	[202]
1185[a]....	Ni 3.67, Fe 0.09	Forged; vacuum ann 3 hr at 750°C	13.9 (-182° to 0°C)	[g]15.7	......	......	......	......	......	......	[201]
1186[a]....	Ni 9.47, Fe 0.14	...do	13.6 (-182° to 0°C)	[g]15.4	......	......	......	......	......	......	[201]
1187[a]....	Ni 13.84, Fe 0.11	...do	13.3 (-182° to 0°C)	[g]15.1	......	......	......	......	......	......	[201]
1188[a]....	Ni 19.52, Fe 0.15	...do	13.0 (-182° to 0°C)	[g]14.7	......	......	......	......	......	......	[201]
1189[a]....	Cu 62.16, Ni 20.22, Mn 0.13, Fe 0.05, C 0.012, Pb 0.005, S 0.005, 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	......	......	[203]
1191[a]....	Ni 25.60, Fe 0.49, Mn 0.41, Si 0.06, C 0.03.	Cast	......	......	......	......	......	......	17.2	......	[69]
1192.....	Ni 28.68, Fe 7.00, Si 0.46, C 0.20, Mn 0.11, S 0.023, P 0.012.	...do	......	......	15.5	15.8	16.2	16.5	16.9	......	[69]
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)	[g]14.4	......	......	......	......	......	......	[201]
1195[a]....	Cu 62.02, Ni 29.77, Mn 0.14, Fe 0.09, C 0.019, Si 0.007, Pb 0.003, S 0.002, Zn rem.	Cast; ann	......	......	16.2	16.6	17.0	17.8	......	......	[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	......	[69]
1197[a]....	Constantan: Ni 45	Drawn	......	[b]14.9	......	......	......	......	16.3	18.8 (0° to 1,000°C)	[69]
1198[a]....	Ni 49.79, Fe 0.15, Mn 0.04	Forged; vacuum ann 3 hr at 750°C	11.8 (-182° to 0°C)	[g]13.7	......	......	......	......	......	......	[201]

COPPER-SILICON ALLOYS

1199.....	Si 3.04, Mn 1.03, Fe 0.09	Annealed	......	......	17.4	17.6	18.1	18.2	18.7	19.1 (20° to 600°C) 19.6 (20° to 700°C) 20.1 (20° to 800°C) 20.8 (20° to 900°C)	[716]
1200[h]....	Si 3.3, Fe 2.6	Sand-cast; slowly cooled to r-t	......	......	15.4	13.7	13.8	14.1	14.8	15.8 (15° to 600°C) 16.6 (15° to 700°C) 17.3 (15° to 800°C) 18.0 (15° to 900°C)	[714]
1201.....	Si 4.40, Mn 0.96, Fe 0.11	Cast	......	......	17.4	17.5	18.0	18.2	18.9	19.8 (20° to 600°C) 20.6 (20° to 700°C) 21.1 (20° to 800°C) 21.7 (20° to 900°C)	[716]
1202[h]....	Si 6.17, Fe 3.7	Sand-cast; slowly cooled to r-t	......	......	10.6	11.8	12.8	14.4	15.8	16.9 (15° to 600°C) 17.6 (15° to 700°C) 18.0 (15° to 800°C)	[714]
1203[h]....	Si 10	...do	......	......	14.9	14.6	14.9	15.4	16.2	16.2 (15° to 600°C) 16.1 (15° to 700°C)	[714]

COPPER-TIN ALLOYS

1204.....	Sn 1.3, Fe 0.02	Hot-rolled; ann	......	[i]16.8	16.8	......	......	......	......	......	[716]
1205.....	Sn 1.95, Pb 2.32, P 0.03	Sand-cast from 1,165°C	......	17.1	17.2	17.3	......	......	......	......	[199]

[a] Base temperature 0°C instead of 20°C. [b] 0° to 50°C. [c] Base temperature 25°C instead of 20°C. [d] 25° to 100°C. [e] 20° to 150°C. [f] 20° to 40°C. [g] 0° to 40°C. [h] Base temperature 15°C instead of 20°C. [i] 20° to 50°C.

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

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade: 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	Reference
	COPPER-TIN ALLOYS—Continued										
	Percent		× 10⁻⁶	× 10⁻⁶	× 10⁻⁶	× 10⁻⁶	× 10⁻⁶	× 10⁻⁶	× 10⁻⁶	× 10⁻⁶	
1206	Sn 6.16, Zn 2.93, Pb 0.69, P 0.04, Fe 0.03.	Cast	...	...	18.1	18.4	18.8	19.1	19.4	...	[69]
1207	Sn 6.5, Zn 2.0, Pb 1.5	...do	...	...	17.4	17.9	18.7	...	...	...	[69]
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	...	...	...	...	[199]
1209[g]	Sn 7.67, P 0.11	Cast	...	...	17.6	17.9	18.2	...	...	...	[715]
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	...	...	...	...	[199]
1211	Sn 9.16, Pb 8.57, P 0.24	Cast	...	...	19.1	19.2	19.4	19.5	19.6	...	[69]
1212	Sn 9.5, Pb 2.5, Zn 2.0	...do	...	...	17.7	18.3	19.2	...	...	...	[69]
1213	Sn 9.58, Pb 9.45, Zn 0.60, Sb 0.15, Ni 0.15, P 0.04.	Sand-cast from 1,165°C	...	18.0	18.4	18.6	...	...	...	...	[199]
1214	Sn 9.97, Zn 2.75, Pb 0.53, P 0.03.	...do	...	17.6	17.8	...	...	...	...	...	[199]
1215	Sn 10.0, Ni 3.5, Pb 2.5	Cast	...	...	17.1	17.8	19.0	...	...	...	[69]
1216	Sn 10, Pb 10	...do	...	...	17.8	18.4	19.2	...	...	...	[69]
1217	Sn 10, Zn 2	...do	...	17.8	18.1	18.5	18.8	...	...	...	[716]
1218	Sn 10.10, Ni 5.46, P 0.06	...do	...	...	17.3	17.7	18.1	18.4	18.8	...	[69]
1219	Sn 11.0, Pb 1.5	...do	...	...	17.4	18.2	19.1	...	...	...	[69]
1220	Sn 11.08, Pb 11.90, P 0.02	Sand-cast from 1,165°C	...	17.7	18.6	18.6	...	...	...	...	[199]
1221	Sn 11.30, Ni 8.04, P 0.12	Cast	...	...	16.3	16.8	17.4	18.0	18.6	...	[69]
1222	Sn 11.65, P 0.08	...do	...	...	17.2	17.8	18.4	19.0	19.6	...	[69]
1223	Sn 11.96, Pb 4.22, P 0.02	Sand-cast from 1,165°C	...	17.4	17.9	18.3	...	...	...	...	[199]
1224	Sn 12.0, Pb 7.5, P 1.0	Cast	...	...	18.3	18.7	19.4	...	...	...	[69]
1225	Sn 14.95, Pb 0.21	...do	...	...	18.0	18.2	18.6	18.8	19.3	19.8 (20° to 600°C)	[719]
1226	Sn 17.60, P 0.08	...do	...	...	18.4	18.7	19.0	19.3	19.6	...	[69]
	COPPER-ZINC ALLOYS										
1227[c]	Zn 2.97, Fe 0.02, Pb 0.01	Cast	...	...	17.2	17.5	17.9	...	...	...	[715]
1228	Zn 5.1, Sn 5.0, Pb 4.9	...do	...	...	17.8	18.1	18.5	18.9	19.3	20.0 (20° to 600°C) 20.6 (20° to 700°C)	[719]
1229[c]	Zn 9.70, Fe 0.03, Pb 0.01	...do	...	...	17.4	17.9	18.3	...	...	...	[715]
1230	Zn 19.25, Pb 3.53, Sn 3.61, Ni 0.10, Fe 0.09.	...do	...	...	17.9	18.4	19.0	19.6	20.2	...	[69]
1231[c]	Zn 19.89, Pb 0.05, Fe 0.03	...do	...	...	17.8	18.4	19.0	...	...	...	[715]
1232[a]	Cu 62.43, Ni 15.35, Mn 0.10, Fe 0.04, C 0.014, S 0.004, Pb 0.003, Si 0.003, Zn rem.	Cast; ann	...	...	15.0	15.6	16.2	16.8	...	...	[203]
1233	Zn 23.0, Al 6.8, Mn 3.8, Fe 2.8	Cast	...	...	17.8	18.8	20.9	...	...	...	[69]
1234[a]	Cu 63.17, Ni 12.33, Mn 0.13, Fe 0.04, C 0.009, Si 0.007, Pb 0.005, S 0.003, Zn rem.	Cast; ann	...	...	14.8	15.4	16.2	16.8	...	...	[203]
1235[a]	Cu 62.62, Ni 10.05, Mn 0.13, Fe 0.04, Si 0.009, C 0.007, Pb 0.005, S 0.003, Zn rem.	...do	...	...	15.0	15.8	16.4	17.0	...	...	[203]
1236	Zn 28	Rolled; ann	...	...	17.8	18.5	19.1	19.8	20.5	...	[69]
1237	Zn 34	...do	...	...	19.5	20.0	20.5	21.1	21.6	...	[69]
1238	Zn 37.67, Al 1.08, Sn 0.90, Fe 0.69, Mn 0.36.	Cast	...	...	20.0	20.4	20.8	21.6	22.7	...	[69]
1239[j]	Zn 38.86, Sn 0.71, Pb 0.20, Fe 0.02.	Hot-rolled	...	...	20.7	21.3	21.9	22.7	26.6	...	[715]
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	25.5 (20° to 600°C)	[204]

[a] Base temperature 0°C instead of 20°C. [c] Base temperature 25°C instead of 20°C. [g] 0° to 40°C. [j] Base temperature 30°C instead of 20°C.

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

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal properties: Conductivity	Thermal properties: Temperature coefficient of conductivity	Reference
	PURE AND COMMERCIAL COPPER (SEE ALSO FIGS. 69, 70 AND 71)							
	Percent		*Percent IACS*	*Microhm cm*	*per* $^{\circ}C \times 10^{-4}$	*Watts* cm^{-1} $^{\circ}C^{-1}$	per $^{\circ}C \times 10^{-4}$	
1241....	Cu 99.999	Annealed at 500°C and rapidly quenched	103.06 (20°C)	1.6730 (20°C)	...	...	...	[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)	1.696 (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	...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; ann 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, ann 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, ann 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)	...	[78]
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) .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]

[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: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal properties: Conductivity	Thermal properties: Temperature coefficient of conductivity	Reference
				COPPER-ALUMINUM ALLOYS—Continued				
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10⁻⁴*	*Watts cm⁻¹ °C⁻¹*	*per °C × 10⁻⁴*	
1267....	Al 12.15, Fe 0.09	Rolled: 2 hr at 750 °C, very slowly cooled.	11.9 (20 °C) 9.9 (200 °C)	14.4 (20 °C) 17.4 (200 °C)	11.5 (20°–200 °C)	0.54 (20 °C) .67 (200 °C)	14.0 (20°–200 °C)	[205]
1268....	Al 12.78	Chill-cast	....	....	....	.71 (60°–270 °C)	....	[78]
				COPPER-ARSENIC ALLOYS				
1269....	As 0.144	Chill-cast	....	....	....	2.11 (60°–270 °C)	....	[78]
1270....	As 0.495	...do	....	....	....	1.22 (60°–270 °C)	....	[78]
				COPPER-BERYLLIUM ALLOYS				
1271....	Be 1.52	Cast; quenched from 815 °C, 18 hr at 315 °C.	36.1	1.78	....	....	....	[211]
1272....	Be 1.92, Zr 1.36, Fe 0.109	Cast	18.1	9.53	....	....	....	[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	5.65	....	....	....	[211]
1275....	Be 2.00–2.25, Ni 0.25–0.50	Quenched from 800 °C	17	10.1	....	....	....	[212]
1276....	...do	Quenched from 800 °C; tempered at 250°–300 °C.	18–25	6.9–9.6	....	....	....	[212]
1277....	...do	Quenched from 800 °C, rolled (37% red.).	17	10.1	....	....	....	[212]
1278....	...do	Quenched from 800 °C, rolled (37% red.), tempered at 250°–300 °C.	30	5.8	....	....	....	[212]
1279....	Be 2.04	Cast	22.0	7.81	....	....	....	[211]
1280....	...do	Cast; quenched from 800 °C	19.5	8.84	....	....	....	[211]
1281....	...do	Cast; quenched from 800 °C, 5 hr at 370 °C.	32.8	5.26	....	....	....	[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) 14.9 (200 °C)	8.96 (20 °C) 11.6 (200 °C)	10.6 (20°–200 °C)	0.86 (20 °C) 1.04 (200 °C)	11.9 (20°–200 °C)	[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) 17.4 (200 °C)	7.84 (20 °C) 9.63 (200 °C)	12.7 (20°–200 °C)	1.03 (20 °C) 1.17 (200 °C)	8.0 (20°–200 °C)	[205]
1284....	...do	Rod, 1/2 hr at 815 °C, quenched, cold-drawn.	16.7 (20 °C) 14.1 (200 °C)	10.3 (20 °C) 12.2 (200 °C)	9.75 (20°–200 °C)	0.74 (20 °C) .93 (200 °C)	13.8 (20°–200 °C)	[205]
1285....	...do	Rod, 1/2 hr 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)	9.33 (20°–200 °C)	.82 (20 °C) 1.00 (200 °C)	12.5 (20°–200 °C)	[205]
1286....	Be 2.5	Quenched from 750 °C	17	10.1	....	....	....	[212]
1287....	...do	Quenched from 750 °C, h-t	32	5.4	....	....	....	[212]
				COPPER-CADMIUM ALLOYS				
1288....	Cd 0.61, O_2 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) 53.8 (200 °C)	1.98 (20 °C) 3.21 (200 °C)	34.5 (20°–200 °C)	3.15 (20 °C) 3.52 (200 °C)	1.2 (20°–200 °C)	[205]
1291....	Cd 0.90, 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)	2.76 (20 °C) 3.11 (200 °C)	7.2 (20°–200 °C)	[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) 4.29 (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.....	84.5	2.01	....	....	....	[213]
1294....	...do...................................	Wire, 0.064 in. diam, 2 hr at 500°C..	91.0	1.83	....	....	....	[213]
				COPPER-CHROMIUM ALLOYS				
1295....	Cr 0.31, Ag 0.103.........................	Heat-treated.........................	96	1.80	....	....	....	[214]
1296....	Cr 0.38, Be 0.08.........................	Rod, 1 1/4 in. diam, cast; 1 hr at 900°C, w-q.	47.4	3.64	....	....	....	[119]
1297....	...do...................................	Rod, 1 1/4 in. diam, cast; 1 hr at 900°C, w-q, 1 1/2 hr at 500°C.	69.0	2.50	....	....	....	[119]
1298....	Cr 0.49, Ag 0.401.........................	....	91	1.89	....	....	....	[214]
				COPPER-COBALT ALLOY				
1299....	Co 2.6, Be 0.4...........................	Rod, 1 in. diam, cast; 1 hr at 900°C, w-q.	19.6	8.80	....	....	....	[119]
1300....	...do...................................	Rod, 1 in. diam, cast; 1 hr at 900°C, w-q, 3 hr at 500°C.	48	3.6	....	....	....	[119]
				COPPER-IRON ALLOYS				
1301....	Fe 0.20.................................	Quenched from 650°C..................	....	....	....	2.98 (60°-270°C)	....	[78]
1302....	...do...................................	Quenched from 1,000°C................	....	....	....	2.91 (60°-270°C)	....	[78]
1303....	Fe 1.07.................................	Quenched from 650°C..................	....	....	....	2.39 (60°-270°C)	....	[78]
1304....	...do...................................	Quenched from 1,000°C................	....	....	....	1.43 (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)	8.1 (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)	0.42 (20°C) .61 (200°C)	24.7 (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) 4.54 (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) 9.4 (200°C)	17.9 (20°C) 18.4 (200°C)	1.40 (20°-200°C)	0.49 (20°C) .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.	....	....	[a]0.52 (20°-30°C)	....	....	[209]
1311....	Mn 10...................................	Wire, 0.02 in. diam, cold-drawn (75% red.).	4.9 (25°C)	35 (25°C)	....	....	....	[209]
1312....	...do...................................	Wire, 0.02 in. diam, cold-drawn (75% red.); 18 hr at 140°C.	....	....	[a]0.20 (20°-30°C)	....	....	[209]
1313....	Mn 14, Al 2..............................	Wire, 0.02 in. diam, cold-drawn (75% red.).	3.1 (25°C)	55 (25°C)	....	....	....	[209]
1314....	...do...................................	Wire, 0.02 in. diam, cold-drawn (75% red.); 18 hr at 140°C.	....	....	[a]-0.24 (20°-30°C)	....	....	[209]
1315....	Mn 15...................................	Wire, 0.02 in. diam, cold-drawn (75% red.).	3.5 (25°C)	19 (25°C)	....	....	....	[209]
1316....	...do...................................	Wire, 0.02 in. diam, cold-drawn (75% red.); 18 hr at 140°C.	....	....	[a]0.30 (20°-30°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) .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, $R_t = R_{25}\,[1 + \alpha\,(t - 25)]$.

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal properties: Conductivity	Thermal properties: Temperature coefficient of conductivity	Reference
			COPPER-NICKEL ALLOYS					
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10⁻⁴*	*watts cm⁻¹ °C⁻¹*	*per °C × 10⁻⁴*	
1319....	Ni 1.97, Mg 0.04, Fe 0.02	Cold-rolled; 1 hr at 800°C	39.2 (20°C) 30.3 (200°C)	1.40 (20°C) 5.69 (200°C)	16.1 (20°–200°C)	1.72 (20°C) 2.01 (200°C)	9.6 (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)	[205]
1321....	...do	Rod, 7/8 in. diam, cold-rolled; 3 hr at 870°C, f-c.	39.0 (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)	[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)	[205]
1323....	Ni 5.14, Sn 1.96, Zn 1.65	Cast	....	....	....	0.46 (100°C) .62 (100°C)	....	[210]
1324....	Ni 15	....	8.8 (20°C)	19.6 (20°C)	3.44 (20°C)	.47 (20°C) .60 (200°C)	16.1 (20°–200°C)	[216]
1325....	Ni 16.06, Sn 9.67, Zn 0.99	Cast	....	....	....	.36 (100°C) .50 (400°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)	29.4 (20°C) 30.8 (200°C)	2.57 (20°–200°C)	.33 (20°C) .42 (200°C)	14.2 (20°–200°C)	[205]
1327....	Ni 19.79, Mn 0.30, Fe 0.23	Rod, cold-rolled; ann at 800°C	6.5 (20°C) 6.2 (200°C)	26.6 (20°C) 27.8 (200°C)	2.37 (20°–200°C)	.36 (20°C) .47 (200°C)	16.3 (20°–200°C)	[205]
1328....	Ni 19.89, Zn 8.22, Pb 5.40, Sn 3.31, Mn 0.23, Fe 0.14.	Sand-cast	5.0 (20°C) 4.7 (200°C)	34.3 (20°C) 36.5 (200°C)	3.50 (20°–200°C)	.28 (20°C) .37 (200°C)	18.1 (20°–200°C)	[205]
1329....	Ni 29.44, Zn 5.69, Mn 0.52, Fe 0.07	Rod, 7/8 in. diam, cold-drawn; ann at 750°C.	4.6 (20°C) 4.4 (200°C)	37.8 (20°C) 38.7 (200°C)	1.28 (20°–200°C)	.28 (20°C) .36 (200°C)	14.3 (20°–200°C)	[205]
1330....	Ni 30.23, Mn 0.13, Fe 0.05, Mg 0.05	Rod, cold-rolled; 4 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)	.29 (20°C) .37 (200°C)	15.6 (20°–200°C)	[205]
1331....	Ni 44	....	3.6	48	....	.23 (95°C) .23 (129°C) .24 (290°C) .26 (437°C)	....	[217]
1332....	Constantan: Ni 45	....	3.5 (20°–100°C)	19 (20°–100°C)	....	.23 (20°–100°C)	....	[218]
			COPPER-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 0.930, Fe 0.06	...do	11.3 (20°C)	15.3 (20°C)	....	0.54 (20°C) .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	Rod, 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) .73 (200°C)	20.0 (20°-200°C)	[205]
1341....	Si 2, Sn 1.8	....	8 (20°C)	21.6 (20°C)	....	....	....	[208]
1342....	Si 3.11, Zn 1.12, Fe 0.02	Rod, 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)	4.69 (20°-200°C)	.37 (20°C) .52 (200°C)	22.0 (20°-200°C)	[205]
1343....	Si 3.91, Fe 0.02	Rod, 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)	.34 (20°C) .47 (200°C)	20.6 (20°-200°C)	[205]
1344....	Si 1.68, 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)	.25 (20°C) .36 (200°C)	23.9 (20°-200°C)	[205]
	COPPER-SILVER ALLOY							
1345....	Ag 1.52, Cr 0.75	....	80	2.16	....	....	....	[211]
	COPPER-TIN ALLOYS							
1346....	Sn 0.99, Fe 0.01, P 0.002	Rod, 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) 2.58 (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	....	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	....	24 (20°C)	7.2 (20°C)	....	....	....	[208]
1351....	Sn 1.92, Fe 0.01, P 0.01	Rod, 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	....	35 (20°C)	4.9 (20°C)	....	....	....	[208]
1354....	Sn 3	....	21 (20°C)	8.2 (20°C)	....	....	....	[208]
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) .82 (200°C)	17.1 (20°-200°C)	[206]
1356....	...do	...do	11.4 (200°C)	15.1 (200°C)	5.90 (20°-200°C)	....	....	[205]
1357....	Sn 4.92, P 0.06, Fe 0.05, Pb 0.01	...do	18.4 (20°C)	9.3 (20°C)	....	.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) .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)	.54 (20°C) .72 (200°C)	18.1 (20°-200°C)	[205]
1362....	Sn 10.10, Fe 0.05, P 0.03, Pb 0.01	Wrought	11.1 (20°C)	15.5 (20°C)	....	.51 (20°C) .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 14.15	Cast, fully ann.	9.0 (0°C)	19.1 (0°C)	5.14 (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)	45.9 (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: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal properties: Conductivity	Thermal properties: Temperature coefficient of conductivity	Reference
			COPPER-ZINC ALLOYS					
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10⁻⁴*	*Watts cm⁻¹ °C⁻¹*	*per °C × 10⁻⁴*	
1369....	Zn 0.35, Fe 0.02, Pb 0.01	Wrought; 1 hr at 700°C, a-c	95.3 (20°C)	1.81 (20°C)	....	3.70 (20°C) 3.72 (200°C)	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.	63.1 (20°C) 43.5 (200°C)	2.73 (20°C) 3.97 (200°C)	25.0 (20°-200°C)	2.68 (20°C) 2.89 (200°C)	4.3 (20°-200°C)	[205]
1374....	Zn 4.09, 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)	14.1 (20°C) 15.9 (200°C)	6.82 (20°-200°C)	0.56 (20°C) .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) .40 (200°C)	22.8 (20°-200°C)	[205]
1383....	Zn 17.65, Ni 13.24, Pb 10.44, 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 4.44, Mn 3.34, 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) 1.42 (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)	4.89 (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]

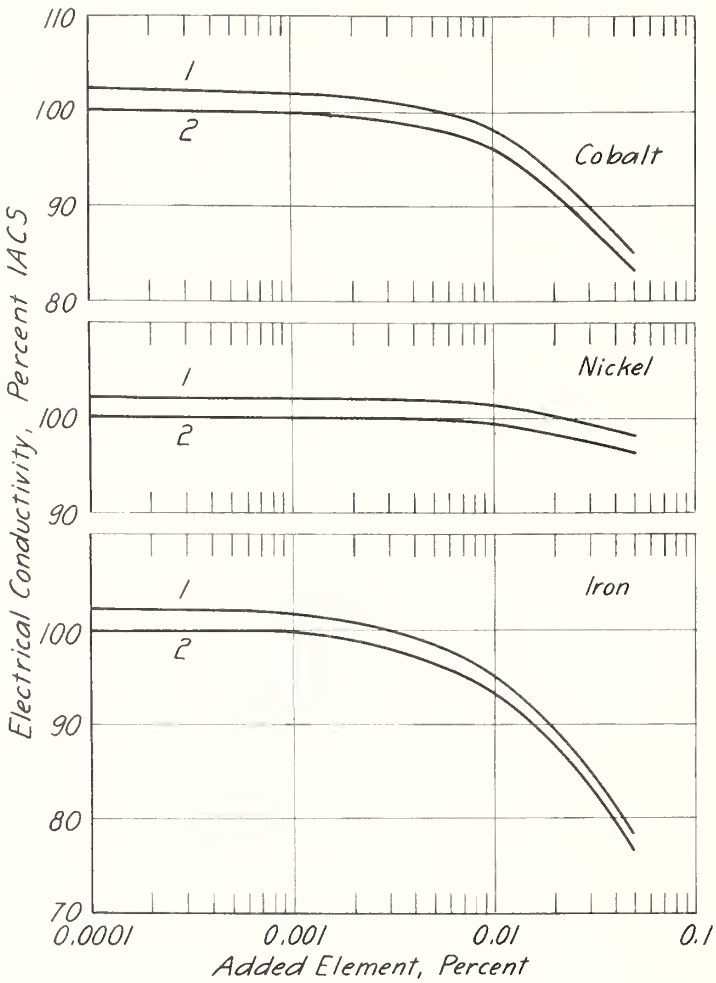


FIGURE 69.—*Effect of iron, nickel, and cobalt on the electrical conductivity of high-purity oxygen-free copper (Smart and Smith [207]).*

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

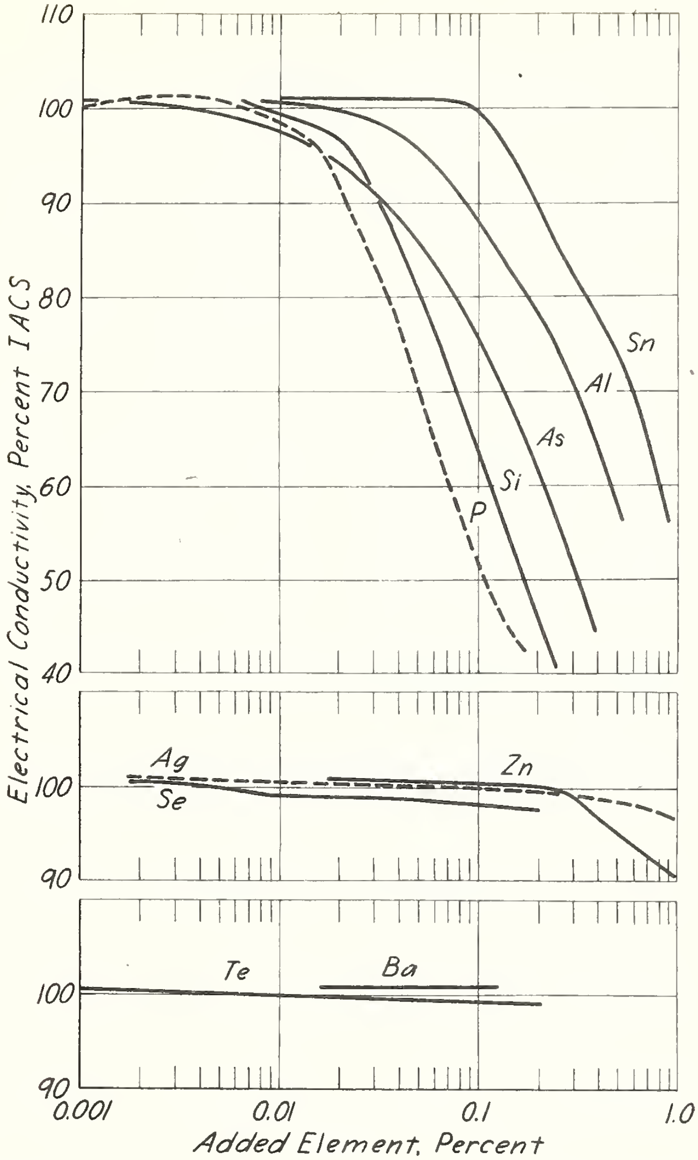


FIGURE 70.—*Effect of various elements on the electrical conductivity of annealed oxygen-bearing copper (Skowronski and Wyman [659]).*

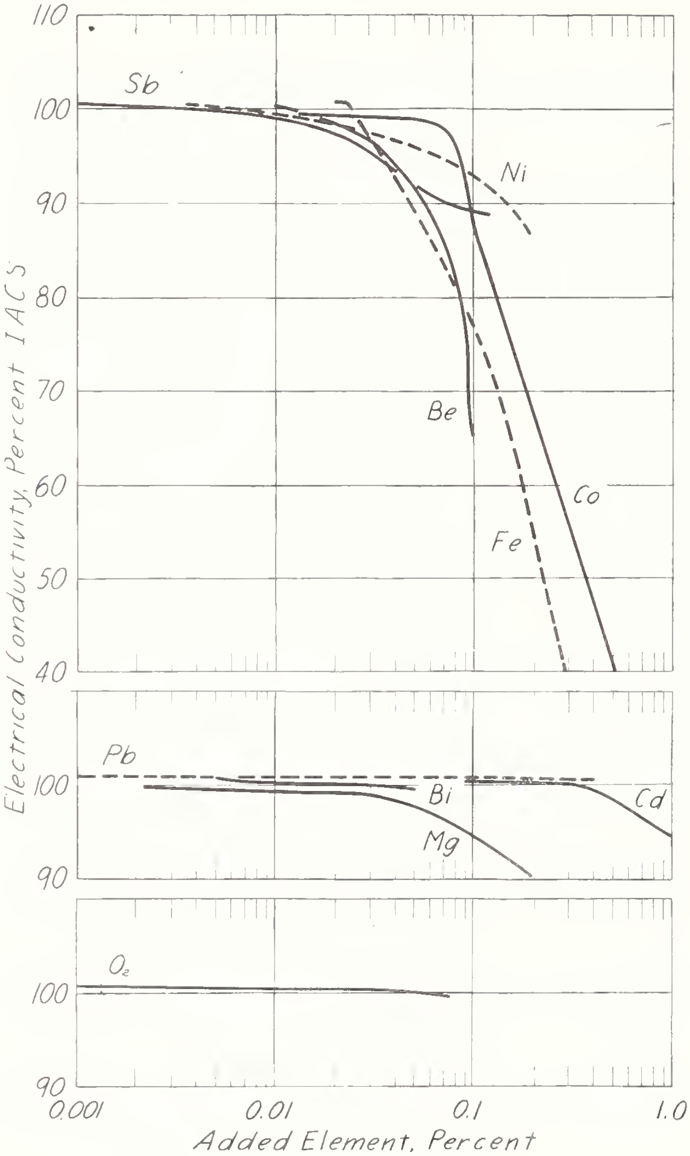


FIGURE 71.—*Effect of various elements on the electrical conductivity of annealed oxygen-bearing copper (Skowronski and Wyman [659]).*

VII. IRON AND STEEL

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:

Type of steel	*Numerals (and digits)*
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)											
C 1008	1008	0.10	0.30-.50	0.040	0.050						1439, 1440, 1441, 2431, 2532.
C 1010	1010	.08-.13	.30-.50	.040	.050						1445, 1448, 2302, 2303.
C 1015	1015	.13-.18	.30-.50	.040	.050						1449, 1453, 2210, 2211; figure 88.
C 1016	1016	.13-.18	.60-.90	.040	.050						
C 1020	1020	.18-.23	.30-.50	.040	.050						1454, 1455, 1456, 1458, 1461, 2213.
C 1022	1022	.18-.23	.70-1.00	.040	.050						1460, 2304, 2305.
C 1024	1024	.20-.26	1.35-1.65	.040	.050						2257.
C 1025	1025	.22-.28	0.30-.50	.040	.050						1462,* 1465, 1466, 2308.*
C 1030	1030	.28-.34	.60-.90	.040	.050						1470, 1471, 1472, 2215, 2309.
C 1035	1035	.32-.38	.60-.90	.040	.050						1473, 1474, 1475, 1476, 1477, 1478, 2216;* figure 88.
C 1036	1036	.32-.39	1.20-1.50	.040	.050						
C 1040	1040	.37-.44	0.60-.90	.040	.050						1479, 1480, 1481, 1482, 1483, 2217, 2310, 2311.
C 1045	1045	.43-.50	.60-.90	.040	.050						1485, 1486, 1487, 2218, 2312, 2313, 2314, 2432, 2533.
C 1050	1050	.48-.55	.60-.90	.040	.050						1488, 1489, 1490, 1491.
C 1052	1052	.47-.55	1.20-1.50	.040	.050						
C 1055	1055	.50-.60	0.60-.90	.040	.050						1492, 2219; figures 88 and 120.
C 1060	1060	.55-.65	.60-.90	.040	.050						1493, 1494, 1495.
C 1066	1066	.60-.71	.80-1.10	.040	.050						Figure 89.*
C 1070	1070	.65-.75	.70-1.00	.040	.050						1496, 2315.
C 1080	1080	.75-.88	.60-.90	.040	.050						1501,* 1502.*
C 1085	1085	.80-.93	.70-1.00	.040	.050						
C 1095	1095	.90-1.05	.30-.50	.040	.050						1506, 1507, 1508, 1510, 2318; figure 88.
FREE CUTTING STEELS (CONDENSED)											
B 1111	1111	0.08-.13	0.60-.90	0.09-.13	0.10-.15						1447.
B 1112	1112	.08-.13	.60-.90	.09-.13	.16-.23						
B 1113	1113	.08-.13	.60-.90	.09-.13	.24-.33						
C 1115	1115	.13-.18	.70-1.00	.045	.10-.15						1451, 1459.*
C 1117	1117	.14-.20	1.00-1.30	.045	.08-.13						
C 1118	1118	.14-.20	1.30-1.60	.045	.08-.13						
C 1132	1132	.27-.34	1.35-1.65	.045	.08-.13						
C 1137	1137	.32-.39	1.35-1.65	.045	.08-.13						
C 1141	1141	.37-.45	1.35-1.65	.045	.08-.13						
	1145	.42-.49	0.70-1.00	.045	.04-.07						
MANGANESE STEELS											
A 1320	1320	0.18-.23	1.60-1.90	0.040	0.040	0.20-.35					2582.*
NE 1330	1330	.28-.33	1.60-1.90	.040	.040	.20-.35					1887, 1888, 1890.
NE 1335	1335	.33-.38	1.60-1.90	.040	.040	.20-.35					1889, 1893, 1894.
NE 1340	1340	.38-.43	1.60-1.90	.040	.040	.20-.35					
NE 1345		.43-.48	1.60-1.90	.040	.040	.20-.35					
NE 1350		.48-.53	1.60-1.90	.040	.040	.20-.35					2583

* 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				
A 2330	2330	.28-.33	.60-.80	.040	.040	.20-.35	3.25-3.75				1965,* 2471.*
A 2335		.33-.38	.60-.80	.040	.040	.20-.35	3.25-3.75				2330,* 2386, 2387, 2590.*
A 2340	2340	.38-.43	.70-.90	.040	.040	.20-.35	3.25-3.75				1970,* 1971,* 2279;* figure 121.
A 2345	2345	.43-.48	.70-.90	.040	.040	.20-.35	3.25-3.75				1966, 1967.
E 2512		.09-.14	.45-.60	.025	.025	.20-.35	4.75-5.25				
A 2515	2515	.12-.17	.40-.60	.040	.040	.20-.35	4.75-5.25				2395.*
E 2517		.15-.20	.45-.60	.025	.025	.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	0.60-.80			
A 3115	3115	.13-.18	.40-.60	.040	.040	.20-.35	1.10-1.40	.55-.75			
A 3120	3120	.17-.22	.60-.80	.040	.040	.20-.35	1.10-1.40	.55-.75			
A 3130	3130	.28-.33	.60-.80	.040	.040	.20-.35	1.10-1.40	.55-.75			2001,* 2002,* 2003,* 2004,* 2588.*
A 3135	3135	.33-.38	.60-.80	.040	.040	.20-.35	1.10-1.40	.55-.75			1998, 1999, 2000, 2272, 2587.*
A 3140	3140	.38-.43	.70-.90	.040	.040	.20-.35	1.10-1.40	.55-.75			2469.
A 3141	3141	.38-.43	.70-.90	.040	.040	.20-.35	1.10-1.40	.70-.90			
A 3145	3145	.43-.48	.70-.90	.040	.040	.20-.35	1.10-1.40	.70-.90			
A 3150	3150	.48-.53	.70-.90	.040	.040	.20-.35	1.10-1.40	.70-.90			
A 3240	3240	.38-.45	.40-.60	.040	.040	.20-.35	1.65-2.00	.90-1.20			2005, 2006.
E 3310	3310	.08-.13	.45-.60	.025	.025	.20-.35	3.25-3.75	1.40-1.75			
E 3316		.14-.19	.45-.60	.025	.025	.20-.35	3.25-3.75	1.40-1.75			
						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	.25-.30	.70-.90	.040	.040	.20-.35			.20-.30		
A 4032	4032	.30-.35	.70-.90	.040	.040	.20-.35			.20-.30		
A 4037	4037	.35-.40	.75-1.00	.040	.040	.20-.35			.20-.30		
A 4042	4042	.40-.45	.75-1.00	.040	.040	.20-.35			.20-.30		
A 4047	4047	.45-.50	.75-1.00	.040	.040	.20-.35			.20-.30		
A 4063	4063	.60-.67	.75-1.00	.040	.040	.20-.35			.20-.30		
A 4068	4068	.64-.72	.75-1.00	.040	.040	.20-.35			.20-.30		
NE 8020		.18-.23	1.00-1.30	.040	.040	.20-.35			.10-.20		2259.*
NE 8022		.20-.25	1.00-1.30	.040	.040	.20-.35			.10-.20		
NE 8339		.35-.42	1.30-1.60	.040	.040	.20-.35			.20-.30		2260.*
NE 8442		.40-.45	1.30-1.60	.040	.040	.20-.35			.30-.40		1918, 1919.
A 4119	4119	.17-.22	0.70-.90	.040	.040	.20-.35		0.40-.60	.20-.30		
A 4120		.17-.22	.70-.90	.040	.040	.20-.35		.60-.80	.20-.30		2327.*
A 4125	4125	.23-.28	.70-.90	.040	.040	.20-.35		.40-.60	.20-.30		1667,* 2325,* 2326.*
A 4130	4130	.28-.33	.40-.60	.040	.040	.20-.35		.80-1.10	.15-.25		1674,* 1675,* 1676.*
A 4134		.32-.37	.40-.60	.040	.040	.20-.35		.80-1.10	.15-.25		1673,* 1677, 1678, 2221, 2435.
E 4135		.33-.38	.70-.90	.025	.025	.20-.35		.80-1.10	.18-.25		1680.*
A 4137	4137	.35-.40	.70-.90	.040	.040	.20-.35		.80-1.10	.15-.25		1679.*
A 4140	4140	.38-.43	.75-1.00	.040	.040	.20-.35		.80-1.10	.15-.25		1682.
A 4142		.40-.45	.75-1.00	.040	.040	.20-.35		.80-1.10	.15-.25		
A 4145	4145	.43-.48	.75-1.00	.040	.040	.20-.35		.80-1.10	.15-.25		
A 4150	4150	.46-.53	.75-1.00	.040	.040	.20-.35		.80-1.10	.15-.25		
NE 8613		.12-.17	.70-.90	.040	.040	.20-.35	0.40-.60	.40-.60	.15-.25		
NE 8615		.13-.18	.70-.90	.040	.040	.20-.35	.40-.60	.40-.60	.15-.25		
NE 8617		.15-.20	.70-.90	.040	.040	.20-.35	.40-.60	.40-.60	.15-.25		
NE 8620		.18-.23	.70-.90	.040	.040	.20-.35	.40-.60	.40-.60	.15-.25		
NE 8630		.28-.33	.70-.90	.040	.040	.20-.35	.40-.60	.40-.60	.15-.25		Figure 94.
NE 8715		.13-.18	.70-.90	.040	.040	.20-.35	.40-.60	.40-.60	.20-.30		
NE 8720		.18-.23	.70-.90	.040	.040	.20-.35	.40-.60	.40-.60	.20-.30		
NE 8722		.20-.25	.70-.90	.040	.040	.20-.35	.40-.60	.40-.60	.20-.30		

NE 8735		0.33-.38	0.70-.90	0.040	0.040	0.20-.35	0.40-.60	0.40-.60	0.20-.30		
NE 8739		.35-.40	.70-.90	.040	.040	.20-.35	.40-.60	.40-.60	.20-.30		Figure 95.
NE 8744		.40-.45	.70-.90	.040	.040	.20-.35	.40-.60	.40-.60	.20-.30		
NE 8749		.45-.50	.70-.90	.040	.040	.20-.35	.40-.60	.40-.60	.20-.30		Figure 97.
NE 8949		.45-.50	1.00-1.30	.040	.040	.20-.35	.40-.60	.40-.60	.30-.40		Figure 96.
A 4320	4320	.17-.22	0.45-.65	.040	.040	.20-.35	1.65-2.00	.40-.60	.20-.30		
E 4337		.35-.40	.60-.80	.025	.025	.20-.35	1.65-2.00	.70-.90	.23-.30		2033,* 2034.*
A 4340	4340	.38-.43	.60-.80	.040	.040	.20-.35	1.65-2.00	.70-.90	.20-.30		2031, 2274.
A 4608		.06-.11	.40	.040	.040	.25	1.40-1.75		.15-.25		
A 4615	4615	.13-.18	.45-.65	.040	.040	.20-.35	1.65-2.00		.20-.30		2077.
E 4617		.15-.20	.45-.65	.025	.025	.20-.35	1.65-2.00		.20-.27		2273.
A 4620	4620	.17-.22	.45-.65	.040	.040	.20-.35	1.65-2.00		.20-.30		
A 4640	4640	.38-.43	.60-.80	.040	.040	.20-.35	1.65-2.00		.20-.30		2078, 2079.
A 4645		.43-.48	.60-.80	.040	.040	.20-.35	1.65-2.00		.20-.30		
A 4815	4815	.13-.18	.40-.60	.040	.040	.20-.35	3.25-3.75		.20-.30		
A 4820	4820	.18-.23	.50-.70	.040	.040	.20-.35	3.25-3.75		.20-.30		

CHROMIUM STEELS

A 5045		0.43-.48	0.70-.90	0.040	0.040	0.20-.35		0.55-.75			
A 5120	5120	.17-.22	.70-.90	.040	.040	.20-.35		.70-.90			1532.*
A 5130		.28-.33	.70-.90	.040	.040	.20-.35		.80-1.10			2540.
A 5140	5140	.38-.43	.70-.90	.040	.040	.20-.35		.70-.90			1537, 2222.*
A 5145		.43-.48	.70-.90	.040	.040	.20-.35		.70-.90			
A 5150	5150	.48-.55	.70-.90	.040	.040	.20-.35		.70-.90			1534.*
A 5152		.45-.55	.70-.90	.040	.040	.20-.35		.90-1.20			
E 52095		.90-1.00	.30-.50	.025	.025	.20-.35		.45-.65			
E 52098		.90-1.05	.30-.50	.025	.025	.20-.35		1.00-1.25			
E 52099		.90-1.05	.30-.50	.025	.025	.20-.35		1.30-1.65			
NE 52100A		.95-1.10	.25-.45	.040	.040	.20-.35	0.35	0.40-.60	0.08		
NE 52100B		.95-1.10	.25-.45	.040	.040	.20-.35	.35	.90-1.15	.08		
NE 52100C		.95-1.10	.25-.45	.040	.040	.20-.35	.35	1.30-1.60	.08		
E 52100	52100	.95-1.10	.30-.50	.025	.025	.20-.35		1.20-1.50			
E 52101		.95-1.10	.30-.60	.025	.025	.20-.35		1.30-1.65			
E 52107		1.00-1.15	.30-.50	.025	.025	.20-.35		1.35-1.65			

CHROMIUM-VANADIUM STEELS

A 6120		0.17-.22	0.70-.90	0.040	0.040	0.20-.35		0.70-.90		V 0.10 minimum	1806,* 1807.*
A 6145		.43-.48	.70-.90	.040	.040	.20-.35		.80-1.10		V .15 minimum	2223.*
	6150	.48-.55	.65-.90	.040	.040	.20-.35		.80-1.10		V .15 minimum	1801,* 1802,* 1805, 1810, 1811, 1812, 1814, 1815.
E 6151		.47-.53	.70-.90	.025	.025	.20-.35		.80-1.10		V .15 minimum	1813.
A 6152		.48-.55	.70-.90	.040	.040	.20-.35		.80-1.10		V .10 minimum	1803, 1804, 2436.

SILICON-MANGANESE STEELS

NE 9255		0.50-.60	0.70-.95	0.040	0.040	1.80-2.20					2113, 2114, 2115.
NE 9260	9260	.55-.65	.75-1.00	.040	.040	1.80-2.20					2111, 2112.
NE 9262		.55-.65	.75-1.00	.040	.040	1.80-2.20		0.20-.40			

OTHER NATIONAL EMERGENCY STEELS

NE 9415		0.13-.18	0.80-1.10	0.040	0.040	0.40-.60	0.20-.40	0.20-.40	0.08-.15		
NE 9420		.18-.23	.80-1.10	.040	.040	.40-.60	.20-.40	.20-.40	.08-.15		
NE 9422		.20-.25	.80-1.10	.040	.040	.40-.60	.20-.40	.20-.40	.08-.15		
NE 9430		.28-.33	.90-1.20	.040	.040	.40-.60	.20-.40	.20-.40	.08-.15		
NE 9435		.33-.38	.90-1.20	.040	.040	.40-.60	.20-.40	.20-.40	.08-.15		
NE 9437		.35-.40	.90-1.20	.040	.040	.40-.60	.20-.40	.20-.40	.08-.15		
NE 9440		.38-.43	.90-1.20	.040	.040	.40-.60	.20-.40	.20-.40	.08-.15		
NE 9442		.40-.45	1.00-1.30	.040	.040	.40-.60	.20-.40	.20-.40	.08-.15		
NE 9445		.43-.48	1.00-1.30	.040	.040	.40-.60	.20-.40	.20-.40	.08-.15		
NE 9450		.48-.53	1.20-1.50	.040	.040	.40-.60	.20-.40	.20-.40	.08-.15		
NE 9537		.35-.40	1.20-1.50	.040	.040	.40-.60	.40-.60	.40-.60	.15-.25		
NE 9540		.38-.43	1.20-1.50	.040	.040	.40-.60	.40-.60	.40-.60	.15-.25		

*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	
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 9630		.28-.33	1.20-1.50	.040	.040	.40-.60		.40-.60			
NE 9635		.33-.38	1.20-1.50	.040	.040	.40-.60		.40-.60			
NE 9637		.35-.40	1.20-1.50	.040	.040	.40-.60		.40-.60			
NE 9640		.38-.43	1.20-1.50	.040	.040	.40-.60		.40-.60			
NE 9642		.40-.45	1.30-1.60	.040	.040	.40-.60		.40-.60			1898.*
NE 9645		.43-.48	1.30-1.60	.040	.040	.40-.60		.40-.60			
NE 9650		.48-.53	1.30-1.60	.040	.040	.40-.60		.40-.60			
STAINLESS STEELS										
301		0.08-.20	2.00				6.00-8.00	16.00-18.00			1724, 1725, 1735, 2343, 2344, 2345; figure 98.
302		.08-.20	2.00				8.00-10.00	17.00-19.00			1721, 1723, 1728, 2248, 2249, 2349, 2352, 2354, 2559, 2562.
302B		.08-.20	2.00			2.00-3.00	8.00-10.00	17.00-19.00			
303		.20	2.00		[a]0.07		8.00-10.00	17.00-19.00	0.60		1732, 1733.
304		.08	2.00				8.00-10.00	18.00-20.00			1736, 2244, 2346, 2347, 2348, 2353, 2449, 2565.
308		.08	2.00				10.00-12.00	19.00-22.00			1738, 1739, 1741, 1742.
309		.20	2.00				12.00-15.00	22.00-24.00			1749, 1754, 2251.
309S		.08	2.00				12.00-15.00	22.00-24.00			2574.
310		.25	2.00				19.00-22.00	24.00-26.00			1750, 1752, 1753, 1756, 2453, 2572.
311		.25	2.00				24.00-26.00	18.00-20.00			2283,* 2475.*
316		.10	2.00				10.00-14.00	16.00-18.00			2341.
317		.10	2.00				10.00-14.00	17.00-20.00	3.00-4.00		2351.*
321		.10	2.00				8.00-12.00	17.00-19.00		[b]Ti	1734, 2246, 2357, 2358, 2561.
325		.50					19.50-23.50	7.00-10.00		Cu 1.00-1.50	
329		.20					2.50-5.00	23.00-28.00	1.00-2.00		1761, 1762, 2252.
330		.25					33.00-36.00	14.00-16.00			2483.
347		.10	2.00				8.00-12.00	17.00-19.00		[b]Cb	1730, 2355, 2356.
403		.15						11.50-13.00			2548.
405		.08						11.50-13.50		Al 0.10-.30	
406		.15						12.00-14.00		Al 3.50-4.50	
410		.15						10.00-14.00			1575, 1576, 1577, 1582, 1583, 2241, 2252, 2444, 2445, 2545, 2547; figure 121.
414		.15					2.50	10.00-14.00			
416		.15			[a]0.07			12.00-14.00	0.60		
420		.15 minimum						12.00-14.00			1578, 1579, 1580, 1581, 2550, 2554.
420F		.15 minimum			[a]0.07			12.00-14.00	.60		1701, 1702.
430		.12						14.00-18.00			1590, 1591, 1592, 2245, 2248, 2557.
430F		.12			[a]0.07			14.00-18.00	.60		
431		.20					2.50	14.00-18.00			1719, 2342, 2555.
440		.12 minimum						14.00-18.00			1587, 1588, 1589.
441		.20 minimum					2.50	14.00-18.00			1720.
442		.35						18.00-23.00			1593, 1594, 1595, 2569.
446		.35						23.00-30.00			1597, 1598, 1599, 1600, 2454, 2455, 2456, 2576.
501		.10 minimum						4.00-6.00			1563, 1564, 2235, 2236, 2440, 2542.
502		.10						4.00-6.00			1560, 1561, 1562, 1565, 1566, 1567, 2441, 2541.

*Indicates a composition approximately the standard.

[a]S or Se 0.07 minimum.

[b]Minimum 4 times carbon.

TABLE 18.—*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	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 52095	...	NE 52100C.
A 3135	3135	NE 1335, NE 9435, NE 9635	E 52098	...	NE 52100B.
A 3140	3140	NE 1345, NE 9440, NE 9640	E 52099	...	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	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, NE 9422.
A 4042	4042	NE 1330, NE 9430, NE 9630			
A 4047	4047	NE 1335, NE 9435, NE 9635	NE 8233	...	NE 1330, NE 9430, NE 9630.
A 4063	4063	NE 9255	NE 8339	...	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. NE 1350, NE 9445, NE 9645.
A 4150	4150	NE 9450, NE 9650			
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 9450, NE 9650.

[a]Recommended 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	...	95	352	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	...	84	311	183	183	9	90	27	91
601	717	58	...	81	298	179	179	8	89	27	89
578	675	57	...	78	287	174	174	7	88	26	87
555	633	55	...	75	276	170	170	6	87	26	85
534	598	53	...	72	266	166	166	4	86	25	83
514	567	52	...	70	256	163	163	3	85	25	82
495	540	50	...	67	247	159	159	2	84	24	80
477	515	49	...	65	238	156	156	1	83	24	78
461	494	47	...	63	229	153	153	...	82	23	76
444	472	46	...	61	220	149	149	...	81	23	75
429	454	45	...	59	212	146	146	...	80	22	74
415	437	44	...	57	204	143	143	...	79	22	72
401	420	42	...	55	196	140	140	...	78	21	71
388	404	41	...	54	189	137	137	...	77	21	70
375	389	40	...	52	182	134	134	...	76	21	68
363	375	38	...	51	176	131	131	...	74	20	66
352	363	37	...	49	170	128	128	...	73	20	65
341	350	36	...	48	165	126	126	...	72	...	64
331	339	35	...	46	160	124	124	...	71	...	63
321	327	34	...	45	155	121	121	...	70	...	62
311	316	33	...	44	150	118	118	...	69	...	61
302	305	32	...	43	146	116	116	...	68	...	60
293	296	31	...	42	142	114	114	...	67	...	59
285	287	30	105	40	138	112	112	...	66	...	58
277	279	29	104	39	134	109	109	...	65	...	56
269	270	28	104	38	131	107	107	...	64	...	55
262	263	26	103	37	128	105	105	...	62	...	54
255	256	25	102	37	125	103	103	...	61	...	53
248	248	24	102	36	122	101	101	...	60	...	52
241	241	23	100	35	119	99	99	...	59	...	51
235	235	22	99	34	116	97	97	...	57	...	50
229	229	21	98	33	113	95	95	...	56	...	49

[a]This 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.

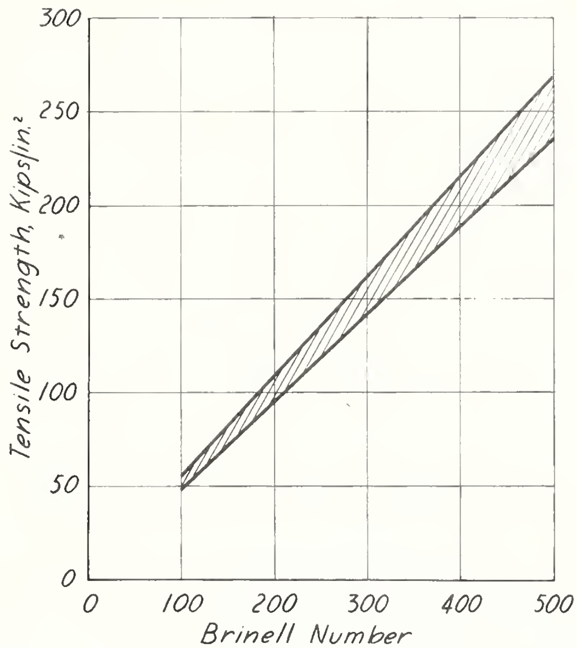


Figure 72.—*Relation between hardness and tensile strength for steels [411].*

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.

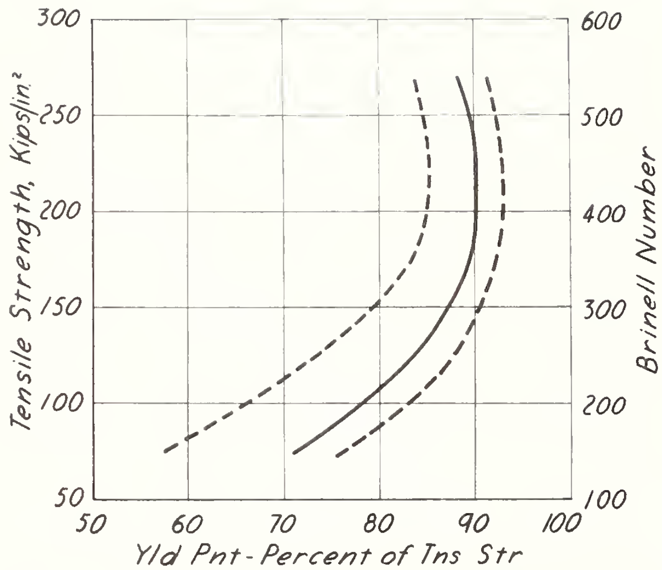


FIGURE 73.—*Relation between tensile strength and yield point for steels* [411].

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.

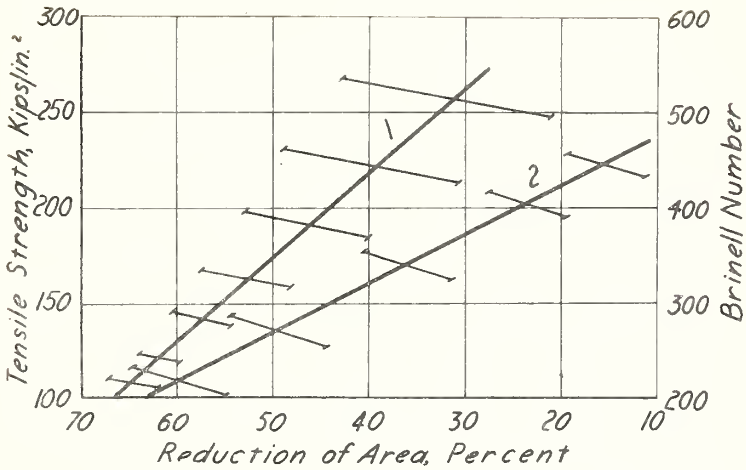


FIGURE 74.—*Relation between tensile strength and reduction of area for steels [411].*

Curves: 1, alloy steels SAE 1300, 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.

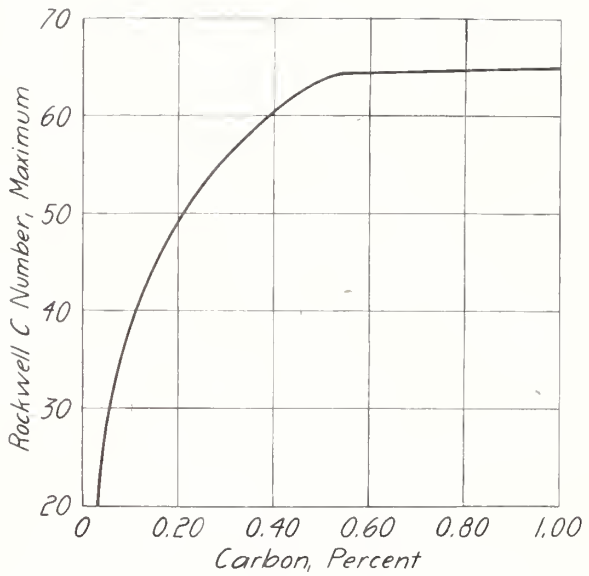


FIGURE 75.—*Maximum hardness obtainable in quenched carbon and alloy steels (Burns, Moore, and Archer [58]).*

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.

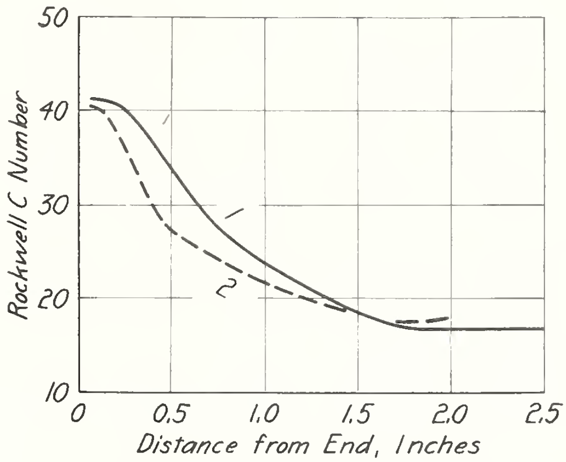


FIGURE 76.—*Comparison of the hardenability of a standard steel and an alternate emergency steel* [607].

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 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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	PURE AND INGOT IRON (SEE ALSO FIGS. 77, 78, AND 79)												
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
1409..	Fe 99.99........	Rod, 1/4 in., swaged, ann 4 hr at 1,600°F.	28,500	....	8.1-8.6 (0.2% offset)	28.5-29.7	36-46 (2 in.)	85-94	....	60	....	....	[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 $\sqrt{area}$)	100	....	....	....	....	[227]
1411..	Armco iron: Fe 99.819..	....	....	....	....	....	....	....	....	....	....	Melting point 2,794°F........	[288]
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........	Fused, ann........	....	....	10-20	35-40	40-60 (1.5 in.)	70-90	....	45-90	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<0.0008, 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-q, 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 kips/in.^{2}..	[86]
1423..	Ingot iron........	Rod, ann........	....	....	....	....	....	....	{ 26.0 [a]12.8 }	....	....	Comp yld str....20.6 kips/in.^{2}..	[229]

1424..	Iron....................	....	....	....	....	....	....	....	....	....	....	Poisson's ratio..0.28............	[88]
1425..	Electro iron powder (-325 mesh).	Compacted at 15 tons/in.^{2}, sintered 8 hr at 1,830°F in hydrogen.	....	....	....	13.4	....	....	4.5	....	....	Porosity........32.5%..........	[87]
1426..	...do..................	Compacted at 50 tons/in.^{2}, sintered 8 hr at 1,830°F in hydrogen.	....	....	....	31.9	....	....	11.5	....	....	Porosity........18.3%..........	[87]
1427..	...do..................	Compacted at 50 tons/in.^{2}, sintered 8 hr at 1,830°F in hydrogen, recompacted at 50 tons/in.^{2}, resintered 8 hr at 1,830°F in hydrogen.	....	....	....	37.7	....	....	23.0	....	....	Porosity........6.0%...........	[87]
1428..	Swedish iron powder....	Cold-pressed from 0.266 in. to 0.148 in.; hot-pressed to 0.105 in.	....	....	....	68.3	12	10	....	....	....	....	[232]
						WROUGHT IRON							
1429..	C 0.017, Si 0.122, P 0.084, S 0.019, Mn 0.004, Slag 2.24.	Longitudinal........	....	....	29.9	47.0	15 (2 in.)	16	30.5	....	42	....	[233]
1430..	...do..................	Transverse..........	....	....	28.6	46.8	17 (2 in.)	16	28.0	....	6.5	....	[233]
1431..	C 0.024, Si 0.112, P 0.102, Mn 0.034, S 0.018, Slag 1.22.	Longitudinal........	....	....	39.8	47.2	38 (2 in.)	48	25.0	....	29	....	[233]
1432..	...do..................	Transverse..........	....	....	23.7	37.5	6.5 (2 in.)	12	25.0	....	11	....	[233]
1433..	C 0.030, Si 0.16, P 0.083, Mn 0.040, S 0.012, Slag 4.20.	....	....	....	42.1 (yld pnt)	47.7	33 (2 in.)	46	30.4	74	20	....	[234]
1434..	C 0.045, P 0.246, Mn 0.024, Si 0.023, S 0.017.	Eye-bar, 1 in. x 5 in., longitudinal.	....	20.1	24.0 (yld pnt)	46.9	35 (2 in.)	29	23.0	105	18	....	[38]
1435..	...do..................	Eye-bar, 1 in. x 5 in., transverse.	....	13.9	22.7 (yld pnt)	34.4	6.2 (2 in.)	5.1	....	105	4.8	....	[38]
1436..	C 0.030, Ni 3.0, Si 0.11, P 0.077, Mn 0.040, S 0.027, Slag 2.75.	Hot-rolled..........	....	....	58.1 (yld pnt)	63.9	31 (2 in.)	50	42.6	149	24	....	[234]
1437..	...do..................	Normalized at 1,600°F.	....	....	....	....	....	....	41.1	....	....	....	[234]
						CARBON STEELS (SEE ALSO FIGS. 80 TO 90, INCLUSIVE)							
1438..	C 0.07, Mn 0.41, P 0.060, S 0.050 (bessemer).	Strip, 0.104 in., rolled.	....	....	41.8 (yld pnt)	57.0	30 (2 in.)	....	....	R_B 66	....	....	[235]

[a] Reversed torsion.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					CARBON STEELS—Continued								
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
1439..	C 0.08, Mn 0.41, S 0.033, P 0.024 (open-hearth rimming).	Strip, 0.104 in., rolled.	....	....	38.4 (yld pnt)	52.6	35 (2 in.)	....	....	R_B55	....	....	[235]
1440..	C 0.09, Mn 0.42, S 0.038, P 0.016.	Sheet, ann..........	....	....	29.1	48.6	40 (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 kips/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 kips/in.².... Compressive str.........55.8 kips/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	....	[239]

1455..	...do	Cast; ann at 1,650°F	....	....	36.2	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.	....	38.2	40.3 (yld pnt)	61.5	41 (2 in.)	67	28.0	.....	....	....	[38]
1457..	C 0.18, Mn 0.92, P 0.115, S 0.12, Si 0.02.	Cold-rolled	29,800	....	66.0 (0.001% offset)	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 0.090, Si 0.03, P 0.025	Bar, 7/16 in., cold-drawn.	....	55.2	....	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	....	....	38.6 (yld pnt)	63.7	41 (2 in.)	57	32.0	R_B 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; normalized.	....	30.5	39.4 (yld pnt)	72.0	40 ($4\sqrt{area}$)	61	....	140	Iz 35	....	[63]
1463..	C 0.24, Mn 0.57, Si 0.006.	1 hr at 1,650°F, w-q, tempered 2 hr at 900°F.	....	50.0	58.0 (0.01% perm)	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.	....	....	54 (0.2% perm)	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	....	32.4 (0.001% offset) 31.8 (yld pnt)	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	....	....	38.7 (yld pnt)	64.6	43 (2 in.)	56	24.0	R_B 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 0.050, S 0.044, Cr 0.04.	Water-quenched from 1,650°F, tempered at 750°F.	....	....	85.1 (yld pnt)	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	....	37.5	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	....	55.0	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.	....	....	39.2 (0.1%)	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	Hard-ness number	Impact value	Miscellaneous	Ref-er-ence
			Modulus of elas-ticity	"Propor-tional limit"	Yield strength	Tensile strength	Elongation	Reduc-tion of area					
			CARBON STEELS—Continued										
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/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	5.8	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	13	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........96.8 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, Mo 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	....	....	....	[c] 514	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	17	....	[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	6.4	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]

1486..	C 0.45, Mn 0.60, Si 0.18, S 0.040. P 0.015.	Bar, 3/4 in., ann 2/3 hr at 1,470°F, f-c.	....	....	....	81.0	....	....	36.0 [d] 25.5	153	....	....	[251]
1487..	...do..............	Bar, 3/4 in., 1/3 hr at 1,525°F, o-q, tempered 1 hr at 1,100°F.	....	....	....	102	....	....	46.5 [d] 46.0	207	....	....	[251]
1488..	C 0.48, Mn 0.81, S 0.035, P 0.015.	Bar, 1/2 in. diam, cold-rolled.	....	....	....	115	16 (4.5 √area)	34	51.6	220	Iz 9	....	[252]
1489..	C 0.50, Mn 0.70, Si 0.18, Ni 0.10.	Normalized at 1,510°F.	....	....	49.3 (0.1%)	99.0	24 (2 in.)	44	38.1	......	Iz 18	....	[238]
1490..	C 0.52, Mn 0.56, Si 0.24, P 0.037, S 0.029.	Billet, 4 in. square, normalized 1/4 hr at 1,550°F.	....	45.4	47.6 (yld pnt)	98.0	24 (2 in.)	42	42.0	193	13	....	[38]
1491..	...do..............	Billet, 4 in. square, norm 1/4 hr at 1,550°F, 1/4 hr at 1,450°F, w-q, tempered at 1,200°F.	....	80.3	84.3 (yld pnt)	111	22 (2 in.)	57	55.0	227	21	....	[38]
1492..	C 0.55, Mn 0.74, S 0.05, P <0.04.	Bar, 1 1/2 in., rolled; 1 hr at 1,600°F, a-c; w-q from 1,550°F, tempered at 1,200°F, f-c to 900°F, a-c.	28,200	73.6	....	107	24 (8 in.)	57	57.0	207	24	Shear str.............74.9 kips/in.^{2}.... Mod-el (shear).........11,400 kips/in.^{2} Specific gravity.......7.84.	[96]
1493..	C 0.57, Mn 0.65, Si 0.17, S 0.028, P 0.012.	Oil-quenched from 1,490°F.	....	....	105 (yld pnt)	152	16 (2 in.)	40	....	311	....	....	[239]
1494..	...do..............	Oil-quenched from 1,490°F, tempered at 860°F.	....	....	97.5 (yld pnt)	146	16 (2 in.)	46	....	293	....	....	[239]
1495..	C 0.65, Mn 0.55.....	Wire, 0.148 in. diam, oil-tempered.	....	....	202 (0.1% perm)	217	....	....	65.0 [d] 51.0	.....	....	....	[241]
1496..	C 0.67, Mn 0.68, P <0.045, S <0.045.	Wire, 0.062 in. diam, quenched, tempered, coiled, tempered at 850°F.	....	....	....	....	....	....	....	......	....	Mod-el (shear).........11,600 kips/in.^{2}..	[153]
1497..	C 0.70, Mn 0.11, Si 0.10, S 0.045.	Cast................	....	....	41.5	45.1	1.5 (2 in.)	1.8	....	......	....	....	[239]
1498..	C 0.70, Mn 0.42.....	Wire, 0.039 in. diam, oil-tempered.	....	....	....	....	....	....	....	......	....	Mod-el (shear).........10,900 kips/in.^{2}..	[16]
1499..	C 0.72, Mn 0.31, Si 0.24, S 0.019, P 0.017.	Bar, 3/4 in., ann 2/3 hr at 1,410°F, f-c.	....	....	....	92.0	....	....	35.0 [d] 29.0	192	....	....	[251]
1500..	...do..............	Bar, 3/4 in., 1/3 hr at 1,425°F, o-q, tempered 1 hr at 840°F.	....	....	....	168	....	....	94.0 [d] 62.5	332	....	....	[251]
1501..	C 0.75, Mn 0.50.....	Galvanized wire, 0.192 in. diam, cold-drawn.	....	....	170 (0.1% perm)	230	....	....	[d] 24.0	......	....	....	[241]
1502..	...do..............	Galvanized wire, 0.192 in. diam, o-q, tempered.	....	....	198 (0.1% perm)	225	....	....	50.0 [d] 24.5	.....	....	....	[241]
1503..	C 0.83, Mn 0.38, P <0.045, S <0.045.	Wire, 0.080 in., quenched, tempered, coiled, tempered at 850°F.	....	....	....	....	....	....	....	......	....	Mod-el (shear).........11,400 kips/in.^{2}..	[153]

[c] Surface hardness.

[d] Axial.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	CARBON STEELS—Continued												
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
1504..	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.	....	56.0	69.4 (0.2% perm)	139	15 (2 in.)	22	....	268	....	Comp yld str (0.2%)..75.0 kips/in.^{2}....	[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	....	132	Iz 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	....	144 (0.01%) 179 (0.2%)	225	7 (2 in.)	....	80.0 [a]5[illegible] [e]10[illegible]	444	....	Mod rupture.........173 kips/in.^{2}..... Mod-el (shear)......10,800 kips/in.^{2}	[254]
1507..	C 0.93, Mn 0.38, S 0.045, Si 0.03, P 0.017.	Bar, 2 in. × 7/8 in., hot-rolled.	....	51.1	....	133	7.2 (2 in.)	12	....	250	2.2	....	[38]
1508..	...do..................	Bar, 2 in. ×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	162	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 0.36, 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	....	144 (0.01%) 194 (0.2%)	237	5 (2 in.)	....	98.0 [e]123	430-470	....	Mod rupture.........194 kips/in.^{2}..... Mod-el (shear)......10,800 kips/in.^{2}	[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. ×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	224	1.9	....	[38]
1513..	...do..................	Bar, 2 in. ×1 in., 1/4 hr at 1,580°F, f-c, 1/2 hr at 1,420°F, o-q, tempered 1/2 hr at 800°F.	....	108	113 (yld pnt)	180	9.2 (2 in.)	22	85.0	338	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.	....	....	....	....	....	......	....	....	....	Mod-el (shear)......11,100 kips/in.^{2}..	[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	Iz 59	....	[256]
1523..	C 0.36, Al 2.03, Cr 1.62, Mn 0.57, Si 0.31, Ni 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.	....	102	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	101 (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.	....	....	51.1	81.3	35 (2 in.)	65	....	159	Iz 57	....	[259]
1527..	C 0.20, Cr 0.45, Mn 1.19, Si 0.67, P 0.033, S 0.019.	Rolled..............	30,400	....	54.3	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.............	....	....	59.8 (yld pnt)	103	22 (2 in.)	37	....	192	Iz 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	....	80.6 (0.005% perm)	125	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	Iz 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	Iz 22	Mod rupture.........135 kips/in.^{2}.... Mod-el (shear)......12,100 kips/in.^{2}	[259]

[a] Reversed torsion.

[e] Zero to maximum torsion.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
CHROMIUM STEELS—Continued													
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
1532..	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	76.0	35	68	....	131	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	144	7.0 (2 in.)	17	....	286	Iz 3.0	....	[259]
1535..	C 0.42, Cr 0.83, Mn 0.56.	Oxy-acetylene flame-hardened.	....	135	....	150	....	....	....	{325 ^{c}495}	Iz 48	....	[249]
1536..	C 0.29, Cr 0.87, Mn 0.43.	Annealed...........	....	....	40.3	74.4	34 (2 in.)	57	....	142	Iz 41	....	[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.	....	....	44.4 (0.5% extn)	60.0	42 (2 in.)	75	....	....	Iz 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	Iz 12	Mod rupture......186 kips/in.^{2}.. Mod-el (shear)...11,400 kips/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	Iz 50	Mod rupture......144 kips/in.^{2}.. Mod-el (shear)...11,500 kips/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	Iz 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 930°F.	....	....	91.4	112	20 (2 in.)	63	....	....	Iz 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 1,580°F, tempered 1 hr at 1,110°F.	....	....	86.7	111	22 (2 in.)	63	....	211	Iz 16	....	[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	Iz 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...	Oil-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, 2 hr at 1,380°F, 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 2.97, 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.	....	....	60.5 (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...	Oil-quenched from 1,650°F, tempered 1 hr at 980°F.	....	....	142	167	14 (2 in.)	54	....	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, tempered at 1,380°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)	66.0	38 (2 in.)	76	....	....	47	....	[262]
1563..	C 0.30, Cr 5.27, Mn 0.39, 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, 4 hr at 1,380°F, a-c.	....	....	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 0.54, 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: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					CHROMIUM STEELS—Continued								
	Percent		*Kips/in.*²	*Kips/in.*²	*Kips/in.*²	*Kips/in.*²	*Percent*	*Percent*	*Kips/in.*²		*ft-lb*		
1569..	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.	...	...	76.3 (0.5% extn)	104	28 (2 in.)	71	...	...	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; ann 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	90.0	105	21 (2 in.)	68	...	235	Iz 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	Iz 8.0	Compressive str...438 kips/in.²...	[265]
1574..	...do...	Oil-quenched from 1,700°F, tempered at 600°F.	...	...	...	...	...	...	...	R_c 60	Iz 5.5	Compressive str...397 kips/in.²...	[265]
1575..	C 0.10, Cr 12, Mn 0.5, Si 0.3, P 0.02, S 0.02.	Annealed...	...	...	...	...	...	...	...	...	...	Specific gravity..7.65... Melting range.....2,750°-2,790°F.	[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	39.0	...	...	...	[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	49.0	...	...	...	[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	{88.0 [a]43.0}	...	...	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	{62.5 [a]37.0}	...	...	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	Iz 10	...	[264]
1581..	...do...	Oil-quenched from 1,740°F, tempered at 1,290°F.	31,900	58.0	80.5	101	26 (2 in.)	59	...	238	Iz 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	Iz 27	...	[264]
1583..	...do...	Oil-quenched from 1,740°F, tempered at 1,290°F.	31,600	60.2	72.1	97.5	28 (2 in.)	69	...	206	Iz 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 [a]65.0	....	....	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 [a]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 [a]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 [a]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 840°F.	32,800	50.6	88.8	189	10 (2 in.)	....	....	357	....	....	[264]
1590..	C 0.09, Cr 16.53........	Sheet, 0.18 in., hot-rolled.	....	....	104	133	4.5 (8 in.)	....	....	R_B 103	....	....	[264]
1591..	...do........	Sheet, 0.18 in., ann.	....	....	49	70	20 (8 in.)	....	....	R_B 82	....	....	[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	....	202	....	....	[264]
1594..	...do........	Cold-drawn........	....	79.0	88.5	102	22 (2 in.)	67	....	223	Iz 71	....	[264]
1595..	C 0.07, Cr 18.56, Si 0.73, Mn 0.43, P 0.037, S 0.020.	Bar, 5/8 in. diam, rolled.	....	....	51.2 (yld pnt)	76.5	31 (2 in.)	72	15.0	....	....	....	[268]
1596..	C 0.75, Cr 23.12, Si 0.75.	Forged; f-c from 1,560°F in 5 days.	....	....	....	95.8	11 (2 in.)	12	....	223	....	....	[264]
1597..	C 0.35, Cr 25.08........	Cast........	....	....	51.0	59.0	1.0 (2 in.)	1.0	....	169	....	....	[264]
1598..	C 0.14, Cr 26.28, Mn 0.50, Si 0.36.	Forged........	....	....	62.0	89.0	9.0 (2 in.)	11	....	170	Iz 2.0	....	[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	....	2.9	....	[264]
						CHROMIUM-ALUMINUM STEELS							
1601..	C 0.32, Cr 1.24, Al 0.93, Mn 0.72, Mo 0.34, Si 0.22.	Water-quenched from 1,545°F, tempered at 1,110°F.	....	....	106	130	15 (5 diam)	55	69	....	....	....	[269]

[a] Reversed torsion.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	CHROMIUM-ALUMINUM STEELS—Continued												
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
1602..	C 0.32, Cr 1.24, Al 0.93, Mn 0.72, Mo 0.34, Si 0.22.	Water-quenched from 1,545°F, tempered at 1,110°F, nitrided 48 hr at 930°F.	....	....	114	144	7.2 (5 diam)	14	88	....	....	....	[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 1,690°F, tempered at 1,200°F.	....	....	92.4	115	22 (5 diam)	68	59.7	....	....	....	[269]
1605..	...do..............	Oil-quenched from 1,690°F, tempered at 1,200°F, nitrided 48 hr at 930°F.	....	....	95.3	118	....	25	78.2	....	....	....	[269]
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, nitrided 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, nitrided 48 hr at 950°F.	....	....	140 (0.2%)	165	4 (4 diam)	....	87.0	V 1,003–1,064	....	....	[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	Iz 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	Iz 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, tempered 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, tempered at 1,165°F, nitrided 90 hr at 930°F.	29,300	60.5	113 (0.5%)	144	....	....	{ 86.0 / d 52.4 }	V 1,090	....	....	[272]

1613..	C 0.37, Cr 8.29, Al 4.60, Si 1.08, Mn 0.33.	Bar, 11/16 in. diam, rolled.	....	70.0	....	90.0	5.6 (2 in.)	5.1	....	R_c 15	[f] Iz 40	....	[273]
1614..	C 0.67, Cr 8.59, Al 6.30, Si 1.10, Mn 0.41.	...do...............	....	105	....	125	3.1 (2 in.)	3.5	....	R_c 31	[f] Iz 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] 1.5	....	[274]
1616..	C 0.13, Cr 18.0, Co 17.6, Mo 3.10, Mn 0.52, Si 0.33.	....	....	....	41.2 (0.2%)	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.	....	....	49.5 (yld pnt)	66.8	35 (2 in.)	78	....	131	Iz 98	....	[261]
1618..	C 0.06, Cr 3.76, Cb 0.56.	...do...............	....	....	44.0 (yld pnt)	73.5	31 (2 in.)	79	....	131	Iz 95	....	[261]
1619..	C 0.09, Cr 5.62, Cb 1.04.	Bar, 1 in. diam, rolled.	....	....	98.0	111	16 (2 in.)	62	....	192	Iz 59	....	[259]
1620..	...do.................	Bar, 1 in. diam, 4 hr at 1,380°F, a-c.	....	....	32.0	62.0	29 (2 in.)	78	....	112	Iz 108	....	[259]
1621..	...do.................	Bar, 1 in. diam, 1/6 hr at 1,650°F, a-c.	....	....	61.0	82.0	27 (2 in.)	70	....	143	Iz 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.	....	....	39.0 (yld pnt)	75.0	35 (2 in.)	78	....	143	Iz 95	....	[261]
1623..	C 0.10, Cr 12.42, Cb 1.18.	Bar, 1 in. diam, rolled.	....	....	39.2 (yld pnt)	63.3	30 (2 in.)	53	....	121	Iz 15	....	[276]
1624..	C 0.07, Cr 19.20, Cb 1.00.	...do...............	....	....	52.0 (yld pnt)	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 0.088.	Bar, 1 in. diam, normalized.	....	....	56.6 (yld pnt)	82.5	29 (2 in.)	51	....	....	Iz 38	....	[277]
1626..	C 0.10, Cr 0.55, Cu 0.34, Mn 0.98, Si 0.80, Cb 0.12, P 0.086.	...do...............	....	....	63.5 (yld pnt)	82.0	27 (2 in.)	56	....	....	Iz 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	98.5	19 (2 in.)	37	....	255	Iz 10	....	[259]
1628..	...do.................	Furnace-cooled from 1,600°F.	....	....	49.3	64.5	28 (2 in.)	60	....	146	Iz 57	....	[259]
1629..	C 0.08, Cr 0.99, Cu 0.35, Mn 0.45, Si 0.23, Cb 0.11, P 0.084.	Bar, 1 in. diam, normalized.	....	....	56.5 (yld pnt)	73.0	27 (2 in.)	56	....	....	Iz 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)	76.5	30 (2 in.)	70	....	....	Iz 57	....	[277]

[b] Notch impact value, m-kg/cm.^{2} [d] Axial. [f] Unnotched.

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	CHROMIUM-COPPER STEELS—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
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.	30,000	....	60.0 (0.005% perm)	78.4	40 (2 in.)	72	54.0	156	....	Mod-el (shear)..11,900 kips/in.²..	[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 0.19, 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	Iz 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	Iz 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	Iz 24	....	[259]
1636..	...do..........	Furnace-cooled from 1,600°F.	....	....	61.5	67.5	24 (2 in.)	61	....	126	Iz 43	....	[259]
1637..	C 0.24, Cr 3.12, Cu 0.23, Si 0.34.	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.	....	36.0	42.0 (0.01% perm)	79.8	32 (2 in.)	66	39.0	....	....	....	[17]
1641..	C 0.61, Cr 15.81, Cu 1.10, Mn 0.39, 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 / [a]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 / [a]47.0}	....	....	Torsion str...119 kips/in.²....	[267]
1643..	C 0.08, Cr 16.56, 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	Iz 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 pnt)	87.8	27 (2 in.)	57	....	174	Iz 25	....	[278]

1646..	C 0.06, Cr 12.05, Mn 3.91.	Wrought; o-q from 1,695°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.	33,600	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	205	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 2.99.	Water-quenched from 1,920°F.	....	....	56.0	128	36 (2 in.)	37	....	187	Iz 120	....	[264]
1654..	C 0.07, Cr 17.88, Mn 8.26, Si 0.29.	...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 0.08, Cr 18.25, Mn 8.68, 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, N_2 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........	....	....	41.0	73.0	15 (2 in.)	....	....	170	Iz 21	....	[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 14.90, Si 0.37.	...do........	....	....	70.6	90.0	20 (2 in.)	40	....	159	Iz 10	....	[264]

[a] Reversed torsion.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					CHROMIUM-MOLYBDENUM STEELS								
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
1667..	C 0.31, Cr 0.57, Mo 0.22.	Cast; normalized at 1,650°F, tempered at 1,100°F.	....	....	71.0	104	20 (2 in)	35	....	207	Iz 22	....	[279]
1668..	C 0.30, Cr 0.66, Mo 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, Mo 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, Mo 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, Mo 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, Mo 0.24, Mn 0.54, Si 0.21, S 0.029, P 0.025.	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	....	229	....	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, Mo 0.17, Mn 0.56.	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, Mo 0.15, Mn 0.71, Si 0.13.	1 hr at 1,575°F, o-q, 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, Mo 0.33, Mn 0.58, Ni 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, Mo 0.18, Mn 0.69.	Oxy-acetylene flame-hardened.	....	130	....	147	....	....	....	350 [c]514	Iz 40	....	[249]
1683..	C 0.50, Cr 1.03, Mo 0.19, Mn 0.48, Si 0.24.	Furnace-cooled from 1,600°F.	....	....	50.8	111	21 (2 in.)	41	49.5	....	4.8	Torsion str.....76.7 kips/in.^{2}..	[259]
1684..	...do..................	Water-quenched from 1,600°F, tempered at 900°F.	....	....	128	172	12 (2 in.)	42	88.0	....	12	Torsion str.....126 kips/in.^{2}...	[259]
1685..	C 0.99, Cr 1.05, Mo 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, Mo 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, Mo 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, Mo 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, Mo 0.23, Mn 0.84, Si 0.33, Ni 0.13, P 0.017, S 0.004.	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, Mo 0.58, Mn 0.51.	Bar, 1 1/8 in., o-q from 1,650°F, tempered at 1,200°F.	....	....	118 (yld pnt)	142	23 (2 in.)	68	....	....	Iz 87	....	[283]
1692..	C 0.07, Cr 3.68, Mo 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, Mo 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, Mo 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.	....	....	143 (yld pnt)	173	4 (2 in.)	16	....	340	Iz 12	....	[261]
1697..	C 0.13, Cr 8.72, Mo 0.53, V 0.26, Mn 0.38, Si 0.07.	Bar, 1 in. diam, forged; ann at 1,600°F.	....	....	40.4 (yld pnt)	70.2	36 (2 in.)	75	....	140	48	....	[263]
1698..	C 0.16, Cr 9.30, Mo 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	....	....	[284]

[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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	CHROMIUM-MOLYBDENUM STEELS—Continued												
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
1699..	C 0.12, Cr 9.42, Mo 1.41, Mn 0.38, Si 0.09.	Bar, 1 in. diam, forged; ann at 1,600°F.	....	....	41.8 (yld pnt)	81.5	34 (2 in.)	77	....	143	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	Iz 56	Compressive str., [a]404 kips/in.^{2}..	[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	Iz 85	....	[285]
1702..	...do........	Heat-treated........	....	....	82.5 (0.2% perm)	105	20 (2 in.)	57	55.6	217	Iz 70	....	[285]
1703..	C 1.20, Cr 13.50, Mo 1.15, Co 1.15, Mn 0.40, Si 0.05.	Oil-quenched from 1,650°F, tempered at 1,290°F.	....	....	....	120	12 (4 in.)	18	....	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, Cu 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	Iz 5	....	[259]
1707..	...do........	Furnace-cooled from 1,600°F.	....	....	52.3	68.0	24 (2 in.)	52	....	....	....	....	[259]
1708..	C 0.30, Cr 0.72, Ni 0.50, Mn 0.50, Mo 0.30.	Cast; f-c from 1,650°F.	....	....	46.0 (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	....	Iz 40	....	[238]
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	287	[b]14	....	[281]
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 0.007.	...do...............	....	....	110 (0.02%) 120 (0.2%)	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 0.004.	...do...............	....	....	90.6 (0.02%) 130 (0.2%)	168	11 (10 diam)	52	75.4	301	[b]5.0	....	[281]
1715..	C 0.32, Cr 3.20, Ni 0.70, Mn 0.53, Si 0.20, S 0.026, P 0.023.	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..	C 0.40, Cr 13.5, Ni 13.5, W 2.5, Si 1.5.	Forged..............	....	....	83 (yld pnt)	134	37	42	....	260	Iz 50	....	[287]
1717..	C 0.22, Cr 14.18, Ni 6.88, Mn 5.17, Cu 2.93, Si 0.11.	Hot-rolled..........	....	29.0	45.5	90.7	45 (2 in.)	62	....	....	Iz 79	....	[274]
1718..	C 0.17, [illegible] 15.64, Ni 1.29.	Plate, 1/4 in., o-q from 1,785°F, tempered 3 hr at 840°F.	30,600	134	178	202	9 (2 in.)	....	....	387	....	....	[264]
1719..	C 0.16, Cr 17.20, Ni 2.30.	Air-cooled from 1,740°F, tempered at 1,200°F.	....	....	86.8	110	24 (2 in.)	62	....	248	Iz 68	....	[264]
1720..	C 0.35, Cr 17.40, Ni 2.01.	...do...............	....	....	138	151	17 (2 in.)	47	....	302	Iz 20	....	[264]
1721..	C 0.09, Cr 17.51, Ni 9.24, Mn 0.39, Si 0.02, S 0.02, P 0.008.	Annealed............	....	....	....	88.0	70 (2 in.)	77	33.0	....	77	....	[233]
1722..	C 0.10, Cr 17.80, Ni 10.10, Cu 2.20, Si 0.36.	Water-quenched from 2,010°F.	....	....	31.9	66.5	66 (2 in.)	78	....	126	Iz 100	....	[264]
1723..	C 0.10, Cr 18, Ni 8....	Cast; w-q from 2,010°F.	....	....	32.0	72.0	61 (2 in.)	63	....	131	Iz 85	....	[264]
1724..	C 0.10, Cr 18, Ni 8, Mn 0.5, Si 0.5, P 0.02, S 0.02.	Annealed............	....	....	....	....	....	....	....	....	....	Specific gravity..7.92........... Melting range....2,550°-2,590°F.	[266]
1725..	C 0.17, Cr 18, Ni 8....	Water-quenched from 2,100°F.	....	30.0	....	93.0	68 (2 in.)	75	38.0	170	....	....	[288]
1726..	Cr 18, Ni 8 (-200 mesh powder).	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..	Cr 18, Ni 8 (-200+325 mesh powder).	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..	C 0.11, Cr 18.03, Ni 8.88 Mn 0.57, Si 0.41, P 0.022, S 0.007.	Sheet, ann..........	....	....	28.0 (0.1% perm)	89.0	65 (2 in.)	....	32-34	R_B 76	....	....	[290]

[a]Reversed torsion.

[b]Notch impact value, m-kg/cm.^{2}

[c]Compression 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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	CHROMIUM-NICKEL STEELS—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
1729..	C 0.10, Cr 18.07, Ni 15.09, Mn 0.41, Si 0.06.	Water-quenched from 2,010°F.	....	21.8	34.8 (0.5%)	79.7	55 (2 in.)	77	....	....	Iz 105	....	[291]
1730..	C 0.07, Cr 18.2, Ni 9.42, Cb 0.51.	Water-quenched from 2,100°F	....	....	36.0	89.5	60 (2 in.)	72	....	137	Iz 120	....	[264]
1731..	C 0.15, Cr 18.32, Ni 9.82, W 3.09, Si 2.57.	....	....	....	57.0	116	51 (2 in.)	63	....	....	....	....	[264]
1732..	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	150	Iz 73	....	[285]
1733..	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	34.5	140	Iz 100	....	[285]
1734..	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]
1735..	C 0.12, Cr 18.9, Ni 8.0.	Hard-drawn.........	27,700	....	....	....	....	....	....	....	....	....	[237]
1736..	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	302	Iz 34	....	[292]
1737..	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	....	....	....	....	[293]
1738..	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.)	....	....	172	Iz 65	....	[294]
1739..	...do................	Weld, deposit only; ann 1/4 hr at 1,950°F, w-q.	....	....	40.1	74.0	45 (2 in.)	....	....	154	Iz 81	....	[294]
1740..	C 0.27, Cr 19.52, Ni 7.28, W 4.70, Si 2.12, Mn 0.54.	Air-cooled from 1,650°F.	....	74.2	....	132	28 (4 in.)	39	....	273	[b] 5.8	....	[274]
1741..	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.)	....	....	132	Iz 106	....	[294]
1742..	...do................	Cast; ann 1/4 hr at 1,950°F, w-q.	....	....	33.0	66.5	63 (2 in.)	....	....	116	Iz 111	....	[294]
1743..	C 0.25, Cr 20, Ni 7, Si 1.5.	Forged.............	....	....	67 (yld pnt)	125	42	46	....	190	Iz 50	....	[287]
1744..	C 0.30, Cr 20, Ni 7, W 4, Si 1.5.	...do..............	....	....	85 (yld pnt)	137	34	41	....	260	Iz 35	....	[287]

1745..	C 0.11, Cr 20.71, Ni 10.78, 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% perm)	.08	20 (2 in.)	30	30-40	....	Iz 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%)	108	25	35	47.0	269	Iz 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 (yld pnt)	78.4	44 (8 in.)	....	....	R_B 72	....	....	[288]
1750..	C <0.20, Cr 23-27, Ni 17-21.	...do...............	....	....	45.2 (yld.pnt)	91.0	32 (8 in.)	....	....	R_B 82	....	....	[288]
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	Iz 42	....	[297]
1752..	C 0.22, Cr 24.0, Ni 20.0, Si 1.07.	Bar, 1 in. diam, rolled.	....	....	37.0 (yld 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 (yld 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...........	....	....	....	....	....	....	....	....	....	Specific gravity..7.83.......... Melting range.....2,550°-2,570°F.	[266]
1755..	C 0.25, Cr 25, Ni 18, Si 2.	Forged.............	....	....	74 (yld pnt)	112	29	46	....	195	Iz 50	....	[287]
1756..	C 0.15, Cr 25, Ni 20, Mn 1.0, Si 0.7, P 0.02, S 0.02.	Annealed...........	....	....	....	....	....	....	....	....	....	Specific gravity..7.9........... Melting range.....2,550°-2,600°F.	[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	Iz 29	....	[264]
1758..	...do.................	Cast; air-cooled from 2,010°F.	....	....	46.5	85.0	49 (2 in.)	65	....	146	Iz 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 (yld pnt)	94.0	2 (2 in.)	50	....	183	Iz 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 (yld 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.)	18	....	....	Iz 13	....	[298]
1762..	...do.................	Wrought; 1/2 hr at 1,925°F, w-q.	....	....	80.0	107	33 (2 in.)	55	....	228	Iz 56	....	[298]

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 (yld pnt)	151	10 (2 in.)	15	....	293	Iz 5	....	[278]
1764..	...do.................	Bar, 1 in. diam, o-q from 1,740°F, tempered 2 hr at 1,110°F.	....	....	66.0 (yld pnt)	95.5	23 (2 in.)	60	....	187	Iz 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: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	CHROMIUM-NITROGEN STEELS—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
1765..	C 0.07, Cr 16.39, N_2 0.12.	Bar, 1 in. diam, 3 hr at 1,380°F, a-c.	....	....	61.0 (yld pnt)	92.0	27 (2 in.)	66	....	183	Iz 86	....	[278]
1766..	C 0.08, Cr 18.46, N_2 0.17.	...do..........	....	....	68.0 (yld pnt)	103	25 (2 in.)	57	....	174	Iz 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	Iz 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	Iz 13	....	[278]
	CHROMIUM-SILICON STEELS												
1769.	C 0.37, Cr 1.65, Si 1.05, Mn 0.33.	Bar, 3/4 in. × 1 3/4 in., forged; a-c from 1,650°F.	....	....	77.7	128	22 (2 in.)	57	....	....	Iz 22	....	[259]
1770..	...do..........	Bar, 3/4 in. × 1 3/4 in., forged; o-q from 1,600°F, tempered at 1,020°F.	....	....	154	174	12 (2 in.)	45	....	358	Iz 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	Iz 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, Ni 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 800°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	Iz 9	....	[264]
1778..	C 0.50, Cr 30, Si 1.5..	Forged..........	....	....	56 (yld pnt)	101	18	30	....	215	Iz 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	....	163	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	....	112	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	....	112	Iz 112	....	[259]
1783..	C 0.11, Cr 13.35, Ti 0.85.	Hot-rolled..........	....	....	36.0	63.4	25 (2 in.)	70	....	126	....	....	[264]
1784..	C 0.07, Cr 19.20, Ti 1.00.	...do...............	....	....	52.0	72.0	22 (2 in.)	41	....	149	....	....	[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	....	163	....	....	[276]

CHROMIUM-TUNGSTEN STEELS

1786..	C 0.88, Cr 0.50, W 0.40, Mn 1.15, Si 0.26, P 0.010, S 0.007.	....	....	....	....	95.0	....	....	....	175	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 0.28, 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 1.48, 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 1,090°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., normalized 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	48	....	[283]

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					CHROMIUM-TUNGSTEN STEELS—Continued								
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
1796..	C 0.46, Cr 11.94, W 4.80, Si 2.89, Mn 0.49.	Oil-quenched from 1,875°F, tempered at 1,470°F.	....	101	....	129	5.0 (4 in.)	....	....	300	[b]0.3	....	[274]
					CHROMIUM-VANADIUM STEELS								
1797..	C 0.29, Cr 0.51, V 0.28, Mn 0.53.	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 0.24.	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	42.0	....	....	....	[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	69.0	....	....	....	[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.)	....	104 [a]75.0 [e]128	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., normalized 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., normalized 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	[a]58.7	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, tempered 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, tempered 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.	....	....	....	....	....	....	....	....	....	....	Melting point.....2,721°F...........	[228]
1814..	C 0.55, Cr 0.99, V 0.19.	Furnace-cooled from 1,650°F.	....	....	51.5	102	26 (2 in.)	48	44.5	....	16	Torsion str.......77.0 kips/in.^{2}....	[259]
1815..	...do..................	Water-quenched from 1,650°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 1,650°F, tempered at 860°F.	....	179	....	202	9.5	31	[a]62.7	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 1,560°F, tempered at 750°F.	30,300	....	237	250	5.6 (8 in.)	12	105	500	Iz 9	Mod rupture.......205 kips/in.^{2}..... Mod-el (shear)....11,800 kips/in.^{2}	[259]
1819..	...do..................	Oil-quenched from 1,560°F, tempered at 1,110°F.	30,700	....	169	178	7.4 (8 in.)	31	95.2	386	Iz 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 1,450°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)....12,500 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 1,560°F, tempered at 915°F.	....	....	161 (0.1%)	195	16 (2 in.)	48	94.1	....	Iz 24	....	[238]
1823..	...do..................	Oil-quenched from 1,560°F, tempered at 1,200°F.	....	....	71.7 (0.1%)	125	22 (2 in.)	60	56.0	....	Iz 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	....	....	Iz 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-kg/cm.^{2}

[e] Zero to maximum torsion.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
CHROMIUM-VANADIUM STEELS—Continued													
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
1826..	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.	....	....	28.8 (yld pnt)	68.9	38 (2 in.)	75	....	124	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.	....	....	....	....	....	....	....	R_c 62	Iz 20	Compressive str..426 kips/in.^{2}...	[265]
1828..	...do..................	Oil-quenched from 1,800°F, tempered at 600°F.	....	....	....	....	....	....	....	R_c 60	Iz 21	Compressive str..389 kips/in.^{2}...	[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	175	7	Shear str........68.5 kips/in.^{2}.. Mod-el (shear)...12,400 kips/in.^{2} Specific gravity..7.73.	[96]
CHROMIUM-ZIRCONIUM STEEL													
1830..	C 0.12, Cr 0.55, 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 16.97.......	...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%)	154	....	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 (0.2%)	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	....	[305]
1842..	C 0.10, Cu 0.30, Mn 0.50, Si 0.24, P 0.088.	Bar, 1 in. diam, normalized.	....	....	45.5 (yld pnt)	67.5	33 (2 in.)	60	....	....	Iz 53	....	[277]
1843..	C 0.11, Cu 0.34, Mn 0.95, Si 0.28, Mo 0.12, P 0.090.	...do...............	....	....	40.0 (yld pnt)	74.5	32 (2 in.)	59	....	....	Iz 38	....	[277]
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	....	....	....	....	[306]
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	Iz 127	....	[307]
1846..	...do.................	Bar, 7/8 in. diam, rolled; w-q from 2,000°F.	....	....	96.5	112	18 (2 in.)	62	....	255	Iz 42	....	[307]
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	....	[308]
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	....	Iz 75	....	[306]
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	....	[305]
1850..	C 0.27, Cu 0.82, Mn 0.47, 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)	93.1	26 (2 in.)	62	49.5	....	40	....	[309]
1851..	C 0.19, Cu 1.00, Al 0.95.	Normalized at 1,590°F.	....	....	61.5 (0.5% extn)	77.3	34 (2 in.)	64	....	149	....	....	[310]
1852..	...do.................	Normalized at 1,590°F, reheated 4 hr at 930°F.	....	....	77.2 (0.5% extn)	95.0	26 (2 in.)	59	....	191	....	....	[310]
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	....	....	Iz 10	....	[311]
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	....	....	Iz 5	....	[311]
1855..	C 0.27, Cu 1.06, Mn 0.60, Si 0.21, P 0.040, S 0.035.	Cast...............	....	31.4	48.4 (0.2% perm)	81.5	11 (2 in.)	13	....	....	Iz 8	....	[311]
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	....	....	Iz 10	....	[311]

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
						COPPER STEELS—Continued							
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
1857..	C 0.24, Cu 1.0, Mo 0.98.	Normalized at 1,650°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 1,590°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	28	....	[305]
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	50.0	145	112	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	49	....	55	....	[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.)	54	49.0	....	19	....	[233]
1867..	...do.................	Cast; 1 hr at 1,650°F, tempered 3 hr at 930°F.	....	....	79.4	106	24 (2 in.)	48	58.0	....	12	....	[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	45	....	25	....	[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 1,590°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 1.91.	Normalized at 1,590°F.	....	....	109 (0.5% extn)	199	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 1,560°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 1.58, 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 1,525°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: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	MANGANESE STEELS—Continued												
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
1890..	C 0.30, Mn 1.68, Ti 0.042.	Cast; a-c from 1,600°F, tempered at 1,050°F.	....	....	78.0 (yld pnt)	106	28 (2 in.)	59	....	....	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	179	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	196	28	....	[316]
1895..	C 0.27, Mn 1.71, Mo 0.25.	Rolled.............	....	....	78.0 (yld pnt)	120	19 (2 in.)	37	....	240	....	....	[286]
1896..	...do.................	Rolled; normalized at 1,600°F.	....	....	88.0 (yld pnt)	127	20 (2 in.)	32	....	265	Iz 28	....	[286]
1897..	...do.................	Rolled; w-q from 1,550°F, tempered at 1,100°F.	....	....	119 (yld pnt)	136	20 (2 in.)	43	....	290	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	56	....	159	17	....	[242]
1900..	...do.................	Water-quenched from 1,525°F, tempered at 1,125°F.	....	....	113	121	20	55	....	225	20	....	[242]
1901..	C 0.42, Mn 1.78, Si 0.24, V 0.048.	Oil-quenched from 1,500°F, tempered at 450°F.	....	....	232 (yld pnt)	270	12 (2 in.)	50	....	....	Iz 18	....	[317]
1902..	C 0.36, Mn 2.24........	Oil-quenched from 1,650°F, tempered at 1,110°F.	....	82.9	96.8 (yld pnt)	117	25 (2 in.)	61	....	249	Iz 21	....	[286]
1903..	C 0.30, Mn 2.30, Mo 0.52.	...do...............	....	116	138 (yld pnt)	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	....	230	....	....	[318]
1905..	...do.................	Cast, h-t..........	....	....	....	80-100	15-35 (2 in.)	15-35	....	180-220	....	Shear str.........84 kips/in.^{2}..	[318]
1906..	...do.................	Cast and ground, h-t.	....	42.9	....	118	44 (2 in.)	39	39.0	....	....	Comp yld str......24.0 kips/in.^{2}	[318]

1907..	C 0.15, Mn 16.59, Cr 7.49, Si 4.00, Ti 0.55.	Air-cooled from 1,920°F.	....	....	60.3 (0.2%)	141	28 (5 diam)	28	....	....	....	....	[275]
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 0.28, Mn 17.96, Si 2.33.	...do..............	....	....	44.8	133	17 (10 diam)	....	....	....	....	....	[319]
1912..	C 0.26, Mn 18.41, Ni 1.56, Si 0.47.	...do..............	....	....	39.8	120	44 (10 diam)	54	....	....	....	....	[319]
1913..	C 0.26, Mn 20.25, Cr 18.08, Si 0.25.	Water-quenched from 2,100°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 0.28, 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 0.34, Mn 1.29.	Oil-quenched from 1,600°F, tempered at 700°F.	....	....	165 (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	98.0	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	38.8	....	....	....	[313]
1921..	C 0.30, Mo 0.52, V 0.215.	Rolled.............	....	....	102	135	18 (2 in.)	46	....	282	....	....	[286]
1922..	...do.................	Rolled; w-q from 1,560°F, tempered at 1,110°F.	....	....	113	141	19 (2 in.)	60	....	320	....	....	[286]
1923..	C 0.11, Mo 0.54, 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	....	R_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.................	Bar, 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: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Import value	Miscellaneous	Reference
					MOLYBDENUM STEELS—Continued								
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
1926..	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.	....	....	88.5 (0.02%) 99.1 (0.2%)	125	14 (10 diam)	64	61.2	261	[b] 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........	....	....	113 (0.02%) 151 (0.2%)	172	5.4 (10 diam)	44	61.2	373	[b] 3.1	....	[281]
1928..	C 0.33, Mo 0.96........	Rolled; o-q from 1,650°F, tempered at 1,020°F.	....	....	111	133	18	55	....	281	....	....	[286]
1929..	C 0.84, Mo 1.02........	Rolled........	....	....	116	179	14 (2 in.)	34	....	....	....	....	[286]
1930..	C 0.87, Mo 1.02........	Rolled; ann at 1,750°F.	....	....	58.2	121	17 (2 in.)	22	....	228	....	....	[286]
1931..	...do........	Rolled; normalized at 1,650°F.	....	....	103	152	13 (2 in.)	28	....	302	....	....	[286]
1932..	...do........	Rolled; 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........	Rolled........	....	....	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........	Rolled; ann at 1,750°F.	....	....	58.4	95.5	5.6 (2 in.)	7.5	....	207	....	....	[286]
1937..	...do........	Rolled; 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 1,290°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; compacted at 12 1/2 tons/in.², sintered 1 hr at 2,200°F in hydrogen.	....	....	....	....	....	....	....	R_B 50	....	Density........7.49 gm/cm³.. 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............	....	....	51.5	82.9	30 (2 in.)	57	....	160	....	....	[286]
1945..	C 0.58, Mo 7.91, Co 5.41, Cr 3.9, V 0.99, W 0.36, Mn 0.12.	....	....	....	109	128	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.	....	....	....	74.3	14	....	....	....	....	Density...........8.42 gm/cm^3..	[52]
1948..	C 0.09, Mo 12.5........	Forged............	....	....	62.7	110	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.	....	....	....	79.9	15	....	....	....	....	Density...........8.77 gm/cm^3..	[52]
1951..	C 0.08, Mo 18.70.......	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	....	Iz 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	Iz 40	....	[324]
1954..	...do..................	Wrought, 1 3/4 in. x 3/4 in., w-q from 1,560°F, tempered at 1,110°F.	....	82.9	89.2 (0.2% perm)	112	22	61	....	247	Iz 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	Iz 53	....	[324]
1956..	...do..................	Wrought, 1 3/4 in. x 3/4 in., w-q from 1,560°F, tempered at 1,110°F.	....	96.3	103 (0.2% perm)	119	23	61	....	256	Iz 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	....	....	Iz 9	....	[311]
1958..	C 0.08, Ni 1.99, Mn 0.48.	Normalized, tempered at 1,200°F.	....	....	47.0 (yld pnt)	61.5	40	70	....	....	63	....	[325]

[b] Notch impact value, m-kg/cm.^{2}

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					NICKEL STEELS—Continued								
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
1959..	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)	53.7	41 (2 in.)	73	....	106	58	....	[326]
1960..	C 0.12, Ni 2.2, Mn 0.4, Si 0.1.	Annealed at 1,620°F, w-q from 1,400°F.	....	....	35.8 (0.1%)	85.1	32 (2 in.)	65	33.6	....	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, tempered 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	....	....	54.0	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	48.2	....	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	[a]41.2	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	79.0	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	....	....	....	[c]578	Iz 69	....	[249]
1973..	C 0.14, Ni 4.9, Mn 0.29, Si 0.16.	Normalized at 1,545°F, w-q from 1,400°F.	....	....	60.5 (0.1%)	136	18 (2 in.)	47	59.4	....	Iz 24	....	[238]

1974..	C 0.10, Ni 5.02, Mn 0.25, Si 0.10, S 0.022, P 0.008.	....	....	....	....	....	....	....	....	....	....	Melting point....2,765°F........	[328]
1975..	C 0.05, Ni 9.98, Mn 0.35, Si 0.10.	Hot-worked........	....	41.8	89.0	119	7.0 (2 in.)	22	....	287	Iz 44	....	[274]
1976..	...do........	Water-quenched from 1,650°F.	....	47.0	119	150	13 (2 in.)	44	....	334	Iz 34	....	[274]
1977..	...do........	Water-quenched from 1,650°F, tempered 1 hr at 750°F.	....	102	117	121	18 (2 in.)	56	....	268	Iz 53	....	[274]
1978..	Ni 15.0........	....	27,200	....	....	....	....	....	....	....	....	....	[329]
1979..	Ni 19.0........	....	25,200	....	....	....	....	....	....	....	....	....	[329]
1980..	C 0.06, Ni 20.48, Mn 0.34, Si 0.12.	Hot-worked........	....	39.1	88.1	158	10 (2 in.)	26	....	339	Iz 28	....	[274]
1981..	...do........	Water-quenched from 1,650°F.	....	26.6	86.1	154	9.5 (2 in.)	18	....	326	Iz 28	....	[274]
1982..	...do........	Water-quenched from 1,650°F, tempered at 750°F.	....	96.9	115	121	21 (2 in.)	61	....	368	Iz 48	....	[274]
1983..	Ni 24.1........	Magnetic........	24,700	....	....	....	....	....	....	....	....	....	[329]
1984..	...do........	Nonmagnetic........	27,500	....	....	....	....	....	....	....	....	....	[329]
1985..	Ni 27.9........	....	25,700	....	....	....	....	....	....	....	....	....	[329]
1986..	C 0.04, Ni 29.11, Mn 0.34, Si 0.09.	Hot-worked........	....	28.0	45.5	70.3	39 (2 in.)	70	....	126	Iz 96	....	[274]
1987..	...do........	Water-quenched from 1,650°F.	....	13.9	21.9	65.3	48 (2 in.)	71	....	113	Iz 85	....	[274]
1988..	Invar: C low, Ni 36, Mn 0.50.	Annealed at 1,450°F, relief ann at 700°F.	20,500	32.0	41.8	71.4	41 (2 in.)	72	....	131	....	....	[274]
1989..	Invar: C 0.10, Ni 36, Mn 0.50.	Hot-rolled or forged.	21,400	20-30	40-60 (yld pnt)	65-85	30-45	55-70	....	160	....	Specific gravity..8.0........ Melting point....2,600°F.	[330]
1990..	Ni 39.4........	....	21,500	....	....	....	....	....	....	....	....	....	[329]
1991..	Ni 44.3........	....	23,200	....	....	....	....	....	....	....	....	....	[329]

NICKEL-BERYLLIUM STEEL

1992..	C low, Ni 36, Be 1.....	Quenched from 2,190°F.	....	....	....	83.8	27 ($11.3\sqrt{area}$)	46	....	....	....	....	[274]
1993..	...do........	Quenched from 2,190°F, tempered at 930°F.	....	....	....	159	5 ($11.3\sqrt{area}$)	14	....	....	....	....	[274]

NICKEL-CHROMIUM STEELS (SEE ALSO FIG. 90)

1994..	C 0.60, Ni 1.25, Cr 0.60, Mn 0.75.	Plate, 1/2 in., rolled.	....	....	61.0 (yld pnt)	124	22 (2 in.)	41	....	245	....	....	[327]
1995..	...do........	Plate, 1/2 in., rolled; a-c from 1,550°F.	....	....	81.0 (yld pnt)	138	22 (2 in.)	50	....	275	....	....	[327]
1996..	C 0.45, Ni 1.25, Cr 0.66, Mn 0.83, Si 0.29, Pb 0.18, S 0.027, P 0.012.	Annealed at 1,475°F..	....	....	59.0	104	24	49	....	187	18	....	[242]

[a]Reversed torsion.

[c]Surface hardness.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	NICKEL-CHROMIUM STEELS—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
1997..	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.	....	....	140	151	19	58	....	290	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 920°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)	88.3	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 0.21, 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 0.028, 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 kips/in.².. Mod-el (shear)..11,300 kips/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 kips/in.²... Mod-el (shear)..12,100 kips/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, tempered 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 0.14.	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.	....	....	....	....	....	....	....	....	....	....	Melting point...2,750°F........	[328]
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.)	15	101	....	Iz 12	....	[238]
2015..	C 0.14, Ni 4.49, Cr 1.20, Mn 0.40, Si 0.21.	Oil-quenched from 1,400°F.	....	....	108 (0.1%)	199	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 1,830°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 (yld pnt)	67.2	20 (2 in.)	22	....	131	....	....	[407]
2021..	..do........	Forged........	....	13.5	53.5 (yld pnt)	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 (yld pnt)	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, nitrided 48 hr at 930°F.	....	....	....	169	0 (5 diam)	2	96.7	....	....	....	[269]

[a] Reversed torsion.

[b] Notch impact value, m-kg/cm.^{2}

[c] Surface hardness.

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	NICKEL-CHROMIUM-MOLYBDENUM STEELS (SEE ALSO FIG. 90)												
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
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 pnt)	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	....	241	14	....	[242]
2031..	C 0.39, Ni 1.74, Cr 0.72, Mo 0.32, Mn 0.68, Si 0.27.	Bar, o-q from 1,525°F, tempered at 1,125°F.	....	128	135	145	20 (2 in.)	58	....	285	52	....	[333]
2032..	C 0.20, 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	....	207	33	....	[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	....	202	....	Shear str.......95.B kips/in.^{2}.. Mod-el (shear)..11,500 kips/in.^{2} Poisson's ratio..0.288.	[247]
2034..	...do..................	Wrought; o-q from 1,530°F, tempered at 1,100°F.	28,500	....	105	140	32 (2 in.)	64	....	229	....	Shear str.......122 kips/in.^{2}... Mod-el (shear)..11,700 kips/in.^{2} Poisson's ratio..0.285.	[247]
2035..	C 0.31, Ni 2.07, Cr 2.05, Mo 0.33, 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	292	[b] 15	....	[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	367	[b] 7.2	....	[281]
2037..	C 0.32, Ni 2.42, Cr 0.49, Mo 0.38, Mn 0.88, 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, tempered at 1,200°F.	29,300	70.0	98.0	118	10 (4 $\sqrt{area}$)	16	{ 60.0 [a] 40.0 }	260	Iz 25	Shear str.......105 kips/in.^{2}... Mod-el (shear)..11,500 kips/in.^{2}	[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	....	....	Iz 28	....	[332]
2039..	C 0.31, Ni 2.60, Cr 0.75, Mo 0.60, Mn 0.18.	Forged; o-q from 1,650°F, tempered 1 hr at 1,110°F.	....	125	159 (0.2% perm)	173	16	52	....	....	Iz 30	....	[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 0.44, Mn 0.42, Si 0.20, P 0.023, S 0.015.	....	....	....	....	....	....	....	....	....	....	Melting point...2,745°F.........	[328]
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 7.92, 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 [a]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 [a]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	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 1,560°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 1,830°F, tempered 3 hr at 1,290°F.	....	60.0	75.0	130	37 (2 in.)	61	....	....	Iz 84	....	[274]

[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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					NICKEL-CHROMIUM-TUNGSTEN STEELS								
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
2055..	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.	....	....	77.8 (0.02%) 128 (0.2%)	185	8.9 (10 diam)	60	95.3	348	[b] 14	....	[281]
2056..	C 0.20, Ni 4.21, Cr 1.55, W 0.89, Mn 0.38, Si 0.19, P 0.009, S 0.003.	...do...............	....	....	106 (0.02%) 115 (0.2%)	129	15 (10 diam)	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	Iz 49	....	[238]
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 0.19.	Forged; o-q from 1,650°F, tempered at 1,110°F.	....	116	129 (0.2% perm)	145	20	57	....	....	Iz 24	....	[332]
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	....	....	Iz 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	....	Iz 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	....	....	Iz 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	....	....	Iz 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	....	....	Iz 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	....	....	Iz 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)..11,800 kips/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]477	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	....	240	....	....	[286]
2082..	...do........	Forged; o-q from 1,550°F, tempered at 1,100°F.	....	123	....	132	21 (2 in.)	62	....	300	....	....	[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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	NICKEL-MOLYBDENUM STEELS—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
2084..	C 0.26, Ni 4.54, Mo 0.51.	Oil-quenched from 1,650°F, tempered at 1,110°F.	....	121	139 (yld pnt)	145	19 (2 in.)	57	....	312	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 0.41, Ni 3.00, Si 2.47, Mn 0.70.	...do........	....	146	....	170	14 (2 in.)	26	85.0	360	Iz 12	....	[286]
2088..	C 0.46, 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 0.47, 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 0.14, 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.	Rolled............	....	....	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	....	....	[259]
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	....	....	[259]
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.	....	....	57.0	84.0	26	38	....	....	[b] 5.9	....	[340]
2106..	C 0.24, Si 1.44, Mn 0.49, P 0.030, S 0.022.	Rolled............	....	....	58.0	88.0	25 (8 in.)	50	....	....	Iz 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	....	....	Iz 23	....	[340]
2109..	...do.................	Normalized at 1,650°F.	....	....	80.0 (yld pnt)	111	25 (2 in.)	50	....	....	Iz 28	....	[340]
2110..	C 0.53, Si 1.74, Mn 0.50.	Oil-quenched, tempered 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	....	Iz 13	....	[238]
2112..	C 0.53, Si 1.96, Mn 0.83.	2/3 hr at 1,600°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.	Rolled............	31,400	....	101	152	11	....	76.8	....	....	....	[340]

[b] Notch impact value, m-kg/cm.^{2}

[e] Zero to maximum torsion.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					TITANIUM STEEL								
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
2117..	C 0.29, Ti 0.20, Mn 0.67, Si 0.27.	Cast; f-c from 1,650°F.	....	....	50.0 (yld pnt)	80.0	25 (2 in.)	42	....	163	Iz 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	Iz 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	Iz 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 0.92, Cr 0.51, Si 0.20, S 0.033, P 0.032.	Wrought; f-c from 1,450°F.	28,500	....	48.0	82.5	40 (2 in.)	56	....	185	....	Shear str.......84.8 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	Iz 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.)	35	....	....	....	....	[299]

2133..	C 0.81, W 9.99........	Forged.............	....	....	145	192	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 3.9, 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	....	....	[286]
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	122	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 2,190°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 1,200°F.	....	....	47.5 (yld pnt)	79.8	31 (2 in.)	59	....	....	Iz 52	....	[313]
2147..	C 0.32, V 0.18, Mn 0.83, Si 0.38.	Cast; normalized at 1,650°F, tempered at 1,200°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]

[b] Notch impact value, m-kg/cm.^{2}

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	GRAPHITIC STEELS—Continued												
	Percent		*Kips/in.*²	*Kips/in.*²	*Kips/in.*²	*Kips/in.*²	*Percent*	*Percent*	*Kips/in.*²		*ft-lb*		
2152..	TC 1.51, CC 0.55, Si 0.96, Mn 0.40, P 0.015, S 0.014.	Furnace-cooled from 1,500°F.	....	....	47.7 (yld pnt)	99.0	20 (2 in.)	30	....	201	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	....	255	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	....	302	....	....	[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	....	388	....	....	[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 $\sqrt{\text{area}}$)	0	{ 40.5 / [a] 32.0 }	260	Iz 1	Shear str....86.5 kips/in.².. Mod-el (shear)....11,400 kips/in.²	[334]
	PLAIN CAST IRONS (SEE ALSO FIGS. 90 AND 109 TO 111, INCLUSIVE)												
2157..	TC 2.50, GC 1.50, CC 1.00, Si 0.79, Mn 0.74, S 0.09, P 0.04.	Cast........	[h] 20,000	....	....	47.7	....	....	25.2	266	[f] Iz 4.4	Compressive str....159 kips/in.²... Shear str....60.8 kips/in.² Mod rupture....92.0 kips/in.² Deflection (18-in. span).....0.230 in.	[343]
2158..	TC 2.88, GC 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........	[h] 14,800	....	....	40.9	....	....	19.6	189	3	Compressive str....119 kips/in.²... Shear str....47.3 kips/in.² Mod rupture....84.2 kips/in.² Deflection (18-in. span).....0.439 in. Melting 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, GC 2.44, CC 0.68, Si 2.18, P 0.63, Mn 0.44, S 0.10.	...do........	[h] 13,600	....	....	32.5	....	....	16.5	192	[f] Iz 4.2	Compressive str....121 kips/in.²... Shear str....44.6 kips/in.² Mod rupture....73.2 kips/in.² Deflection (18-in. span).....0.301 in.	[343]

2163..	TC 3.32, GC 2.56, Si 1.75, Mn 0.51, P. 0.48, S 0.138, Cu 0.05, Ni 0.04, Cr 0.01.	Cast bar, 3 in. x 3 in.	....	....	....	22.2	....	....	9.0 [a]11.0	....	....	Compressive str..............80.0 kips/in.^{2}.. Torsion str..................31.7 kips/in.^{2}	[346]
2164..	TC 3.41, GC 2.85, CC 0.56, Si 2.44, P 0.63, Mn 0.57, S 0.070, Ti 0.10, Cu 0.03, As 0.02, Cr 0.02, Sn 0.02, V 0.02, Ni 0.01.	Cast................	[h]8,000	....	....	20.0	....	....	9.4	159	0.8	Compressive str..............87.2 kips/in.^{2}.. Shear str....................27.7 kips/in.^{2} Mod rupture..................48.8 kips/in.^{2} Deflection (18-in. span).....0.274 in. Melting point................2,082°F.	[344]
2165..	TC 3.52, GC 3.41, CC 0.11, Si 2.55, Mn 1.01, P 0.215, S 0.086.	Bar, 7/8 in. diam, cast in permanent mold, ann.	17,600	....	....	34.1	....	....	20.0	163	....	Compressive str..............112 kips/in.^{2}... Shear yld str................23.2 kips/in.^{2} Shear str....................43.8 kips/in.^{2} Mod-el (shear) ....7,400 kips/in.^{2} Mod rupture..................75.9 kips/in.^{2} Deflection (12-in. span).....0.166 in.	[347]
2166..	...do..............	Bar, 2 in. diam, cast in permanent mold, ann.	12,000	....	....	22.5	....	....	13.5	164	....	Compressive str..............99.8 kips/in.^{2}.. Shear yld str................20.2 kips/in.^{2} Shear str....................36.5 kips/in.^{2} Mod-el (shear)...............6,300 kips/in.^{2} Mod rupture..................62.7 kips/in.^{2} Deflection (24-in. span).....0.240 in.	[347]
2167..	TC 3.60, GC 2.93, CC 0.68, Si 2.06, P 0.75, Mn 0.52, S 0.06.	Cast................	[h]8,700	....	....	22.4	....	....	11.4	163	[f]Iz 3.6	Compressive str..............91.0 kips/in.^{2}.. Shear str....................33.0 kips/in.^{2} Mod rupture..................49.2 kips/in.^{2} Deflection (18-in. span).....0.251 in.	[343]

ALLOY CAST IRONS (SEE ALSO FIG. 112)

2168..	TC 3.0, Al 7.25, Si 1.0, Cr 0.75, Mn 0.60	Cast................	....	....	....	34-43	....	....	....	290-340	[f]Iz 7	Mod rupture..................49-67 kips/in.^{2}.. Deflection (18-in. span).....0.10-0.15 in. Specific gravity.............6.77. Melting point................2,275°F.	[348]
2169..	TC 3.18, GC 2.31, CC 0.87, Si 2.06, Mn 0.92, Cr 0.21, Cu 0.21, P 0.17, S 0.103.	...do..............	18,600	....	....	43.5	....	....	....	241	[f]Iz 9.2	Mod rupture..................71.8 kips/in.^{2}.. Deflection (12-in. span).....0.13 in.	[349]
2170..	TC 2.84, GC 2.10, Si 1.52, Mn 1.05, Cu 0.37, Cr 0.31, Ni 0.20, S 0.124, P 0.07, Ti 0.020, As 0.013, V 0.005.	Plate, 1 3/4 in., cast.	....	....	....	46.0	....	....	20.1 [a]17.1	....	....	Compressive str..............140 kips/in.^{2}... Torsion str..................62.6 kips/in.^{2}	[346]
2171..	TC 3.73, GC 3.14, CC 0.59, Si 1.77, Mo 0.29	Cast................	....	....	....	22.6	....	....	....	200	[f]1.0	Compressive str..............109 kips/in.^{2}... Mod rupture..................40.0 kips/in.^{2} Deflection (16.5-in. span)..0.30 in.	[286]

[a]Reversed torsion. [f]Unnotched. [h]At 1/2 load.

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					
	ALLOY CAST IRONS—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
2172..	T C 2.75, Si 1.59, Mn 0.88, Mo 0.29, P 0.08, S 0.07.	Cast (processed iron).	21,700	5.5	....	52.0	0.4 (4 √area)	0.4	{ 29.0 [a] 25.5 }	245	Iz 1.5	Shear str................71.5 kips/in.²..... Mod-el (shear)..........8,600 kips/in.²	[334]
2173..	T C 3.40, G C 2.92, C C 0.48, Si 1.88, Mo 0.57, V 0.20.	Cast...............	....	....	....	35.3	....	......	....	238	[b] 1.2	Compressive str..........152 kips/in.²..... Mod rupture..............64.0 kips/in.² Deflection(16.5-in.span)..0.31 in.	[286]
2174..	T C 2.95, C C 0.57, Si 1.94, Mo 0.90, Mn 0.64, P 0.076, S 0.023.	...do..............	....	....	....	50.5	0 (2 in.)	0	28.0	....	1	....	[233]
2175..	T C 3.28, G C 2.47, Si 2.19, Mn 0.95, Mo 0.95, Cr 0.42, P 0.17, S 0.10.	...do..............	20,100	5.5	....	46.5	0.8 (4 √area)	0	{ 24.0 [a] 24.5 }	280	Iz 0.8	Shear str................73.0 kips/in.²..... Mod-el (shear)..........8,600 kips/in.²	[334]
2176..	T C 2.50, G C 1,85, C C 0.65, Si 2.80, Mo 1.04, Mn 0.99.	Bar, 2 in. diam, cast.	....	....	....	74.8	....	......	....	286	......	Transverse str...........17.1 kips/in.²..... Deflection (24-in. span)..0.455 in.	[350]
2177..	T C 2.79, G C 1.94, C C 0.85, Si 2.44, Mn 0.50, Ni 0.50, Cu 0.36, Cr 0.09, As 0.06, S 0.060, P 0.03, Ti 0.02, Sn 0.01, V 0.01.	Cast...............	[h] 16,400	....	....	56.7	....	......	25.0	234	3	Compressive str..........136 kips/in.²..... Shear str................57.1 kips/in.² Mod rupture..............112 kips/in.² Deflection (18-in. span)..0.490 in. Melting point............2,138°F.	[344]
2178..	T C 3.05, G C 2.20, C C 0.85, Si 2.70, Mn 0.79, Ni 0.60, Mo 0.45, Cr 0.24, P 0.16, S 0.09.	...do..............	[h] 14,300	....	....	39.2	....	......	18.2	228	[f] Iz 5.1	Compressive str..........131 kips/in.²..... Shear str................44.2 kips/in.² Mod rupture..............81.8 kips/in.² Deflection (18-in. span)..0.301 in.	[343]
2179..	T C 3.46, G C 2.82, C C 0.64, Si 2.35, Mn 0.69, Ni 0.65, P 0.15, S 0.092, Ti 0.04, Cu 0.03, Cr 0.02, Mo 0.02, As 0.01, Sn 0.01.	...do..............	[h] 10,000	....	....	24.4	....	......	12.0	160	1	Compressive str..........90.8 kips/in.²..... Shear str................34.2 kips/in.² Mod rupture..............58.3 kips/in.² Deflection (18-in. span)..0.335 in. Melting point............2,127°F.	[344]
2180..	T C 2.61, G C 1.73, C C 0.88, Si 2.38, Ni 1.08, Mn 0.77, S 0.105, Cr 0.09, P 0.06, Cu 0.05, Ti 0.02, As 0.01, Sn 0.01.	...do..............	[h] 16,200	....	....	51.4	....	.....	24.0	270	1	Compressive str..........157 kips/in.²..... Shear str................61.0 kips/in.² Mod rupture..............92.5 kips/in.² Deflection (18-in. span)..0.272 in. Melting point............2,217°F.	[344]

2181..	T C 3.49, G C 2.78, C C 0.71, Si 2.08, Ni 1.17, Cr 0.65, Mn 0.55, P 0.19, S 0.08.	...do...............	[h] 10,700	....	....	30.0	....	....	13.5	181	[f] 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..	T C 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..	T C 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..	T C 3.19, G C 2.20, C C 0.99, 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..	T C 3.11, G C 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 [a] 22.0	....	....	Compressive str..........236 kips/in.^{2}...... Torsion str..............84.1 kips/in.^{2}	[346]
2186..	T C 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..	T C 3.06, Si 2.17, Ni 1.70, Mn 0.62, Mo 0.62.	...do...............	18,400	....	....	52.9	....	....	27.5	241	....	....	[351]
2188..	T C 3.36, G C 2.39, Ni 1.87, Si 1.22, 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 [a] 20.0	265	Iz 0.4	Shear str................47.0 kips/in.^{2}..... Mod-el (shear)...........7,100 kips/in.^{2}	[334]
2189..	T C 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..	T C 2.46, G C 1.65, C C 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..	T C 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..	T C 2.63, G C 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 [a] 12.0	....	....	Compressive str..........182 kips/in.^{2}...... Torsion str..............43.8 kips/in.^{2}	[346]
2193..	T C 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]

[a] Reversed torsion. [b] Notch impact value, m-kg/cm.^{2} [f] Unnotched. [h] At 1/2 load.

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

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
												ALLOY CAST IRONS—Continued	
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
2194..	T C 3.25, G C 2.66, C C 0.59, Si 2.08, P 1.99, Mn 0.53, Ti 0.16, As 0.05, S 0.05, Ni 0.03, V 0.03, Cu 0.02, Sn 0.02.	Cast................	h 10,500	....	....	21.3	....	....	12.3	185	0.4	Compressive str.............90.9 kips/in.².. Shear str....................27.5 kips/in.² Mod rupture..................33.3 kips/in.² Deflection (18-in. span).....0.141 in. Melting point................2,021°F.	[344]
2195..	T C 3.18, Si 1.12, P 0.58, V 0.44, Mn 0.34, S 0.07.	Bar, 2 in. diam, cast.	....	....	....	38.5	....	....	....	....	....	Mod rupture..................67.5 kips/in.²..	[350]
												MALLEABLE CAST IRONS (SEE ALSO FIGS. 113 TO 116, INCLUSIVE)	
2196..	T C 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.)	....	25-26.5	110-145	16	Shear str....................48.0 kips/in.².. Mod-el (shear)...............12,500 kips/in.² Poisson's ratio..............0.17.	[354]
2197..	T C 2.25-2.70, Si 0.80-1.10.	....	25,000	....	32.5 (yld pnt)	50.0	14 (2 in.)	....	....	....	12	Shear str....................48.0 kips/in.².. Mod-el (shear)...............12,500 kips/in.² Poisson's ratio.............0.17.	[354]
2198..	T C 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..	T C 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..	T C 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	7.8	Comp yld str.................59.8 kips/in.².. Compressive str (2%).........70.6 kips/in.² Mod-el (shear)...............7,700 kips/in.² Mod rupture..................131 kips/in.² Deflection (14-in. span).....0.998 in.	[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	8.9	Comp yld str.................57.8 kips/in.².. Compressive str (2%).........66.9 kips/in.² Mod-el (shear)...............7,500 kips/in.² Mod rupture..................118 kips/in.² Deflection (14-in. span).....1.025 in.	[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	11	Comp yld str.................35.5 kips/in.².. Compressive str (2%).........52.9 kips/in.² Mod-el (shear)...............7,200 kips/in.² Mod rupture..................78.3 kips/in.² Deflection (14-in. span).....2.24 in.	[357]
2203..	T C 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, Si 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	Comp yld str.................79.0 kips/in.^{2}.. Compressive str (2%).........111 kips/in.^{2} Mod-el (shear)...............9,600 kips/in.^{2} Mod rupture..................139 kips/in.^{2} Deflection (14-in. span).....0.430 in.	[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	Comp yld str.................77.2 kips/in.^{2}.. Compressive str (2%).........105 kips/in.^{2} Mod-el (shear)...............9,500 kips/in.^{2} Mod rupture..................136 kips/in.^{2} Deflection (14-in. span).....0.561 in.	[357]
2207..	...do..............	Cast; 15 hr at 1,700°F, f-c to 1,325°F in 3 hr, held 20 hr.	....	....	37.2 (yld pnt)	54.5	15 (2 in.)	....	23.0	130	10	Comp yld str.................43.7 kips/in.^{2}.. Compressive str (2%).........81.0 kips/in.^{2} Mod-el (shear)...............8,100 kips/in.^{2} Mod rupture..................91.0 kips/in.^{2} Deflection (14-in. span).....1.56 in.	[357]

[h] At 1/2 load.

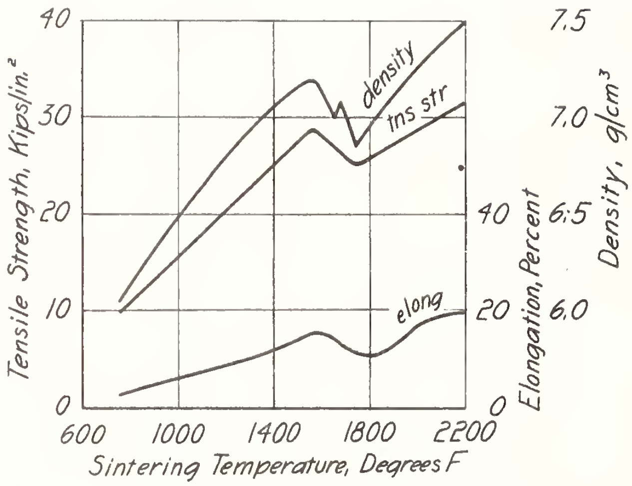
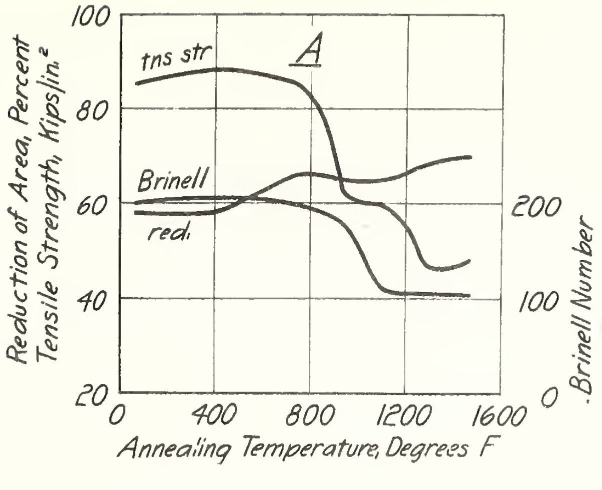


FIGURE 77.—*Effect of sintering temperature on the tensile properties and density of electrolytic iron powder compacts (Libsch, Volterra, and Wulff [52]).*

Compressed and sintered in hydrogen.

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



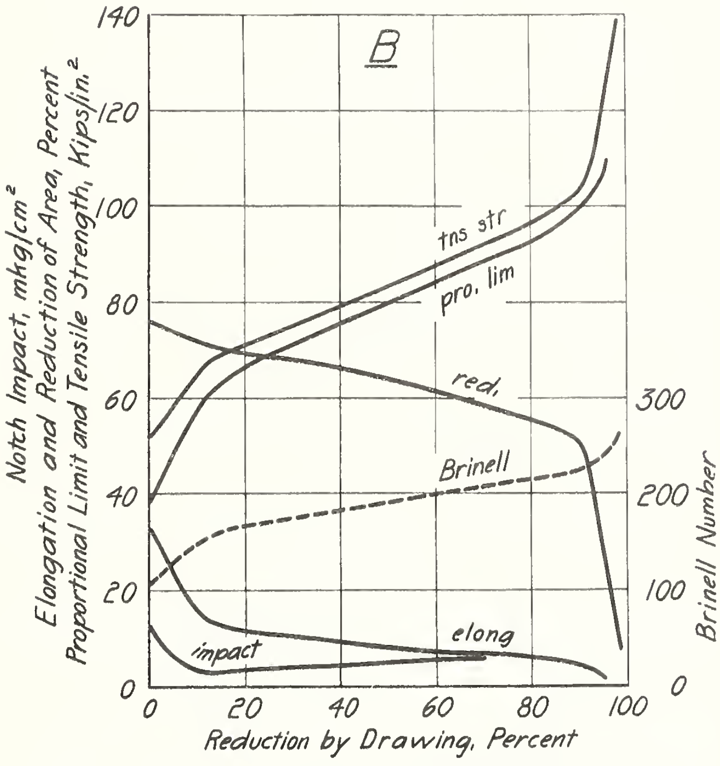


FIGURE 78.—*Effect of annealing and cold-drawing on the tensile properties, impact value, and hardness of ingot iron (Broniewski and Ročowski [660])*

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.

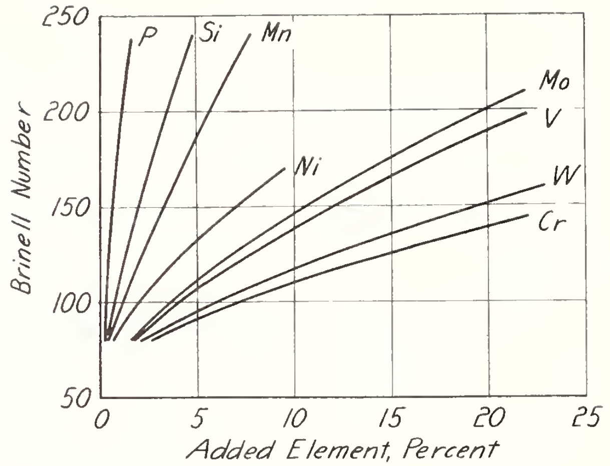


FIGURE 79.—*Probable hardening effect of various elements in pure iron (Bain [661]).*

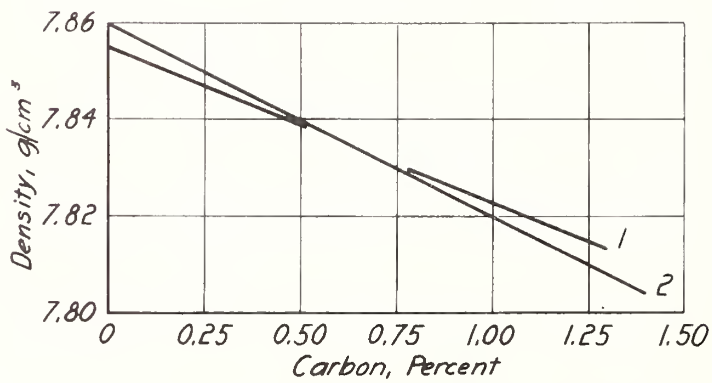


FIGURE 80.—*Densities of hot-rolled and annealed carbon steels (Cross and Hill [662]).*

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)

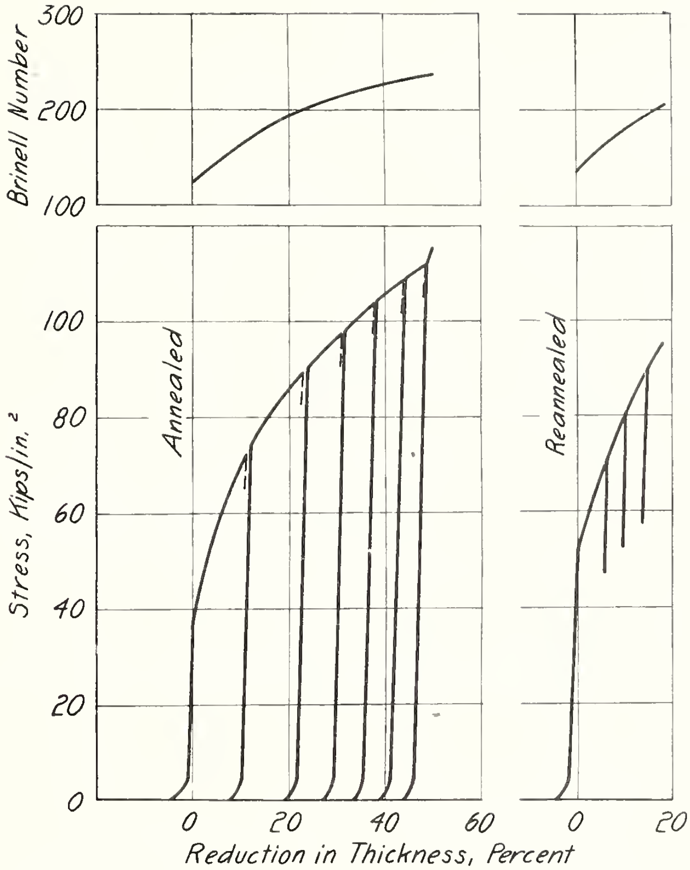


FIGURE 81.—*Compressive strength of a 0.15 percent carbon steel (Crane [642])*

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.

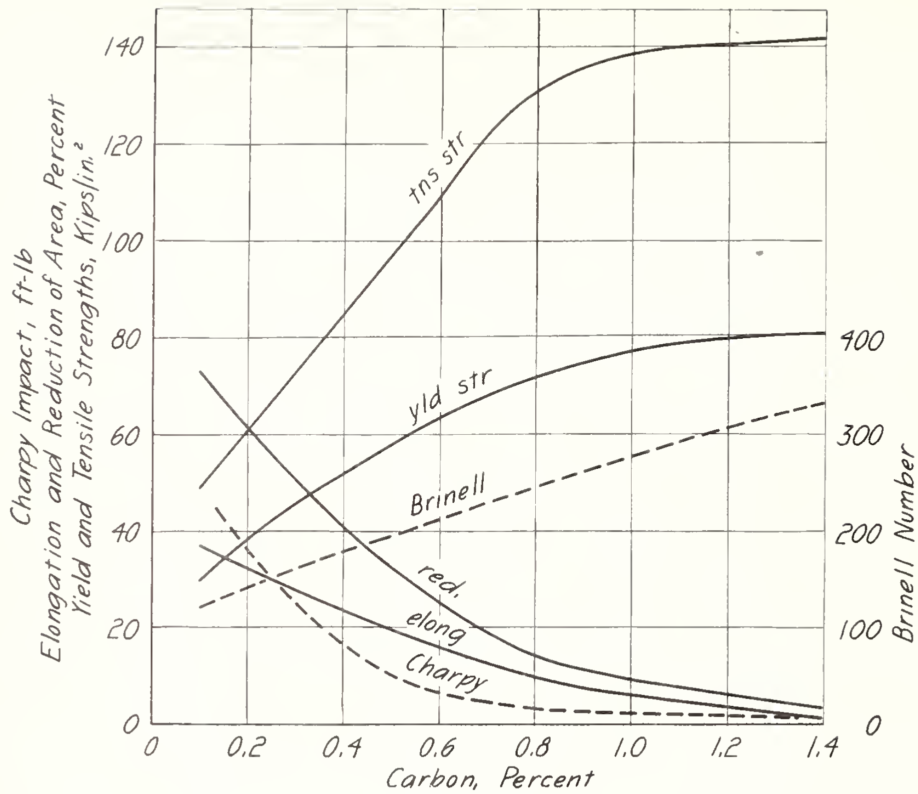


FIGURE 82.—*Average tensile properties, impact value, and hardness of hot-worked carbon steels (Sisco [239]).*

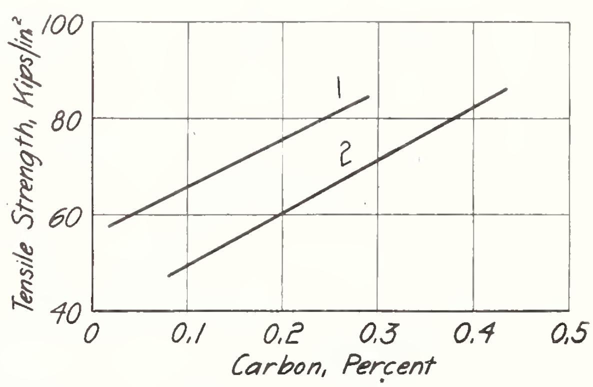


FIGURE 83.—*Comparative tensile strengths of hot-rolled Bessemer and open-hearth steels of similar carbon contents (McGinley and Woodworth [663]).*

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

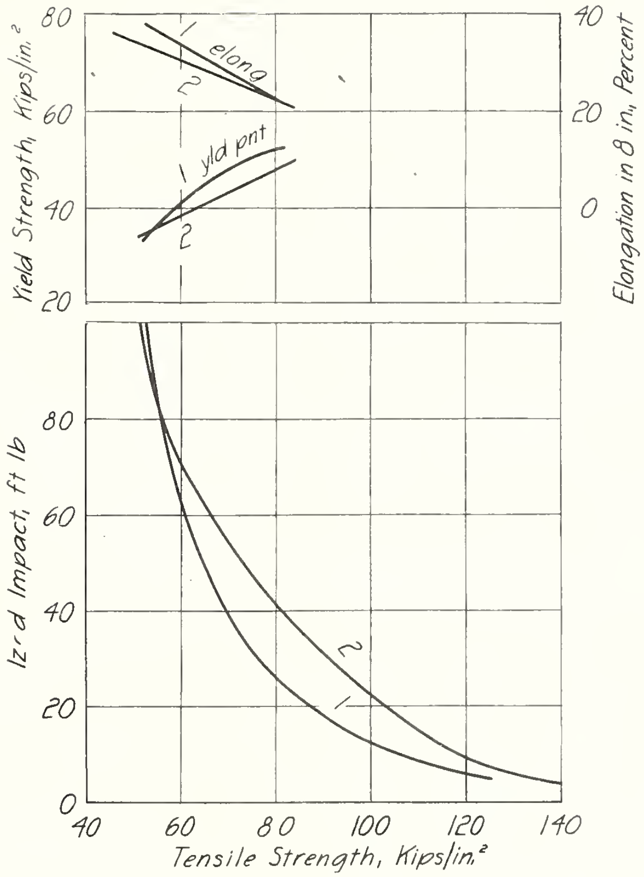


FIGURE 84.—*Comparison between yield point, elongation, and impact value for Bessemer and open-hearth steels of equivalent tensile strengths (McGinley and Woodworth [663]).*

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

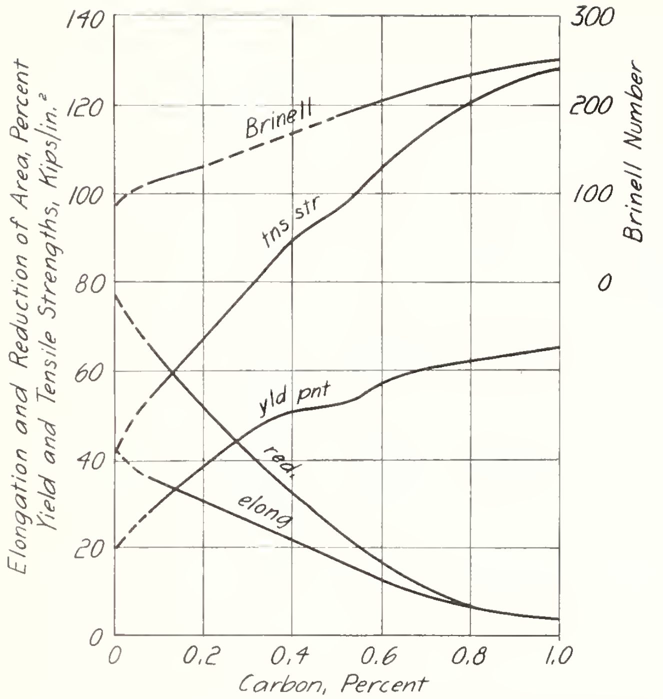


FIGURE 85.—*Average tensile properties and hardness of fully annealed cast carbon steels* [313].

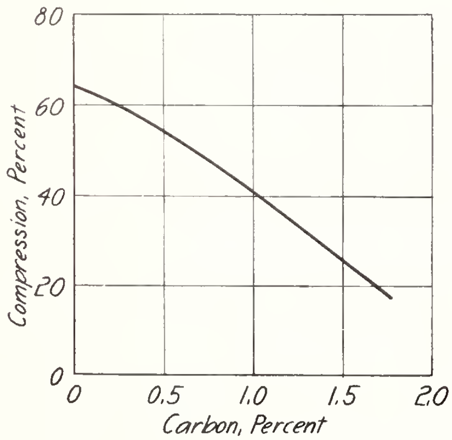


FIGURE 86.—*Compression of cast carbon steels under load of 224 kips/in.*^{2} *(Sisco* [239]*).*

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

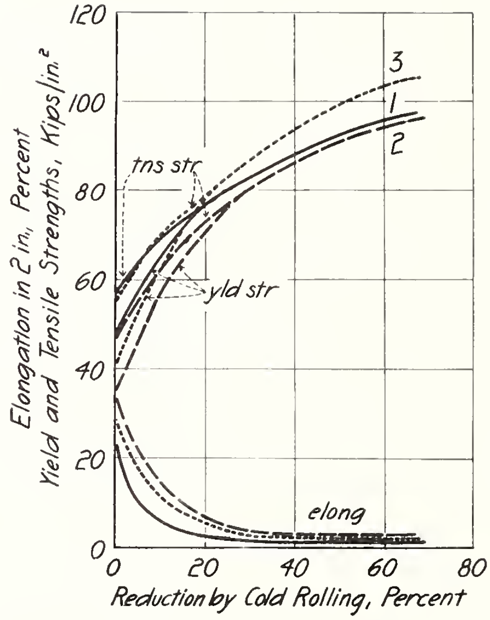


FIGURE 87.—*Effect of cold-rolling on the tensile properties of hot-rolled carbon steel (Sisco* [239]*).*

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.

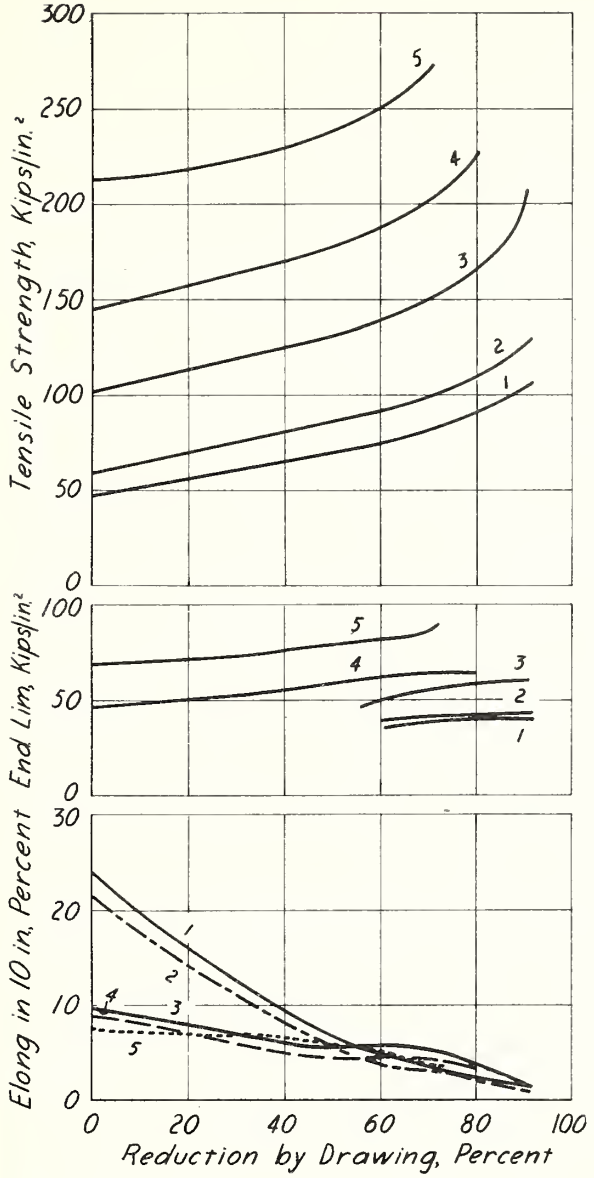


FIGURE 88.—*Tensile properties and endurance limit of cold-drawn steel wire (Godfrey [664]).*

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).

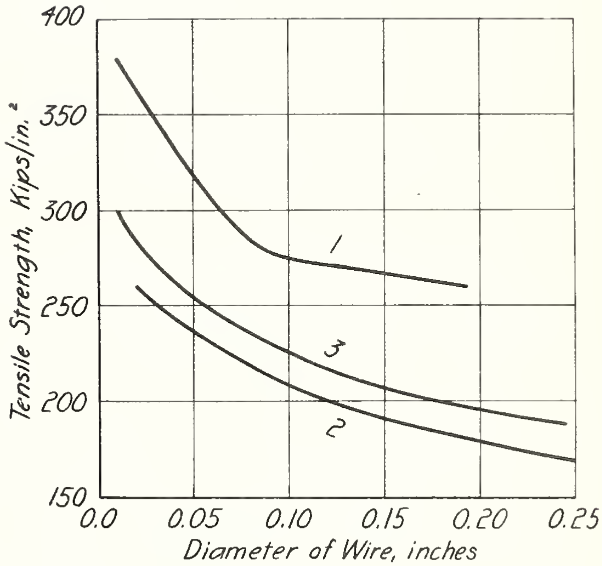


FIGURE 89.—*Tensile strength of steel wire (Eakin [665]).*

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.

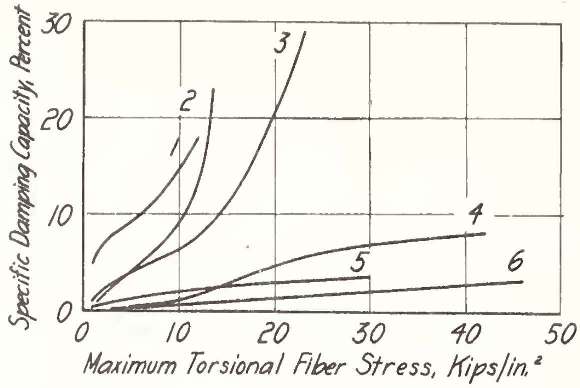


FIGURE 90.—*Damping characteristics of steels and cast iron (von Heydekampf [666]).*

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..............	.3	.....	.....	0.95	4.2	.....	.....	.....	......
6.......	Ni-Cr-Mo-W steel.........	.4	.45	.3	1.15	2.5	0.9	.25	.....	......

[1] Pearlitic

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.

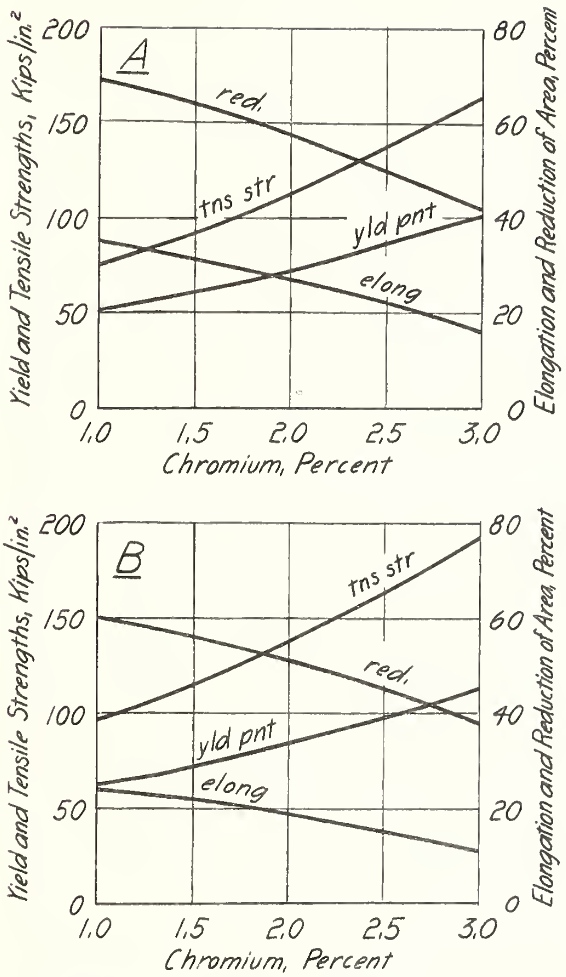


FIGURE 91.—*Tensile properties of normalized chromium steels (French [327]).*

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

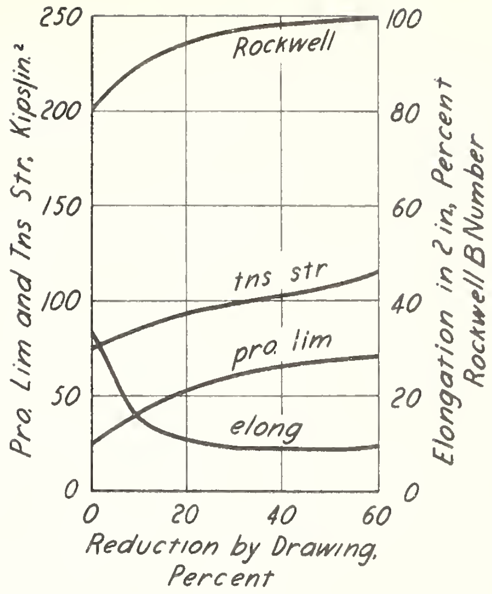


FIGURE 92.—*Effect of cold-drawing on the tensile properties and hardness of annealed stainless-steel wire containing 12 percent of chromium (Watkins [667]).*

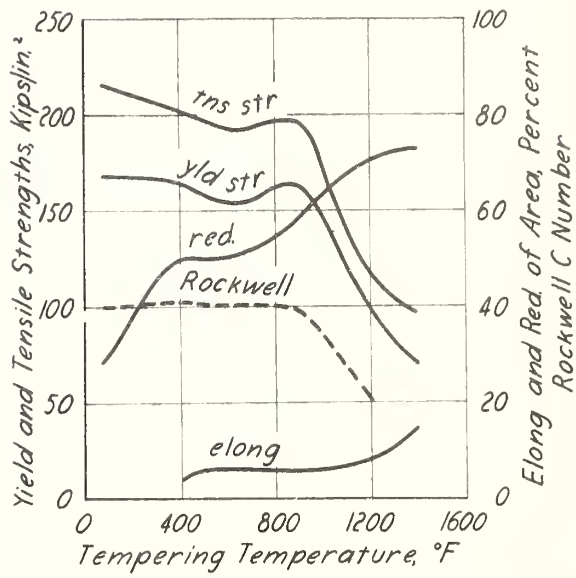


FIGURE 93.—*Effect of tempering on the tensile properties and hardness of stainless-steel wire containing 12 percent of chromium (Watkins [667]).*

(Elongation in 2 in.)

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

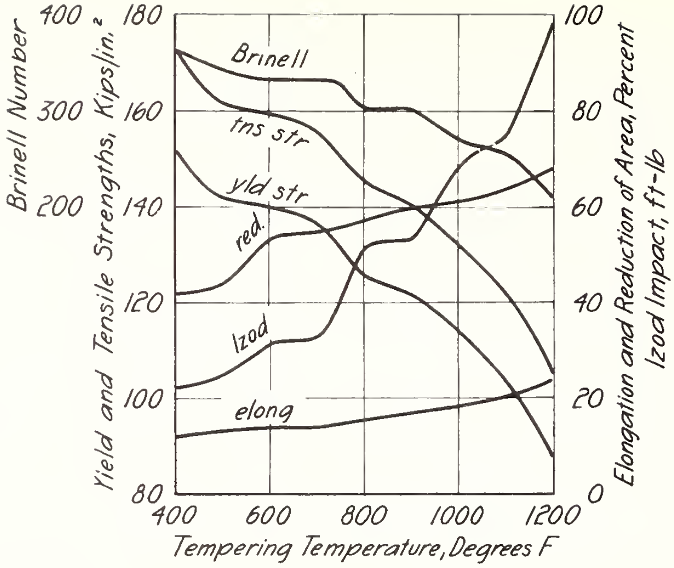


FIGURE 94.—*Tensile properties, impact value, and hardness of NE 8630 steel (Jones [668]).*

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.

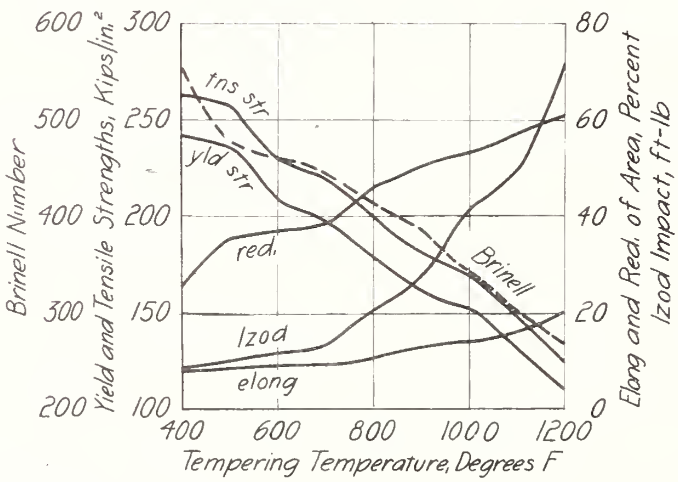


FIGURE 95.—*Tensile properties, impact value, and hardness of NE 8739 steel (Jones [668]).*

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.

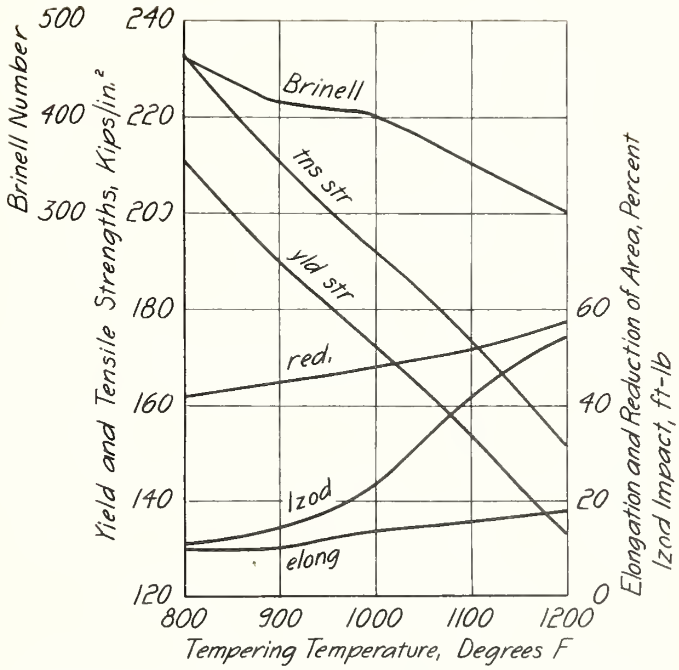


FIGURE 96.—*Tensile properties, impact value, and hardness of NE 8949 steel (Jones [668]).*

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.

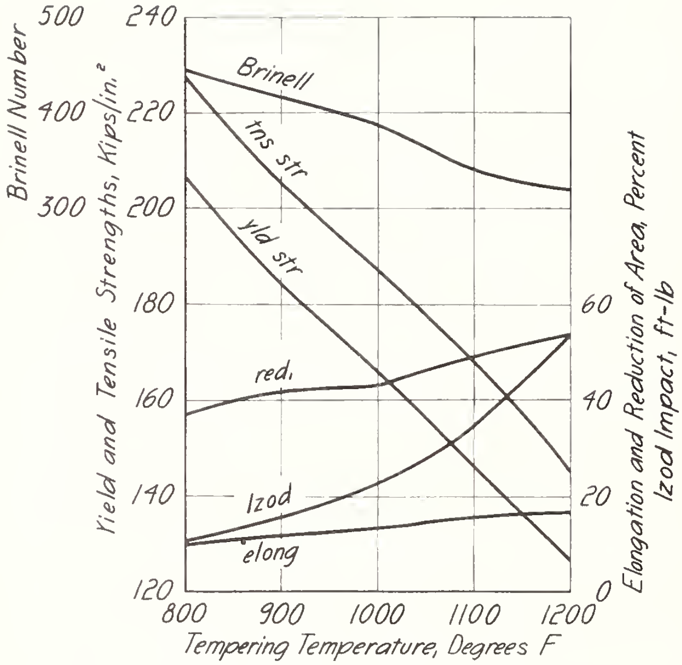


FIGURE 97. *Tensile properties, impact value, and hardness of NE 8749 steel (Jones |668|).*

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.

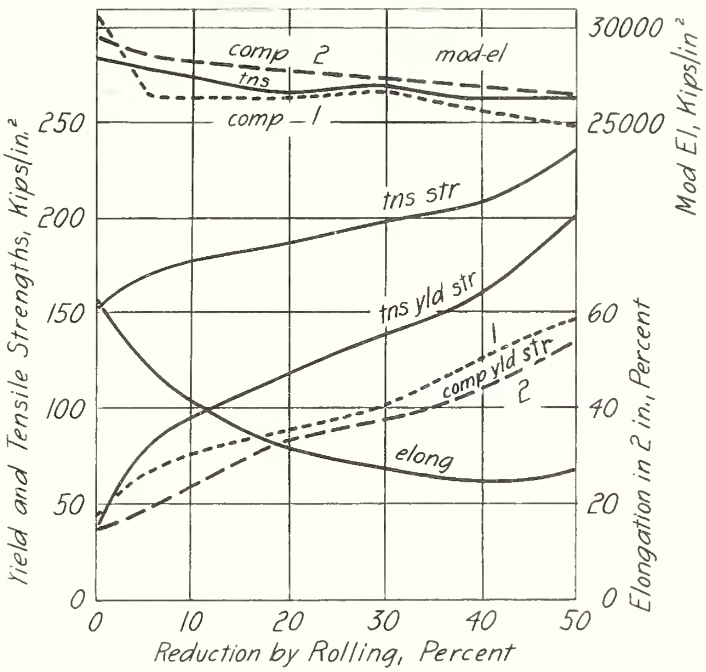


FIGURE 98.—*Effect of cold-rolling on the tensile and compressive properties of stainless-steel sheet (Aitchison, Tuckerman, Ramberg, and Whittemore [669]).*

(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.

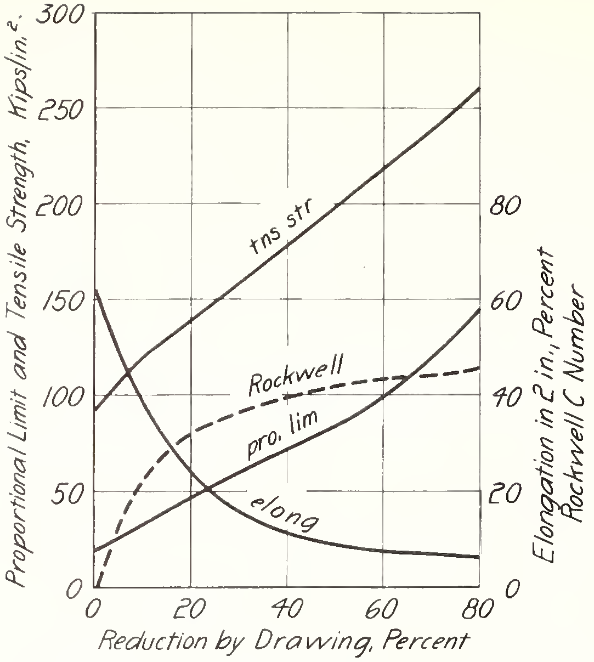


FIGURE 99.—*Effect of cold-drawing on the tensile properties and hardness of annealed stainless-steel wire (Watkins [667]).*

Cr 18%, Ni 8%.

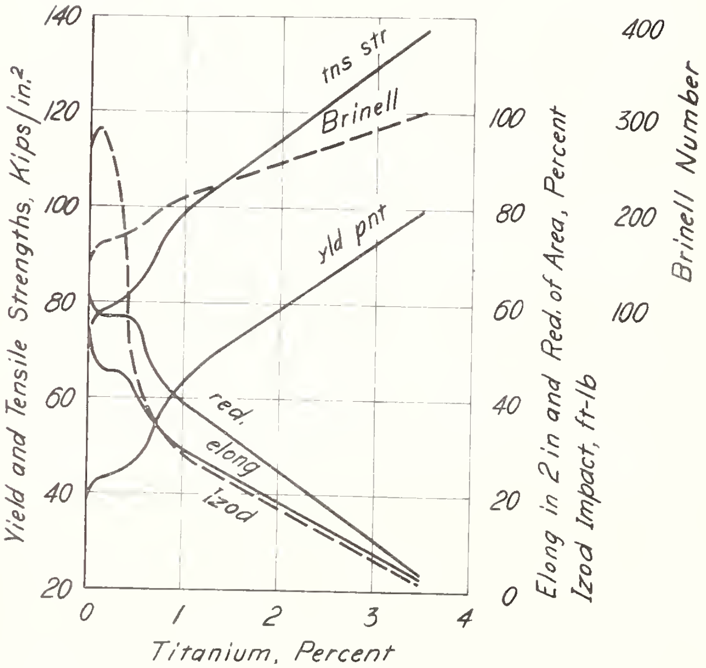


FIGURE 100.—*Effect of titanium on the tensile properties, impact value, and hardness of cast chromium-nickel steels (Duma [144]).*

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.

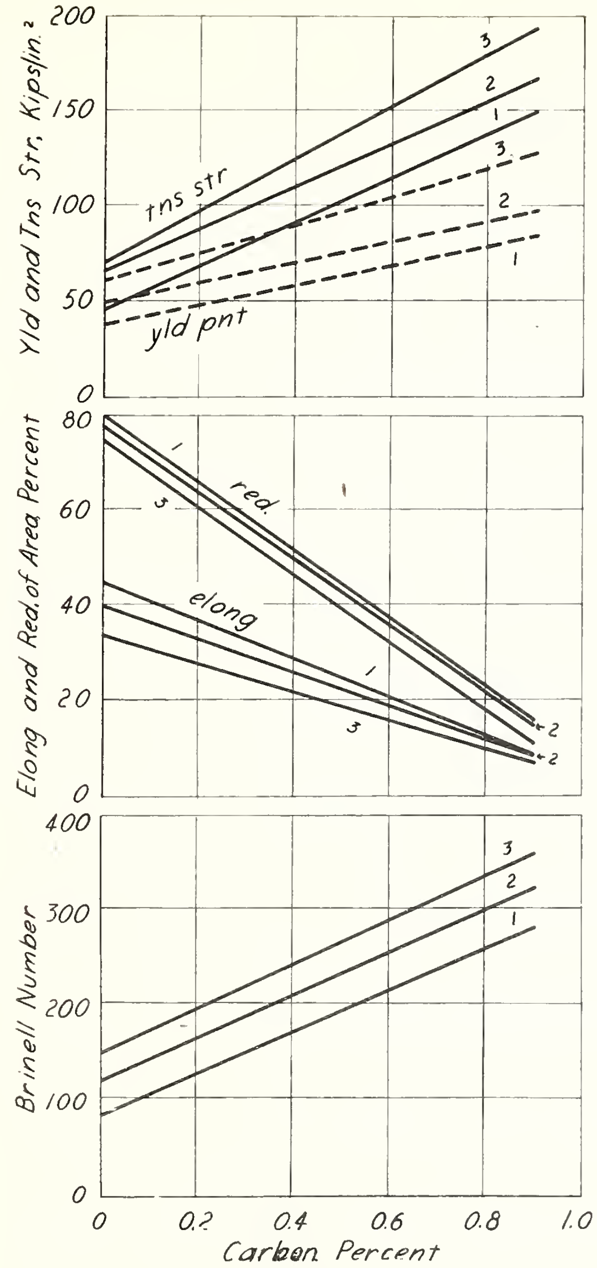


FIGURE 101.—*Tensile properties and hardness of normalized copper steels (Lorig [670]).*

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

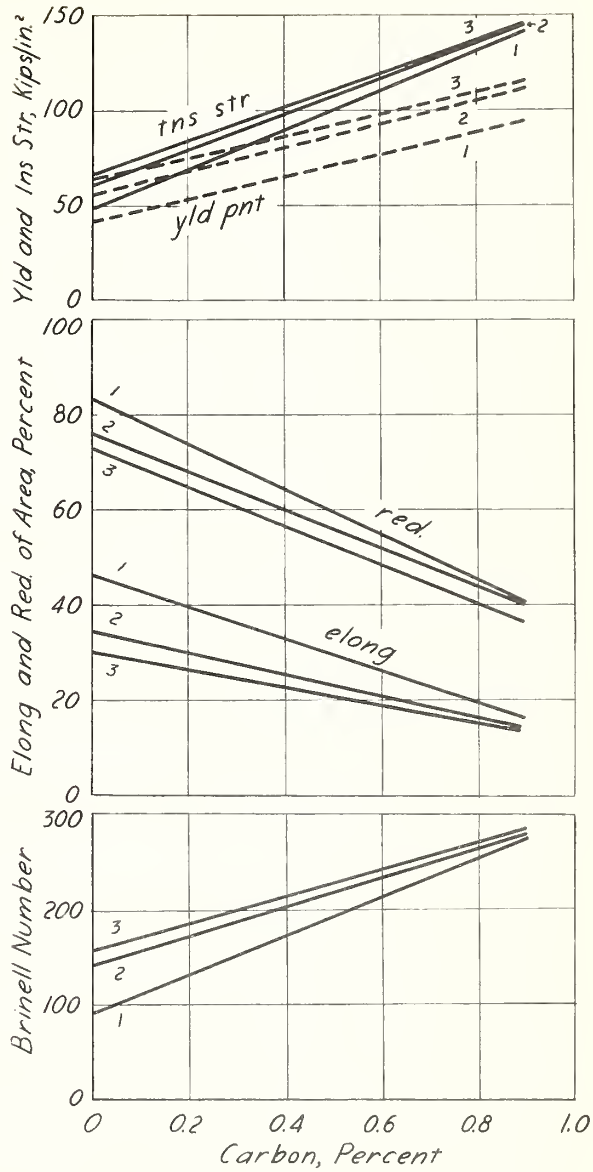


FIGURE 102.—*Tensile properties and hardness of quenched and tempered copper steels (Lorig [670]).*

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

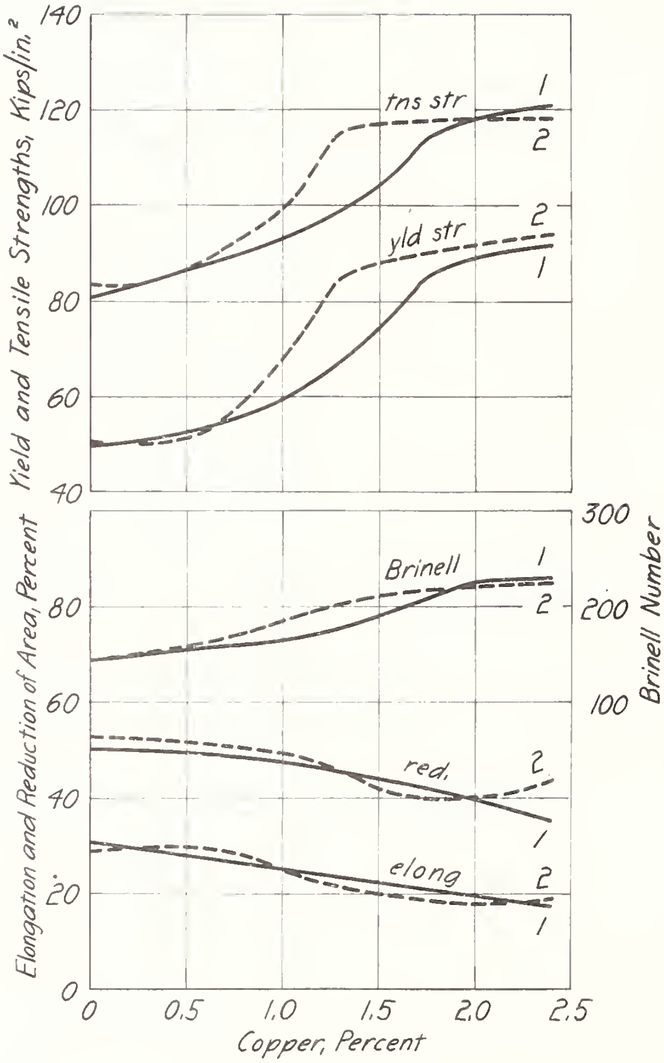


FIGURE 103.—*Tensile properties and hardness of cast copper steels (Greenidge and Lorig [671]).*

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.

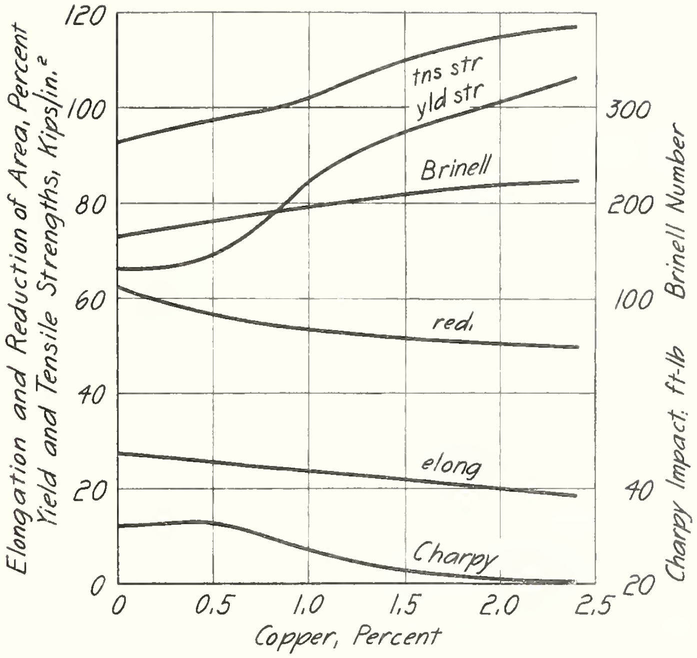


FIGURE 104.—*Tensile properties, impact value, and hardness of quenched and tempered cast copper steels (Greenidge and Lorig [671]).*

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.

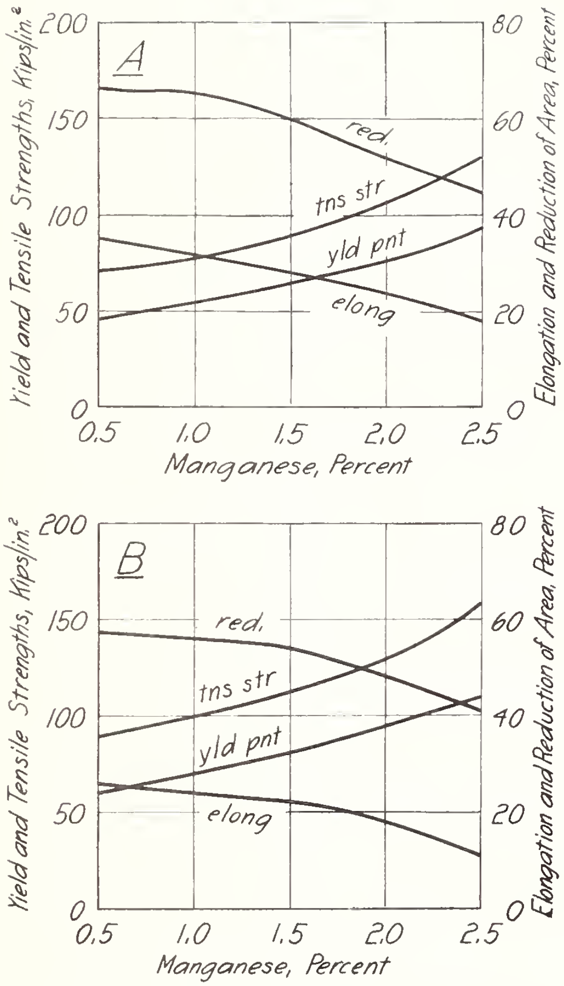


FIGURE 105.—*Tensile properties of normalized manganese steels (French [327]).*

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

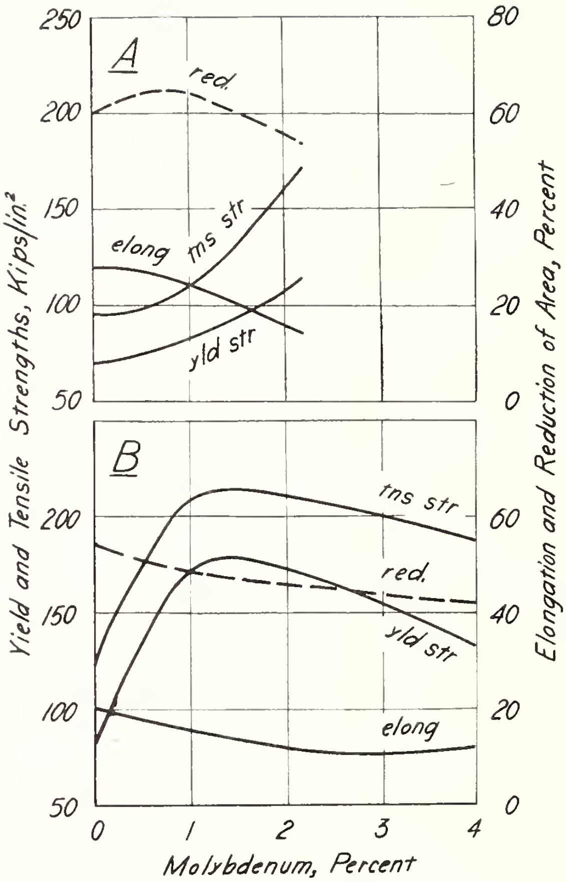


FIGURE 106.—*Tensile properties of quenched and tempered molybdenum steels (Gregg [286]).*

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

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

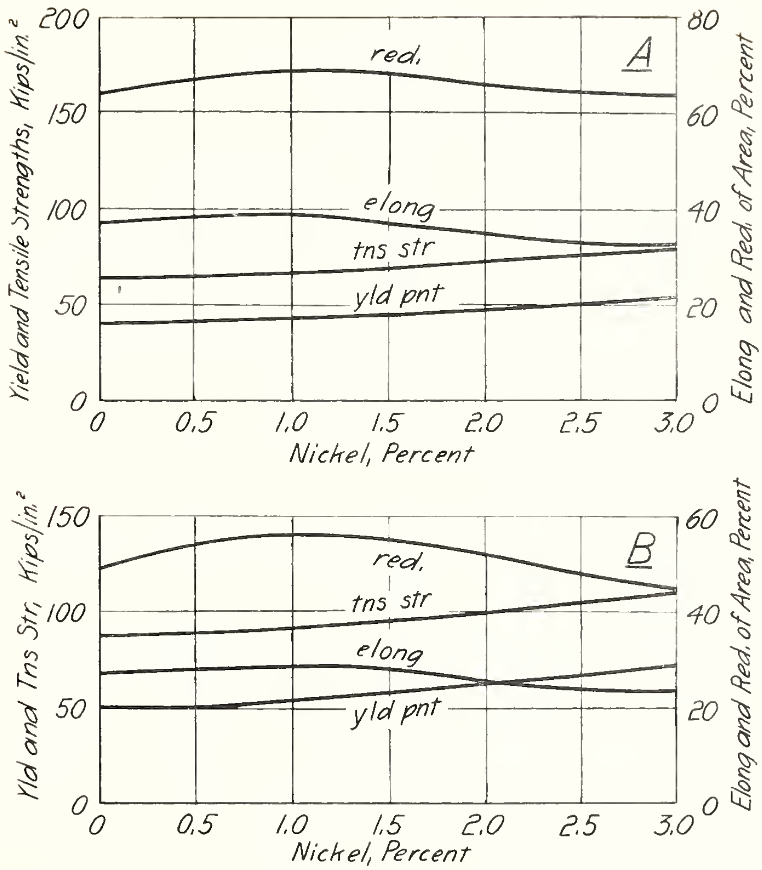


FIGURE 107.—*Tensile properties of normalized nickel steels (French [327]).*

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

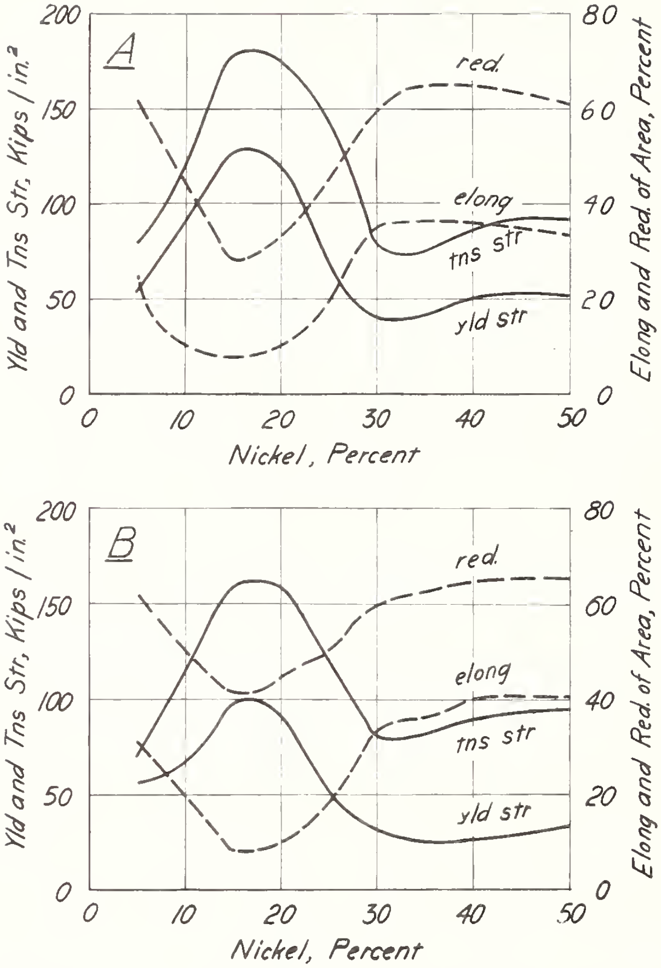


FIGURE 108.—*Tensile properties of iron-nickel alloys containing 0.2 percent carbon (Marsh [274]).*

A, Hot-rolled; B, annealed.

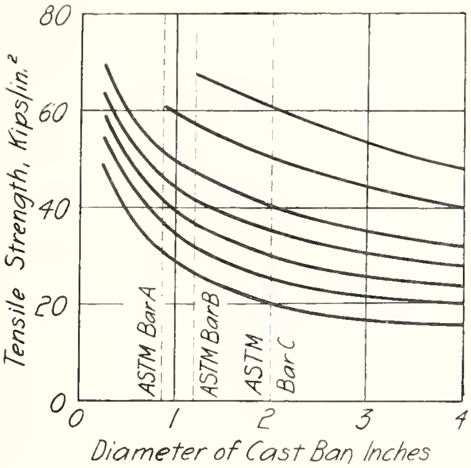


FIGURE 109.—*Effect of section thickness on the tensile strength of gray cast iron (Campbell [672]).*

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.

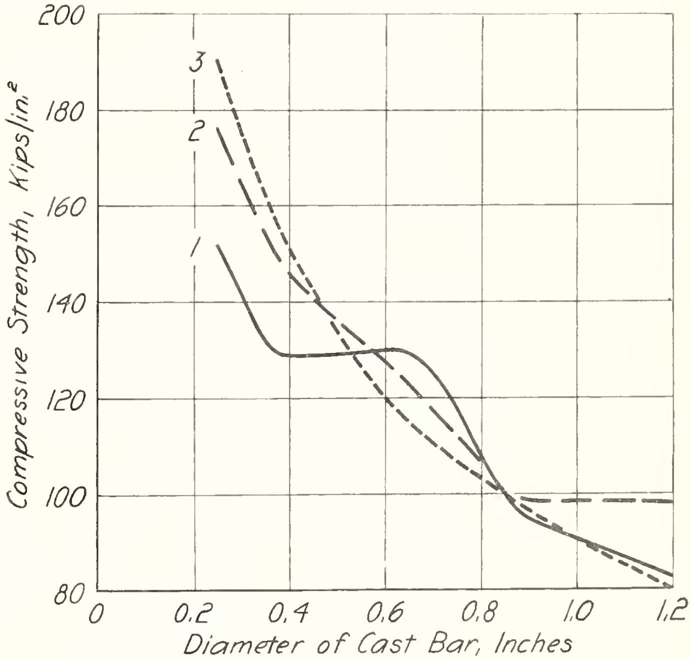


FIGURE 110.—*Effect of section thickness on the compressive strength of cast iron (Campbell [672]).*

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.

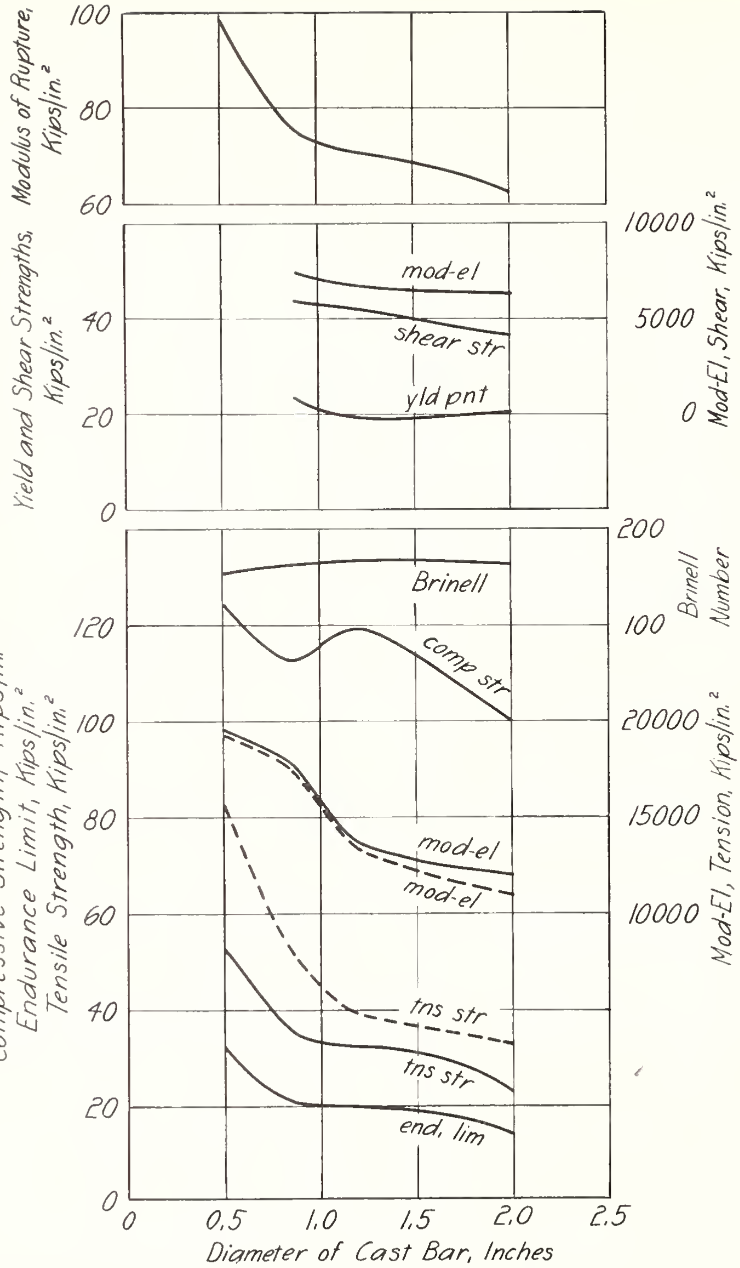


Figure 111.—*Effect of section thickness on the tensile, compressive, shear, and endurance properties of permanent mold gray cast iron (Schneidewind and Hoenicke [347]).*

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.)

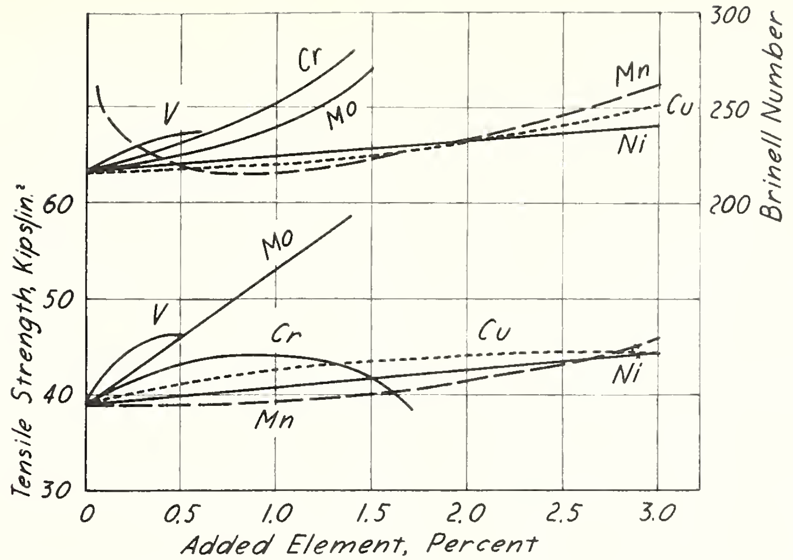


FIGURE 112.— *Effect of various elements on the tensile strength and hardness of an electrically melted cast iron [177].*

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%.

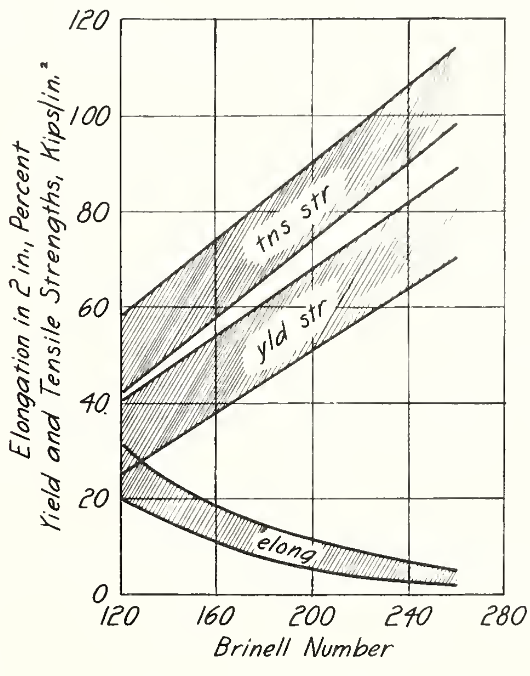


FIGURE 113.—*Relation between hardness and tensile properties for malleable cast iron [354].*

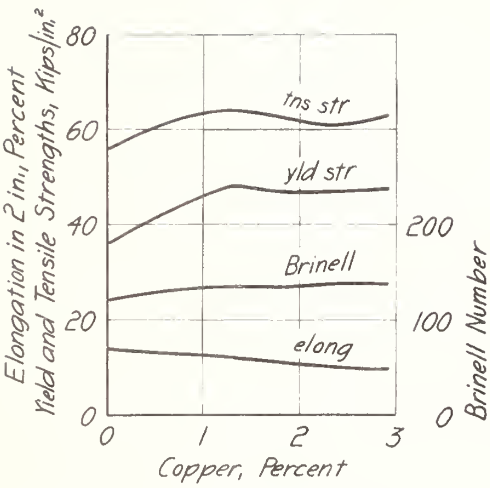


FIGURE 114.—*Effect of copper on the tensile properties and hardness of malleable cast iron (Lorig and Smith [358]).*

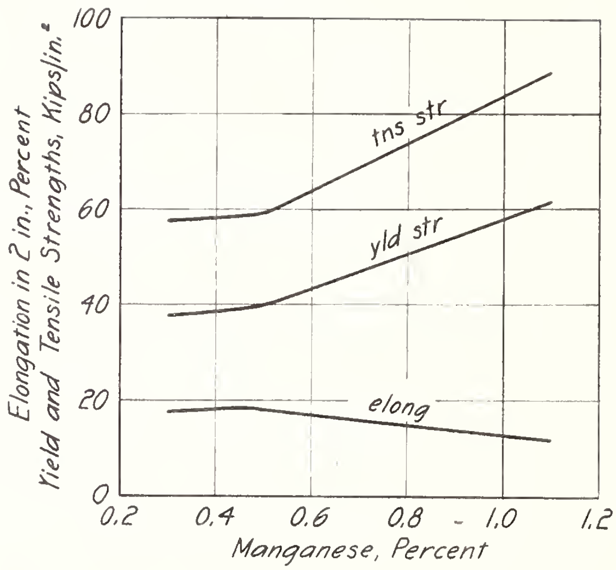


FIGURE 115.—*Effect of manganese on the tensile properties of malleable cast iron [354].*

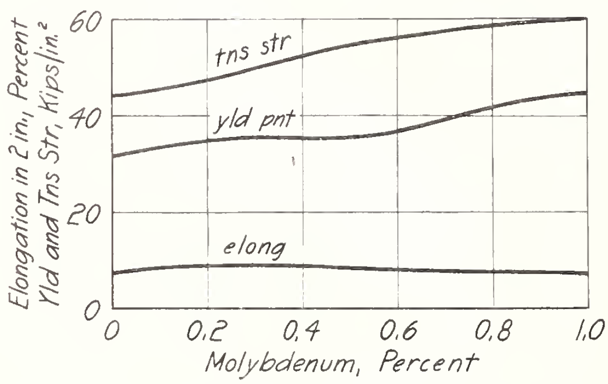


FIGURE 116.—*Effect of molybdenum on the tensile properties of malleable cast iron [286].*

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 (°F)			°C (°F)	
Hydrogen	1,300 (2,340) computed	0 to ?	Sulfur	25 (45)	0 to 0.08
Nitrogen	90 (162) computed	0 to 0.03	Arsenic	14 (25)	0 to 0.5
Oxygen	80 (144) computed	0 to 0.03	Tin	10 (18)	0 to 0.03
Carbon	Varies as follows:	0 to 3.8	Silicon	8 (14)	0 to 3
	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)	0 to 0.7	Tungsten	1 (1.8)	18% W with 0.66% C

[a]This 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 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	Short-time properties: "Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Impact value	Creep properties: Stress (kips/in.^{2}) for designated creep rate per 1,000 hours: 0.01%	0.1%	1.0%	Duration	Reference
			PURE AND INGOT IRONS (SEE ALSO FIGS. 117 AND 119)												
	Percent		°F	*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Percent*	*Percent*		*ft-lb*				*Hours*	
2208[a]..	Armco iron: C <0.02, Mn 0.043, S 0.03, P 0.013.	Wrought........................	59	26.9	30.1	47.5	41 (2 in.)	....	....	......	....	....	....	......	[359]
			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	26 (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	....	......	....	....	....	......	[360]
			1,472	....	....	4.6	54	58	....	......	....	....	....	......	
			CARBON STEELS (SEE ALSO FIGS. 119 AND 120)												
2210...	C 0.15, Mn 0.46, 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 5-6 (ASTM Std), normal.	85	15.9	34.1 (0.2% perm)	57.3	40 (2 in.)	68	111	42	....	....	....	......	[63]
			750	10.0	17.6 (0.2% perm)	51.5	41 (2 in.)	71	....	44	....	....	....	......	
			800	....	....	....	....	....	....	......	12.0	17.2	25.0	1,000	
			1,000	5.0	13.5 (0.2% perm)	30.5	53 (2 in.)	83	....	30	1.80	3.30	6.00	1,000	
			1,200	1.0	7.1 (0.2% perm)	16.3	71 (2 in.)	92	....	62	0.14	0.54	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)	62.4	36 (2 in.)	67	123	41	....	....	....	......	[63]
			750	13.1	24.6 (0.2% perm)	58.0	34 (2 in.)	67	....	36	....	....	....	......	
			800	....	....	....	....	....	....	......	18.5	26.8	38.5	1,000	
			900	11.2	23.5 (0.2% perm)	45.5	38 (2 in.)	71	....	29	12.8	16.9	22.1	1,000	
			1,000	8.8	20.1 (0.2% perm)	36.5	42 (2 in.)	77	....	30	2.70	5.75	12.1	1,000	
			1,100	5.0	14.2 (0.2% perm)	27.2	57 (2 in.)	82	....	39	0.85	1.80	3.85	1,000	
			1,200	1.9	10.2 (0.2% perm)	20.0	54 (2 in.)	89	....	59	.29	0.62	1.30	1,000	
			1,400	0	3.8 (0.2% perm)	9.0	70 (2 in.)	77	....	......	....	....	....	......	

2212...	C 0.15, Mn 0.55, S 0.026, P 0.018, Si 0.009 (basic open-hearth; rimmed steel).	Bar, 7/8 in. diam, wrought; ann 3/4 hr at 1,525°F, grain size 1 (ASTM Std).	Room	....	30.8 (yld pnt)	53.8	38 (2 in.)	62	103	......	....	....	....	......	63
			800	....	....	....	....	......	......	......	8.40	13.8	....	1,000	
			900	....	21.2 (yld pnt)	37.2	41 (2 in.)	76	......	......	5.55	8.20	....	1,000	
			1,000	....	....	....	....	......	......	......	1.45	3.05	....	1,000	
2213...	C 0.18, Mn 0.51, Si 0.09, S 0.029, P 0.02 (basic open-hearth; deoxidized with Si).	Bar, 7/8 in. diam, wrought; ann 3/4 hr at 1,525°F, grain size 1-50% and 4-50% (ASTM Std).	Room	....	35.8 (yld pnt)	59.1	38 (2 in.)	62	103	......	....	....	....	......	63
			800	....	....	....	....	......	......	......	13.2	19.5	....	1,000	
			900	....	20.0 (yld pnt)	37.8	42 (2 in.)	81	......	......	8.30	15.1	....	1,000	
			1,000	....	....	....	....	......	......	......	2.15	7.20	....	1,000	
2214...	C 0.23, Mn 0.70, Si 0.30, P 0.031, S 0.029.	Bar, 7 x 1 x 1 in., cast 4 coupons per block; ann 4 hr at 1,650°F.	70	26.2	42.8 (yld pnt)	75.6	36 (2 in.)	76	......	......	....	....	....	......	63
			750	....	....	....	....	......	......	......	10.0 (0.008%)	....	30.0 (1.35%)	500	
			800	19.2	28.0 (yld pnt)	59.8	32 (2 in.)	53	......	......	20.0 (0.03%)	....	....	2,500	
			1,000	13.5	21.5 (yld pnt)	38.4	37 (2 in.)	59	......	......	....	....	....	......	
2215...	C 0.27, Mn 0.63, Si 0.18, Cu 0.08, Ni 0.035, S 0.035, P 0.013, Mo 0.005 (basic open-hearth; deoxidized with Si and Al).	Tee, 6 in. forged; normalized 4 1/2 hr at 1,550°F.	Room	....	37.0 (yld pnt)	67.6	32 (2 in.)	52	131	26-36	....	....	....	......	63
			750	....	22.4 (0.2% perm)	62.9	38 (2 in.)	54	......	22	....	19.0	....	1,000	
			850	....	22.8 (0.2% perm)	53.5	34 (2 in.)	63	......	18	....	12.0	....	1,000	
			950	....	20.7 (0.2% perm)	42.8	40 (2 in.)	65	......	15	....	5.0	....	1,000	
2216[b]..	C 0.35, Mn 0.55, Si 0.19, S 0.030, P 0.016 (basic open-hearth; deoxidized with Si and Al).	Bar, 1 in. diam, wrought; heated to 1,550°F in 2 hr, f-c to 1,000°F, a-c; reheated to 1,280°F in 4 hr, f-c to 1,000°F, a-c; straightened; heated to 950°F, a-c; heated to 950°F, a-c; grain size 6-8 (ASTM Std).	Room	21.5-24.0	....	68-70	35-39 (2 in.)	62-66	128-131	......	....	....	....	......	361
			850	5.0-18.5	18.0-23.0 (0.2% perm)	40.2-49.4	33-59 (2 in.)	78-84	......	......	....	7.5 (0.07-0.125%)	....	1,000	
2217...[a]	C 0.40, Mn 0.70, Si 0.32, P 0.022, S 0.015.	Bar, 7 in. x 1 in. x 1 in., cast 4 coupons per block; ann 4 hr at 1,650°F.	70	30.0	37.8 (yld pnt)	81.1	24 (2 in.)	35	163	......	....	....	....	......	63
			550	....	....	....	....	......	......	......	10.0 (0.02%)	....	....	500	
			600	17.9	28.3 (yld pnt)	79.2	20 (2 in.)	25	......	......	....	....	....	......	
			750	....	....	....	....	......	......	......	10.0 (0.022%)	....	....	750	
			850	12.0	26.8 (yld pnt)	62.8	31 (2 in.)	57	......	......	....	....	....	......	
			900	....	....	....	....	......	......	......	3.8 (0.03%)	5.0 (0.05%)	....	500	
			1,000	....	....	....	....	......	......	......	....	4.0 (0.14%)	....	9,000	
			1,070	6.0	16.0 (yld pnt)	36.3	34 (2 in.)	57	......	......	....	....	....	......	
2218...	C 0.43, Mn 0.68, Si 0.20, P 0.035, S 0.033 (basic open-hearth; deoxidized with Si and Al).	Bar, 1 in. diam, wrought; ann 1 hr at 1,550°F, grain size 4-5 (ASTM Std), normal.	85	32.5	44.6 (0.2% perm)	88.8	26 (2 in.)	42	167	17	....	....	....	......	63
			750	15.6	30.8 (0.2% perm)	77.4	32 (2 in.)	60	......	22	....	....	....	......	
			800	....	....	....	....	......	......	......	13.0	18.5	27.0	1,000	
			1,000	6.0	21.6 (0.2% perm)	48.4	35 (2 in.)	54	......	12	2.80	5.55	9.30	1,000	
			1,200	4.0	11.4 (0.2% perm)	25.4	48 (2 in.)	65	......	34	0.14	0.86	2.65	1,000	

[a]Modulus of elasticity: 57°F, 28,900 Kips/in.^{2}; 302°F, 27,100 Kips/in.^{2}; 392°F, 25,500 Kips/in.^{2}
[b]Cooperative test on carbon steel K-20. Values are the overall ranges reported by the group of cooperating laboratories.

TABLE 22.—*Iron and steel, high-temperature properties*—Continued

Serial number	Composition	Condition	Temperature	Short-time properties: "Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Impact value	Creep properties: Stress (kips/in.^{2}) for designated creep rate per 1,000 hours: 0.01%	0.1%	1.0%	Duration	Reference
			CARBON STEELS—Continued												
	Percent		°F	*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Percent*	*Percent*		*ft-lb*	0.01%	0.1%	1.0%	*Hours*	
2219...	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.	61	39.9	50.4 (yld pnt)	93.7	33 ($4\sqrt{area}$)	43	....	Iz 10	....	....	....	......	[63]
			752	17.2	....	82.7	33 ($4\sqrt{area}$)	60	....	Iz 34	....	....	....	......	
			842	....	....	72.6	32 ($4\sqrt{area}$)	62	....	......	....	21.0	....	1,000	
			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.	70	100	124 (yld pnt)	138	19 (2 in.)	54	286	......	....	....	....	......	[63]
			800	40.0	87.0 (yld pnt)	104	21 (2 in.)	74	....	......	30.0 (0.039%)	....	....	750	
			900	....	....	....	....	....	....	......	....	30.0 (0.084%)	....	500	
			1,000	30.0	64.0 (yld pnt)	88.4	25 (2 in.)	84	....	......	10.0 (0.027%)	....	....	750	
			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.	70	76.5	79.0 (yld pnt)	101	27 (2 in.)	70	198	......	....	....	....	......	[63]
			550	50.0	66.0 (yld pnt)	108	27 (2 in.)	68	....	......	40.0	....	....	500	
			800	43.0	56.5 (yld pnt)	79.0	30 (2 in.)	81	....	......	10.0 (0.032%)	33.0	....	500	
			1,200	4.5	15.5 (yld pnt)	35.6	36 (2 in.)	94	....	......	....	4.2	25.0	500	
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.	70	104	110 (yld pnt)	131	19 (2 in.)	64	270	......	....	....	....	......	[63]
			800	54.1	71.1 (yld pnt)	102	24 (2 in.)	80	....	......	....	10.0 (0.054%)	....	1,000	
			1,000	10.0	36.0 (yld pnt)	78.0	28 (2 in.)	86	....	......	....	3.0 (0.11%)	....	1,000	
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.	70	128	147 (yld pnt)	158	19 (2 in.)	58	316	......	....	....	....	......	[63]
			800	55.7	103 (yld pnt)	118	21 (2 in.)	76	....	......	10.0 (0.014%)	28.5	....	1,000	
			1,000	13.9	47.8 (yld pnt)	93.7	25 (2 in.)	87	....	......	3.0 (0.04%)	....	....	1,000	
			1,200	2.0	11.0 (yld pnt)	41.8	39 (2 in.)	93	....	......	....	....	....	......	
2224...	C 0.35, Cr 1.13, Mn 1.01, Si 0.76, Mo 0.58, Ni 0.16.	Cast and ann.................	900	....	....	....	....	....	....	......	16.8	35.0	....	1,000	[63]
			1,000	....	....	....	....	....	....	......	2.50	5.30	....	1,000	

2225...	C 0.48, Cr 1.20, Si 0.62, Mo 0.52, Mn 0.49, P 0.016, S 0.015 (basic electric furnace; deoxidized with Si and Al).	Bar, 1 in. diam, wrought; normalized 1 hr at 1,725°F, tempered at 1,180°F, grain size 5 (ASTM Std), normal.	85	80.0	108 (0.2% perm)	146	17 (2 in.)	42	285	15	....	....	....	......	[63]
			750	68.8	97.0 (0.2% perm)	130	20 (2 in.)	59	....	32	....	....	....	......	
			800	....	....	....	....	....	....	......	47.0	92.0	....	500	
			1,000	50.0	80.2 (0.2% perm)	100	22 (2 in.)	74	....	22	7.80	23.0	68.0	500	
			1,200	6.0	31.8 (0.2% perm)	62.8	29 (2 in.)	88	....	63	0.22	0.90	3.90	500	
2226...	C 0.07, Cr 1.25, Si 0.72, Mo 0.54, Mn 0.42 (basic electric furnace; deoxidized with Si and Al).	Bar, 1 in. diam, wrought; ann 1 hr at 1,550°F, grain size 4-5 (ASTM Std), normal.	85	24.0	35.2 (0.2% perm)	66.5	36 (2 in.)	73	123	68	....	....	....	......	[63]
			800	....	....	....	....	....	....	......	20.0	29.0	42.5	500	
			1,000	15.0	24.9 (0.2% perm)	57.8	26 (2 in.)	73	....	35	....	....	....	......	
			1,020	....	....	....	....	....	....	......	13.0	22.0	37.8	1,000	
			1,100	13.5	23.1 (0.2% perm)	47.5	31 (2 in.)	83	....	38	4.30	6.80	10.8	1,000	
			1,200	3.5	16.0 (0.2% perm)	33.3	36 (2 in.)	88	....	60	1.08	2.40	4.60	1,000	
2227...	C 0.45, Cr 1.40, W 0.98, Si 0.77, Mn 0.47, V 0.25, S 0.015, P 0.014 (basic electric furnace; deoxidized with Si and Al).	Bar, 7/8 in. diam, wrought; normalized 1 hr at 1,725°F, tempered at 1,300°F, grain size 8 (ASTM Std), normal.	85	110	128 (0.2% perm)	140	20 (2 in.)	55	285	29	....	....	....	......	[63]
			750	62.5	90.5 (0.2% perm)	119	21 (2 in.)	60	....	48	....	....	....	......	
			800	....	....	....	....	....	....	......	48.0	68.0	96.0	500	
			1,000	35.0	71.1 (0.2% perm)	91.0	22 (2 in.)	74	....	25	13.8	24.0	42.5	500	
			1,200	2.0	19.3 (0.2% perm)	57.0	25 (2 in.)	86	....	45	0.54	1.20	2.65	500	
2228...	C 0.11, Cr 2.08, Mo 0.50, Mn 0.45, Si 0.42, S 0.015, P 0.012 (basic electric furnace; deoxidized with Si and Al).	Bar, 1 in. diam, wrought; ann 1 hr at 1,550°F, grain size 7-8 (ASTM Std).	85	26.2	40.6 (0.2% perm)	65.9	40 (2 in.)	74	131	62	....	....	....	......	[63]
			900	14.0	21.2 (0.2% perm)	53.8	34 (2 in.)	72	....	41	14.5	19.2	26.0	1,000	
			1,000	12.5	19.8 (0.2% perm)	46.5	36 (2 in.)	78	....	40	5.60	8.90	14.2	1,000	
			1,100	10.0	18.5 (0.2% perm)	38.2	46 (2 in.)	84	....	36	4.00	6.00	8.00	1,000	
			1,200	5.0	15.5 (0.2% perm)	28.6	60 (2 in.)	88	....	38	1.50	3.50	5.70	1,000	
2229...	C 0.48, Cr 2.99, Si 2.36, Mn 0.72, W 0.31, V 0.25, S 0.017, P 0.015.	Bar, 3/4 in. diam, wrought; normalized at 1,675°F, tempered at 1,225°F.	70	120	127 (yld pnt)	151	22 (2 in.)	55	302	......	....	....	....	......	[63]
			800	62.0	86.0 (yld pnt)	120	24 (2 in.)	64	....	......	....	30.0	....	250	
			900	....	....	....	....	....	....	......	10.0 (0.028%)	13.5	22.5	500	
			1,000	30.0	52.5 (yld pnt)	77.2	38 (2 in.)	84	....	......	....	10.0 (0.19%)	....	1,000	
2230...	C 0.10, Cr 4.83, Si 1.55, Mo 0.51, Mn 0.38, S 0.016, P 0.009 (basic electric furnace; deoxidized with Si and Al).	Bar, 1 in. diam, ann 1 hr at 1,550°F, grain size 4-5 (ASTM Std).	85	36.2	45.0 (0.2% perm)	82.1	39 (2 in.)	76	156	69	....	....	....	......	[63]
			1,000	15.0	25.6 (0.2% perm)	45.5	43 (2 in.)	84	....	59	5.45	8.70	12.1	1,000	
			1,100	8.0	20.2 (0.2% perm)	33.6	59 (2 in.)	90	....	56	2.60	4.80	6.95	1,000	
			1,200	5.5	15.0 (0.2% perm)	24.0	71 (2 in.)	94	....	51	1.60	2.90	4.20	1,000	
2231...	C 0.15, Cr 4.85, Mo 0.51, Mn 0.46, Si 0.17 (induction furnace).	Bar, 1 1/4 in. square, cast; ann 1 1/2 hr at 1,600°F, grain size 5 (ASTM Std).	Room	....	31.5 (yld pnt)	72.7	35 (2 in.)	68	146	......	....	....	....	......	[63]
			800	....	....	....	....	....	....	......	16.5	25.0	....	1,000	
			900	....	28.5 (yld pnt)	57.0	25 (2 in.)	62	....	......	10.2	15.0	....	1,000	
			1,000	....	....	....	....	....	....	......	8.0 (0.02%)	....	....	1,000	
			1,100	....	....	....	....	....	....	......	....	6.3 (0.18%)	....	1,000	

TABLE [illegible].—*Iron and steel, high-temperature properties*—Continued

Serial number	Composition	Condition	Temperature	"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: 0.01%	0.1%	1.0%	Duration	Reference
	CHROMIUM STEELS—Continued														
	Percent		°F	*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Percent*	*Percent*		*ft-lb*				*Hours*	
2232...	C 0.09, Cr 5.00, Cb 0.59, Mo 0.55, Mn 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	...	...	...	...	...	169	49	...	...	...	...	[362]
			1,900	...	...	...	...	...	...	...	...	16.4	...	2,000	
2233...	C 0.24, Cr 5.06, Mo 0.53, Mn 0.35, Si 0.27, S 0.025, P 0.012.	Bar, 1 in. diam, wrought; o-q from 1,650°F, tempered 4 3/4 hr at 1,100°F.	70	87.0	111 (yld pnt)	140	19 (2 in.)	68	300	...	...	...	...	...	[63]
			800	83.0	98.0 (yld pnt)	114	18 (2 in.)	67	...	...	30.0 (0.03%)	...	...	1,000	
			1,000	33.0	65.5 (yld pnt)	95.1	24 (2 in.)	79	...	...	...	10.0 (0.13%)	...	1,000	
			1,200	11.6	28.8 (yld pnt)	56.0	29 (2 in.)	89	...	...	...	3.0 (0.056%)	...	1,000	
2234...	C 0.10, Cr 5.09, Mo 0.55, Mn 0.45, Si 0.18, P 0.017, S 0.017 (deoxidized with Si and Al).	Bar, 1 in. diam, wrought; ann 1 hr at 1,550°F, grain size 4-5 (ASTM Std).	85	19.0	26.2 (0.2% perm)	66.6	39 (2 in.)	80	128	81	...	...	...	...	[63]
			900	11.5	19.6 (0.2% perm)	48.4	28 (2 in.)	77	...	64	11.5	15.2	20.5	1,000	
			1,000	7.5	17.3 (0.2% perm)	44.5	28 (2 in.)	74	...	59	7.60	10.1	12.8	1,000	
			1,100	6.0	15.4 (0.2% perm)	34.4	39 (2 in.)	87	...	54	3.20	5.85	...	1,000	
			1,200	1.5	11.3 (0.2% perm)	25.8	46 (2 in.)	91	...	54	1.70	2.80	4.45	1,000	
2235...	C 0.15, Cr 5.10, (electric furnace; deoxidized).	Bar, 1 in., wrought; ann at 1,600°F, tempered 168 hr at 1,200°F.	Room	...	27.8 (yld pnt)	63.8	38 (2 in.)	...	149	...	...	...	...	...	[63]
			1,000	...	...	...	...	...	...	...	3.7	6.60	8.60	500	
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	79.0	99.7 (yld pnt)	122	22 (2 in.)	66	241	...	...	...	...	...	[63]
			800	64.0	78.0 (yld pnt)	92.2	19 (2 in.)	68	...	...	...	30.0 (0.22%)	...	750	
			900	...	...	...	...	...	...	...	...	10.0 (0.052%)	...	500	
			1,000	23.0	50.0 (yld pnt)	70.1	30 (2 in.)	78	...	...	...	...	10.0 (3.6%)	750	
2237...	C 0.11, Cr 5.81, W 0.92, Mn 0.33, Si 0.20 (induction furnace).	Bar, 1 in. diam, wrought; ann at 1,600°F, f-c to 1,000°F, a-c, grain size 5 (ASTM Std).	Room	...	29.8 (yld pnt)	64.1	38 (2 in.)	71	116-123	...	...	...	...	...	[63]
			900	...	27.5 (yld pnt)	39.1	32 (2 in.)	69	...	...	7.00	9.80	...	1,000	
			1,000	...	...	...	...	...	...	...	4.65	6.60	...	1,000	
2238...	C 0.27, Cr 5.87, W 0.86, Si 0.53, Mn 0.45, S 0.035, P 0.026.	Cast; 5 hr at 1,800°F, a-c, tempered 5 hr at 1,250°F.	Room	...	91.1 (yld pnt)	117	19 (2 in.)	51	...	...	...	...	...	...	[63]
			900	...	...	...	...	...	...	...	12.0 (0.019%)	23.7	...	1,000	
			1,000	...	...	...	...	...	...	...	...	6.0 (0.052%)	...	1,000	
2239...	C 0.21, Cr 8.36, Mn 0.80, Ni 0.80, Si 0.52, Mo 0.47 (basic electric furnace).	Cast; normalized at 1,800°F, tempered at 1,270°F.	70	...	99.3 (yld pnt)	120	21 (2 in.)	49	R_B 100	...	...	...	...	...	[63]
			1,000	35.0	45.5 (yld pnt)	66.3	31 (2 in.)	76	...	...	...	10.0 (0.24%)	...	500	
			1,200	...	...	43.2	34 (2 in.)	88	...	...	3.0 (0.044%)	...	...	500	

2240...	C 0.08, Cr 12.00, W 3.01, Mn 0.57, Si 0.37, Ni 0.24, P 0.018, S 0.014.	Bar, 1 in. diam, wrought; a-c from 2,000°F.	70	44.0	97.2 (yld pnt)	163	14 (2 in.)	29	315	......	....	....	....	......	[63]
			800	38.0	70.0 (yld pnt)	165	18 (2 in.)	46	....	......	30.0 (0.017%)	....	....	250	
			1,000	20.0	60.0 (yld pnt)	147	18 (2 in.)	51	....	......	....	....	30.0 (0.58%)	500	
			1,200	3.0	28.0 (yld pnt)	57.8	28 (2 in.)	82	....	......	....	3.0 (0.032%)	....	250	
2241...	C 0.12, Cr 12.23, Mn 0.56, Si 0.32, Ni 0.15, P 0.020, S 0.008.	Bar, 3/4 in. diam, rolled; normalized at 1,800°F, tempered at 1,100°F.	70	60.0	92.0 (yld pnt)	111	19 (2 in.)	57	225	......	....	....	....	......	[63]
			800	40.5	65.5 (yld pnt)	80.5	15 (2 in.)	62	....	......	30.0 (0.014%)	40.0 (0.25%)	....	1,000	
			1,000	14.0	42.5 (yld pnt)	65.7	22 (2 in.)	74	....	......	2.8 (0.02%)	7.8	....	1,000	
			1,200	4.0	15.5 (yld pnt)	35.3	32 (2 in.)	88	....	......	3.0 (0.021%)	....	....	750	
2242...	C 0.12, Cr 12.45, Mn 0.42, Si 0.15, Ni 0.10, S 0.026, P 0.01 (basic electric furnace).	Bar, 1 in. diam, hot-rolled; 1/2 hr at 1,750°F, quenched, tempered 2 hr at 1,150°F.	78	64.0	90.0 (0.2% perm)	105	24 (2 in.)	71	223	lz 87	....	....	....	......	[63]
			850	29.3	69.4 (0.2% perm)	78.4	19 (2 in.)	70	....	......	15.0	29.0	39.0	1,000	
2243...	C 0.19, Cr 15.22, Ni 9.13, Mo 2.60, Mn 0.53, Si 0.26.	Bar, 3/4 in. diam, wrought; ann.	70	35.5	45.5 (yld pnt)	97.4	56 (2 in.)	74	173	......	....	....	....	......	[63]
			1,400	12.5	23.0 (yld pnt)	45.1	16 (2 in.)	25	....	......	10.0 (0.032%)	....	....	250	
			1,500	8.5	19.0 (yld pnt)	28.7	10 (2 in.)	16	....	......	10.0 (0.04%)	....	....	250	
2244...	C 0.06, Cr 17.75, Ni 9.25, Si 0.61, Mn 0.50, P 0.008, S 0.008 (basic electric furnace; deoxidized with Si).	Bar, 1 in. diam, wrought; 1 hr at 2,000°F, w-q.	85	12.5	27.9 (0.2% perm)	85.2	62 (2 in.)	74	137	74	....	....	....	......	[63]
			1,000	7.5	14.5 (0.2% perm)	53.8	44 (2 in.)	70	....	49	10.8	18.0	....	1,000	
			1,100	7.5	12.4 (0.2% perm)	48.8	39 (2 in.)	58	....	55	7.95	13.2	....	1,200	
			1,200	5.2	11.1 (0.2% perm)	43.1	37 (2 in.)	44	....	57	4.30	8.20	....	1,000	
			1,400	5.0	10.8 (0.2% perm)	27.8	31 (2 in.)	28	....	......	....	....	....	......	
			1,500	....	....	....	....	....	....	......	1.45	2.85	....	1,000	
2245...	C 0.10, Cr 18.08, Mn 0.44, Si 0.23.	Bar, 3/4 in. diam, wrought; normalized at 1,800°F.	70	20.5	39.5 (yld pnt)	72.4	36 (2 in.)	67	150	......	....	....	....	......	[63]
			1,000	12.1	23.9 (yld pnt)	41.7	32 (2 in.)	70	....	......	3.0 (0.038%)	....	....	1,000	
			1,200	....	12.0 (yld pnt)	23.9	50 (2 in.)	91	....	......	....	3.0 (0.2%)	....	1,000	
2246...	C 0.08, Cr 18.30, Ni 8.55, Si 0.46, Ti 0.42, Mn 0.37, P 0.020, S 0.014.	Bar, 3/4 in. diam, wrought; w-q from 1,800°F, reheated 2 hr at 1,500°F.	70	20.5	29.7 (yld pnt)	88.6	53 (2 in.)	75	140	......	....	....	....	......	[63]
			1,200	12.0	18.0 (yld pnt)	42.2	41 (2 in.)	74	....	......	....	....	....	......	
			1,300	....	....	....	....	....	....	......	10.0 (0.024%)	....	....	500	
			1,500	....	11.0 (yld pnt)	18.1	52 (2 in.)	89	....	......	....	30.0 (0.36%)	....	1,000	
2247...	C 0.15, Cr 18.32, Ni 9.82, W 3.09, Si 2.57, Mn 0.60.	Bar, 3/4 in. diam, rolled.....	70	35.0	57.0 (yld pnt)	116	51 (2 in.)	63	229	......	....	....	....	......	[63]
			1,200	19.0	30.5 (yld pnt)	68.2	28 (2 in.)	30	....	......	....	10.0 (0.12%)	....	500	
			1,400	....	21.5 (yld pnt)	43.1	39 (2 in.)	54	....	......	....	3.0 (0.2%)	....	500	
			1,600	....	12.0 (yld pnt)	25.8	48 (2 in.)	79	....	......	....	10.0 (0.28%)	....	250	

TABLE 22.—*Iron and steel, high-temperature properties*—Continued

Serial number	Composition	Condition	Temperature	Short-time properties: "Proportional limit"	Short-time properties: Yield strength	Short-time properties: Tensile strength	Short-time properties: Elongation	Short-time properties: Reduction of area	Short-time properties: Hardness number	Short-time properties: Impact value	Creep properties: Stress (kips/in.^{2}) for designated creep rate per 1,000 hours: 0.01%	0.1%	1.0%	Creep properties: Duration	Reference
					CHROMIUM STEELS—Continued										
	Percent		°F	*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Percent*	*Percent*		*ft-lb*	0.01%	0.1%	1.0%	*Hours*	
2248[c]..	C 0.12, Cr 18.50, Ni 9.67, Si 0.58, Mn 0.47, N_2 0.035 (induction furnace; deoxidized with Ca Si and Al).	Bar, 1 in. square, cast; w-q from 2,000°F.	Room	...	31.2 (yld pnt)	64.5	59 (2 in.)	...	132	Iz 93	...	...	...	...	[63]
			1,000	...	...	49.2	38 (2 in.)	40	...	...	19.5 (0.024%)	26.5	...	1,000	
			1,200	...	...	40.4	37 (2 in.)	50	...	...	8.2 (0.03%)	9.1	12.8	1,000	
2249...	C 0.10, Cr 18.72, Ni 10.00, Mn 0.48, Si 0.28 (basic electric furnace).	Cast; w-q from 1,900°F......	70	18.3	30.8 (yld pnt)	71.4	55 (2 in.)	62	128	...	...	...	...	...	[63]
			1,000	...	14.5 (yld pnt)	51.8	39 (2 in.)	48	...	...	...	20.0 (0.09%)	...	1,000	
			1,200	7.5	14.0 (yld pnt)	41.0	30 (2 in.)	42	...	...	3.0 (0.016%)	...	...	500	
			1,500	...	...	...	...	...	...	...	3.0	...	...	500	
			1,600	...	10.8 (yld pnt)	16.0	15 (2 in.)	39	...	...	...	3.0 (0.21%)	...	250	
2250...	C 0.14, Cr 19.73, Ni 9.43, Cu 1.24, Mo 0.90, Mn 0.32, Si 0.25.	Bar, 3/4 in. diam, wrought; w-q from 2,100°F.	70	27.0	34.5 (yld pnt)	85.8	54 (2 in.)	74	140	...	...	...	...	...	[63]
			1,200	10.0	15.0 (yld pnt)	54.3	33 (2 in.)	40	...	...	10.0 (0.011%)	...	...	250	
			1,400	9.0	15.0 (yld pnt)	30.6	17 (2 in.)	18	...	...	...	...	...	...	
			1,500	8.0	10.5 (yld pnt)	19.8	19 (2 in.)	27	...	...	...	...	30.0 (0.51%)	500	
2251...	C 0.17, Cr 22.93, Ni 12.69, Mn 2.04, Si 0.47.	...do......................	70	54.0	69.5 (yld pnt)	98.3	47 (2 in.)	60	197	...	...	...	...	...	[63]
			900	...	...	...	...	...	...	...	30.0 (0.041%)	...	...	1,000	
			1,000	30.0	42.0 (yld pnt)	72.2	34 (2 in.)	54	...	...	...	...	...	...	
			1,100	...	...	...	...	...	...	...	10.0	...	...	500	
			1,200	27.0	41.0 (yld pnt)	54.5	29 (2 in.)	42	...	...	...	...	...	...	
			1,400	22.0	32.5 (yld pnt)	43.2	30 (2 in.)	37	...	...	...	3.0 (0.086%)	...	500	
2252...	C 0.09, Cr 24.40, Ni 3.41, Mo 1.60.	Bar, 3/16 in. diam, wrought; 1/4 hr in hydrogen at 1,650°F, a-c.	1,112	...	...	...	...	...	...	...	...	2.0 (0.14%)	4.0 (1.8%)	250	[363]
			1,292	...	...	...	...	...	...	...	...	...	2.0 (3.5%)	250	
2253...	C 0.31, Cr 27.1, Ni 10.8, Mo 1.05, Si 0.55, Mn 0.48, N_2 0.16.	Cast......................	Room	...	...	92.5	22 (2 in.)	...	...	...	...	...	...	...	[364]
			1,800	...	...	...	...	...	...	...	...	0.83	...	<2,000	
					COPPER STEELS										
2254...	C 0.16, Cu 1.20, Mo 0.57, Mn 0.51, Si 0.18.	Bar, 5 1/2 x 19 x 1 1/4 in., wrought; normalized 1 hr at 1,650°F.	1,000	...	...	...	...	...	...	Iz 77	...	15.0 (0.23%)	...	1,000	[63]
2255...	...do..................	Bar, 5 1/2 x 19 x 1 1/4 in., wrought; normalized 1 hr at 1,650°F, tempered 10 hr at 1,112°F.	Room	...	...	...	...	...	181	...	...	...	...	...	[63]
			1,000	...	...	...	...	...	...	Iz 80	15.0 (0.027%)	...	...	1,000	

2256...	C 0.16, Cu 1.38, Mn 0.50, Si 0.16.	...do...	1,000	...	...	...	...	...	...	...	...	10.0	...	1,000	[63]
			1,200	...	...	...	...	...	...	...	...	1.58 (0.12%)	...	1,000	
							MANGANESE STEELS								
2257...	C 0.23, Mn 1.67, Si 0.12, P 0.032, S 0.028.	Bar, 1 in. diam, hot-rolled; normalized at 1,490°F.	65	37.6	57.2 (yld pnt)	88.7	34 (4√area)	68	175	...	...	...	...	...	[63]
			572	20.6	46.2 (0.2% perm)	97.5	30 (4√area)	51	...	...	61.0	81.0	...	500	
			752	13.0	44.8 (0.2% perm)	79.5	32 (4√area)	66	...	...	...	32.0	45.0	500	
			932	4.5	39.9 (0.2% perm)	61.6	28 (4√area)	64	...	...	...	11.5	16.8	500	
2258...	C 0.47, Mn 14.77, Si 0.41, P 0.040, S 0.004.	Bar, 1 in. diam, rolled...	70	25.5	40.5 (yld pnt)	111	20 (2 in.)	20	218	...	...	...	...	...	[63]
			800	18.5	24.0 (yld pnt)	64.4	60 (2 in.)	81	...	...	...	10.0 (0.59%)	...	500	
			900	...	...	...	...	...	...	...	...	10.0 (0.53%)	...	500	
			1,000	7.5	17.0 (yld pnt)	49.2	52 (2 in.)	74	...	...	...	...	...	...	
							MOLYBDENUM STEELS (SEE ALSO FIG. 125)								
2259...	C 0.15, Mo 0.25, Mn 1.25, Si 0.19, P 0.026, S 0.018 (basic open-hearth; deoxidized with Si and Al).	Bar, 1 in. diam, wrought; normalized at 1,725°F, tempered 1 hr at 1,200°F, grain size 4-5 (ASTM Std), normal.	85	45.0	51.2 (0.2% perm)	72.1	36 (2 in.)	72	140	60	...	...	...	...	[63]
			750	23.8	35.8 (0.2% perm)	74.5	26 (2 in.)	64	...	52	...	...	...	...	
			800	...	...	...	...	...	...	...	27.0	38.5	55.0	500	
			1,000	15.6	30.9 (0.2% perm)	52.2	32 (2 in.)	82	...	34	7.40	13.2	16.8	500	
			1,200	4.0	17.4 (0.2% perm)	29.9	53 (2 in.)	90	...	67	0.46	1.08	2.50	500	
2260...	C 0.30, Mo 0.31, Mn 1.38, Si 0.28, P 0.024, S 0.021.	Bar, 4 1/2 in. square, cast; ann 6 hr at 1,652°F; ann 4 hr at 1,562°F, tempered 4 hr at 1,292°F.	Room	51.0	51.4 (yld pnt)	89.0	22 (2 in.)	31	...	...	...	...	...	...	[63]
			850	...	...	...	...	...	...	...	14.0	...	...	23,000	
2261...	C 0.17, Mo 0.42, Mn 0.88, Si 0.20, Al 0.016, Al_2O_3 0.007 (open-hearth; deoxidized with Al).	Plate, 4 in., rolled; normalized 8 hr at 1,560°F, tempered 4 hr at 1,200°F, fine grain.	Room	39.0	...	68.1	36 (2 in.)	64	...	37	...	...	...	...	[365]
			900	...	...	...	...	...	...	28	20.0	27.0	...	1,500	
			1,000	...	...	...	...	...	...	15	7.2	20.0	...	1,500	
2262...	...do...	Plate, 4 in., rolled; normalized 8 hr at 1,750°F, tempered at 1,200°F, coarse grain.	Room	41.0	...	70.9	32 (2 in.)	63	...	24	...	...	...	...	[365]
			900	...	...	...	...	...	...	11	24.3	30.0	...	1,500	
			1,000	...	...	...	...	...	...	31	11.0	22.0	...	1,500	
2263...	C 0.34, Mo 0.50, Mn 0.52, Ni 0.16, Cr 0.05, P 0.036, Si 0.035, S 0.010 (basic electric furnace).	Bar, 7 x 1 1/2 x 7/8 in., cast; ann 4 hr at 1,650°F.	70	40.0	41.0 (yld pnt)	83.9	26 (2 in.)	38	151-165	12	...	...	...	...	[63]
			800	18.0	28.0 (yld pnt)	70.5	29 (2 in.)	41	...	...	...	30.0 (0.17%)	...	1,000	
			1,000	16.0	25.0 (yld pnt)	46.1	43 (2 in.)	71	...	...	2.6 (0.016%)	5.6	15.4	1,000	
			1,100	...	...	...	...	...	...	...	...	3.0 (0.18%)	...	1,000	
			1,200	8.0	13.0 (yld pnt)	23.1	48 (2 in.)	78	...	...	...	...	...	...	

[c] Endurance limit: room, 35.0 kips/in.^{2}; 1,200°F, 23.0 kips/in.^{2}

TABLE 22.—*Iron and steel, high-temperature properties*—Continued

Serial number	Composition	Condition	Temperature	Short-time properties: "Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Impact value	Creep properties: Stress (kips/in.²) for designated creep rate per 1,000 hours			Duration	Reference
					MOLYBDENUM STEELS—Continued										
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*		*ft-lb*	0.01%	0.1%	1.0%	*Hours*	
2264...	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; ann at 1,550°F, grain size 8 (ASTM Std).	85	34.0	36.0 (0.2% perm)	62.5	37 (2 in.)	65	121	40	...	...	...	...	[63]
			900	8.2	23.9 (0.2% perm)	50.5	27 (2 in.)	68	...	29	12.7	18.8	...	1,000	
			1,000	6.0	21.2 (0.2% perm)	42.5	32 (2 in.)	80	...	24	6.7	10.6	15.3 (0.55%)	1,000	
			1,100	2.0	16.2 (0.2% perm)	37.5	32 (2 in.)	73	...	43	1.8	4.1	7.1	1,000	
			1,200	0.5	13.0 (0.2% perm)	27.5	37 (2 in.)	72	...	64	0.92	2.2	3.8	1,000	
2265...	C 0.22, Mo 1.06, Mn 0.50, Si 0.13 (induction furnace).	Bar, 1 1/4 in. square, cast; ann 1 hr at 1,650°F, grain size 7 (ASTM Std).	Room	...	40.2 (yld pnt)	70.2	28 (2 in.)	50	146	...	...	...	...	...	[63]
			800	...	...	...	...	...	...	...	21.0	28.0	...	1,000	
			900	...	...	...	...	...	...	...	12.0	20.8	...	1,000	
			1,000	...	...	...	...	...	...	...	...	11.2	...	1,000	
2266...	...do...	Bar, 3/4 in. diam, wrought; ann 1 hr at 1,625°F, grain size 7 (ASTM Std).	Room	...	43.5 (yld pnt)	73.0	28 (2 in.)	55	137	...	...	...	...	...	[63]
			800	...	...	...	...	...	...	...	25.0	35.0	...	1,000	
			900	...	37.5 (yld pnt)	62.5	40 (2 in.)	68	...	...	11.8	27.5	...	1,000	
			1,000	...	...	...	...	...	...	...	5.65	11.8	...	1,000	
2267...	C 0.13, Mo 1.95, Mn 0.33, S 0.022, P 0.014, Si 0.01.	Bar, 1 in. diam, normalized 1/2 hr at 1,650°F, grain size 8-9 (ASTM Std).	Room	...	...	...	...	...	152	42	...	...	...	...	[362]
			1,000	...	...	...	...	...	...	...	...	18.8	...	3,000	
2268...	...do...	Bar, 1 in. diam, normalized 1/2 hr at 1,650°F, tempered 5 hr at 1,300°F, grain size 8-9 (ASTM Std).	Room	...	...	...	...	...	173	38	...	...	...	...	[362]
			1,000	...	...	...	...	...	...	...	...	15.9	...	3,000	
2269...	C 0.08, Mo 14.12, Mn 0.18, Si 0.05, P 0.030, S 0.005.	Cast and h-t...	1,000	...	...	...	...	...	...	...	11.0	...	...	1,000	[63]
			1,200	...	...	...	...	...	...	...	10.5	18.5	...	...	
					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; ann at 1,900°F, tempered 2 hr at 1,100°F.	Room	...	89.7 (yld pnt)	113	15 (2 in.)	34	...	...	...	...	...	...	[63]
			900	...	...	...	...	...	...	...	33.0 (0.04%)	...	...	1,000	
			1,000	...	...	...	...	...	...	...	7.2 (0.015%)	13.2	...	2,500	
2271...	C 0.36, Ni 1.19, Mn 0.58, Cr 0.51, Mo 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	78.5	84.9 (yld pnt)	109	25 (2 in.)	62	R_c 18	Iz 25	...	...	...	...	[63]
			850	...	...	...	...	...	...	...	21.0	40.0	...	500	
			1,000	...	...	...	...	...	...	...	6.4	12.3	24.3	1,000	
			1,100	...	...	...	...	...	...	...	1.66	3.60	7.70	1,000	
			1,200	...	...	...	...	...	...	...	...	1.60	3.10	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).	Bar, 3/4 in. diam, wrought; 1 hr at 1,550°F, o-q, tempered at 1,000°F, grain size 7-8 (ASTM Std), normal.	85	118	131 (0.2% perm)	141	19 (2 in.)	62	285	41	....	....	....	.....	[63]
			900	17.5	52.4 (0.2% perm)	89.0	22 (2 in.)	80	....	22	....	....	....	.....	
			1,000	5.5	25.5 (0.2% perm)	62.1	20 (2 in.)	82	....	23	0.19	1.02	5.20	500	
			1,200	1.0	7.5 (0.2% perm)	30.3	51 (2 in.)	81	....	74	....	....	....	.....	
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).	Bar, 1 in. diam, wrought; normalized 1 hr at 1,725°F, tempered 1 hr at 1,200°F, grain size 5 (ASTM Std), normal.	85	47.5	52.5 (0.2% perm)	72.4	38 (2 in.)	70	149	62	....	....	....	.....	[63]
			900	14.5	30.4 (0.2% perm)	52.0	26 (2 in.)	77	....	32	....	....	....	.....	
			1,000	8,0	25.5 (0.2% perm)	43.5	25 (2 in.)	82	....	25	4.6	7.7	13.0	500	
			1,200	4.2	12.0 (0.2% perm)	24.8	59 (2 in.)	80	....	70	....	....	....	.....	
2274...	C 0.40, Ni 2.03, Cr 0.82, Mn 0.57, Si 0.28, Mo 0.23, S 0.015, P 0.011.	Bar, 7 x 1 x 1 in., cast; normalized 4 hr at 1,650°F, tempered 4 hr at 1,276°F.	70	75.0	86.0 (yld pnt)	115	21 (2 in.)	47	....	......	....	....	....	.....	[63]
			550	61.0	75.0 (yld pnt)	110	18 (2 in.)	45	....	......	....	63.0	....	250	
			800	42.5	66.0 (yld pnt)	94.8	22 (2 in.)	58	....	......	20.0 (0.016%)	38.0	....	1,000	
			1,000	33.0	51.5 (yld pnt)	70.2	26 (2 in.)	74	....	......	3.00 (0.026%)	....	....	1,000	
2276...	C 0.41, Ni 2.10, Cr 0.86, Mn 0.74, Si 0.19.	Bar, 1 in. diam, hot-rolled; normalized 1 hr at 1,550°F, tempered 3 hr at 1,250°F.	Room	59.0	71.0 (yld pnt)	111	24 (2 in.)	55	R_c 16	64	....	....	....	.....	[63]
			1,000	....	....	....	....	......	....	......	2.20	3.60	5.80	1,000	
2276...	C 0.42, Ni 2.12, Cr 0.87, Mn 0.73, Mo 0.19, Si 0.18 (induction furnace).	Bar, 1 in. diam, hot-rolled; normalized 1 hr at 1,550°F, tempered 3 hr at 1,250°F.	Room	63.0	81.1 (yld pnt)	118	26 (2 in.)	63	R_c 18	54	....	....	....	.....	[63]
			850	....	....	....	....	......	....	......	10.6	18.0	....	1,000	
			1,000	....	....	....	....	......	....	......	3.60	6.60	12.3	1,000	
			1,100	....	....	....	....	......	....	......	1.80	4.80	....	1,000	
2277...	C 0.31, Ni 2.96, Cr 1.11, Mn 0.65, Mo 0.49, Si 0.26, Cu 0.06, P 0.013, S 0.004.	Bar, 1 in. diam, hot-rolled; hardened and tempered.	77	58.2	123 (yld pnt)	145	24 (4√area)	69	313	Iz 94	....	....	....	.....	[63]
			842	26.2	85.2 (0.2% perm)	111	26 (4√area)	64	....	Iz 71	18.0 (0.02%)	41	....	500	
			1,022	12.3	46.8 (0.2% perm)	81.3	33 (4√area)	87	....	Iz 56	....	3.4	9.2 (0.55%)	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).	Bar, 1 in. diam, wrought; normalized 1 hr at 1,550°F, tempered 3 hr at 1,250°F.	Room	39.8	74.8 (yld pnt)	130	20 (2 in.)	45	R_c 22	Iz 54	....	....	....	.....	[63]
			1,000	....	....	....	....	......	....	......	2.4	6.0	15.0	1,000	
2279...	C 0.42, Ni 3.41, Mn 0.66, Si 0.21, S 0.023, P 0.020.	Bar, 3/4 in. diam, wrought; ann at 1,550°F.	70	58.9	62.9 (yld pnt)	99.7	26 (2 in.)	46	195	......	....	....	....	.....	[63]
			800	20.0	38.8 (yld pnt)	78.2	30 (2 in.)	62	....	......	....	12.3	....	500	
			1,000	11.0	25.0 (yld pnt)	46.5	39 (2 in.)	78	....	......	....	....	10.0 (1.9%)	250	
2280...	C 0.33, Ni 3.43, Mn 0.63, Si 0.13, P 0.019, S 0.019.	Bar, 1 in. diam, hot-rolled; o-q from 1,560°F, tempered at 1,110°F.	61	51.1	83.6 (yld pnt)	107	28 (4√area)	64	215	......	....	....	....	.....	[63]
			572	31.8	....	109	32 (4√area)	47	....	Iz 100	65.0 (0.047%)	70.0	....	1,000	
			752	27.8	....	84.2	28 (4√area)	56	....	Iz 79	12.0 (0.027%)	22.0	....	1,000	
			932	10.3	....	56.7	34 (4√area)	69	....	Iz 45	....	5.0	9.0	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.	Bar, 1 in. diam, hot-rolled...	68	....	....	127	30 (4√area)	44	....	......	....	....	....	.....	[63]
			1,112	....	....	79.6	32 (4√area)	47	....	......	....	13.5	22.8	500	
			1,292	....	....	58.5	55 (4√area)	58	....	......	....	8.0 (0.42%)	10.5	500	
			1,472	....	....	38.1	58 (4√area)	64	....	......	....	2.2 (0.05%)	....	500	

TABLE 22.—*Iron and steel, high-temperature properties*—Continued

Serial number	Composition	Condition	Temperature	Short-time properties: "Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Impact value	Creep properties: Stress (kips/in.^{2}) for designated creep rate per 1,000 hours: 0.01%	0.1%	1.0%	Duration	Reference
			°F	*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Percent*	*Percent*		*ft-lb*				*Hours*	
	NICKEL STEELS—Continued														
2282...	*Percent* C 0.35, Ni 24.53, Cr 7.18, Si 1.65, Mn 0.68.	Bar, 1 in. diam, wrought; ann..	70	28.0	38.5 (yld pnt)	91.0	38 (2 in.)	58	...	...	...	...	...	...	[63]
			1,000	19.0	25.5 (yld pnt)	68.7	32 (2 in.)	58	...	...	...	...	...	...	
			1,200	19.0	23.5 (yld pnt)	52.8	42 (2 in.)	58	...	...	...	...	...	...	
			1,400	10.0	16.6 (yld pnt)	32.9	49 (2 in.)	53	...	...	...	2.0 (0.28%)	...	250	
			1,500	...	...	...	...	...	...	...	...	1.0 (0.22%)	...	750	
2283...	C 0.37, Ni 25.73, Cr 16.35, Si 2.55, Mn 0.93, S 0.040, P 0.014.	Bar, 1 in. diam, hot-rolled...	1,112	9.0	33.6 (0.2% perm)	73.7	30 (4√area)	28	...	...	...	11.0	17.0	500	[63]
			1,292	7.2	29.1 (0.2% perm)	56.0	28 (4√area)	33	...	...	3.9	5.2	7.1	500	
2284...	C 0.46, Ni 26.5, Cr 14.0, W 3.59, Si 1.20, Mn 1.09, S 0.028, P 0.026.	Bar, 2 in. square, forged.....	59	...	...	103	34 (4√area)	42	200	...	...	...	...	...	[63]
			1,292	...	...	55.1	21 (4√area)	30	...	...	...	...	15.5 (0.6%)	500	
			1,472	...	...	38.5	39 (4√area)	43	...	...	...	...	...	...	
	SILICON STEEL														
2285...	C 0.11, Si 1.35, Mo 0.50, Mn 0.19, S 0.012, P 0.010 (basic electric furnace; deoxidized with Si and Al).	Bar, 1 in. diam, wrought; ann 1 hr at 1,550°F, grain size 6-8 (ASTM Std), normal.	85	33.8	47.6 (0.2% perm)	71.8	35 (2 in.)	66	146	36	...	...	...	...	[63]
			750	16.2	25.4 (0.2% perm)	64.4	36 (2 in.)	70	...	42	...	...	...	...	
			800	...	...	...	...	...	...	...	18.0	29.0	48.5	1,000	
			1,000	11.2	23.4 (0.2% perm)	44.5	39 (2 in.)	79	...	28	5.00	9.20	17.0	1,000	
			1,200	4.0	11.8 (0.2% perm)	25.6	60 (2 in.)	81	...	38	0.72	1.85	3.25	1,000	
	TUNGSTEN STEELS														
2286...	C 0.45, W 2.04, Cr 1.29, Si 0.28, Mn 0.26.	Bar, 3/4 in. diam, wrought; ann at 1,500°F.	Room	...	...	...	...	...	176	...	...	...	...	...	[63]
			800	28.0	49.5 (yld pnt)	67.0	30 (2 in.)	68	...	...	...	...	...	...	
			1,000	16.0	31.0 (yld pnt)	54.8	28 (2 in.)	65	...	...	10.0 (0.017%)	15.0	...	500	
			1,200	14.0	22.0 (yld pnt)	35.3	41 (2 in.)	83	...	...	...	2.5	...	500	
2287...	C 0.44, W 3.12, Cr 1.47, Mn 0.32, V 0.25, P 0.042, S 0.010.	Bar, 1 in. octagon, wrought; o-q from 1,650°F, tempered at 1,250°F.	70	127	130 (yld pnt)	139	16 (2 in.)	45	300	...	...	...	...	...	[63]
			1,000	48.3	65.9 (yld pnt)	81.5	26 (2 in.)	72	...	...	...	...	30.0 (1.9%)	250	
			1,100	...	...	...	...	...	...	...	...	...	10.0 (3.8%)	250	
			1,200	13.0	25.0 (yld pnt)	53.7	44 (2 in.)	87	...	...	...	...	...	...	

2288...	C 0.67, W 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)	55.8	39 (4√area)	65	......	......	......	11.2 (0.23%)	......	500	[63]
			1,292	......	20.2 (0.2% perm)	35.4	60 (4√area)	78	......	......	......	......	......	......	
			1,472	......	......	18.8	75 (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	0.5 (4√area)	......	249	......	......	......	......	......	[63]
			700	......	......	35.2	0.5 (4√area)	......	......	......	15.5 (0.02%)	24.0	......	1,000	
			842	......	......	33.1	0.5-1.0 (4√area)	......	......	......	3.65 (0.015%)	8.00	14.5	1,000	
2290...	TC 3.19, CC 0.65, Si 2.13, P 0.80, Ni 0.67, Mn 0.58, Cr 0.34, S 0.09.	...do......................	60	......	......	35.8	0.5 (4√area)	......	......	......	......	......	......	......	[63]
			842	......	......	31.3	1.0-1.5 (4√area)	......	......	......	7.40 (0.046%)	9.60	16.7	1,000	
			1,000	......	......	21.1	1.0 (4√area)	......	......	......	......	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	0.5 (4√area)	......	205	......	......	......	......	......	[63]
			842	......	......	22.6	0.5 (4√area)	......	......	......	8.80 (0.045%)	13.8	......	1,000	
			1,000	......	......	21.5	0.5 (4√area)	......	......	......	3.60	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 0.039.	...do......................	62	......	......	25.1	1.5-2.5 (4√area)	......	134	......	......	......	......	......	[63]
			842	......	......	18.6	0.5-1.5 (4√area)	......	......	......	......	4.90	9.20	170	
			1,000	......	......	17.2	1.5 (4√area)	......	......	......	......	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	0.6 (4√area)	......	245	......	......	......	......	......	[63]
			700	......	......	30.6	0.5 (4√area)	......	......	......	22.5 (0.025%)	......	......	1,000	
			842	......	......	31.8	0.5-1.0 (4√area)	......	......	......	6.7 (0.017%)	......	......	1,000	
			1,000	......	......	19.7	0.5-1.0 (4√area)	......	......	......	2.25 (0.03%)	3.75	8.70	1,000	
						MALLEABLE CAST IRONS									
2294[d]..	TC 2.78, CC 0.005, Si 0.91, Mn 0.47, P 0.17, S 0.092.	Cast and malleablized.........	80	21.2	30.5 (0.2% perm)	41.5	9 (2 in.)	8	......	......	......	......	......	......	[366]
			600	18.0	25.5 (0.2% perm)	38.7	5.5 (2 in.)	5	......	......	21	28	......	2,000	
			800	14.4	23.0 (0.2% perm)	33.2	5.5 (2 in.)	5	......	......	8.3	12	16	2,000	
			1,000	9.3	14.5 (0.2% perm)	16.2	10 (2 in.)	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-q, tempered 2 hr at 1,325°F (pearlitic).	80	39.0	......	76.2	6.5 (2 in.)	......	......	7.8	......	......	......	......	[357]
			400	33.8	......	74.7	4.1 (2 in.)	......	......	8.2	......	......	......	......	
			800	20.0	......	65.8	6.7 (2 in.)	......	......	6.3	......	......	......	......	

[d] Modulus 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	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Impact value	Creep properties: Stress (kips/in.^{2}) for designated creep rate per 1,000 hours: 0.01%	0.1%	1.0%	Duration	Reference
							MALLEABLE CAST IRONS—Continued								
	Percent		°F	*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Percent*	*Percent*		*ft-lb*	0.01%	0.1%	1.0%	*Hours*	
2296...	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.	80	18.0	....	52.1	15 (2 in.)	....	....	11	....	....	....	......	[357]
			400	13.8	....	48.2	8.2 (2 in.)	....	....	10	....	....	....	......	
			800	11.7	....	44.5	10 (2 in.)	....	....	8.3	....	....	....	......	
2297...	TC 2.51, Si 1.40, 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).	80	....	....	77.8	3.5 (2 in.)	....	....	4.0	....	....	....	......	[357]
			400	40.0	....	77.8	1.4 (2 in.)	....	....	4.3	....	....	....	......	
			800	29.2	....	75.5	2.8 (2 in.)	....	....	3.3	....	....	....	......	
2298...	...do....................	Cast; 15 hr at 1,700°F, cooled to 1,325°F in 3 hr and held 20 hr.	80	....	....	54.5	15 (2 in.)	....	....	10	....	....	....	......	[357]
			400	17.5	....	52.9	3.0 (2 in.)	....	....	9.7	....	....	....	......	
			800	13.8	....	45.6	5.5 (2 in.)	....	....	7.0	....	....	....	......	

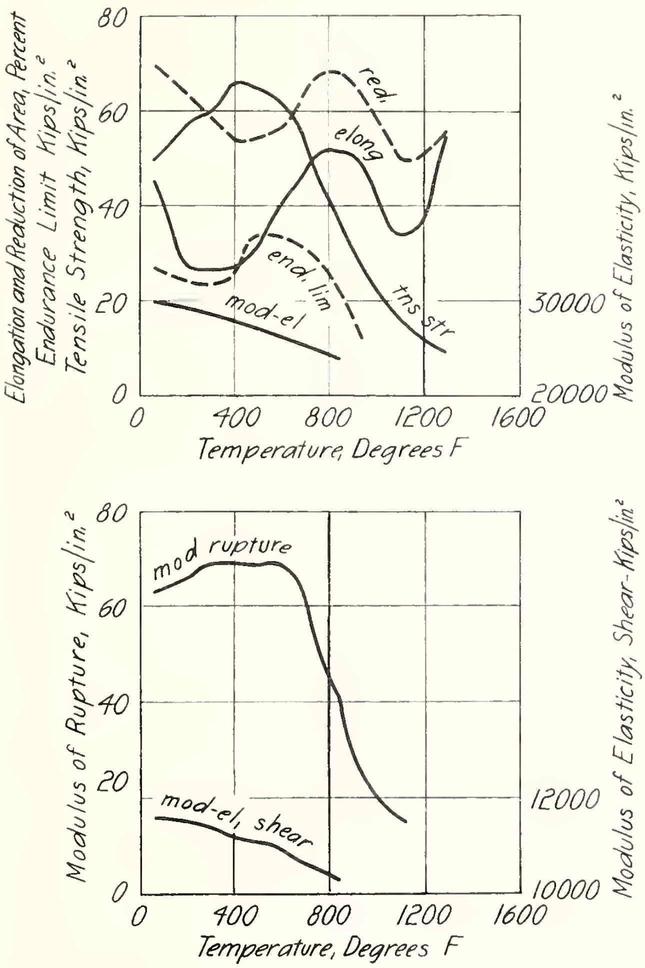


FIGURE 117.—*Tensile, shear, rupture, and endurance properties of ingot iron (Armco) at high temperatures (Kenyon [229]).*

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

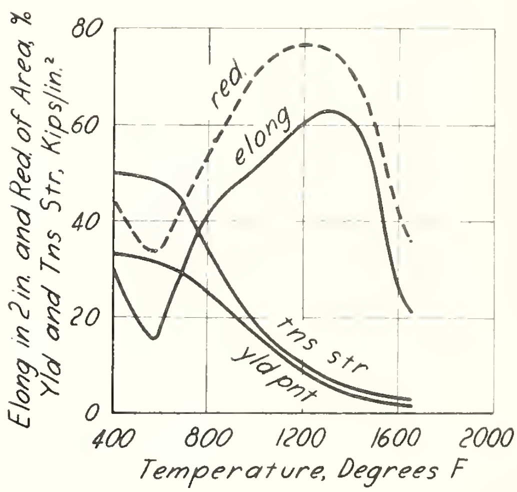


FIGURE 118.—*Short-time tensile properties of wrought iron at high temperatures (Green [674]).*

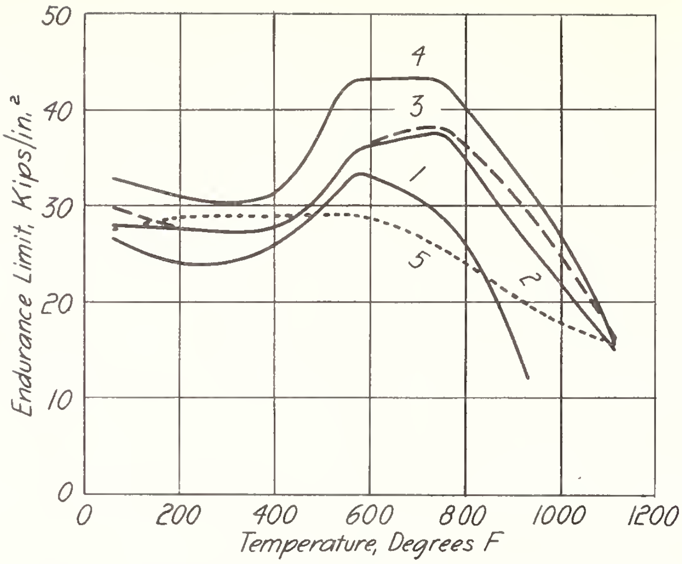


FIGURE 119.—*Endurance limit of iron-carbon alloys at high temperatures (Batson and Tapsell [675]).*

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.

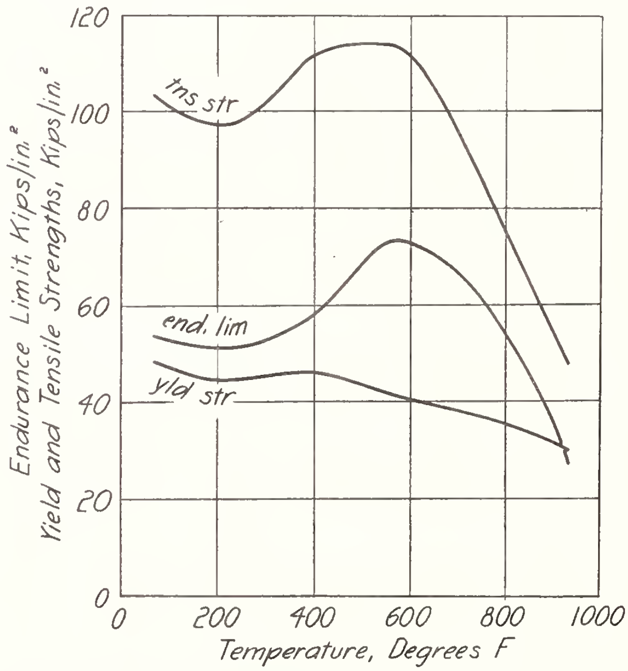


FIGURE 120.—*Short-time tensile properties and endurance limit of a carbon steel at high temperatures (Hempel and Tillmanns [676]).*

(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.

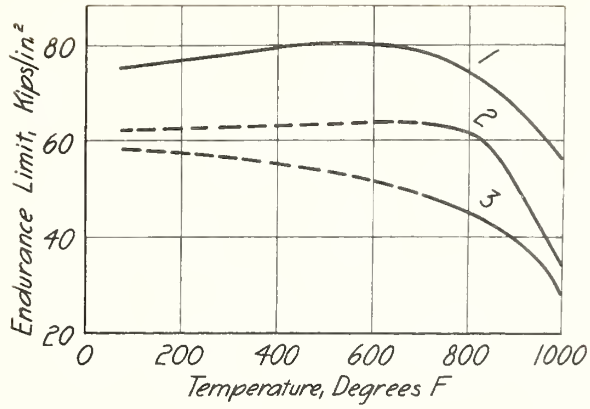


FIGURE 121.—*Endurance limit of alloy steels at high temperatures (Kinney [677]).*

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.)

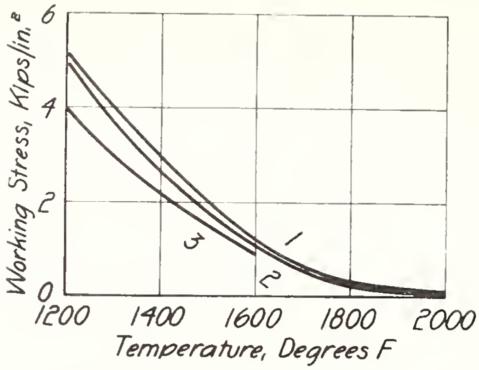


FIGURE 122.—*Design strengths for iron-chromium-nickel alloys at high temperatures (Corfield [678]).*

Curves: 1, Cr 24%, Ni 12%; 2, Cr 28%, Ni 10%; 3, Cr 18%, Ni 8%.

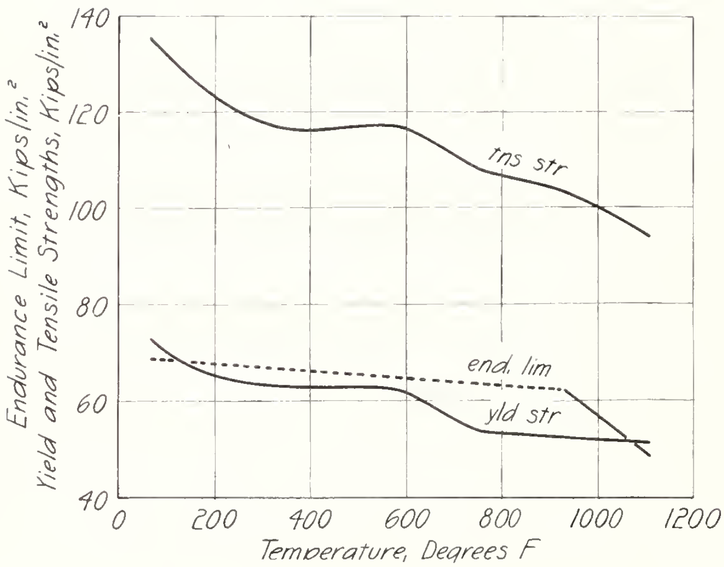


FIGURE 123.—*Short-time tensile properties and endurance limit of a chromium-nickel-tungsten steel at high temperatures (Hempel and Tillmanns [676]).*

(Yield strength, 0.2%; endurance limit at 2×10^6 cycles)

C 0.56%, Cr 15.5%, Ni 13.3%, W 2.02%, Si 1.58%, Mn 0.52%.

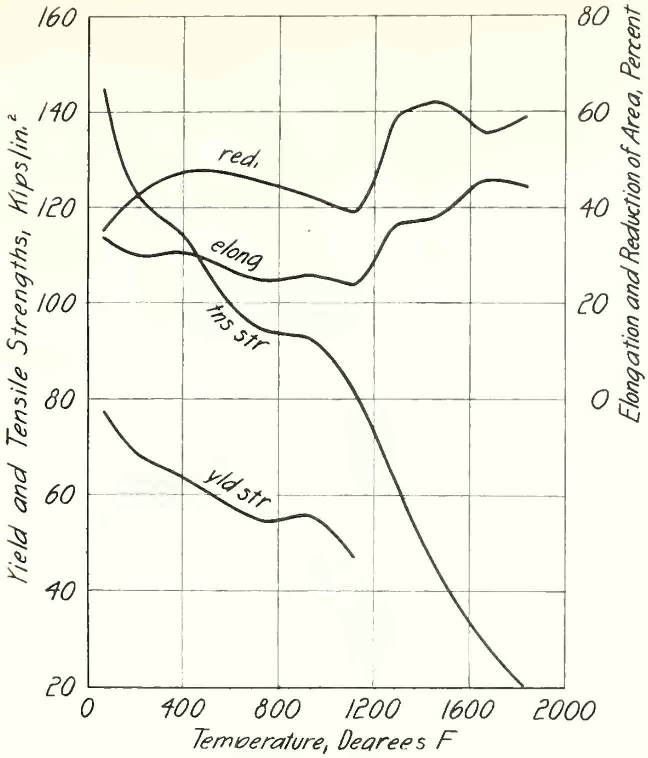


FIGURE 124.—*Short-time tensile properties of a chromium-nickel-tungsten steel at high temperatures (Hatfield [383]).*

(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.

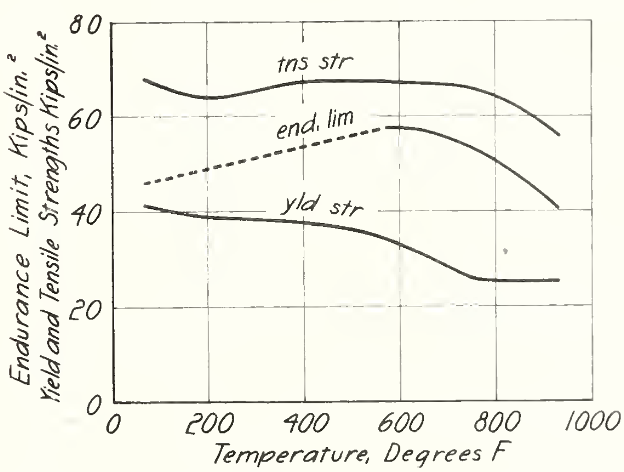


FIGURE 125.—*Short-time tensile properties and endurance limit of a molybdenum steel at high temperatures (Hempel and Tillmanns [676]).*

(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.

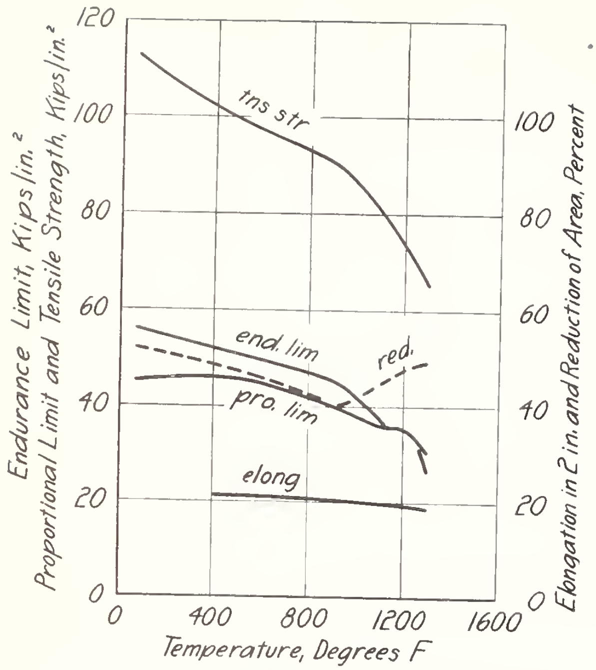


FIGURE 126.—*Short-time tensile properties and endurance limit of a nickel-chromium steel at high temperatures (Marsh [274]).*

C 0.33%, Ni 19.70%, Cr 8.31%, Si 1.16%, Mn 0.49%.

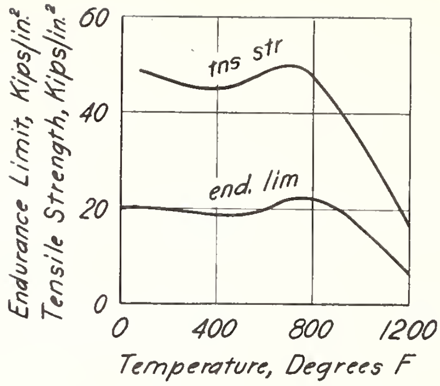


FIGURE 128.—*Tensile strength and endurance limit of a cast iron at high temperatures (Collins and Smith [679]).*

(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%.

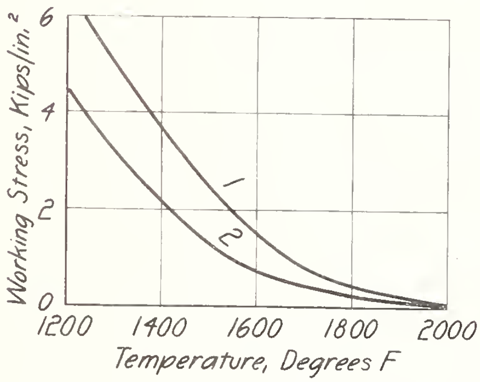


FIGURE 127.—*Design strengths for iron-nickel-chromium alloys at high temperatures (Corfield [678]).*

Curves: 1, Ni 35%, Cr 15%; 2, Ni 65%, Cr 15%.

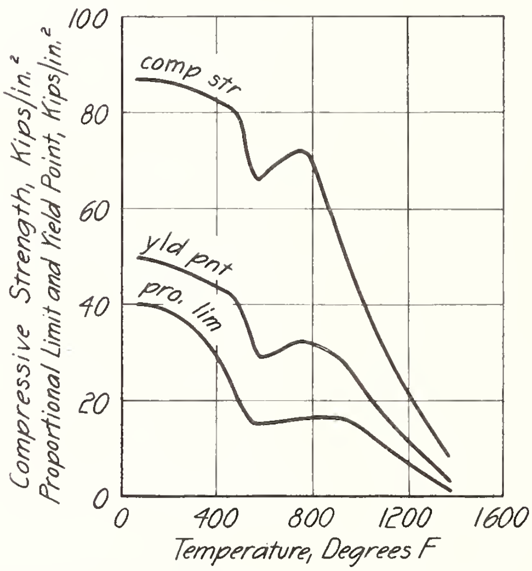


FIGURE 129.—*Compressive strength of a cast iron at high temperatures [177].*

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_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: Modulus of elasticity	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Hardness number	Impact value	Remarks	Reference
					PURE AND INGOT IRONS							
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*		*ft-lb*		
2299...	Fe 99.89, C 0.03, Mn 0.04, Si 0.01.	Forged...	Room	...	41.7 (yld pnt)	52.4	25 (10 diam)	81	104	...	...	[66]
			-423	...	...	117	0 (10 diam)	0	...	...		
2300...	Armco: C 0.035, Mn 0.02, S 0.016, P 0.003.	Bar, 1 in. diam...	Room	...	...	45.7	28 (2 in.)	73	...	Iz 78	Tensile specimen, 0.25 in. diam; Impact specimen, 10 × 10 mm with three 45° notches.	[367]
			-58	...	42.1 (yld pnt)	59.4	43 (2 in.)	74	...	...		
			-94	...	43.5 (yld pnt)	61.6	38 (2 in.)	72	...	[a] Iz 4		
			-148	...	57.1 (yld pnt)	66.8	26 (2 in.)	70	...	...		
			-184	...	66.8 (yld pnt)	77.1	17 (2 in.)	68	...	...		
			-292	...	...	112	0 (2 in.)	0	...	Iz 1.5		
					WROUGHT IRON							
2301...	C 0.009, P 0.24, Si 0.12, Mn 0.03, S 0.01.	Chain, 3/4 in...	Room	...	33.1	54.9	24 (1 in.)	16	...	65	Impact specimen, Charpy bar with Izod notch.	[368]
			32	...	...	...	...	...	...	28		
			-4	...	...	...	...	...	...	13		
			-58	...	...	...	...	...	...	5.3		
			-108	...	...	...	...	...	...	3.0		
					CARBON STEELS							
2302...	C 0.09, Mn 0.43, S 0.024, Ni 0.02, P 0.018.	Plate, 1 1/4 in., rolled...	Room	...	24.5	45.5	44	76	...	52	...	[25]
			-25	...	...	...	...	...	...	44		
			-50	...	...	...	...	...	...	1.5		
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.	Room	...	...	...	...	...	...	59	...	[25]
			-25	...	...	...	...	...	...	44		
			-50	...	...	...	...	...	...	6		
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.	Room	29,800	68.5	84.0	18	58	169	Iz 54	...	[25]
			-20	...	...	...	...	...	...	Iz 16		
			-40	29,800	76.5	96.5	20	56	...	Iz 12		
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.	Room	30,000	76.0	92.5	16	52	192	Iz 28	...	[25]
			-20	...	...	...	...	...	...	Iz 8.5		
			-40	30,000	82.5	100	14	52	...	Iz 6.5		
2306...	C 0.23, Mn 0.65, Si 0.35, P 0.020, S 0.015.	Cast; ann at 1,650°F, f-c..	Room	...	...	...	...	...	...	16	...	[25]
			-50	...	...	...	...	...	...	9.5		

[a] -101°F.

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TABLE 23.—*Iron and steel, low-temperature properties*—Continued

Serial number	Composition	Condition	Temperature	Tensile properties: Modulus of elasticity	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Hardness number	Impact value	Remarks	Reference
					CARBON STEELS—Continued							
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*		*ft-lb*		
2307...	C 0.23, Mn 0.65, 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	...	...	...	...	...	...	27	...	[25]
			-25	...	...	...	...	...	...	18		
			-50	...	...	...	...	...	...	16		
			-100	...	...	...	...	...	...	15		
			-150	...	...	...	...	...	...	5		
2308...	C 0.25, Mn 0.61, Si 0.05, P 0.040, S 0.034 (deoxidized with Si).	Bar, 1/2 in., cold-drawn...	Room	29,500	83.0	99.0	12	51	190	Iz 20	...	[25]
			-20	...	...	...	...	...	...	Iz 3.5		
			-40	29,600	89.5	110	14	49	...	Iz 2.5		
2309...	C 0.28, Mn 0.67, P <0.040, S 0.025.	Bar, 3/4 in. diam, cold-drawn.	Room	...	68.0 (0.1% offset)	89.0	16 (4 diam)	51	...	Iz 23	...	[31]
			-40	...	77.0 (0.1% offset)	102	16 (4 diam)	52	...	Iz 4		
2310...	C 0.44, Mn 0.70, Si 0.05..	Forged; a-c from 1,650°F...	Room	...	...	...	...	...	174	8.5	...	[25]
			-40	...	...	...	...	...	...	4.5		
			-94	...	...	...	...	...	...	4		
2311...	...do...	Forged: w-q from 1,525°F, tempered at 940°F.	Room	...	...	...	...	...	228	38	...	[25]
			-40	...	...	...	...	...	...	11		
			-94	...	...	...	...	...	...	7.5		
2312...	C 0.45, Mn 0.77, Si 0.21, S 0.022, P 0.013.	Cold-drawn...	Room	...	86.0	91.0	14 (2 in.)	50	R_c 12	6	Impact specimen, Charpy bar with Izod notch.	[369]
			-40	...	...	...	...	...	R_c 16	3		
			-108	...	92.0	106	16 (2 in.)	47	R_c 19	4		
2313...	...do...	Normalized 1 hr at 1,600°F..	Room	29,200	63.0	113	17 (2 in.)	49	R_c 16	15	...do...	[369]
			-40	...	...	...	...	...	R_c 20	9		
			-108	28,400	74.0	130	16 (2 in.)	44	R_c 22	8		
2314...	...do...	3/4 hr at 1,475°F, w-q, tempered 1 hr at 1,000°F.	Room	29,600	125	135	12 (2 in.)	54	R_c 27	51	...do...	[369]
			-40	...	...	...	...	...	R_c 29	26		
			-108	28,800	136	152	14 (2 in.)	52	R_c 29	17		
2315...	C 0.72, Mn 0.75, Si 0.15, P 0.030, S 0.023.	Rolled...	+80	...	...	...	...	...	...	...	Endurance limit 61.0 kips/in.²..	[195]
			-40	...	...	...	...	...	...	...	Endurance limit 73.0 kips/in.²	
2316...	C 0.78, Mn 0.10, Si 0.10..	Wrought; a-c from 2,015°F, f-c from 1,430°F.	Room	...	...	116	13	...	...	...	...	[66]
			-295	...	...	155	0	...	...	...		
2317...	...do...	Wrought; f-c from 1,470°F..	Room	...	95.0 (yld pnt)	98.8	12 (10 diam)	35	163	...	...	[66]
			-423	...	...	123	0.2 (10 diam)	0	244	...		
2318...	C 0.93, Mn 0.27, Si 0.15..	Normalized at 1,475°F...	Room	...	60.0	124	12	26	R_c 22	4	...	[25]
			-40	...	...	...	...	...	R_c 26	2-3		
			-105	...	71.5	146	12	22	R_c 26	3-6		

	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	...	...	62.7	25	...	...	...	...	[66]
			-295	...	...	125	12	...	...	...		
2320...	...do...	Wrought; f-c from 1,470°F..	Room	...	...	67.2	18 (10 diam)	66	137	...	...	[66]
			-423	...	...	137	0.1 (10 diam)	2.0	...	...		
	CHROMIUM STEELS											
2321...	C 0.15, Cr 0.46, Mn 0.68, Si 0.12.	Normalized at 1,830°F......	Room	...	...	...	...	...	...	118	Impact specimen with V notch....	[25]
			-10	...	...	...	...	...	...	31		
			-56	...	...	...	...	...	...	2.5		
2322...	...do...	Water-quenched from 1,650°F, tempered at 1,250°F.	Room	...	...	...	...	...	...	118	...do...	[25]
			-10	...	...	...	...	...	...	78		
			-56	...	...	...	...	...	...	26		
			-85	...	...	...	...	...	...	12		
			-108	...	...	...	...	...	...	3		
2323...	C 0.16, Cr 0.49, Mn 0.83, Si 0.13, Al 0.044.	Normalized at 1,830°F......	Room	...	46.0	68.0	38 (1.8 in.)	76	...	120	...do...	[25]
			-40	...	...	...	...	...	...	120		
			-85	...	...	...	...	...	...	110		
			-108	...	...	...	...	...	...	21		
			-247	...	...	...	...	...	...	1.5		
2324...	...do...	Water-quenched from 1,650°F, tempered at 1,250°F.	Room	...	...	...	...	...	...	120	...do...	[25]
			-108	...	...	...	...	...	...	120		
			-140	...	...	...	...	...	...	120		
			-185	...	...	...	...	...	...	99		
			-247	...	...	...	...	...	...	3		
2325...	C 0.31, Cr 0.69, Mn 0.65, Mo 0.22, Si 0.20, P <0.03, S <0.03.	Bar, 5/8 in., o-q from 1,625°F, tempered at 1,100°F.	Room	30,000	122 (0.1% offset)	128	20 (4 diam)	65	285	Iz 81	Endurance limit 69.0 kips/in.[2]..	[31]
			-40	30,000	130 (0.1% offset)	149	19 (4 diam)	64	296	Iz 80	Endurance limit 73.0 kips/in.[2]..	
2326...	...do...	Bar, 5/8 in., o-q from 1,625°F, tempered at 650°F.	Room	30,000	196 (0.1% offset)	219	13 (4 diam)	57	429	Iz 13	Endurance limit 96.0 kips/in.[2]..	[31]
			-40	30,500	200 (0.1% offset)	228	13 (4 diam)	55	432	Iz 14	Endurance limit 100 kips/in.[2]...	
2327...	C 0.22, Cr 0.83, Mn 0.60, 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.	68	...	95.3 (0.2% perm)	114	22 (5 diam)	75	234	[b]22	...	[370]
			-148	...	...	...	...	...	...	[b]16		
			-297	...	165 (0.2% perm)	172	22 (5 diam)	57	329	[b]1.3		
2328...	C 0.29, Cr 0.96, Mn 0.69, V 0.17, Si 0.01.	Air-cooled from 1,700°F....	Room	...	97.0	134	13	59	R_c 28	8	Impact specimen, Charpy bar with Izod notch.	[25]
			-10	...	...	...	...	...	R_c 30	5.5		
			-105	...	104	150	14	53	R_c 30	6.5		
2329...	...do...	Oil-quenched from 1,625°F, tempered at 1,175°F.	Room	...	118	129	12	65	R_c 28	103	...do...	[25]
			-40	...	...	...	...	...	R_c 31	26		
			-105	...	140	149	15	56	R_c 35	16		
2330...	C 0.40, Cr 1.80, Mn 0.64, Mo 0.36, Si 0.21, V 0.19, Ni 0.06, P 0.018, S 0.003.	Oil-quenched from 1,470°F, tempered at 1,155°F.	68	...	134 (0.2% perm)	147	18 (5 diam)	64	285	[b]15	...	[370]
			-148	...	...	...	...	...	...	[b]6.5		
			-297	...	196 (0.2% perm)	200	20 (5 diam)	50	418	[b]5.0		
			-423	...	...	...	...	...	...	[b]3.5		

[b] Notch impact value, m-kg/cm.

TABLE 23.—*Iron and steel, low-temperature properties*—Continued

Serial number	Composition	Condition	Temperature	Tensile properties: Modulus of elasticity	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Impact number	Remarks	Reference
					CHROMIUM STEELS—Continued							
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*		*ft-lb*		
2331...	C 0.31, Cr 2.36, Mn 0.67, Si 0.29, Mo 0.24, V 0.19, P 0.010, S 0.006.	Oil-quenched from 1,560°F, tempered at 1,130°F.	68	...	123 (0.2% perm)	140	18 (5 diam)	70	294	[b] 18	...	[370]
			-148	...	...	...	...	...	...	[b] 7.0		
			-297	...	191 (0.2% perm)	206	19 (5 diam)	45	400	[b] 2.0		
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	...	133 (0.2% perm)	150	17 (5 diam)	63	288	[b] 9.0	...	[370]
			-297	...	...	...	...	...	376	[b] 1.5		
2333...	C 0.54, Cr 3.50, Si 2.20, Mn 0.22.	Wrought; a-c from 2,015°F, f-c from 1,430°F.	Room	...	...	137	15	...	...	...	...	[66]
			-295	...	...	157	0	...	...	...		
2334...	...do...	Wrought; f-c from 1,470°F..	Room	...	116 (yld pnt)	141	16 (10 diam)	44	272	...	...	[66]
			-423	...	...	138	0.4 (10 diam)	0	...	...		
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	...	...	125	10	...	...	...	...	[66]
			-296	...	...	168	5	...	...	...		
2336...	...do...	Wrought; f-c from 1,470°F..	Room	...	108 (yld pnt)	117	14 (10 diam)	48	214	...	...	[66]
			-423	...	...	114	2.0 (10 diam)	0	...	...		
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	...	...	139	12	...	...	...	...	[66]
			-295	...	...	172	0	...	...	...		
2338...	...do...	Wrought; f-c from 1,470°F..	Room	...	125 (yld pnt)	134	10 (10 diam)	36	262	...	...	[66]
			-423	...	...	103	0.3 (10 diam)	0	...	...		
2339...	C 0.11, Cr 12.7, Ni 12.0..	Water-quenched from 2,010°F.	Room	...	34.0 (yld pnt)	82.9	58 (2 in.)	77	...	Iz 118	Tensile specimen 0.25 in. diam; impact specimen 10 x 10 mm with three 45° notches.	[367]
			-75	...	53.8 (yld pnt)	133	50 (2 in.)	72	...	[c] Iz 118		
			-185	...	43.5 (yld pnt)	182	38 (2 in.)	64	...	Iz 98		
			-292	...	63.2 (yld pnt)	235	36 (2 in.)	50	...	Iz 102		
2340...	C 0.11, Cr 15.6, Ni 10.5..	...do...	Room	...	...	...	...	...	...	Iz 113	...do...	[367]
			-292	...	77.1 (yld pnt)	232	30 (2 in.)	45	...	Iz 86		
2341...	C 0.11, Cr 16.2, Ni 11.5..	...do...	Room	...	44.8 (yld pnt)	93.6	48 (2 in.)	52	...	Iz 118	...do...	[367]
			-85	...	...	...	...	...	...	Iz 118		
			-292	...	118 (yld pnt)	220	55 (2 in.)	75	...	Iz 118		
2342...	C 0.11, Cr 16.27, Ni 1.72, Mn 0.44, Si 0.29, S 0.025, P 0.014.	Bar, 5/8 in., o-q from 1,800°F, tempered at 850°F.	Room	...	157	199	12	60	R_c 43	19-27	...	[25]
			-40	...	...	...	...	...	R_c 44	18-20		
			-105	...	179	217	14	60	R_c 46	8-14		

2343...	C 0.10, Cr 17.34, Ni 8.67, Si 0.40.	Sheet, 0.032 in., hard.....	Room	25,700	157	180	9 (2 in.)	......	......	....	....	[25]
			-40	23,800	166	192	30 (2 in.)	......	......	....		
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	28,000	64.0 (0.1% offset)	145	38 (4 diam)	52	307	Iz 43	....	[31]
			-40	36,500	60.0 (0.1% offset)	198	33 (4 diam)	35	323	Iz 19		
2345...	...do..................	Bar, 1/2 in. square, ann...	Room	30,000	42.5 (0.1% offset)	123	51 (4 diam)	42	......	....	....	[31]
			-40	37,500	50.0 (0.1% offset)	182	34 (4 diam)	30	......	....		
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	....	35.0	99.0	56	78	R_B 83	150-166	....	[25]
			-40	....	....	....	....	......	R_B 90	140-148		
			-105	....	50.5	179	36	70	R_B 94	117-135		
2347...	...do..................	Hot-rolled (finishing temperature 1,400°-1,450°F)	Room	....	82.0	117	38	73	R_B 23	138-152	....	[25]
			-40	....	....	....	....	......	R_B 27	135-222		
			-105	....	78.0	184	36	68	R_B 30	136-223		
2348...	...do..................	Cold-drawn...............	Room	....	91.5	152	22	64	R_B 36	56-69	....	[25]
			-40	....	....	....	....	......	R_B 38	58-69		
			-105	....	103	196	29	67	R_B 41	53-56		
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	....	94.0 (0.1% offset)	128	32 (4 diam)	58	312	....	Endurance limit 74.0 kips/in.^{2}..	[31]
			-40	....	....	144	31 (4 diam)	57	337	....	Endurance limit 77.0 kips/in.^{2}..	
2350...	C 0.07, Cr 18.41, Ni 7.88, Mo 2.80, Mn 0.73, Si 0.48, S 0.019, P 0.017.	Cold-drawn...............	Room	....	119	133	23	73	R_C 35	89-119	....	[25]
			-40	....	....	....	....	......	R_C 38	87-97		
			-105	....	135	186	31	60	R_C 40	77-100		
2351...	C 0.07, Cr 18.58, Ni 8.93, Mo 3.36, Mn 0.93, Si 0.42, P 0.026, S 0.012.	Annealed.................	Room	....	52.0	102	42	72	R_C 10	67-73	....	[25]
			-40	....	....	....	....	......	R_C 18	67-99		
			-105	....	73.0	153	51	68	R_C 24	60-93		
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	....	160 (0.1% offset)	242	6.5 (4 diam)	51	434	Iz 16	Endurance limit 119 kips/in.^{2}...	[31]
			-40	....	....	275	8.0 (4 diam)	51	434	Iz 20	....	
2353...	C 0.06, Cr 18.80, Ni 8.25, Si 0.43, Mn 0.39.	Sheet, 0.022 in., half-hard	Room	27,800	107	150	26 (2 in.)	......	......	....	....	[25]
			-40	26,600	102	176	27 (2 in.)[c]	......	......	....		
2354...	C 0.12, Cr 18.8, Ni 8.1, Si 0.43, Mn 0.24.	Wrought; w-q from 2,100°F..	Room	....	58.0 (yld pnt)	118	56 (10 diam)	54	176	....	....	[66]
			-423	....	125 (yld pnt)	269	25 (10 diam)	30	......	....		
2355...	C 0.07, Cr 18.97, Ni 10.29, Cb 0.95, Mn 0.42, Si 0.32, S 0.028, P 0.027.	Wrought; w-q from 2,000°F..	Room	....	50.0	92.0	41	76	R_C 10	123-127	....	[25]
			-40	....	....	....	....	......	R_C 17	117-127		
			-105	....	52.0	146	40	69	R_C 22	115-133		
2356...	...do..................	Cold-drawn...............	Room	....	128	145	14	60	R_C 35	31-39	....	[25]
			-40	....	....	....	....	......	R_C 40	32-42		
			-105	....	135	165	33	63	R_C 41	36-39		
2357...	C 0.05, Cr 19.04, Ni 9.15, Si 0.62, Mn 0.39, Ti 0.29, S 0.015, P 0.010.	Water-quenched from 1,900°F.	Room	....	36.0	86.0	45	79	R_B 80	178-186	....	[25]
			-40	....	....	....	....	......	R_B 89	172-189		
			-105	....	38.0	143	46	74	R_B 94	161-180		
2358...	...do..................	Cold-drawn...............	Room	....	85.0	131	22	69	R_C 32	89-96	....	[25]
			-40	....	....	....	....	......	R_C 35	86-89		
			-105	....	89.0	174	32	67	R_C 36	75-93		

[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: Modulus of elasticity	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Hardness number	Impact value	Remarks	Reference
						CHROMIUM STEELS—Continued						
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*		*ft-lb*		
2359...	C 0.05, Cr 20.8, Ni 8.87..	Bar, 1/2 in. diam, ann.....	Room	28,200	35.0	83.0	64	76	150	Iz 118	Impact specimen, round bar......	[25]
			-40	28,000	43.0	110	58	68	......	Iz 119		
2360...	...do....................	Bar, 1/2 in. diam, cold-drawn.	Room	27,700	110	132	32	72	296	Iz 68	...do.........................	[25]
			-40	27,800	116	154	40	60	......	Iz 70		
						COBALT 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]
			-295	....	....	128	12	......	......	....		
2362...	...do....................	Wrought; f-c from 1,470°F..	Room	....	....	86.5	20 (10 diam)	52	166	....	....	[66]
			-423	....	....	129	0 (10 diam)	0	......	....		
						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]
			-40	....	....	....	....	......	......	22		
			-100	....	....	....	....	......	......	14-18		
			-150	....	....	....	....	......	......	4		
			-240	....	....	....	....	......	......	2		
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]
			-40	....	....	....	....	......	......	27-35		
			-100	....	....	....	....	......	......	22-25		
			-150	....	....	....	....	......	......	14		
			-240	....	....	....	....	......	......	3		
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]
			-20	....	....	....	....	......	......	40		
			-40	....	....	....	....	......	......	38		
			-50	....	....	....	....	......	......	36		
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	......	......	....	....	[66]
			-295	....	....	150	2.5	......	......	....		
2367...	...do....................	Wrought; f-c from 1,470°F..	Room	....	81.1 (yld pnt)	93.4	16	56	185	....	....	[66]
			-423	....	....	174	0.8	0	......	....		
						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]
			-295	....	....	157	17	39	......	....		
2369...	...do....................	Wrought; f-c from 1,470°F..	Room	....	....	....	....	......	208	....	....	[66]
			-423	....	....	173	0.2 (10 diam)	1.0	......	....		
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]
			-296	....	....	161	0	......	......	....		

2371...	...do....................	Wrought; f-c from 1,470°F..	Room	....	....	123	2.5 (10 diam)	0	363	....	....	[66]
			-423	....	....	95.6	0 (10 diam)	0	......	....		
2372...	C 1.23, Mn 12.64.........	Wrought; w-q from 1,920°F..	Room	....	....	125	30	......	198	....	....	[66]
			-295	....	....	137	2.5	......	364	....		
2373...	C 1.27, Mn 12.69, Si 0.12.	Wrought; w-q from 1,830°F..	Room	....	77.3 (yld pnt)	148	44 (10 diam)	49	227	....	....	[66]
			-423	....	....	146	0 (10 diam)	0	......	....		
2374...	C 0.15, Mn 15.27.........	Wrought; w-q from 1,920°F..	Room	....	....	87.4	5	......	......	....	....	[66]
			-295	....	....	103	2.5	......	......	....		
2375...	...do....................	...do....................	Room	....	....	95.0	5.5 (10 diam)	0	278	....	....	[66]
			-423	....	....	115	0.7 (10 diam)	0	......	....		
					MOLYBDENUM STEELS							
2376...	C 0.33, Mo 0.24, Mn 1.23..	Cast; w-q from 1,600°F, tempered at 1,275°F.	65	....	....	....	....	......	......	56	....	[313]
			-40	....	....	....	....	......	......	34		
			-94	....	....	....	....	......	......	14		
2377...	C 0.30, Mo 0.35, Mn 1.18..	Cast; a-c from 1,650°F, tempered at 1,200°F.	65	....	....	....	....	......	......	37	....	[313]
			-25	....	....	....	....	......	......	22		
			-75	....	....	....	....	......	......	18		
					NICKEL STEELS							
2378...	C 0.26, Ni 0.58, Si 0.33, Mn 0.18.	Wrought; a-c from 2,015°F, f-c from 1,430°F.	Room	....	....	75.0	25	......	......	....	....	[66]
			-295	....	....	143	15	......	......	....		
2379...	C 0.47, Ni 1.08, Cr 1.04, Mn 0.80, Si 0.29, Mo 0.22.	Furnace-cooled from 1,450°F.	Room	....	72.0	96.5	23	67	R_c 11	90	Impact specimen, Charpy bar with Izod notch.	[25]
			-40	....	....	....	....	......	R_c 14	47-60		
			-105	....	90.0	116	26	62	R_c 18	26		
2380...	...do....................	Oil-quenched from 1,520°F, tempered at 1,175°F.	Room	....	141	157	12	57	R_c 34	37-44	...do...........................	[25]
			-40	....	....	....	....	......	R_c 36	36-40		
			-105	....	156	176	13	52	R_c 38	22-26		
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	....	39.0 (0.5% extn)	53.7	41 (2 in.)	73	106	58	....	[371]
			-100	....	....	....	....	......	......	34		
			-150	....	....	....	....	......	......	20		
			-200	....	....	....	....	......	......	4		
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 (0.2% perm)	167	17 (5 diam)	65	337	[b]12	....	[370]
			-148	....	....	....	....	......	......	[b]6.5		
			-297	....	203 (0.2% perm)	225	19 (5 diam)	52	411	[b]5.5		
			-423	....	....	....	....	......	......	[b]3.5		
2383...	...do....................	...do....................	Room	....	148	167	16	65	337	[b]12	....	[25]
			-94	....	164	182	17	63	......	[d]8		
			-300	....	202	225	19	52	411	[b]5.5		
2384...	C 0.33, Ni 2.54, Cr 0.67, Mn 0.64, Mo 0.64, Si 0.16, P 0.035, S 0.012.	Oil-quenched from 1,560°F, tempered at 1,185°F.	Room	....	138 (yld pnt)	152	14	65	......	Iz 58	Tensile specimen 0.25 in. diam; impact specimen 10 × 10 mm with three 45° notches.	[367]
			-89	....	146 (yld pnt)	163	16	62	......	[a]Iz 53		
			-141	....	149 (yld pnt)	170	16	61	......	[e]Iz 50		
			-292	....	184 (yld pnt)	202	17	63	......	Iz 22		

[a] -101°F.
[b] Notch impact value, m-kg/cm.^{2}
[d] Notch impact value, m-kg/cm^2 at -110°F.
[e] -184°F.

TABLE 23.—*Iron and steel, low-temperature properties*—Continued

Serial number	Composition	Condition	Temperature	Tensile properties: Modulus of elasticity	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Hardness number	Impact value	Remarks	Reference
	NICKEL STEELS—Continued											
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*		*ft-lb*		
2385...	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	...	53.0 (0.5% extn)	71.2	36 (2 in.)	73	144	60	...	[371]
			-100	...	...	...	...	...	...	38		
			-150	...	...	...	...	...	...	36		
			-200	...	...	...	...	...	...	24		
2386...	C 0.34, Ni 3.30, Mn 0.72, Si 0.26.	Air-cooled from 1,700°F....	Room	...	74.0	115	16	53	R_c 22	22	Impact specimen, Charpy bar with Izod notch.	[25]
			-40	...	...	...	...	...	R_c 25	10		
			-105	...	79.5	131	18	52	R_c 26	7.5		
2387...	...do...	Air-cooled from 1,475°F, tempered at 1,000°F.	Room	...	126	134	14	64	R_c 32	79-86	...do...	[25]
			-40	...	...	...	...	...	R_c 35	56-69		
			-105	...	143	154	16	60	R_c 36	28		
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	...	133 (yld pnt)	146	14 (10 diam)	60	284	...	...	[66]
			-423	...	...	243	4.5 (10 diam)	48	...	...		
2389...	...do...	Wrought; o-q from 1,560°F, tempered at 570°F.	Room	...	238 (yld pnt)	244	6.0 (10 diam)	54	466	...	...	[66]
			-423	...	297 (yld pnt)	328	0.9 (10 diam)	0	...	...		
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	30,000	45.0 (yld pnt)	63.6	40 (2 in.)	80	...	58	...	[372]
			-100	...	...	...	...	...	...	43		
			-175	...	...	...	...	...	...	26		
2391...	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.	Room	...	43.2 (0.5% extn)	63.5	40 (2 in.)	78	130	70	...	[371]
			-100	...	...	...	...	...	...	43		
			-150	...	...	...	...	...	...	6-14		
			-200	...	...	...	...	...	...	4.5		
2392...	C 0.29, Ni 3.84, Cr 0.26..	Bar, 5/8 in. diam, o-q from 1,500°F, tempered at 1,100°F.	Room	29,500	112	122	24	68	243	Iz 80	Impact specimen, round bar......	[25]
			-40	29,500	...	126	22	65	...	Iz 75		
2393...	...do...	Bar, 5/8 in. diam, o-q from 1,500 F, tempered at 650°F.	Room	29,400	176	200	14	60	403	Iz 12	...do...	[25]
			-40	29,600	192	210	16	58	...	Iz 9		
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	...	148 (0.2% perm)	181	15 (5 diam)	61	376	[b]8.0	...	[370]
			-297	...	...	...	...	...	426	[b]1.5		
2395...	C 0.13, Ni 5.13, Mn 0.41, Cr 0.19, Si 0.15, P 0.03, S 0.03.	...	68	...	...	103	25	74	...	...	...	[373]
			-148	...	...	136	19	61	...	...		
			-242	...	...	153	25	57	...	...		
			-274	...	...	157	27	56	...	...		
			-297	...	...	160	19	47	...	...		
			-319	...	...	175	21	50	...	...		
2 .96...	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	...	51.0 (0.5% extn)	108	26 (2 in.)	66	217	58-64	...	[371]
			-100	...	...	...	...	...	...	35-41		
			-150	...	...	...	...	...	...	27-35		
			-200	...	...	...	...	...	...	20-22		

2397...	C 0.57, Ni 13.0, Mn 6.88, Si 0.31.	Forged....................	68	....	50.5 (0.2% perm)	103	82 (5 diam)	76	184	b 39	....	[370]
			-297	....	85.2 (0.2% perm)	156	46 (5 diam)	48	227	b 16		
			-423	....	....	....	....	....	......	b 7.0		
2398...	C 0.11, Ni 13.8, Cr 12.2..	Water-quenched from 2,010°F.	Room	....	27.1 (yld pnt)	85.1	52 (2 in.)	76	......	Iz 111	Tensile specimen 0.25 in. diam; impact specimen 10 x 10 mm with three 45° notches.	[367]
			-80	....	46.6 (yld pnt)	106	60 (2 in.)	78	......	c Iz 118		
			-148	....	49.3 (yld pnt)	133	56 (2 in.)	75	......	....		
			-287	....	71.7 (yld pnt)	212	44 (2 in.)	58	......	....		
2399...	C 0.83, Ni 14.44, Mn 5.9, Cu 2.25.	Wrought; w-q from 1,920 F..	Room	....	61.8	117	54 (10 diam)	66	174	....	....	[66]
			-423	....	150 (yld pnt)	172	12 (10 diam)	10	......	....		
2400...	C 0.11, Ni 15.92, Cr 12.25.	Water-quenched from 2,010°F.	Room	....	32.5 (yld pnt)	83.3	44 (2 in.)	78	......	Iz 115	Tensile specimen 0.25 in. diam; impact specimen 10 x 10 mm with three 45° notches.	[367]
			-80	....	38.5 (yld pnt)	101	62 (2 in.)	77	......	c Iz 117		
			-186	....	54.9 (yld pnt)	124	69 (2 in.)	73	......	Iz 118		
			-292	....	71.7 (yld pnt)	177	58 (2 in.)	65	......	Iz 118		
2401...	C 1.0, Ni 17.91, Mn 6.05..	Wrought; w-q from 1,920°F..	Room	....	50.8 (yld pnt)	114	51 (10 diam)	64	159	....	....	[66]
			-423	....	151 (yld pnt)	175	13 (10 diam)	26	......	....		
2402...	C 1.18, Ni 24.3, Mn 6.05..	...do......................	Room	....	58.0 (yld pnt)	123	51 (10 diam)	60	191	....	....	[66]
			-423	....	181 (yld pnt)	194	26 (10 diam)	50	......	....		
2403...	C 0.16, Ni 24.51, Mn 1.0, Si 0.30.	Wrought; f-c from 1,470°F..	Room	....	....	170	15 (10 diam)	53	320	....	....	[66]
			-423	....	....	274	8.0 (10 diam)	36	......	....		
2404...	C 0.44, Ni 27.3, Cr 14.60, W 3.5, Si 1.62, Mn 1.34.	Wrought; w-q from 1,830°F..	Room	....	....	124	24 (10 diam)	42	232	....	....	[66]
			-423	....	159 (yld pnt)	187	25 (10 diam)	35	......	....		
2405...	C 0.70, Ni 31.4, Mn 0.82..	Wrought; f-c from 1,470°F..	Room	....	67.2 (yld pnt)	96.6	29 (10 diam)	46	162	....	....	[66]
			-423	....	216 (yld pnt)	265	11 (10 diam)	16	......	....		
2406...	C 0.16, Ni 35.8, Mn 0.86, Si 0.08.	Wrought; w-q from 1,920°F..	Room	....	52.4 (yld pnt)	81.1	32 (10 diam)	58	150	....	....	[66]
			-423	....	127 (yld pnt)	144	20 (10 diam)	60	......	....		
2407...	C 0.04, Ni 35.98, Mn 0.29, Si 0.02.	....	Room	....	60.5	75.0	28	72	149	b 22	....	[25]
			-300	....	91.0	129	32	61	220	b 14		
			-425	....	....	....	....	....	......	b 14		
2408...	C 0.12, Ni 42.06, Mn 0.94, Si 0.24.	....	Room	....	50.5	81.5	36	70	158	b 22	....	[25]
			-300	....	73.0	132	41	62	205	b 25		
			-425	....	....	....	....	....	......	b 22		

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: Modulus of elasticity	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Hardness number	Impact value	Remarks	Reference
					SILICON STEEL							
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*		*ft-lb*		
2409...	C 0.40, Si 1.27, Mn 1.9..	Wrought; f-c from 1,170°F..	Room	...	...	124	1.0 (10 diam)	0	266	...	...	[66]
			-423	...	...	75.7	1.5 (10 diam)	0	...	...		
					TUNGSTEN STEELS							
2410...	C 0.26, W 1.99, Cr 0.66, Mn 0.25, Si 0.05.	Wrought; f-c from 1,170°F..	Room	...	68.6 (yld pnt)	91.2	18	60	174	...	...	[66]
			-423	...	...	124	1.0	0	...	...		
2411...	C 0.38, W 7.47, Mn 0.20, Si 0.11.	...do...	Room	...	91.8 (yld pnt)	119	12 (10 diam)	42	228	...	...	[66]
			-423	...	...	233	0.9 (10 diam)	0	...	...		
					PLAIN CAST IRONS							
2412...	T C 3.07, Si 1.26, Mn 0.90, P 0.15, S 0.08.	Cast (processed iron)...	80	...	...	...	...	...	...	...	Endurance limit 21.0 kips/in.²..	[195]
			-20	...	...	...	...	...	...	...	Endurance limit 23.0 kips/in.²..	
2413...	T C 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.	80	...	...	...	...	...	...	...	Endurance limit 9.0 kips/in.²...	[195]
			-20	...	...	...	...	...	...	...	Endurance limit 9.5 kips/in.²...	
			-40	...	...	...	...	...	...	...	Endurance limit 11.5 kips/in.²..	
2414...	T C 3.42, G C 2.35, Si 1.24, Mn 0.56, P 0.326, S 0.103.	Cast...	73	...	...	31.1	...	...	180	b0.62	Bend str 52.9 kips/in.²... Deflection (24 in. span) 0.429 in.	[374]
			-4	...	...	30.4	...	...	...	b.58	Bend str 55.1 kips/in.²... Deflection (24 in. span) 0.425 in.	
			-112	...	...	...	...	...	...	b.52	...	
2415...	T C 3.44, Si 1.96...	...do...	Room	...	...	...	...	...	...	Iz 39	Impact specimen 1 1/2 in. diam., unnotched.	[25]
			-45	...	...	...	...	...	...	Iz 29		
2416...	T C 3.56, G C 3.06, Si 1.80, Mn 0.60, P 0.527, S 0.080.	...do...	73	...	...	20.6	...	...	134	b0.51	Bend str 43.0 kips/in.²... Deflection (24 in. span) 0.420 in.	[374]
			-4	...	...	21.8	...	...	...	b.51	Bend str 44.7 kips/in.²... Deflection (24 in. span) 0.437 in.	
			-31	...	...	...	...	...	...	b.53	Bend str 43.3 kips/in.²... Deflection (24 in. span) 0.420 in.	
2417...	T C 3.78, G C 3.26, Si 2.03, Mn 0.86, P 0.095, S 0.071.	...do...	73	...	...	18.0	...	...	142	b.58	Bend str 38.7 kips/in.²... Deflection (24 in. span) 0.468 in.	[374]
			-4	...	...	18.8	...	...	...	b.54	Bend str 40.4 kips/in.²... Deflection (24 in. span) 0.476 in.	
			-112	...	...	...	...	...	...	b.50	...	

						ALLOY CAST IRONS						
2418...	TC 2.76, Si 2.02, Ni 1.75..	Cast........................	Room -45	....	....	....	....	....	....	Iz 44 Iz 38	Impact specimen, 1/2 in. diam, unnotched.	[25]
2419...	TC 2.73, Ni 13.76, Cu 6.00 Cr 1.95, Si 1.59.	...do......................	Room -45	....	....	....	....	....	....	Iz 55 Iz 50	...do...........................	[25]
2420...	TC 2.50, Ni 30.00, Cr 4.00, Si 1.40.	...do......................	Room -45	....	....	....	....	....	....	Iz 81 Iz 70	...do...........................	[25]
						MALLEABLE CAST IRON						
2421...	TC 3.05, Si 0.85, Mn 0.55, P 0.15, S 0.15.	Cast; cooled from 1,800°F in 30 hr.	Room -50 -75	....	....	....	....	....	....	4 3 3	....	[25]

[b] Notch impact value, m-kg/cm.^{2}

Table 24.—*Iron and steel, thermal expansion*

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade: 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	Reference
	PURE AND INGOT IRONS													
	Percent		$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	
2422[a]	C 0.004	1 hr at 700°C in vacuum, slowly cooled	11.8	12.2	12.9	13.4	13.8	14.2	14.5	14.6	14.6	14.8	......	[196]
2423[b]	Armco: Fe 99.75	Sheet	......	12.2	12.8	13.4	13.9	14.5	......	......	......	......	......	[69]
	IRON-CARBON ALLOYS													
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 99.69+, 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]
	WROUGHT IRON													
2428	C 0.02, P 0.12, Si 0.12, Mn 0.05, S 0.02, Slag 2-3.	......	......	12.1	......	......	......	......	......	......	......	......	......	[375]
	ALUMINUM STEELS													
2429	C 0.13, Al 2.17, Mn 0.10, Si 0.06	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	[c] 14.7	......	......	......	[378]
2437[b]	C 0.055, Cr 1.32, Mn 0.45, Si 0.101, S 0.031, 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 0.057	......	11.4	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	......	......	[381]
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]

2446.....	C 0.4, Cr 13, Ni 13, W 2.5	......	......	17.4	17.4	17.4	17.6	17.6	17.7	17.9	18.0	......	......	[382]
2447[b]....	C 0.45, Cr 15.89, Ni 10.29, Cu 2.68, Si 1.22, Mn 0.26, P 0.025, S 0.018.	Cast	......	16.8	17.1	17.5	17.9	18.2	......	......	......	......	......	[69]
2448.....	C 0.06, Cr 17.08, Si 0.58, Mn 0.45, Al 0.08	Annealed 1/2 hr at 790°C, f-c	......	10.3	10.6	11.0	11.2	11.4	11.6	11.8	12.4	12.9	......	[713]
2449.....	C 0.06, Cr 17.7, Ni 9.6, Mn 0.36, Si 0.28, P 0.016, S 0.012.	Quenched from 1,080°C	[d] 16.4	16.5	17.2	17.7	18.1	18.3	18.6	19.0	19.5	19.7	20.0	[713]
2450.....	C 1.15, Cr 21.66, Ni 8.41, Al 1.57, Si 1.24, Mn 1.16, Cu 0.10.	Cast at 1,510°C, ann at 1,000°C	[d] 11.9	11.4	11.8	12.1	12.1	12.2	12.6	......	......	......	......	[713]
2451.....	C 0.18, Cr 20.7, Ni 10.4, Mn 0.62, Si 0.56.	Hot-forged and ann at 880°C	[d] 15.9	16.0	16.6	17.1	17.5	17.8	18.3	18.6	18.9	19.4	19.9	[713]
2452.....	C 0.06, Cr 23.4, Al 6.2, Co 1.9	Bar, 5/16 in. diam, hot-rolled	[d] 11.9	11.7	12.0	12.4	12.9	13.4	13.9	14.4	14.7	15.1	......	[384]
2453.....	C 0.14, Cr 24.35, Ni 21.5, Si 1.36, Mn 0.29	Normalized at 1,050°C	......	15	......	16	......	17	......	17	......	18	......	[383]
2454.....	C 0.16, Cr 24.63, Mn 0.62, Si 0.27	Hot-rolled	[d] 10.3	10.0	10.3	10.6	10.9	11.2	11.3	11.6	12.2	12.7	......	[713]
2455.....	C 0.72, Cr 26.7, Ni 1.3, Si 0.66, Mn 0.57	Sand-cast at 1,480°C, ann at 1,000°C	......	9.8	10.3	10.7	11.0	11.3	11.5	11.8	12.2	12.7	13.1	[713]
2456[b]....	C 0.18, Cr 28.23, Mn 0.48, Si 0.39, Ni 0.22, S 0.024, P 0.010.	Hot-rolled	10.6	10.6	10.7	10.8	11.1	11.3	11.5	......	......	......	......	[379]
2457[b]....	C 0.50, Cr 29, Ni 9, Si 1.5, Mn 0.5	Cast	......	13.5	......	......	......	......	......	......	......	......	......	[69]
2458.....	C 0.12, Cr 32.27, Mn 0.36, Si 0.26	Bar, 1/2 in. diam, ann at 940°C	......	......	10.2	10.5	10.8	11.0	11.1	11.4	......	......	......	[380]
2459.....	C 0.05, Cr 38.6, Al 7.9, Si 0.19, Mn 0.17	Bar, 1/4 in. diam, hot-rolled, h-t at 1,000°C.	......	12.0	12.2	12.7	13.1	13.9	14.6	15.4	15.9	16.5	17.1	[384]

COBALT STEEL

2460.....	C 0.07, Co 22.5, Cr 21.2	......	......	15.6	......	......	......	......	......	......	......	......	......	[72]

COPPER STEELS

2461[e]....	C 0.14, Cu 1.85, Cr 1.15, V 0.21, Mn 0.10, S 0.035, P 0.03, Si 0.03.	Annealed	......	11.2	12.1	12.7	13.4	13.9	14.3	14.6	......	......	......	[391]
2462[e]....	C 0.34, Cu 2.70, Si 0.09, Cr 0.82, Mn 0.28, V 0.26, S 0.043, P 0.01.	...do	......	11.6	12.2	12.9	13.7	14.2	14.6	14.9	......	......	......	[391]

MANGANESE STEELS

2463.....	C 0.10, Mn 2.76, Si 0.03	Rod, 3/16 in. diam, slowly cooled from 900°C.	......	12.7	13.2	13.6	14.0	14.3	......	......	......	......	......	[711]
2464.....	C 0.20, Mn 7.81, Si 0.09	...do	......	13.6	14.0	14.5	15.2	15.8	......	......	......	......	......	[711]
2465.....	C 0.20, Mn 12.34, Si 0.13	...do	......	16.6	......	......	......	......	......	......	......	......	......	[711]

MOLYBDENUM STEELS

2466.....	C 0.61, Mo 1.60	......	[f] 12.9	......	......	......	......	......	......	......	......	......	......	[286]
2467.....	C 0.54, Mo 3.65, Ni 1.02	......	[f] 12.9	......	......	......	......	......	......	......	......	......	......	[286]

NICKEL STEELS

2468[e]....	C 0.38, Ni 0.81, Mn 1.17, Si 0.10, S 0.067, P 0.055.	Annealed	......	11.2	12.1	12.9	13.5	14.1	14.5	14.8	......	......	......	[391]
2469[b]....	C 0.45, Ni 1.25, Mn 0.65, Cr 0.60, S 0.045, P 0.04.	Quenched and tempered	......	11.8	12.3	12.9	13.4	14.0	......	......	......	......	......	[69]
2470[e]....	C 0.41, Ni 2.00, Mn 1.11, Si 0.12, P 0.053, S 0.049.	Annealed	......	11.6	11.8	12.6	13.5	14.0	14.1	14.7	......	......	......	[391]
2471[e]....	C 0.33, Ni 3.59, Mn 0.78, Si 0.09, S 0.035, P 0.014.	...do	......	10.9	11.2	12.1	12.9	13.4	13.8	......	......	......	......	[377]
2472[e]....	C 0.17, Ni 3.94, Cr 2.50, V 0.39, Si 0.14, S 0.026, Mn 0.01, P 0.010.	...do	......	10.8	11.3	12.1	12.6	13.0	13.3	......	......	......	......	[391]
2473.....	C 1.25, Ni 19.55, Cr 19.55, Cu 0.48, Mn 0.15, Si 0.09, S 0.037, P 0.017.	Cast at 1,490°C, ann at 1,000°C	......	15.8	16.1	16.4	16.7	16.8	17.1	17.2	17.6	18.0	18.4	[713]
2474.....	C 0.39, Ni 20.2, Cr 7.9, Si 1.12, Mn 0.74, Cu 0.22, S 0.051, P 0.017.	Hot-forged, ann at 900°C	[d] 18.5	18.4	18.4	18.6	18.8	18.9	19.1	19.2	19.4	19.9	20.6	[713]
2475.....	C 0.20, Ni 25, Cr 17, Si 2.5	Sheet, 1/8 in.	......	......	......	15.9	......	......	......	......	......	......	......	[69]

[a] Base temperature 18°C instead of 20°C.
[b] Base temperature 0°C instead of 20°C.
[c] 20° to 650°C.
[d] 20° to 60°C.
[e] Base temperature 25°C instead of 20°C.
[f] Instantaneous coefficient of linear expansion.

TABLE 24.—*Iron and steel, thermal expansion*—Continued

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade: 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	Reference
	NICKEL STEELS—Continued													
	Percent		$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	
2476[b]	C 0.38, Ni 26.16, Cr 6.95, Si 0.70, Mn 0.44, S 0.016, P 0.013.	Cast	......	17.7	18.1	18.5	18.8	19.2	......	......	......	......	......	[69]
2477	C 0.58, Ni 27.78, Cr 18.50, Si 1.90, Mn 0.83, Al 0.08.	Cast at 1,510°C	[d]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	......	16.1	......	16.3	......	......	......	......	[274]
2479[b]	Ni 30		......	8.8	12.5	14.1	15.0	15.6	15.8	16.1	16.6	17.0	17.4	[274]
2480[e]	C 0.14, Ni 34.52	Annealed	......	3.7	6.4	9.2	4.2	12.7	13.6	14.5	......	......	......	[391]
2481[b]	Invar[g]: Ni 36.1, Mn 0.39, Cu 0.39		......	1.5	2.1	3.8	6.3	8.3	9.8	11.2	......	......	......	[72]
2482	C 0.30, Ni 36, Cr 11, Mn 1.5, Si 0.2	Hot-rolled	......	[b]13.6	......	......	......	......	......	......	......	......	......	[69]
2483	C 0.42, Ni 36.0, Cr 16.4, Si 1.03, Mn 0.71	Sand-cast at 1,580°C, ann at 1,000°C	......	12.8	14.2	14.8	15.2	15.7	16.2	16.5	16.9	17.3	......	[713]
2484	C 0.4, Ni 40, Cr 17, Mn 1, Si 1	Cast	......	[b]16.4	......	......	......	......	......	......	......	......	......	[69]
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[e]	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	13.5	13.7	14.0	14.4	14.9	15.4	[340]
2488	C 0.8, Si 14.5, Mn 0.35	Sand-cast	......	[b]6.5	......	......	......	......	......	......	......	......	......	[375]
	TUNGSTEN STEELS													
2489[f]	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[e]	C 0.51, W 1.58, Si 1.45, Mn 0.42, S 0.021, P 0.016.	Annealed	......	10.4	......	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[e]	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	Cast; ann 1/2 hr at 1,000°F	......	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	......	11.1	11.6	12.2	12.7	13.2	......	......	......	......	......	[387]
2497[b]	TC 3.12, GC 2.46, CC 0.66, Si 2.00, Mn 0.93, P 0.255, S 0.151.	...do	......	10.6	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[e]	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[e]	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 1.2[illegible], Mn 0.5	Bar, cast; ann	......	[h]11.8	[i]12.2	[j]12.6	[k]12.8	......	......	......	......	......	......	[386]

2504.....	TC 2.95, Ni 4.86, Cr 1.55, Si 0.90, Mn 0.4...	...do........	......	[h]7.8	[i]9.8	[j]11.3	[k]12.4	......	......	......	......	......	....	[386]
2505.....	TC 3.0, Ni 7.38, Si 1.2, Mn 0.52........	...do........	......	[h]13.0	[i]13.3	[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	[i]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	[i]19.3	[j]19.2	......	......	......	......	......	......	....	[386]
2508.....	TC 2.60, Ni 20.38, Cu 9.08, Cr 2.47, Mn 1.0, Si 1.0.	...do........	......	[h]14.0	[i]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	[i]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	[i]10.4	[j]12.0	......	......	......	......	......	......	....	[386]
2511.....	TC 2.27, Ni 30.82, Cu 15.10, Cr 4.19, Si 1.53, Mn 0.96.	...do........	......	[h]8.6	[i]9.9	[j]11.1	[k]12.3	......	......	......	......	......	....	[386]
2512.....	TC 2.71, Ni 30.96, Cr 2.64, Si 1.59, Mn 0.93..	...do........	......	[h]6.2	[i]9.4	[j]11.6	[k]13.0	......	......	......	......	......	....	[386]
2513.....	TC 2.50, Ni 34.50, Cr 3.59, Si 1.27, Mn 1.0..	...do........	......	[h]5.6	[i]7.2	[j]9.1	[k]10.7	......	......	......	......	......	....	[386]
2514.....	TC 2.25, Ni 43.68, Cr 3.21, Mn 1.80, Si 1.65..	...do........	......	[h]8.6	[i]9.6	[j]10.1	[k]11.1	......	......	......	......	......	....	[386]
2515.....	TC 2.46, Ni 46.45, Cr 3.93, Si 1.40, Mn 0.94..	...do........	......	[h]8.3	[i]9.1	[j]10.0	[k]10.8	......	......	......	......	......	....	[386]
2516.....	TC 2.25, Si 5.8........	...do........	......	......	11.3	11.6	12.0	12.5	12.9	13.3	13.6	......	....	[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: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal conductivity	Reference
	PURE AND INGOT IRONS						
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10⁻⁴*	*Watts cm⁻¹ °C⁻¹*	
2518.....	Impurities under 0.0117	Annealed in vacuum 15 minutes at 850°C	17.8 (20°C)	9.71 (20°C)	...	...	[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 (300°–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) .14 (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]

			WROUGHT IRON				
2531.....	C 0.04, Si 0.265, P 0.136, Mn 0.046, S 0.025....	Bar, 1 in. diam, hot-rolled..................	....	....	....	0.59 (100°C) .54 (200°C) .50 (300°C) .45 (400°C) .41 (500°C)	[394]
			CARBON STEELS				
2532.....	C 0.08, Mn 0.31, Si 0.08, Ni 0.07, S 0.050, Cr 0.045, As 0.032, P 0.029, Mo 0.020, Al 0.002..	Rod, 1 in. diam, ann at 930°C...............	13.5 (0°C) 9.0 (100°C) 6.6 (200°C) 4.3 (350°C)	12.8 (0°C) 19.2 (100°C) 26.1 (200°C) 39.7 (350°C)	....	0.59 (0°C) .58 (100°C) .53 (200°C) .48 (350°C)	[397]
2533.....	C 0.135, Mn 0.69, Si 0.20, Cu 0.06, Ni 0.01, 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...............	9.5 (0°C) 7.0 (100°C) 5.5 (200°C) 4.3 (300°C) 3.8 (350°C)	18.1 (0°C) 24.5 (100°C) 31.5 (200°C) 40.0 (300°C) 44.8 (350°C)	....	.48 (0°C) .48 (100°C) .48 (150°C) .45 (250°C) .43 (350°C)	[397]
2534.....	C 0.80, Mn 0.32, Ni 0.13, Si 0.13, Cr 0.11, Cu 0.070, As 0.021, Mo <0.01, S 0.009, P 0.008, Al 0.004.	Bar, 1 in. diam, ann at 800°C...............	10.1 (0°C) 8.7 (50°C) 7.1 (100°C) 5.6 (200°C) 4.3 (300°C) 3.8 (350°C)	17.1 (0°C) 19.8 (50°C) 23.3 (100°C) 30.6 (200°C) 39.7 (300°C) 45.1 (350°C)	....	.50 (0°C) .49 (50°C) .48 (100°C) .47 (200°C) .43 (300°C) .40 (350°C)	[397]
2535.....	C 0.83, Mn 0.27, Si 0.16, P 0.017, S 0.015......	Bar, 1 in. diam, hot-rolled; 2 hr at 800°C, f-c.	....	....	....	.45 (100°C) .41 (300°C) .39 (400°C) .37 (500°C)	[394]
2536.....	C 1.10, Mn 0.55................................	....	....	....	....	.55 (100°C) .50 (200°C) .33 (400°C) .27 (500°C)	[392]
2537.....	C 1.22, Mn 0.35, Si [illegible], Ni 0.13, Cr 0.11, Cu 0.077, As 0.025, [illegible], Mo 0.01, P 0.009, Al 0.006.	Bar, 1 in. diam, ann at 800°C...............	9.4 (0°C) 8.0 (50°C) 6.9 (100°C) 6.0 (150°C)	18.1 (0°C) 21.6 (50°C) 25.0 (100°C) 28.5 (150°C)	....	.15 (0°C) .15 (50°C) .15 (100°C) .15 (150°C)	[397]
2538.....	C 1.40, Mn 0.53................................	....	....	....	....	.64 (100°C) .50 (200°C) .32 (400°C) .25 (500°C)	[392]
			CHROMIUM STEELS				
2539.....	C 0.35, Cr 0.88, Mn 0.59, Ni 0.26, Si 0.21, Mo 0.20, Cu 0.12, As 0.039, S 0.031, P 0.028, Al 0.004.	Bar, 1 in. diam, ann at 860°C, tempered at 640°C, f-c.	8.1 (0°C) 6.3 (100°C) 5.0 (200°C) 4.0 (300°C) 3.5 (350°C)	21.3 (0°C) 27.5 (100°C) 34.7 (200°C) 43.3 (300°C) 47.9 (350°C)	....	0.43 (0°C) .43 (100°C) .42 (200°C) .41 (300°C) .40 (350°C)	[397]
2540.....	C 0.315, Cr 1.09, Mn 0.69, Si 0.20, Ni 0.073, Cu 0.056, P 0.039, S 0.036, As 0.028, Mo 0.012, Al 0.005.	Bar, 1 in. diam, ann at 860°C...............	8.7 (0°C) 5.8 (150°C) 4.1 (300°C)	19.9 (0°C) 29.8 (150°C) 42.0 (300°C)	....	.49 (0°C) .45 (150°C) .42 (300°C)	[397]
2541.....	C 0.01, Cr 1.98, Mn 0.04, Si 0.02...............	Forged,.....................................	....	....	....	.36 (30°C) .35 (200°C) .30 (500°C) .27 (800°C) .27 (1,200°C)	[395]
2542.....	C 0.10, Cr 5.15, Mn 0.45, Si 0.18, S 0.017, P 0.012.	Bar, 1 1/2 in. diam, hot-rolled; ann........	....	....	....	.37 (100°C) .35 (300°C) .34 (500°C)	[394]

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TABLE 25.—*Iron and steel, electrical and thermal properties*—Continued

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal conductivity	Reference
			CHROMIUM STEELS—Continued				
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10⁻⁴*	*Watts cm⁻¹ °C⁻¹*	
2543	C 0.42, Cr 7.47, Si 3.5, Mn 0.50, Ni 0.19	Oil-quenched from 950°C, tempered at 650°C	2.0-2.3 (15°C)	75-85 (15°C)	...	0.13 (15°C) .31 (900°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)	[391]
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 12.95, Mn 0.25, Si 0.17, Ni 0.14, Cu 0.060, Al 0.034, S 0.024, P 0.018, As 0.015, V 0.012.	Bar, 1 in. diam, normalized at 960°C, tempered 2 hr at 750°C.	3.4 (0°C) 2.9 (100°C) 2.5 (200°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 0.01, 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 13.34, Ni 11.90, W 9.92, Mn 1.17, Si 1.07.	Bar, 15/16 in., rolled	...	...	...	.18 (30°C) .20 (200°C) .39 (1,100°C)	[395]
2552	C 1.36, 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)	[383]
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 960°C, tempered 2 hr at 750°C.	3.4 (0°C) 3.1 (50°C) 2.9 (100°C) 2.5 (200°C) 2.2 (300°C)	50.4 (0°C) 55.0 (50°C) 59.5 (100°C) 68.8 (200°C) 78.0 (300°C)	... ...	.25 (0°C) .26 (50°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]

2557	C 0.08, Cr 15.19, Mn 0.35, Si 0.20, Ni 0.05, P 0.020, S 0.017.	Bar, 1 in. diam, rolled; ann at 845°C	...	...	...	.26 (100°C) .26 (200°C) .26 (300°C) .26 (400°C) .26 (500°C)	[394]
2558	C 1.10, Cr 17.12, Al 1.55, Si 0.47, Ni 0.35, Mn 0.30.	Bar, 1 in. diam, rolled; normalized at 900°C.	...	...	...	.18 (100°C) .19 (200°C) .20 (300°C) .22 (500°C)	[394]
2559	C 0.11, Cr 17.50. Ni 8.85, Mn 0.53, Si 0.48	Bar, 15/16 in., rolled; h-t	...	...	...	.23 (30°C) .25 (200°C) .36 (800°C) .47 (1,100°C)	[395]
2560	Cr 18, Ni 8	Annealed	2.5 (21°C) 1.5 (650°C)	70 (21°C) 117 (650°C)	...	...	[266]
2561	C 0.07, Cr 18.08, Ni 9.12, Mn 0.59, Si 0.47. Ti 0.34, P 0.013, S 0.003.	Bar, 1 1/2 in. diam, rolled; ann	...	...	...	.16 (100°C) .18 (200°C) .19 (300°C) .21 (400°C) .22 (500°C)	[394]
2562	C 0.11, Cr 18.5, Ni 9.21. Mn 0.19	Bar, 1 in. diam, w-q from 1,120°C	...	...	...	.16 (100°C) .19 (300°C) .21 (500°C)	[394]
2563	C 0.08, Cr 19.11, Ni 8.14, Si 0.68, W 0.60, Mn 0.37, Cu 0.030, As 0.025, P 0.022, S 0.011, Al 0.004.	Bar, 1 in. diam, w-q from 1,100°C	2.5 (0°C) 2.2 (100°C) 2.0 (200°C) 1.9 (300°C) 1.8 (350°C)	69.9 (0°C) 78.3 (100°C) 86.3 (200°C) 92.8 (300°C) 95.7 (350°C)	... ...	.16 (0°C) .16 (100°C) .17 (200°C) .18 (300°C) .19 (350°C)	[397]
2564	C 0.34, Cr 19.16, Ni 7.57, S 1.24, W 3.98, Mn 0.69.	Air-cooled from 1,050°C	2.0 (15°C) 1.4 (1,050°C)	85 (15°C) 125 (1,050°C)	... ...	.13 (15°C) .29 (1,050°C)	[383]
2565	C 0.08, Cr 19.32, Ni 9.55, Si 0.6, Mn 0.26	Water-quenched from 1,050°C	...	...	...	.22 (500°C) .24 (600°C) .26 (700°C)	[399]
2566	C 0.24, Cr 19.6, Ni 7.99, Mn 0.28	Bar, 1 in. diam, w-q from 1,120°C	...	...	...	.15 (100°C) .18 (300°C) .21 (500°C)	[394]
2567	C 0.24, Cr 19.6, Ni 8.96, Mn 0.37	Bar, 1 in. diam, 8 hr at 735°C, slowly cooled.	...	...	...	.16 (100°C) .19 (300°C) .22 (500°C)	[394]
2568	C 0.13, Cr 20.25, Ni 12.60, Si 2.20, Mn 0.71	Bar, 15/16 in., rolled	...	...	...	.18 (30°C) .18 (200°C) .25 (800°C) .31 (1,200°C)	[395]
2569	C 0.07, Cr 20.63, Mn 0.06, Si 0.03	...do	...	...	...	.23 (30°C) .23 (200°C) .26 (800°C) .29 (1,000°C)	[395]
2570	C 0.12, Cr 22.75, Ni 20.30, Si 2.38, Mn 1.40	...do	...	...	...	.18 (30°C) .18 (200°C) .21 (500°C) .26 (800°C) .34 (1,200°C)	[395]
2571	C 0.23, Cr 23.20, Ni 11.85, W 2.98, Si 1.65, Mn 0.41.	Air-cooled from 1,050°C	2.0 (15°C) 1.4 (1,050°C)	87 (15°C) 125 (1,050°C)	... ...	.13 (15°C) .29 (1,050°C)	[383]
2572	C 0.14, Cr 24.35, Ni 21.5, Si 1.36, Mn 0.29	...do	2.0 (15°C) 1.5 (1,100°C)	88 (15°C) 113 (1,100°C)	... ...	.14 (15°C) .32 (1,100°C)	[383]

TABLE 25.—*Iron and steel, electrical and thermal properties*—Continued

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal conductivity	Reference
			CHROMIUM STEELS—Continued				
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10⁻⁴*	*Watts cm⁻¹ °C⁻¹*	
2573.....	C 0.19, Cr 24.50, Ni 4.22, Mn 0.51, Si 0.50.....	Bar, 15/16 in., rolled; h-t..................	....	....	....	0.21 (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 0.45, Mn 0.40, Ni 0.18, 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)	[395]
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)	[383]
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.......................	....	....	....	0.20 (30°C) .24 (200°C) .33 (800°C)	[395]
			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, Mo 0.025, Al 0.015.	Bar, 1 in. diam, ann at 860°C................	8.8 (0°C) 5.9 (150°C)	19.6 (0°C) 29.2 (150°C)	....	0.46 (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 (300°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..............	....	....	....	....	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 930°C	14.5 (0°C) 9.7 (100°C) 6.9 (200°C)	11.9 (0°C) 17.8 (100°C) 24.9 (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 0.06, S 0.025, As 0.023, 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) 49.9 (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) 46.8 (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)	[337]
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 0.003.	Bar, 1 in. diam, w-q from 950°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)	[337]
2599	Ni 45	...	3.8	45	...	...	[396]
2600	Ni 47.1	...	...	...	36 (0°–100°C)	.15 (20°–100°C)	[337]
			SILICON STEELS				
2601	C 0.485, 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 (30°C) .27 (200°C) .33 (500°C) .34 (800°C) .34 (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				
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10⁻⁴*	*Watt cm⁻¹ °C⁻¹*	
2603.....	C 0.41, Si 4.33, Cr 2.04, Mn 0.33..............	Forged..	....	....	....	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) .34 (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, ann at 830°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) .46 (100°C) .41 (400°C)	[403]
2608.....	TC 3.93, GC 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) .44 (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) .31 (400°C)	[404]
2616.....	C 1.81, Ni 18.65, Si 5.42, Cr 2.02.............	....	....	....	....	.29 (100°C) .26 (400°C)	[404]

	MALLEABLE CAST IRONS						
2617.....	C 1.75-2.30, Si 0.85-1.20, Mn <0.10, P <0.20, S <0.12.	....	5.7	30	....	....	[177]
2618.....	C 2.25-2.70, Si 0.80-1.10, Mn <0.10, P <0.20, S 0.07-0.15.	....	5.4	32	....	....	[177]

TABLE 26.—*Magnetic properties of commercial permanent magnet alloys* [405]

Serial number	Alloy	Composition	Coercive force (H_c)	Residual induction (B_r)	$B \times H$ maximum
		Percent			
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	930,000
2622	Cobalt-nickel-copper alloy	Co 41, Cu 35, Ni 21	440	5,300	993,000
2623	Iron-nickel copper alloy	Cu 60, Fe 20, Ni 20	450	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 28, Al 12, Co 5, Fe rem	700	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 6, Fe rem	540	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

TABLE 27.—*Classification of some lead alloys (1942)*

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

Designation: Federal Spec.	Designation: Federal Alloy	ASTM Spec.	ASTM Alloy	SAE No.	Pb	Sn	Sb	Cu	Ag	Serial numbers of corresponding alloys in the tables
				LEAD						
....	....	[a]B 29-40T	....	....	99.94	....	....	....	....	2849, 2866.
QQ-L-201, amendment 1	....	[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, 2874, 2892, 2893.
....	....	B 23-26	9	13	85	5	10	[d].50	....	2659, 2665, 2760.
....	....	B 23-26	11	....	85	....	15	[d].50	....	2671, 2674, 2895.
....	....	B 23-26	10	....	83	2	15	[d].50	....	2678, 2761, 2762.
QQ-M-161	Grade 6	B 23-26	8	....	80	5	15	[d].50	....	2673, 2675, 2679, 2763; figure 135.
QQ-M-161	Grade 7	B 23-26	7	14	75	10	15	[d].50	....	2669, 2764.
....	....	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].50	....	2670.
				SOFT SOLDERS						
QQ-S-571	Class G	B 32-40T	....	....	80	20	....	....	....	2742, 2918.
....	....	B 32-40T	....	4A	75	25	[d]0.12	....	....	2745, 2812.
....	....	B 32-40T	....	4B	75	23	[d]2.00	....	....	....
QQ-S-571	Class E	B 32-40T	....	....	70	30	....	....	....	2746, 2747, 2748, 2749, 2861, 2862, 2920, 2921.
....	....	B 32-40T	....	....	65	35	....	....	....	2750, 2815, 2863, 2884.
QQ-S-571	Class B	B 32-40T	....	3A	60	40	[d]0.12	....	....	2754, 2755, 2821, 2885, 2923.
....	....	B 32-40T	....	3B	60	38	[d]2.00	....	....	2822, 2823.
....	....	B 32-40T	....	2A	55	45	[d]0.12	....	....	2825, 2924.
....	....	B 32-40T	....	2B	55	43.5	[d]1.50	....	....	2756, 2826.
QQ-S-571a	Class A	B 32-40T	....	1A	50	50	[d]0.12	....	....	2757, 2758, 2759, 2828, 2865, 2869, 2886.
....	....	B 32-40T	....	1B	50	49.25	[d].75	....	....	2829.
AXS-806, rev. 1[e]	Class R	....	....	....	rem	....	....	[d]0.08	2.5	2712.

[a]Corroding lead, formerly grade I.
[b]Chemical lead, formerly grade II.
[c]Common lead, formerly grade III.
[d]Maximum.
[e]Ordnance 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 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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	PURE AND COMMERCIAL LEAD												
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
2630..	Sb 0.00024, Fe 0.000193, Zn 0.00008, Cu 0.000057.	Die-cast			[a]0.71 (0.5% extn)	[a]1.61	69	100		2.9			[413]
2631..	Sb 0.0030, Bi 0.0030, Fe 0.0008, Zn 0.0007, Ag 0.0004, Cu 0.0003.	...do			[a]0.86 (0.5% extn)	[a]1.97	64	92		4.2			[413]
2632..	Chemical lead	...do			[a]1.64 (0.5% extn)	[a]2.76	50	88		5.5			[413]
2633..	...do	Rod, extruded				[b]1.8	40 (8 in.)						[414]
2634..	"Pure" lead	...do				2.1	92 (2 in.)		0.22 (5×10^7)				[415]
2635..	Refined lead	Cable sheath, 1 in. o-d × 1/8 in. wall, extruded.				[c]2.1	119 (2.5 in.)		0.38 (10^7)	V 4.5			[416]
2636..	Lead		2,560			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					3.0	33			4.3	[d]2.3		[25]
2638..	...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 × 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 × 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 × 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 (3×10^7)				[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]

2648..	Sb 4.0	Sheet, cold-rolled (95% red.).	....	....	....	1.0	48	....	....	....	....	....	[421]
2649..	...do	Sheet, rolled; quenched from 455°F, aged 1 day at r-t.	....	....	....	11.7	6.3	....	....	....	....	....	[421]
2650..	Sb 4.14, Sn 0.22, Cu 0.033, Bi 0.018, As 0.01, Ag 0.004. S 0.001, Fe 0.0003.	Chill-cast; aged 26 days aged 26 days at r-t.	....	....	....	6.0	9.0 (2 in.)	....	....	V 12	....	....	[422]
2651..	...do	Chill-cast; 3 hr at 455°F, w-q, aged 1 day at r-t.	....	....	....	10.2	3.5 (2 in.)	....	....	V 25	....	....	[422]
2652..	Sb 5	Die-cast	....	....	....	6.9	8	....	....	9.2	....	Specific gravity.....10.95	[423]
2653..	Sb 5.94, Sn 0.20, As 0.020, Bi 0.020, Cu 0.010, Ag 0.0028, S 0.0028, Fe 0.0003.	Chill-cast; aged 26 days at r-t.	....	....	....	6.7	5.0 (2 in.)	....	....	V 15	....	....	[422]
2654..	...do	Chill-cast; 3 hr at 455°F, w-q, aged 1 day at r-t.	....	....	....	9.4	3.0 (2 in.)	....	....	V 24	....	....	[422]
2655..	Sb 6.0	Sheet, rolled	2,000	....	2.2 (yld pnt)	4.5	50 (2 in.)	....	....	7.5	....	Specific gravity.....10.88 Melting range........477°-545°F.	[424]
2656..	Sb 7.92, Sn 0.19, Cu 0.034, As 0.03, Bi 0.020, Ag 0.003, S 0.0026, Fe 0.0003.	Chill-cast; aged 26 days at r-t.	....	....	....	7.2	4.0 (2 in.)	....	....	V 16	....	....	[422]
2657..	Sb 8.0	Sheet, cold-rolled (95% red.).	....	....	....	4.6	31	....	....	....	....	....	[421]
2658..	Sb 9.9, Cu 0.12, Sn 0.11.	Cast	....	....	....	....	....	....	....	14	....	Comp yld str (0.125%)..2.8 kips/in.^{2}[a] Comp str (25%).......12.9 kips/in.^{2} Specific gravity.....10.57. Melting range........473°-498°F.	[425]
2659..	Sb 9.9, Sn 5.0, Cu 0.6..	Cast	....	....	....	....	....	....	....	19	....	Comp yld str (0.125%)..3.4 kips/in.^{2}[a] Comp str (25%).......14.7 kips/in.^{2} Specific gravity.....10.24. Melting range........459°-493°F.	[425]
2660..	Sb 10	Die-cast	....	....	....	8.0	6	....	....	14	....	Specific gravity.....10.59	[423]
2661..	...do	Cast	....	....	....	....	....	....	....	....	....	Comp str (75%).......12.9 kips/in.^{2}..	[426]
2662..	Sb 10, Tl 9.0	...do	....	....	....	....	....	....	....	....	....	Comp str (75%).......15.2 kips/in.^{2}..	[426]
2663..	Sb 10, Tl 8.5, Sn 5.0...	...do	....	....	....	....	....	....	....	....	....	Comp str (75%).......18.7 kips/in.^{2}..	[426]
2664..	Linotype: Sb 11.5, Sn 4.4, Cu 0.08.	...do	....	....	....	11.7	9.0 (2 in.)	....	....	21	....	Comp yld str (0.1%)..6.0 kips/in.^{2}...	[427]
2665..	Sb 11.75, Sn 4, Cu 0.5..	....	....	....	....	....	....	....	....	....	....	Melting point........471°F. Shrinkage (volume)...2.18%.	[428]
2666..	Sb 11.88, Sn 0.18, As 0.03, Bi 0.021, Cu 0.016, S 0.0026, Ag 0.0015, Fe 0.0003.	Chill-cast; aged 26 days at r-t.	....	....	....	9.4	5.0 (2 in.)	....	....	V 20	....	....	[422]

[a]Rate of strain 0.026 in./minute to yield strength, then 0.52 in./minute.
[b]Rate of strain 0.05 in./minute.
[c]Rate of strain 0.1 (in./in.)/minute.
[d]Notch impact value, m-kg/cm.^{2}
[e]Haigh tension-compression.
[f]Rate of strain 0.25 (in./in.)/minute.

TABLE 28.—*Lead and lead alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
LEAD-ANTIMONY ALLOYS—Continued													
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
2667..	Sb 12.65, As 2.97, Sn 0.65.	Chill-cast..............	....	....	....	9.8	1.5 (2 in.)	....	4.4 (2×10^6)	22	....	....	[429]
2668..	Stereotype: Sb 13.0, Sn 6.5, Cu 0.18.	Cast.....................	....	....	....	12 0	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.	....	....	....	12.3	....	....	....	....	....	....	[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....................	....	....	....	6.8	8 (2 in.)	....	....	15	....	Melting range........476°-504°F......	[177]
2675..	Sb 15, Sn 5, Cu 0.5, As 0.2.	Chill-cast..............	....	....	....	10.0	5 (2 in.)	....	3.9 (2×10^6)	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	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....................	....	....	....	12.0	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.....................	....	....	....	11.5	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....................	....	....	....	7.4	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.................	....	....	....	....	....	....	[e]1.10 (10^7)	....	....	....	[419]

2683..	Ba 0.04	...do	...	...	...	...	...	...	e1.57 (10^7)	...	...	...	[419]
2684..	Frary metal: Ba 1.3, Ca 0.8.	...	...	...	...	...	...	...	...	30	...	Comp str ... 22.0 kips/in.^{2}	[433]

LEAD-BISMUTH ALLOYS (SEE ALSO FIG. 131)

2685..	Bi 0.065, Cu 0.013, Sb 0.0015.	Cable sheath, 2.87 in. o-d × 0.159 in. wall (ring specimen).	...	...	...	1.9	47	...	...	3.9	...	...	[434]
2686..	Bi 0.075	Extruded	...	...	...	...	...	...	e0.47	...	...	...	[419]
2687..	Bi 0.126, Cu 0.059, Te 0.020, Ag 0.013, Sb 0.004.	Cable sheath 2.81 in. o-d × 0.137 in. wall (ring specimen).	...	...	...	2.7	38	...	...	5.7	...	...	[434]
2688..	Bi 0.15	Extruded	...	...	...	...	...	...	e0.49 (10^7)	...	...	...	[419]

LEAD-CADMIUM ALLOYS

2689..	Cd 0.3	Cold-rolled	...	...	...	...	...	...	e1.06 (10^7)	...	...	...	[419]
2690..	Cd 0.5	...do	...	...	...	...	...	...	e1.46 (10^7)	...	...	...	[419]
2691..	Cd 1.04, Sn 0.96	Cast from 975°F into mold at 350°F.	...	1.4	...	5.0	24 (5.5 in.)	...	...	9.5	...	...	[435]
2692..	Cd 1.74	...do	...	1.4	...	4.8	16 (5.5 in.)	...	...	8.3	...	...	[435]
2693..	Cd 1.98, Sn 0.52	...do	...	1.4	...	5.7	20 (5.5 in.)	...	...	9.3	...	...	[435]
2694..	Cd 2.89	...do	...	2.8	...	6.8	14 (5.5 in.)	...	...	11	...	...	[435]
2695..	Cd 20, Sn 10	Cast	...	...	...	4.9	...	...	...	...	...	Melting range ... 294°-448°F	[436]
2696..	Cd 20, Sn 15	...do	...	...	...	5.5	...	...	...	...	...	Melting range ... 294°-433°F	[436]

LEAD-CALCIUM ALLOYS (SEE ALSO FIG. 132)

2697..	Ca 0.04	Sheet, extruded; aged 2 weeks at r-t.	...	...	...	3.5	33 (2 in.)	...	0.78 (10^8)	gR 58	...	Melting point ... 622°F	[420]
2698..	...do	Sheet, extruded; aged 6 months at r-t.	...	...	...	4.1	35 (2 in.)	...	0.94 (5×10^7)	gR 64	...	...	[420]
2699..	Ca 0.06	...do	...	...	...	4.4	35 (2 in.)	...	1.10 (8×10^7)	gR 65	...	...	[420]
2700..	Ca 0.19	Extruded at 480°F	...	...	...	...	...	...	e1.34 (10^7)	...	...	...	[419]
2701..	Ca 0.41	Extruded at 525°F	...	...	...	...	...	...	e1.86 (10^7)	...	...	...	[419]
2702..	Ca 0.51, Na 0.52, Sn 0.08, Li 0.03.	Cast	3,100	...	10.5 (0.2%)	12.1	0.8 (10 diam)	5.6	3.3	26	...	Comp yld str (0.2%) .. 11.7 kips/in.^{2} Comp str ... 21.3 kips/in.^{2}	[432]
2703..	Ca 0.7, Na 0.6, Li 0.04.	Die-cast from 930°F into mold at 390°F; aged 48 hr at r-t.	...	...	7.4 (yld pnt)	13.6	8.5 (4 diam)	...	...	...	...	...	[430]

[e] Haigh tension-compression.

[g] 30 kg load, 1/4 in. ball, red scale.

TABLE 3c.—*Lead and lead alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	LEAD-CALCIUM ALLOYS—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
2704..	Pb 97.5, (hardeners including Ca and Sn) 2.5.	Cast......	...	...	...	11.1	5.8	...	...	22	...	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 x 0.117 in. wall (ring specimen).	...	...	...	4.4	19	...	...	10	...	...	[434]
2706..	Cu 0.06......	...	...	...	...	h2.2-2.8	50-56	...	0.6	4.5	...	...	[438]
2707..	...do......	Cold-rolled......	...	...	...	...	...	...	e0.63 (10^7)	...	...	...	[419]
2708..	...do......	Cold-rolled; 1 hr at 480°F.	...	...	...	...	...	...	e0.54 (10^7)	...	...	...	[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......	Rolled......	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......	...	...	...	i2.1	92 (8 in.)	...	e1.12 (10^7)	...	...	...	[441]
2721..	Te 0.06......	...	...	...	...	h2.8-3.4	32-37	...	0.9	5.8	...	...	[438]
2722..	Te 0.067......	Extruded......	...	...	...	...	...	...	e0.76 (10^7)	...	...	...	[419]

LEAD-THALLIUM ALLOYS

2723..	Tl 9, Sb 5, Sn 5........	Cast.....................	....	....	....	....	....	....	....	....	....	Comp str (75%).......16.0 kips/in.^{2}..	[426]
2724..	Tl 9.5, Sb 5.0..........	...do....................	....	....	....	....	....	....	....	....	....	Comp str (75%).......13.5 kips/in.^{2}..	[426]

LEAD-TIN ALLOYS (SEE ALSO FIG. 133)

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............ Melting point........619°F.	[424]
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 × 0.140 in. wall (ring specimen).	....	....	....	5.5	8.8	....	....	13	....	....	[434]
2727..	Sn 0.5..................	Cold-rolled..............	....	....	....	....	....	....	[e]0.52 (10^7)	....	....	....	[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.................	....	....	....	....	....	....	[e]0.74 (10^7)	....	....	....	[419]
2730..	Sn 1.2, Cd 0.2, Sb 0.1..	...do....................	....	....	....	....	....	....	1.0 (10^7)	5.0	....	....	[442]
2731..	Sn 1.5, Cd 0.25.........	....	....	....	....	[j]3.8	62	....	1.1	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.................	....	....	....	....	....	....	[e]0.99 (10^7)	....	....	....	[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.................	....	....	....	....	....	....	[e]1.08 (10^7)	....	....	....	[419]
2737..	Sn 10, Ag 2.25..........	Strip, chill-cast........	....	....	....	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..	....	....	....	[k]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}... Comp str (25%).......14.6 kips/in.^{2} Specific gravity.....9.33. Melting range........358°-531°F.	[425]
2742..	Sn 20, Sb 0.12, Bi 0.015, Cu 0.003, Ag 0.0009.	Annealed 16 hr at 212°F..	....	....	....	[k]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........294°-455°F......	[436]

[e]Haigh tension-compression.
[h]Rate of strain 0.25 (in./in.)/minute.
[i]Rate of strain 0.018 in./minute.
[j]Rate of strain 0.60 (in./in.)/minute.
[k]Rate of strain 0.5 in./minute (free head speed).

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TABLE 28.—*Lead and lead alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	LEAD-TIN ALLOYS—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
2745..	Sn 25, Sb 0.12, Bi 0.012, Cu 0.002, Ag 0.0009.	Annealed 16 hr at 212°F..	....	....	....	[k]6.0	27 (2 in.)	....	....	....	13	Shear str............5.3 kips/in.²...	[443]
2746..	Sn 29.8, Sb 1.92........	Cast....................	....	....	....	[l]7.4	19 (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..	....	....	....	[k]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.....9.48. Melting range........361°-495°F.	[445]
2749..	Sn 31.8, Sb 0.94........	...do....................	....	....	....	[l]6.9	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..	....	....	....	[k]6.3	26 (2 in.)	....	....	....	19	Shear str............5.6 kips/in.²...	[443]
2751..	Sn 39.72, Sb 2.61.......	Cast....................	....	....	....	[l]7.9	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..	....	....	....	[k]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°-460°F.	[445]
2756..	Sn 42.4, Sb 1.22........	...do....................	....	....	....	[l]7.1	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..	....	....	....	[k]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]

[k]Rate of strain 0.5 in./minute (free head speed).

[l]Rate of strain 0.1 in./minute.

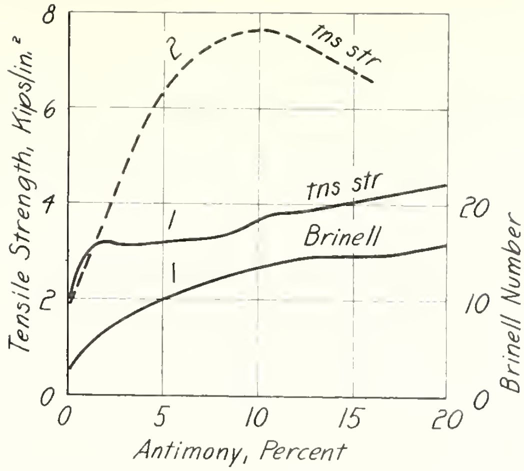


FIGURE 130.—*Tensile strength and hardness of lead-antimony alloys (Schumacher and Hiers [421]).*

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.

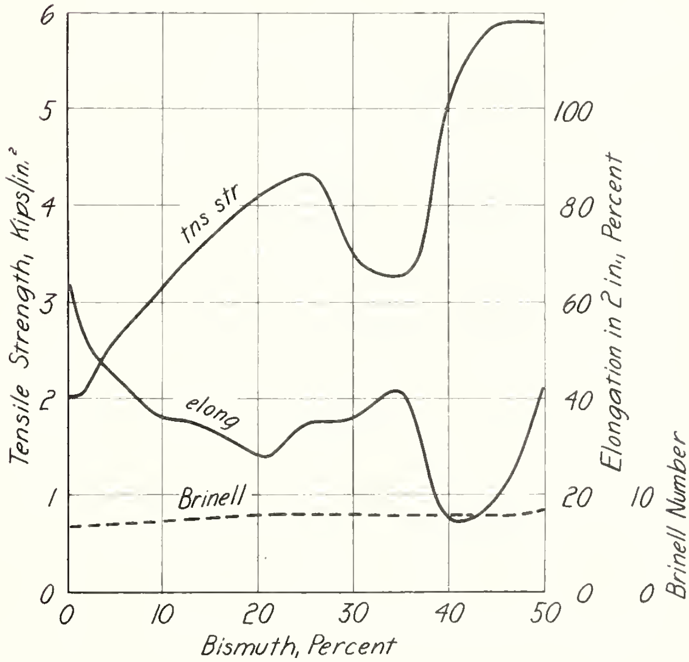


FIGURE 131.—*Tensile properties and hardness of lead-bismuth alloys (Thompson [427]).*

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).

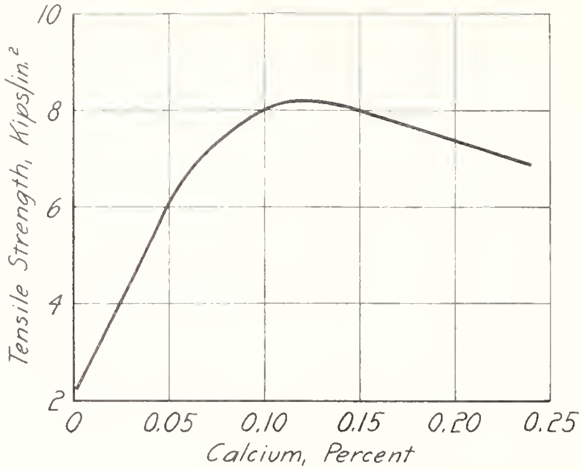


FIGURE 132.—*Tensile strength of lead-calcium alloys (Briggs [680]).*

Aged at room temperature 1 week, then at 212°F for 18 hours.

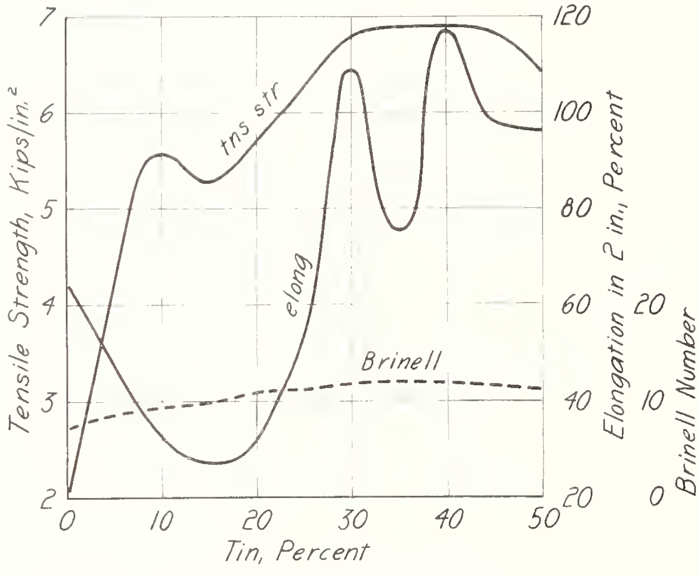


FIGURE 133.—*Tensile properties and hardness of lead-tin alloys (Thompson [427]).*

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	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]		Percent
2760	Lead-base	SAE No. 13	rem	......	10	5	......	21	17	6.4	4.0	....	....
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

[a] 2.5-mm ball, loads of 2 to 5 kg.
[b] Hardness number determined after 24 hours at room temperature. Load applied for 11 seconds.
[c] Aged for 24 hours at 300°F. Load applied for 11 seconds.
[d] Time of application of load.
[e] The "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* [4-E]

Serial number	Composition, percent							Liquidus temperature		Solidus temperature		Tensile strength[a]	Shear strength[a]	Recommended uses
	Sn	Pb	Sb	Cd	Bi	Zn	Others							
							BISMUTH-BASE ALLOYS							
								°F	°C	°F	°C	Kips/in.²	Kips/in.²	
2772	25	......	......	25	50	......	......	151	66	......	......	8.5	8.2	Fusible alloy.
2773	13	27	......	10	50	......	......	158	70	......	......	12.1	6.6	Fusibility; glass metal.
2774	22	28	......	......	50	......	......	212	100	......	......	11.2	7.4	Lead; tin; Britannia.
2775	19	31	......	......	50	......	......	201	94	......	......	5.8	6.5	Britannia.
2776	......	42.7	......	7.1	50	......	......	190	88	......	......	11.9	5.5	Fusible alloy.
2777	33.3	......	......	16.7	50	......	......	151	66	......	......	10.9	9.4	Do.
2778	37.5	......	......	12.5	50	......	......	151	66	......	......	9.0	7.0	Do.
2779	......	42	......	15.7	42.3	......	......	193	89.5	......	......	10.3	5.6	Do.
2780	20	40	......	......	40	......	......	235	113	......	......	12.7	6.5	Lead; tin; Britannia.
							CADMIUM-BASE ALLOYS							
2781	......	......	......	95	......	......	Ag 5	734	390	639	337	9.5	10.6	High-temperature service.
2782	......	......	......	82.6	......	17.4	......	508	264.4	508	264.4	13.3	11.2	High-temperature; galvanized.
2783	5	......	......	65	......	30	......	561	294	444	229	15.8	9.9	......
2784	30	......	......	50	......	20	......	531	277	315	157	12.4	8.9	......
2785	......	......	......	50	......	50	......	619	326	508	264.4	12.6	10.4	High-temperature service.
							LEAD-BASE ALLOYS							
2786	......	100	......	......	......	......	......	621.3	327.4	621.3	327.4	......	......	None.
2787	......	98	......	......	......	......	Ag 2	586	308	579	304	9.6	4.4	Electrical; high-temperature service.
2788	......	98	......	......	......	......	Tl 2	590	310	586	308	8.6	5.9	Do.
2789	......	97	......	......	......	......	Cu 0.25, Ag 2.5	662	350	572	300	11.5	4.8	Electrical equipment.
2790	......	95	......	......	......	......	Ag 5	689	365	579	304	9.1	4.1	Electrical; high-temperature service.
2791	5	95	......	......	......	......	......	595	313	556	291	10.7	6.4	General low grade; coating; high-temperature service.
2792	......	95	......	......	......	5	......	784	418	604	318	9.5	4.8	High-temperature service.
2793	3	93	......	......	......	......	Hg 4	723	384	518	270	11.2	5.3	Galvanized; sheet iron.
2794	......	91.5	......	8.5	......	......	......	529	276	480	249	13.2	7.0	Carbon; copper; zinc; iron.
2795	......	90.8	......	7.8	......	1.4	......	513	267	459	237	16.4	7.4	Copper; iron; tin; galvanized.
2796	4	90	6	......	......	......	......	529	276	462	239	8.5	6.6	High-temperature service.
2797	......	90	......	10	......	......	......	525	274	480	249	13.9	7.1	Copper; zinc; iron.
2798	......	90	10	......	......	......	......	511	266	477	247	3.5	3.1	Lead cable.
2799	10	88	......	2	......	......	......	527	275	293	145	16.8	5.2	General purpose.
2800	......	87.5	......	7.5	......	5	......	694	368	455	235	10.9	5.8	Copper; iron; tin; galvanized.
2801	......	87	13	......	......	......	......	477	247	477	247	2.4	5.8	Lead cable.
2802	2	86	......	12	......	......	......	504	262	462	239	13.9	6.1	General purpose.
2803	6	86	......	......	......	......	Hg 8	540	282	477	247	13.4	5.8	Galvanized; sheet iron.
2804	5	85	......	10	......	......	......	495	257	293	145	11.9	4.8	General purpose.
2805	15	85	......	......	......	......	......	545	285	437	225	13.3	5.6	General low grade; coating; high-temperature service.
2806	10	85	......	5	......	......	......	500	260	293	145	11.7	4.8	General purpose.
2807	......	80	......	20	......	......	......	498	259	480	249	13.4	8.1	......
2808	10	80	......	10	......	......	......	487	253	293	145	13.7	6.4	General; electrical; cans; roofing.
2809	......	79.7	2.6	17.7	......	......	......	462	239	......	......	14.6	7.1	......
2810	15	75	......	10	......	......	......	473	245	293	145	13.7	4.8	Coating and jointing.
2811	3	75	......	22	......	......	......	459	237	293	145	12.9	6.0	General purpose.
2812	25	75	......	......	......	......	......	511	266	361	183	13.5	5.8	General low grade; filler.
2813	......	70	......	30	......	......	......	500	260	480	249	14.0	6.5	......
2814	23	68	......	9	......	......	......	455	235	293	145	16.6	7.9	Wiping.
2815	33	67	......	......	......	......	......	486	252	361	183	17.1	6.4	Do.
2816	31	67	2	......	......	......	......	455	235	370	188	15.3	7.3	Do.
2817	9	65	......	26	......	......	......	437	225	293	145	14.6	7.0	General purpose.
2818	37.3	62.7	......	......	......	......	As 0.1	464	240	361	183	16.6	7.9	Wiping.
2819	37.5	62.5	......	......	......	......	......	462	239	361	183	23.7	8.5	Wiping; radiators.

2820	35.5	62.5	2	......	......	......	......	448	231	370	188	15.1	7.6	Wiping.
2821	40	60	......	......	......	......	......	460	238	361	183	11.1	8.3	Wiping; radiators.
2822	38	60	2	......	......	......	......	442	228	370	188	20.1	7.7	Wiping.
2823	37.5	60	2.5	......	......	......	......	435	224	367	186	17.4	8.2	Do.
2824	41.5	56.5	2	......	......	......	P 0.02	428	220	....	....	10.3	10.0	General purpose.
2825	45	55	......	......	......	......	......	437	225	361	183	28.8	9.1	Radiators; roofing.
2826	43.5	55	1.5	......	......	......	......	428	220	370	188	17.6	7.7	General purpose.
2827	......	53.8	......	15.4	30.8	......	......	176	80	....	....	9.8	5.8	Fusible alloy.
2828	50	50	......	......	......	......	......	421	216	361	183	23.9	7.6	General purpose.
2829	49.25	50	0.75	......	......	......	......	406	208	365	185	16.3	8.8	General; tin plate.
2830	32.5	39.5	......	19	......	2	......	329	165	277	136	18.5	10.0	General purpose.
TIN-BASE ALLOYS														
2831	100	......	......	......	......	......	......	449.4	231.9	449.4	231.9	22.7	6.9	Electrical equipment.
2832	95	......	5	......	......	......	......	464	240	450	232	11.2	11.1	Do.
2833	95	......	......	......	......	......	Ag 5	563	295	430	221	14.1	10.6	Electrical; high-temperature service.
2834	66	27.5	......	6.5	......	......	......	342	172	279	137	17.2	9.9	Wiping.
2835	65	13.5	......	21.5	......	......	......	320	160	279	137	13.0	10.0	Do.
2836	63	37	......	......	......	......	......	361	183	361	183	29.0	8.0	General purpose.
2837	50	25	......	25	......	......	......	320	160	293	145	14.6	9.5	Do.
2838	50	32	......	18	......	......	......	294	145.5	294	145.5	14.9	9.6	Fusible safety devices.
2839	50	25	......	......	25	......	......	266	130	230	110	9.1	6.1	Joining pewter.
2840	50	......	25	25	......	......	......	592	311	417	214	5.1	9.0	Pewter; Britannia; Sb-lead.
2841	50	25	......	......	......	25	......	637	336	311	155	16.0	10.0	Aluminum.
2842	45	27.5	......	......	27.5	......	......	201	94	....	....	10.8	4.9	Pewter; lead; tin; Britannia.
ZINC-BASE ALLOYS														
2843	......	......	......	......	......	98	Ni 2	1,022	550	786	419	9.4	....	Carbon; high-temperature service.
2844	......	......	......	25	......	75	......	687	364	508	264.4	9.1	8.6	High-temperature service.
2845	15	......	......	20	......	65	......	655	346	315	157	11.3	10.5	......
2846	......	......	......	40	......	60	......	635	335	508	261.4	6.7	12.0	Bronze; aluminum to copper.

[a] Copper joint 0.005 in. thick.

TABLE [illegible]1.—*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
				0.001%	0.01%	0.1%	1.0%		
	Percent		°F					*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	.265	...	2,000	[63]
2858	Cu 0.08, grade III Pb rem.	...	110	...	.11	...	...	9,000	[63]
2859	Sn 2.0	...	110	...	.055	.15	...	2,000	[63]
2860	Sn 28.1, Sb 1.7	Cast	Room	...	...	.16	0.31	1,800	[449]
			175	...	...	.052 (0.42%)	...	1,800	
2861	Sn 30.4	...do	Room	...	...	...	.16	4,800	[449]
2862	Sn 31.5, Sb 1.8	...do	Room	...	...	.21	.34	4,800	[449]
2863	Sn 34.3	...do	Room	...	...	...	.19	4,800	[449]
2864	Sn 45.1, Sb 2.7	...do	Room	...	...	.31	.61	4,800	[449]
			175	...	...	.09 (0.42%)	...	4,800	
2865	Sn 49.5	...do	Room	...	...	...	.16	4,800	[449]
			175	...	...	.028 (0.42%)	...	...	

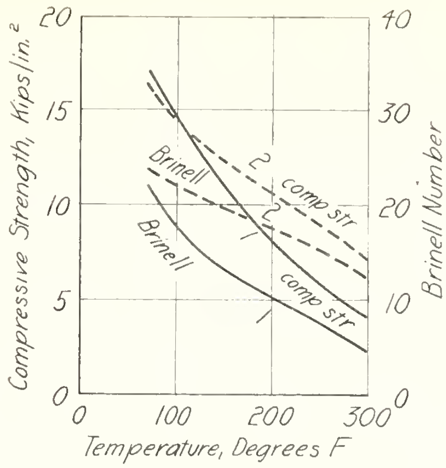


FIGURE 134.—*Compressive strength and hardness of a lead-calcium and of a tin-antimony-copper alloy (tin base babbitt) at high temperatures (Melhuish [59]).*

Curves: 1, Sn 88%, Sb 8%, Cu 4% (babbitt); 2, Pb 98%, Ca 2%.

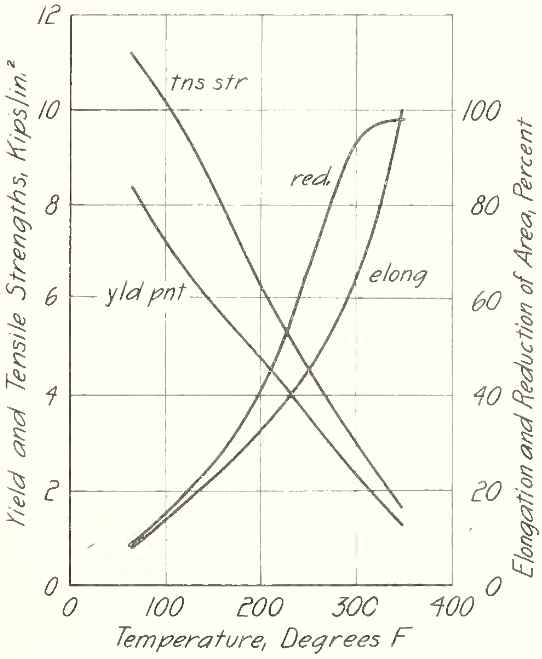


FIGURE 135.—*Short-time tensile properties of a lead-antimony-tin alloy (babbitt) at high temperatures (Greenwood [522]).*

(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.

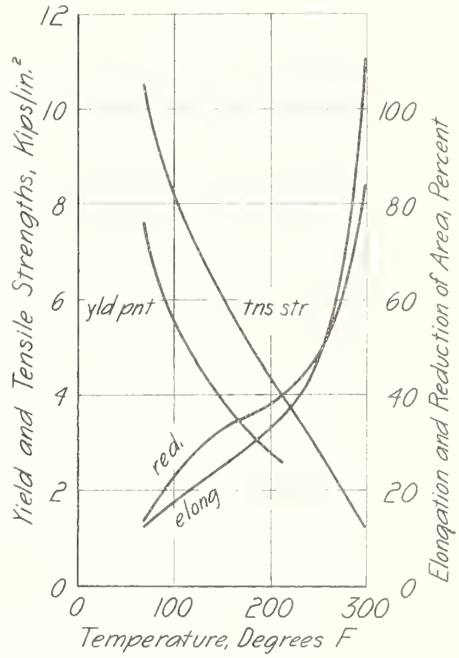


FIGURE 136.—*Short-time tensile properties of a lead-tin-antimony alloy at high temperatures (Greenwood [522]).*

(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 32.—*Lead and lead alloys, low-temperature properties*

Serial number	Composition	Condition	Temperature of test	Tensile properties: Modulus of elasticity	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Hardness number	Impact value	Remarks	Reference
	Percent		°F	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*		*ft-lb*		
2866.....	Pb 99.98............	....	64	2,700	....	....	....	....	....	....	[450]
			-319	3,400	....	....	....	....	....		
2867.....	Commercial lead.....	....	Room	....	3.0	33	....	[a]4.3	[b]2.3	....	[25]
			-300	....	6.2	40	....	[a]9	[b]3.8		
			-425	....	....	....	....	....	[b]4.5		
2868.....	Lead................	Rolled................	59	....	3.6	52	....	....	....	....	[451]
			-4	....	7.2	40	....	....	....		
			-40	....	13.3	31	....	....	....		
			-103	....	15.2	24	....	....	....		
2869.....	Pb 47.4, Sn 53.1....	Rod, 1 in. diam, ann...	Room	....	8.1	28 (2 in.)	54	....	Iz 15	Impact specimen, 10 x 10 mm with three 45° notches.	[64]
			-292	....	15.4	4.0 (2 in.)	3.8	....	Iz 2.0		

[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: Low temperature miscellaneous	-100° to 20°C	20° to 60°C	20° to 100°C	20° to 200°C	20° to 300°C	Reference
	Percent		$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	
2870	Pb 99.8-99.9	Cast	25.1 (-250° to 20°C) 26.5 (-200° to 20°C)	28.3	28.8	29.1	30.0	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]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	24.6	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]

[a]Base temperature 0° instead of 20°C. [b]15° to 110°C.

TABLE 34.—*Lead and lead alloys, electrical and thermal properties*

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal conductivity	Reference
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10⁻⁴*	*Watts cm⁻¹ °C⁻¹*	
2887	"Pure" lead	Cast				0.35 (0°C) .33 (100°C) .31 (200°C) .29 (300°C)	[402]
2888	Lead	Sheet, rolled	33.1 (-190.9°C) 8.8 (0°C)	5.21 (-190.9°C) 19.7 (0°C)	[a]38.6 (20° to -190.9°C)		[457]
2889[b]	...do		8.4 (20°C) 6.4 (100°C) 5.0 (180°C) 4.0 (260°C) 3.2 (320°C)	20.65 (20°C) 27.02 (100°C) 34.41 (180°C) 42.79 (260°C) 54.76 (320°C)	40.6 (0°-100°C) 33.6 (20°-40°C) 31.1 (100°-120°C) 29.1 (180°-200°C) 24.6 (260°-280°C)		[458]
2890	Sb 1	Cast	7.8 (20°C)	22.0 (20°C)			[421]
2891	Sb 5.63		7.4 (25.5°C)	23.2 (25.5°C)			[421]
2892	Sb 10					.26 (54°C)	[459]
2893	Sb 10.56		6.8 (25.4°C)	25.6 (25.4°C)			[460]
2894[c]	Sb 13					.27 (0°C)	[459]
2895	Sb 14	Cast	5.9 (20°C)	29.3 (20°C)			[421]
2896	Sb 20					.23 (54°C)	[459]
2897	Sb 37.1		4.4 (23.4°C)	39.2 (23.4°C)			[421]
2898	Sb 40					.21 (54°C)	[459]
2899	Bi 2.04		7.9 (24.0°C)	21.9 (24.0°C)			[460]
2900	Bi 20		1.2 (0°C) 3.9 (123°C)	41.4 (0°C) 43.8 (123°C)			[460]
2901	Bi 33.1		3.2 (22.5°C)	53.6 (22.5°C)			[460]
2902	Bi 40		2.4 (0°C) 2.7 (123°C)	70.5 (0°C) 65.2 (123°C)			[460]
2903	In 7.5		11.6 (-191.4°C) 6.0 (0°C) 5.6 (20.9°C)	14.8 (-191.4°C) 29.0 (0°C) 30.5 (20.9°C)	[a]25.6 (20.9° to -191.4°C)		[457]
2904	In 20.1		8.0 (-191.5°C) 5.1 (0°C) 4.9 (20.6°C)	21.5 (-191.5°C) 34.0 (0°C) 35.3 (20.5°C)	[a]19.2 (20.6° to -191.5°C)		[457]
2905	In 40.4		8.2 (-190.5°C) 5.6 (0°C) 5.5 (20.8°C)	21.1 (-190.5°C) 30.6 (0°C) 31.6 (20.8°C)	[a]16.3 (20.8° to -190.5°C)		[457]
2906	Ag 2.1		8.9 (25.3°C)	19.5 (25.3°C)			[460]
2907	Ag 21.7		10.0 (26.1°C)	17.2 (26.1°C)			[460]
2908	Ag 34.2		12.0 (15.6°C)	14.4 (15.6°C)			[460]
2909	Tl 3.45		9.0 (0°C)	19.2 (0°C)			[460]
2910	Tl 9.8		6.3 (25°C)	27.4 (25°C)	29.7 (25°-100°C)		[460]
2911	Tl 10					.28 (63°C)	[459]
2912	Tl 20					.25 (63°C)	[459]
2913	Tl 24.7		5.1 (25°C)	33.5 (25°C)	22.3 (25°-100°C)		[460]
2914	Tl 30					.23 (63°C)	[459]
2915	Tl 39.60		4.6 (25°C)	37.5 (25°C)	19.8 (25°-100°C)		[450]
2916	Sn 8.5		9.1 (18.6°C)	18.9 (18.6°C)			[450]
2917	Sn 10					.36 (54°C)	[459]
2918	Sn 20					.37 (54°C)	[459]
2919	Sn 22.8		9.8 (13.0°C)	17.7 (16.0°C)			[460]
2920	Sn 29.8, Sb 1.92	Cast	8.6	20			[444]

2921	Sn 30	...	...	...	...	.38 (54°C)	[459]
2922	Sn 39.72, Sb 2.61	Cast	9.2	19	...	...	[441]
2923	Sn 40	...	...	...	...	.41 (54°C)	[459]
2924	Sn 44.8	Cast	10.5	16	...	...	[441]

[a] This value is alpha of the general equation. $R_t = R_0\ (1 + at)$.

[b] $\frac{R_{t°C}}{R_{0°C}}$ = 0.595 (−103.6°C).
.253 (−195.2°C).
.171 (−216.6°C).
.013 (−258.7°C).

[c] Temperature coefficient of thermal conductivity per °C −2.5 × 10^{-4} (0°–248°C).

IX. MAGNESIUM AND MAGNESIUM ALLOYS

TABLE 35.—*Classification of some magnesium 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
Army		Navy		ASTM		SAE No.	Dow metal	American Magnesium	Al	Mn	Zn	Others	
Spec	Alloy	Spec	Alloy	Spec	Alloy								
SAND-CASTINGS													
								244	4.0	0.3			
AN-QQ-M-56	A	AN-QQ-M-56	A	B 80-41T	4	50	H	265	6.0	.2	3.0		2975, 2977, 2978, 3030, 3031, 3032; figure 154.
								241	8.0	.1			2943.
AN-QQ-M-56	C	AN-QQ-M-56	C	B 80-41T	17	500	C	260	9.0	.1	2.0		2983, 2984, 2985.
				B 80-41T	14		P		10.0	.1	1.0		2987.
				B 80-41T	2		G	240	10.0	.1			2951, 2952, 2953, 3011, 3012, 3013.
				B 80-41T	3		B	246	12.0	.1			2958, 2959.
AN-QQ-M-56	B	AN-QQ-M-56	B	B 80-41T	11		M	403		1.5			2998, 3023; figure 156.
DIE-CASTINGS													
							EX		6.5	0.15		Si 0.1-0.3	2941.
11319[a]		46 M 11						241	8.0	.15			2944.
11319[a]		46 M 11		B 94-40T	12		K	230	10.0	.1		Si 0.5	2964.
11319[a]		46 M 11		B 94-40T	13	501	R	263	9.0	.2	0.6		2986.
FORGINGS													
				B 91-41T	18		FS		2.8	0.3	1.0		
							L		2.5	.2		Cd 3.5	2988.
11316[a]				B 91-41T	16			65S	3.5	.2		Sn 5.0	
		46 M 13	15	B 91-41T	15		X	74S	3.0	.2	3.0		2970.
11345[a]		46 M 13	8	B 91-41T	8		J	57S	6.5	.2	0.7		3033, 3034.
11321-A[a]		46 M 13	9	B 91-41T	9		O	58S	8.5	.2	0.5		3039.
		46 M 13	11				M	3S		1.5			
EXTRUDED BARS, RODS, AND SHAPES													
				B 107-41T	18	52	FS	52S	2.8	0.3	1.0		2968.
11337[a]		M-314C	15	B 107-41T	15	521	X	74S	3.0	.2	3.0		2971, 2972.
							F	53S	4.0	.3			2934, 2938, 3026, 3052; figure 152.
11335[a]		M-314C	8	B 107-41T	8	520	J	57S	6.5	.2	0.7		3029, 3035; figures 153 and 158.
				B 107-41T	9		O	58S	8.5	.2	0.5		2980, 2981.
							G	59S	10.0	.1			2949, 2950, 3045.
11336[a]		M-314C	11	B 107-41T	11		M	3S		1.5			3016, 3017; figure 156.
ROLLED PLATE, SHEET, AND STRIP													
11340[a]		17 M2	18	B 90-41T	18	52	FS	52S	2.7	0.3	1.0		
						510	F	53S	4.0	.3			2935, 2936.
				B 90-41T	7	511	E		6.5	.2			
11338[a]		17 M2	8	B 90-41T	8	520	J-1	57S	6.5	.2	0.7		3036.
11339[a]		17 M2	11	B 90-41T	11	51	M	3S		1.5			2999, 3000, 3001, 3048.

[a] Army Air Forces.

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 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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	PURE AND COMMERCIAL MAGNESIUM (SEE ALSO FIGS. 137 AND 138)												
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
2925..	Fe 0.008-0.01....	Extruded..............	....	....	....	22.2	11	9.0	....	36	....	....	[462]
2926..	...do...........	Extruded; 1/4 hr at 865°F, a-c.	....	....	....	17.0	3.0	2.1	....	......	....	....	[462]
2927..	Mg 99.9.........	....	6,400	....	....	....	....	....	....	......	....	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 ($4\sqrt{\text{area}}$)	....	....	......	....	....	[24]
2929..	...do...........	Rod, 1 in. diam, hot-rolled; ann 5 hr at 660°F.	6,000	....	19.3 (0.15% offset)	32.0	7.0 ($4\sqrt{\text{area}}$)	....	....	......	....	....	[24]
2930..	Fe 0.02, Si 0.02..	Rod, 1/2 in. square, extruded.	6,740	1.2	....	32.5	6.2 (8 in.)	4.4	7.8 (10^8)	41	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	....	30	....	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	....	35	....	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 (5×10^8)	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°-1,160°F.	[466]
2936..	...do...........	Annealed..............	6,500	....	22 (0.2% offset)	36	10 (2 in.)	....	10 (5×10^8)	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	2	Shear str..............14 kips/in.^{2}.... Specific gravity.......1.76. Melting range..........1,050°-1,160°F.	[466]
2938..	Al 4.40, Mn 0.26, 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 (10^8)	58	3.3	Compressive str........53.9 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 ($4\sqrt{\text{area}}$)	....	....	......	....	....	[24]
2940..	...do...........	Cold-rolled; ann 2 hr at 212°F.	6,200	12.5	37.0 (0.1% offset)	50.4	12 ($4\sqrt{\text{area}}$)	....	....	......	....	....	[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.	6,200	15.2	....	44.4	14 (8 in.)	17	15.0 (8×10^7)	65	2.9	Compressive str........50.9 kips/in.^{2}... Shear str..............21.4 kips/in.^{2} Mod-el (shear).........2,300 kips/in.^{2} Specific gravity.......1.79.	[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 (5×10^8)	48	2.2	Shear str..............18 kips/in.^{2}..... Specific gravity.......1.80. Melting range..........915°-1,120°F.	[466]
2944..	...do...........	Die-cast..............	6,500	....	17 (0.2% offset)	30	2.5 (2 in.)	....	....	53	....	....	[466]
2945..	Al 8.68, Fe 0.041, Cu 0.026, Si 0.023.	Billet, 7 in., cast....	5,900	6.9	....	28.0	4.0 (8 in.)	0	12.5 (10^7)	61	1.5	Compressive str........40.0 kips/in.^{2}... Shear str..............20.6 kips/in.^{2} Mod-el (shear).........2,400 kips/in.^{2} Specific gravity.......1.79.	[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	Compressive str........41.9 kips/in.^{2}... Shear str..............19.8 kips/in.^{2} Mod-el (shear).........2,300 kips/in.^{2} Specific gravity.......1.78.	[19]
2947..	Al 10,..........	Sheet, ann............	....	7.0	14.5 (0.25% extn)	44.0	3.5 (2 in.)	3.5	....	70	....	Shear str..............21.0 kips/in.^{2}...	[23]
2948..	...do...........	Sheet, rolled.........	....	4.0	13.0 (0.25% extn)	48.0	5 (2 in.)	5	....	71	....	Shear str..............21.0 kips/in.^{2}...	[23]
2949..	Al 10, Mn 0.1....	Extruded; stretched....	....	....	38.0 (0.2% perm)	50.0	10 (2 in.)	....	16.0 (5×10^8)	70	....	Shear str..............22.5 kips/in.^{2}...	[29]
2950..	...do...........	Extruded; stretched, h-t.	....	....	40.0 (0.2% perm)	56.0	3.5 (2 in.)	....	16.0 (5×10^8)	85	....	Shear str..............25.5 kips/in.^{2}...	[29]
2951..	Al 10, Mn >0.1, Si <0.5, Zn <0.3.	Cast..................	6,500	....	13 (0.2% offset)	22	2 (2 in.)	....	9 (5×10^8)	54	0.6	Compressive str........48 kips/in.^{2}..... Shear str..............18 kips/in.^{2} Specific gravity.......1.81. Melting range..........816°-1,100°F.	[466]
2952..	...do...........	Cast; h-t (T4).........	6,500	....	12 (0.2% offset)	35	9 (2 in.)	....	11 (5×10^8)	52	2	Compressive str........50 kips/in.^{2}..... Shear str..............20 kips/in.^{2}	[466]
2953..	...do...........	Cast; h-t and aged (T61)	6,500	....	19 (0.2% offset)	36	2 (2 in.)	....	9 (5×10^8)	69	0.7	Compressive str........54 kips/in.^{2}..... Shear str..............22 kips/in.^{2}	[466]
2954..	Al 10.08, Mn 0.65, Si 0.19, Cu 0.04.	Rolled; h-t...........	....	....	16.1	57.6	1.9	4.7	....	105	....	Compressive str........74.0 kips/in.^{2}... Shear str..............24.2 kips/in.^{2}	[467]
2955..	Al 10.63, Mn 0.71, Si 0.19, Cu 0.04, Fe 0.03.	Rolled................	....	....	13.0	19.1	11	20	....	85	....	Compressive str........68.3 kips/in.^{2}... Shear str..............21.3 kips/in.^{2}	[467]
2956..	Al 12...........	Sheet, ann............	....	8.0	15.5 (0.25% extn)	45.0	3 (2 in.)	3	....	82	....	Shear str..............22.0 kips/in.^{2}...	[23]
2957..	...do...........	Sheet, rolled.........	....	....	16.0 (0.25% extn)	53.0	3 (2 in.)	2	....	81	....	Shear str..............24.0 kips/in.^{2}...	[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 (5×10^8)	65	0.4	Shear str..............17 kips/in.^{2}..... Specific gravity.......1.82. Melting range..........816°-1,075°F.	[466]
2959..	...do...........	Cast; h-t and aged (T6)	6,500	....	20 (0.2% offset)	32	0.5 (2 in.)	....	7 (5×10^8)	85	0.5	Shear str..............19 kips/in.^{2}.....	[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 ($4\sqrt{area}$)	....	....	......	....	....	[24]
2961..	...do...........	Cold-rolled...........	6,200	16.5	46.6 (0.1% offset)	59.4	4.5 ($4\sqrt{area}$)	....	....	......	....	....	[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, 0.342.

TABLE 36.—*Magnesium and magnesium alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
MAGNESIUM-ALUMINUM-CADMIUM ALLOYS[a]—Continued													
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
2962..	Al 8, Cd 8.......	Cold-rolled; ann.......	6,200	18.5	41.2 (0.1% offset)	56.7	12 (4√area)	....	....	......	....	....	[24]
2963..	Al 8, Cd 8, Ag 2..	Forged; 2 hr at 770°F, w-q, aged 6 days at 265°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	Specific gravity...1.81................. Melting range......816°-1,100°F.	[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 x 10⁸)	50	3.2	Compressive str...60 kips/in.².......... Shear str.........19 kips/in.² Specific gravity..1.79.	[466]
2969..	Al 3, Zn 1.......	Cast...................	....	....	4.3 (0.02%) 7.8 (0.2%)	24.2	8	11	7.8	46	[b]1.0	Compressive str...39.3 kips/in.²........ Shear str.........15.7 kips/in.²	[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 x 10⁸)	59	....	Specific gravity..1.82.................	[466]
2971..	...do...........	Extruded..............	6,500	....	30 (0.2% offset)	42	19 (2 in.)	....	18 (5 x 10⁸)	51	....	Compressive str...72 kips/in.².......... Shear str.........20 kips/in.² Specific gravity..1.81.	[466]
2972..	...do...........	Extruded and aged......	6,500	....	34 (0.2% offset)	44	13 (2 in.)	....	17 (5 x 10⁸)	54	....	Compressive str...72 kips/in.².......... Shear str.........21 kips/in.²	[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	50	[b]0.5	Compressive str...46 kips/in.².......... Shear str.........18 kips/in.²	[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	45-50	....	Compressive str...44.8 kips/in.²........ Shear str.........20.2 kips/in.² Specific gravity..1.81-1.83.	[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	45-60	....	Compressive str...44.8-49.3 kips/in.².. Shear str.........17.9-20.2 kips/in.²	[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°-1,155°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%)	49.2	15 (10 diam)	21-30	....	73	a........	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	....	6.7 (0.02%) 15 (0.2%)	36	10 (10 diam)	12	13	60	b 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.)	....	....	59	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}..	[463]
					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-q 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]

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, 0.342.
b Notch impact value, m-kg/cm^2.

TABLE 36.—*Magnesium and magnesium alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
						MAGNESIUM-COPPER ALLOYS—Continued							
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
2993..	Cu 3............	Rod, 1 in. diam, hot-rolled.	....	....	21.3 (0.15% offset)	33.6	9.0 (4√area)	......	....	......	....	....	[24]
2994..	...do...........	Rod, 1 in. diam, hot-rolled; ann 5 hr at 660°F.	....	....	15.7 (0.15% offset)	26.2	3.0 (4√area)	......	....	......	....	....	[24]
2995..	Cu 4.0, Al 2.0, Cd 2.0, Si <0.5, Zn <0.3, Mn >0.15.	Sand-cast............	6,500	....	8.0 (0.2% perm)	24.0	6 (2 in.)	......	6.0 (5×10^8)	40	....	Compressive str......39.0 kips/in.²..... Specific gravity.....1.86. Melting range........1,050°-1,185°F.	[475]
2996..	Cu 9.65, Fe 0.04..	Rod, extruded from 2 15/16 in. to 3/4 in. diam at 350°-400°F.	6,400	14.2	....	39.0	3.0 (8 in.)	3.6	11.0 (10^8)	60	1.7	Compressive str......51.4 kips/in.²..... Shear str...........19.2 kips/in.² Specific gravity.....1.90.	[96]
2997..	Cu 13...........	Rod, 1 in. diam, hot-rolled.	6,600	7.4	....	39.0	2.5 (4√area)	......	....	......	....	....	[24]
						MAGNESIUM-MANGANESE ALLOYS[a]							
2998..	Mn 1.20, Si <0.3..	Cast...................	6,500	....	4.5 (0.2% offset)	14	5 (2 in.)	......	....	33	3.0	Compressive str......27 kips/in.²....... Shear str...........11 kips/in.² Melting point........1,200°F.	[466]
2999..	...do...........	Sheet, ann............	6,500	....	16 (0.2% offset)	32	16 (2 in.)	......	8 (5×10^8)	48	....	Shear str...........18 kips/in.²....... Specific gravity.....1.76.	[466]
3000..	...do...........	Sheet, hard-rolled.....	6,500	....	29 (0.2% offset)	37	10 (2 in.)	......	....	53	....	....	[466]
3001..	...do...........	Sheet, extruded........	6,500	....	30 (0.2% offset)	42	7 (2 in.)	......	8 (5×10^8)	42	2.1	Compressive str......53 kips/in.²....... Shear str...........18 kips/in.²	[466]
3002..	Mn 2.0, Ce 0.5...	Wrought...............	....	....	30.0 (0.2%)	38.5	20	28	12.8	60	[b] 1.2	Comp yld str (0.2%)..28.4 kips/in.²..... Compressive str......51.1 kips/in.² Shear str...........21.3 kips/in.²	[463]
3003..	Mn 2.5..........	Sheet, ann............	6,000	....	13.4-17.9 (0.1%)	26.9-33.6	7-10	20	11.2	40	....	Compressive str......40.3-44.8 kips/in.².. Shear str...........17.9 kips/in.²....	[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.	....	11.4	15.5 (0.025% perm)	33.6	4.3 (2 in.)	5.3	....	49	....	Specific gravity.....1.77...............	[474]
3005..	...do...........	Rod, forged and rolled from 2 1/2 in. to 7/8 in. diam at 660°-840°F.	....	12.8	18.8 (0.025% perm)	38.5	6.0 (2 in.)	6.9	....	50	....	....	[474]
3006..	...do...........	Rolled; quenched from 840°F.	....	12.1	17.7 (0.025% perm)	36.5	8.0 (2 in.)	7.1	....	46	....	....	[474]
						MAGNESIUM-SILICON ALLOYS (SEE ALSO FIG. 146)							
3007..	Si 1.3, Mn 0.3...	Cast...................	....	....	7-9 (0.2%)	14-18	2-4 (10 diam)	4-7	....	41-46	[b] 0.45	Compressive str......31 kips/in.²....... Shear str...........14-16 kips/in.²....	[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.)	....	....	45	....	....	[129]
3011..	...do...........	Extruded; 1 hr at 940°F, w-q, 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................	....	....	10.1	37.4	16	31	....	55	....	Compressive str.........53.1 kips/in.^{2}.. Shear str..............18.1 kips/in.^{2}	[467]
3014..	Zn 4.38, Cu 0.22, Al 0.15, Si 0.14.	Rod, 1 in. diam, hot-rolled.	6,100	10.1	32.3 (0.15% offset)	39.6	13 ($4\sqrt{\text{area}}$)	....	....	......	....	....	[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 ($4\sqrt{\text{area}}$)	....	....	......	....	....	[24]
MAGNESIUM-ZIRCONIUM ALLOY													
3016..	Zr 0.5..........	Sand-cast.............	....	....	$\left\{\begin{matrix}6.3\\(0.02\%)\\8.5\\(0.2\%)\end{matrix}\right\}$	24.2	18	19	4.3	38	[b] 0.85	....	[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, 0.342.
[b] Notch impact value, m-kg/cm^2.

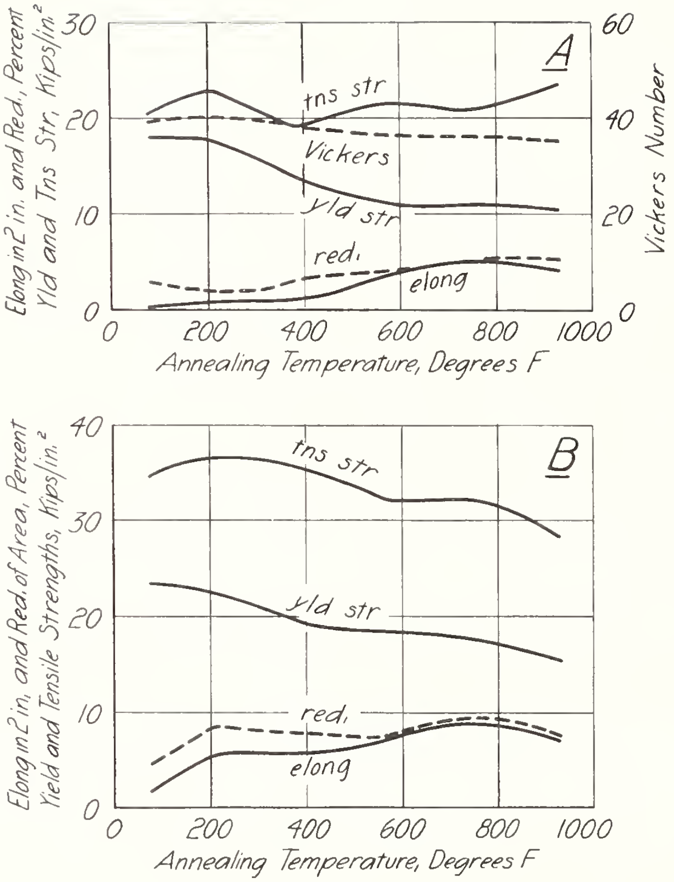


FIGURE 137.—*Effect of annealing on the tensile properties and hardness of cold-rolled magnesium (Jones and Powell [681]).*

(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.

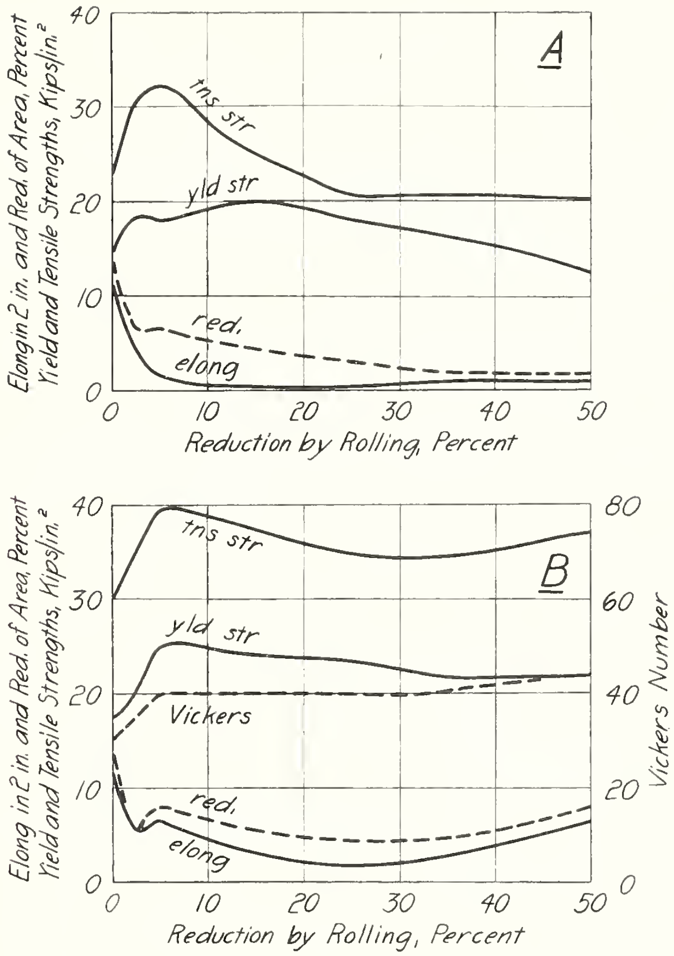


FIGURE 138.—*Effect of cold-rolling on the tensile properties and hardness of magnesium (Jones and Powell [681]).*

(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.

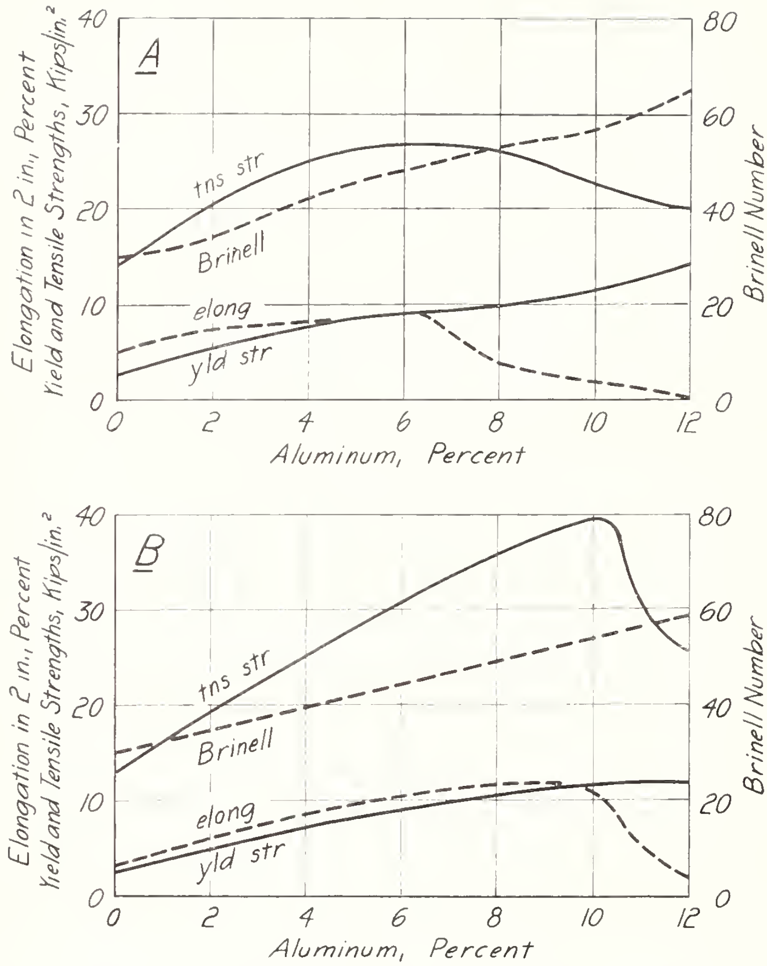


FIGURE 139.—*Tensile properties and hardness of magnesium-aluminum alloys containing small amounts of manganese (Wood [682]).*

(Yield strength, 0.2% offset)

Mn 0.1-0.3%. A, Sand-cast; B, sand-cast and solution heat-treated.

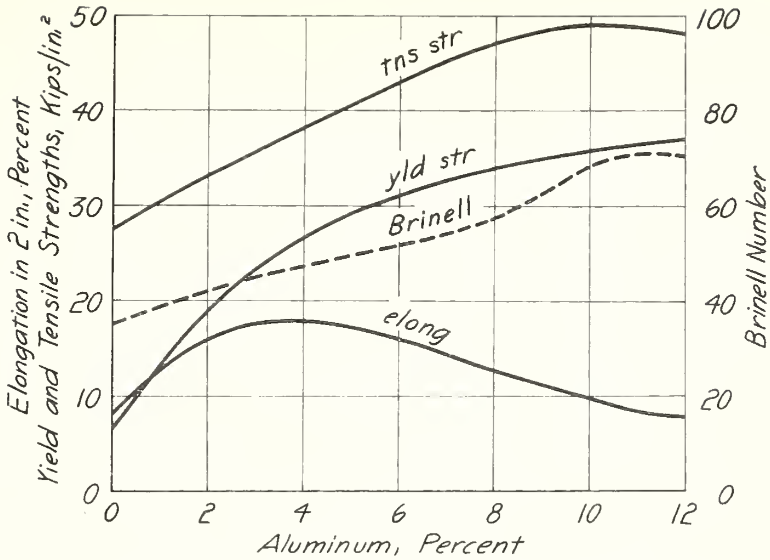


FIGURE 140.—*Tensile properties and hardness of extruded magnesium-aluminum alloys containing small amounts of manganese (Wood [682]).*

(Yield strength, 0.2% offset)

Mn 0.1-0.3%.

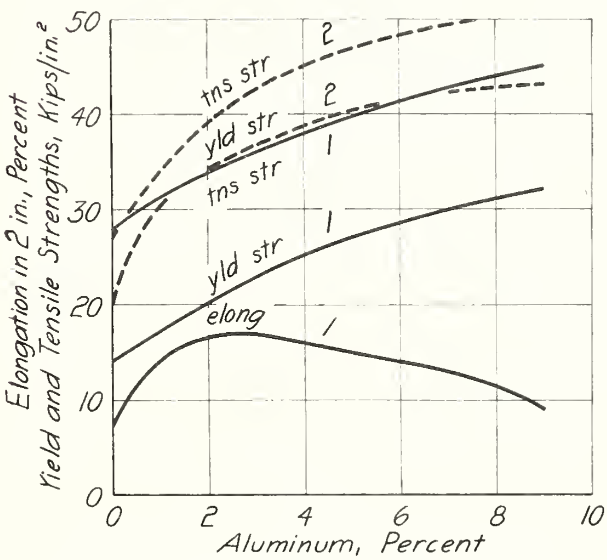


FIGURE 141.—*Tensile properties of rolled magnesium-aluminum alloys (McDonald [683]).*

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

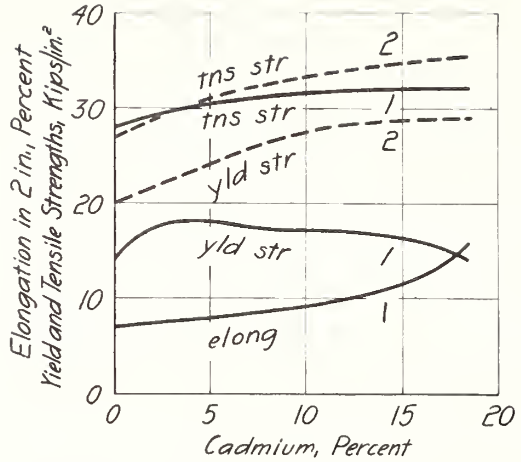


FIGURE 142.—*Tensile properties of rolled magnesium-cadmium alloys (McDonald [683]).*

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

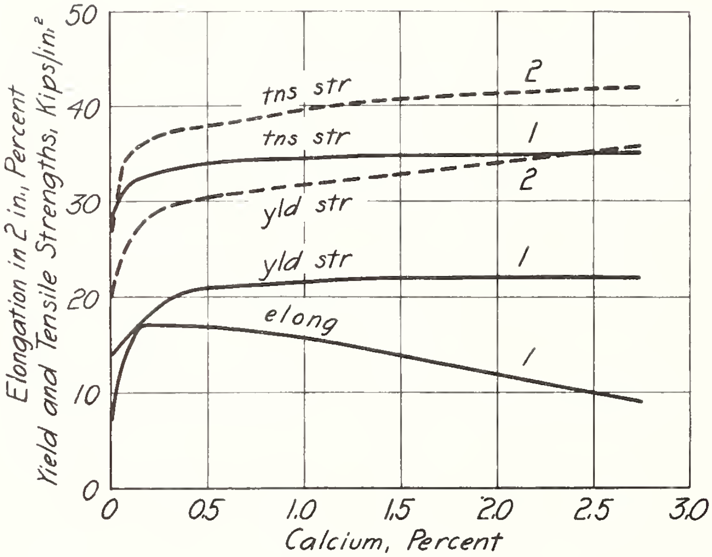


FIGURE 143.—*Tensile properties of rolled magnesium-calcium alloys (McDonald [684]).*

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

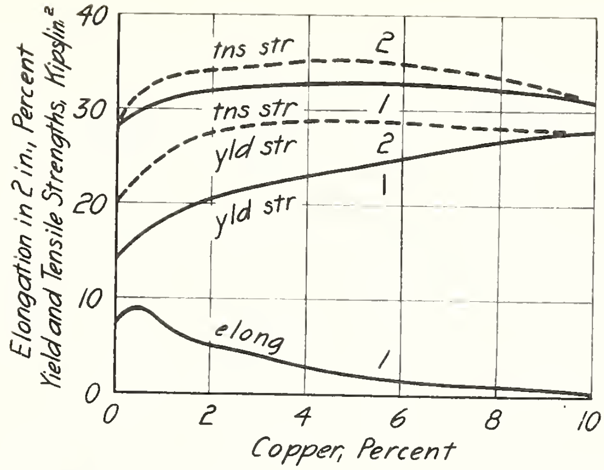


FIGURE 144.—*Tensile properties of rolled magnesium-copper alloys (McDonald [683]).*

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

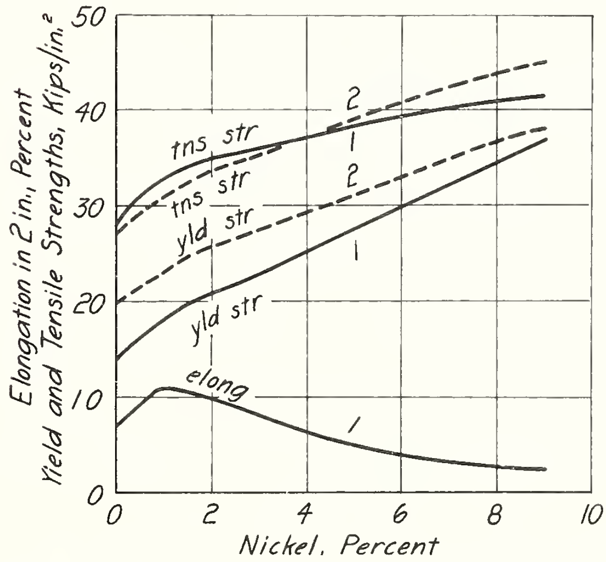


FIGURE 145.—*Tensile properties of rolled magnesium-nickel alloys (McDonald [683]).*

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

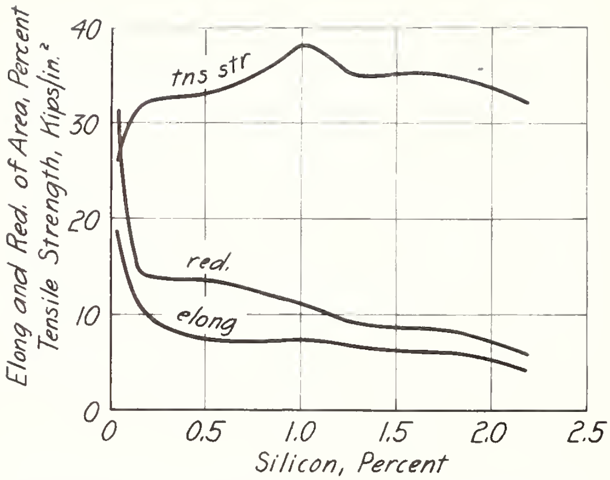


FIGURE 146.—*Tensile properties of extruded magnesium-silicon alloys (Aitchison [685]).*

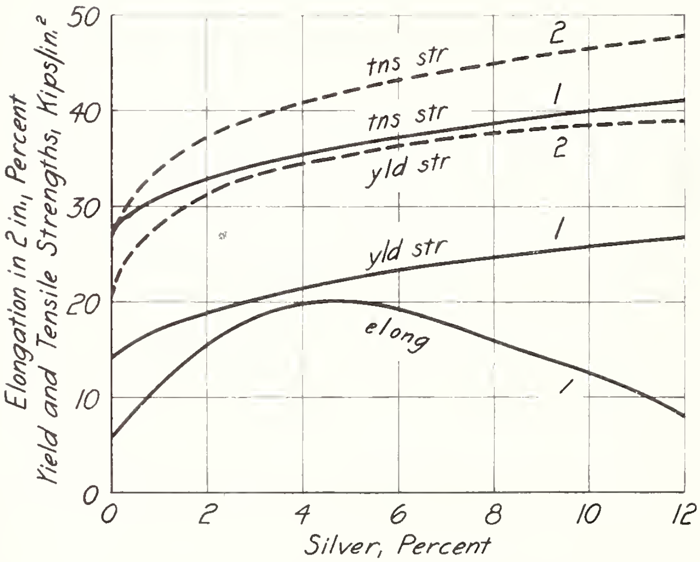


FIGURE 147.—*Tensile properties of rolled-magnesium-silver alloys (McDonald [683]).*

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

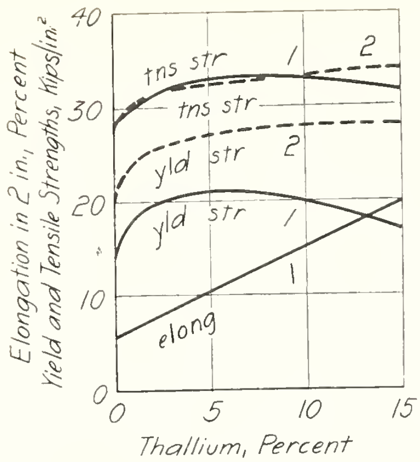


FIGURE 148.—*Tensile properties of rolled magnesium-thallium alloys (McDonald [683]).*

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

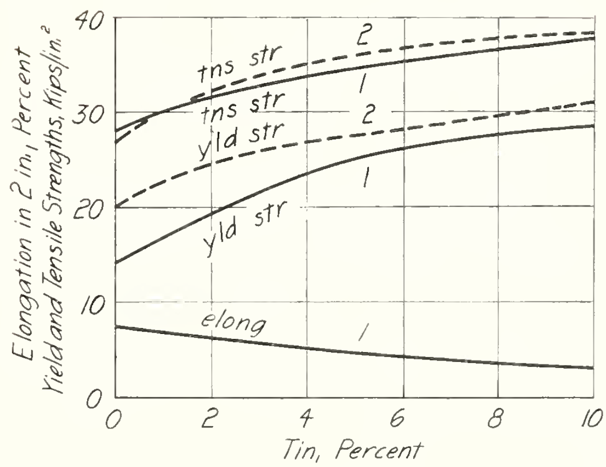


FIGURE 149.—*Tensile properties of rolled magnesium-tin alloys (McDonald [683]).*

Curves: 1, annealed to maximum ductility; 2, cold-rolled to maximum yield strength.

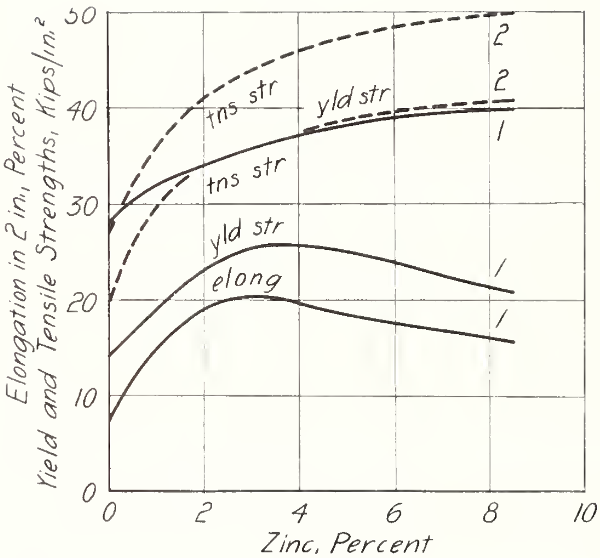


FIGURE 150.—*Tensile properties of rolled magnesium-zinc alloys (McDonald [683]).*

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	
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Kips/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	22.4	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	3.4	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]

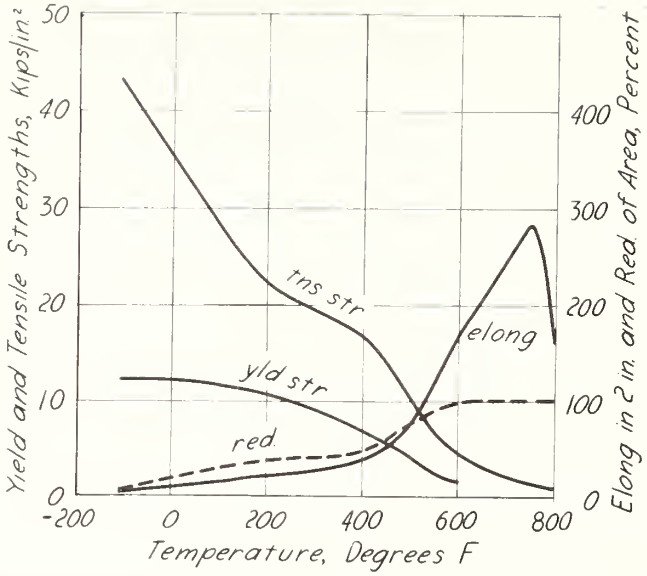


FIGURE 151.—*Short-time tensile properties of extruded magnesium at various temperatures (Templin and Paul [477]).*

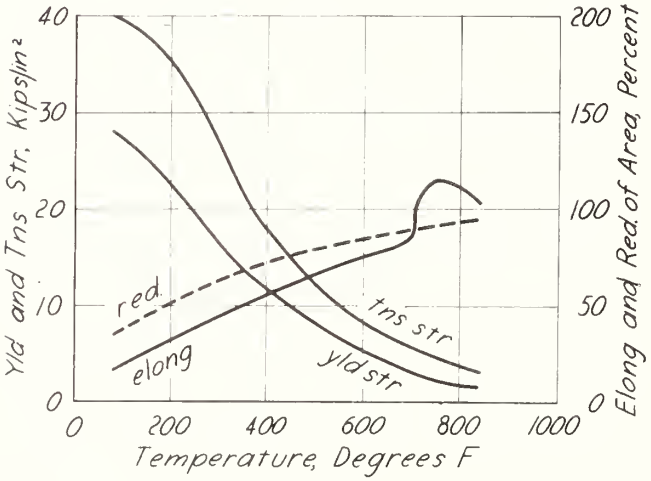


FIGURE 152.—*Short-time tensile properties of an extruded magnesium-aluminum alloy at high temperatures (Templin and Paul [477]).*

(Yield strength, 0.5% extn)

Al 4%, Mn 0.3%.

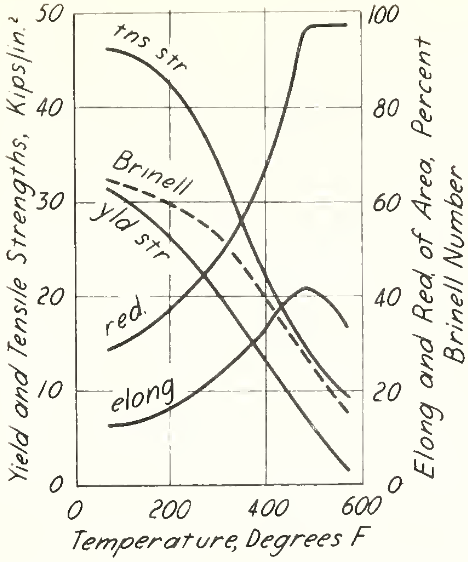


FIGURE 153.—*Short-time tensile properties and hardness of a wrought magnesium-aluminum-zinc alloy at high temperatures (Vosskuhler [686]).*

(Yield strength, 0.2%)
Al 6%, Zn 1%.

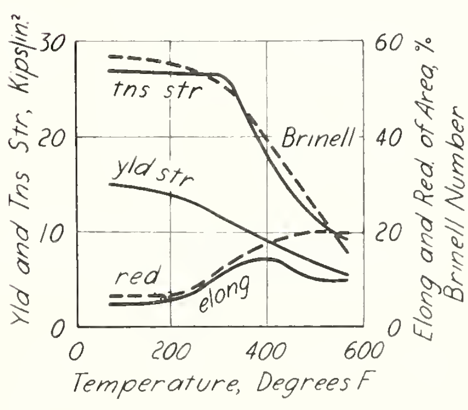


FIGURE 154.—*Short-time tensile properties and hardness of a sand-cast magnesium-aluminum-zinc alloy at high temperatures (Vosskuhler [686]).*

(Yield strength, 0.2%)

Al 6%, Zn 3%.

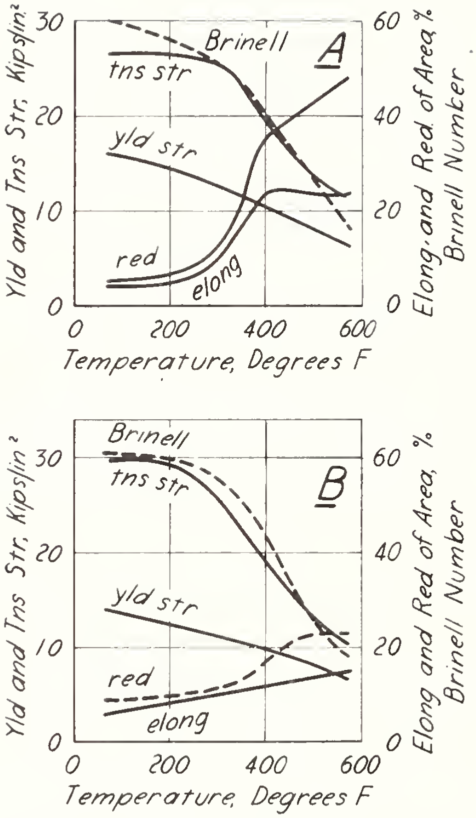


FIGURE 155.— *Short-time tensile properties and hardness of a magnesium-aluminum-zinc alloy at high temperatures (Vosskuhler [686]).*

(Yield strength, 0.2%)

Al 8%, Zn 0.5%. A, Sand-cast; B, die-cast.

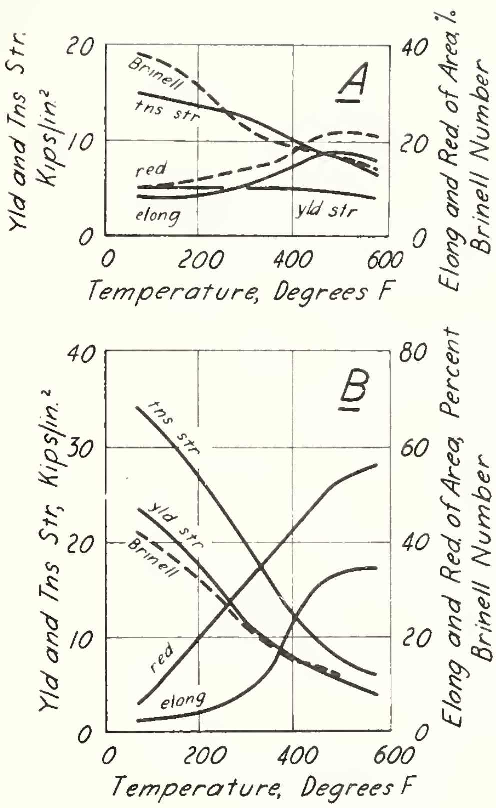


Figure 156.—*Short-time tensile properties and hardness of a magnesium-manganese alloy at high temperatures (Vosskuhler [686]).*

(Yield strength, 0.2%)

Mn 2%. A, Sand-cast; B, wrought.

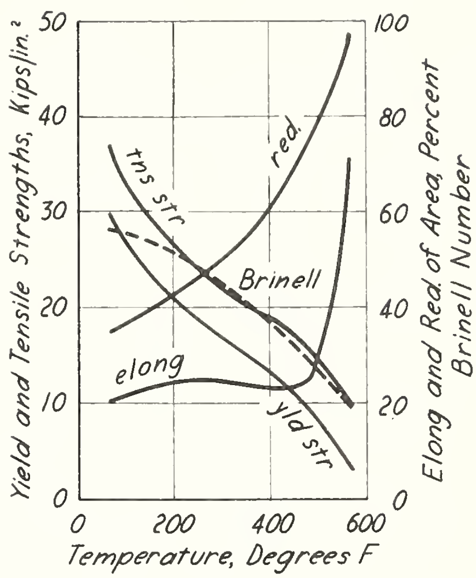


Figure 157.—*Short-time tensile properties of a wrought magnesium-manganese-cerium alloy at high temperatures (Vosskuhler [686]).*

(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_B, 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: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Remarks	Reference
			PURE AND COMMERCIAL MAGNESIUM (SEE ALSO FIG. 151)									
	Percent		°F	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
3025....	"Pure" Mg..............	Extruded..................	75	11.7	29.0	15 (2 in.)	24	....	......	....	....	[477]
			-112	12.0	43.0	7 (2 in.)	8	....	......	....		
			MAGNESIUM-ALUMINUM ALLOYS (SEE ALSO FIG. 158)									
3026....	Al 4, Mn 0.4............	Extruded..................	75	17.5 (0.1% offset)	37.7	20 (2 in.)	33	....	......	....	....	[477]
			-112	20.2 (0.1% offset)	43.1	6.2 (2 in.)	5.6	....	......	....		
3027....	...do..................	Forged....................	75	20.3 (0.1% offset)	34.3	6.0 (2 in.)	5.7	....	......	....	....	[477]
			-112	20.8 (0.1% offset)	38.7	2.3 (2 in.)	1.7	....	......	....		
3028....	...do..................	Chill-cast; h-t............	75	6.4 (0.1% offset)	26.9	10 (2 in.)	10	....	......	....	....	[477]
			-112	7.3 (0.1% offset)	23.4	5.5 (2 in.)	5.1	....	......	....		
3029....	Al 5.8, Zn 1.00, Mn 0.22, Fe 0.06.	Rod, 1/2 in. square, extruded at 750°F.	Room	34.0	47.0	13	11-23	....	R_E 74	6-9	Impact specimen, Charpy bar with Izod notch.	[25]
			-40	....	....	....	......	....	R_E 76	4		
			-105	41.0	50.5	12	14-18	....	R_E 80	3		
3030....	Al 6.3, Zn 2.70, Mn 0.28, Fe 0.02.	Rod, 5/8 in. diam, sand-cast..	Room	14.0	27.0	5	5.5	....	R_E 58	2	...do..........................	[25]
			-40	....	....	....	......	....	R_E 63	2		
			-105	15.5	25.0	3	4.5	....	R_E 68	1.5		
3031....	...do..................	Rod, 5/8 in. diam, sand-cast; 4 hr at 630°F, 16 hr at 720°F, a-c.	Room	14.0	35.0	8.5	10	....	R_E 59	4	...do..........................	[25]
			-40	....	....	....	......	....	R_E 62	3.8		
			-105	17.0	37.0	8	10	....	R_E 68	3.5		
3032....	...do..................	Rod, 5/8 in. diam, sand-cast; 4 hr at 630°F, 16 hr at 715°F, hot w-q, aged 16 hr at 350°F.	Room	22.0	39.0	3-6	5.5	....	R_E 76	1.8	...do..........................	[25]
			-40	....	....	....	......	....	R_E 81	1.5		
			-105	24.5	35.5	2.5	3.5	....	R_E 84	1.5		
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....	Room	26.0 (0.2% offset)	46.0	12 (4 diam)	18	15.0 (3×10^8)	......	....	....	[31]
			-40	....	....	....	......	18.0 (3×10^8)	......	....		
3034....	Al 6.5, Zn 0.8, Mn 0.20..	Forged....................	Room	29.0 (0.2% offset)	43.0	8.5 (4 diam)	10	15.0 (3×10^8)	63	Iz 5.5	Impact specimen 0.5 x 0.5 in. square, V-notch.	[31]
			-40	....	39.0	....	......	16.0 (3×10^8)	63	Iz 4.7		
3035....	Al 6.86, Zn 0.97, Mn 0.18, Cu 0.04, Fe 0.04, Si 0.027.	Extruded..................	68	33.4 (0.2%)	15.8	13 (10 diam)	......	21.3	......	....	....	[26]
			-31	....	....	....	......	21.7	......	....		
			-85	....	....	....	......	22.0	......	....		

3036....	Al 6.92, Zn 0.91, Mn 0.23, Fe 0.045, Cu 0.04, Si 0.04.	Sheet, 1/16 in.	68	30.2 (0.2%)	44.1	17	......	....	.....	[a]0.36	....	[26]
			-31	....	....	....	......	....	.....	[a].34		
			-85	....	....	....	......	....	.....	[a].29		
3037....	Al 7.0, Mn 0.4	Sand-cast; h-t	75	8.1 (0.1% offset)	31.3	9.7 (2 in.)	8.6	....	.....	....	....	[477]
			-112	9.0 (0.1% offset)	30.9	6.8 (2 in.)	7.3	....	.....	....		
3038....	Al 8.83, Mn 0.23, Fe 0.01.	Bar, 2 in., extruded	Room	....	....	....	......	....	.....	Iz 5	Impact specimen 0.5 x 0.5 in. square, V-notch.	[25]
			-40	....	....	....	......	....	.....	Iz 3.5		
3039[b]...	Al 8.86, Zn 0.51, Si 0.40, Mn 0.24.	Forged	Room	38.0 (0.2% offset)	48.0	8.5 (4 diam)	12	....	74	Iz 3	...do	[31]
			-40	40.0 (0.2% offset)	58.0	7 (4 diam)	7	....	78	Iz 2		
3040....	Al 10.08, Mn 0.65, Si 0.19, Cu 0.04.	Extruded; h-t	60	....	....	....	......	....	.....	1.4	....	[477]
			-5	....	....	....	......	....	.....	1.2		
			-60	....	....	....	......	....	.....	1.2		
3041....	Al 10.5, Mn 0.24, Fe 0.02.	Rod, 5/8 in. diam, sand-cast..	Room	16.0	22.5	2	2	....	R_E 69	1	Impact specimen, Charpy bar with Izod notch.	[25]
			-40	....	....	....	......	....	R_E 76	0.8		
			-105	18.0	22.0	1	1.5	....	R_E 76	.8		
3042....	...do	Rod, 5/8 in. diam, sand-cast; 16 hr at 770°F, a-c.	Room	15.0	35.0	8	9.5	....	R_E 65	3	...do	[25]
			-40	....	....	....	......	....	R_E 72	2.8		
			-105	18.5	38.5	7	8.5	....	R_E 73	2.5		
3043....	...do	Rod, 5/8 in. diam, sand-cast; 16 hr at 770°F, aged 16 hr at 350°F.	Room	24.0	38.0	3	2-4	....	R_E 83	1	...do	[25]
			-40	....	....	....	......	....	R_E 90	1		
			-105	26.0	39.0	2	2.5	....	R_E 90	0.5-1		
3044....	Al 10.63, Mn 0.71, Si 0.19, Cu 0.04, Fe 0.03.	Extruded	50	....	....	....	......	....	.....	3.3	....	[477]
			-5	....	....	....	......	....	.....	2.3		
			-60	....	....	....	......	....	.....	2.1		
3045....	Al 10.75, Mn 0.17, Si 0.09, Fe 0.03.	...do	50	....	....	....	......	....	.....	4.9	....	[477]
			-5	....	....	....	......	....	.....	3.5		
			-60	....	....	....	......	....	.....	3.2		

MAGNESIUM-MANGANESE ALLOYS

3046....	Mn 1.6, Al 0.02, Fe 0.01..	Rod, 1/2 in. square, extruded at 750°F.	Room	28.0	39.0	3.5-9.5	3-10	....	R_E 30	3.5-4	Impact specimen, Charpy bar with Izod notch.	[25]
			-40	....	....	....	......	....	R_E 54	2-3.5		
			-105	31.0	52.0	3	3.5-6	....	R_E 66	1.5-3.5		
3047....	Mn 1.72, Zn 0.032, Al 0.022, Cu 0.006, Si 0.005.	Extruded	68	26.0 (0.2%)	41.4	4.1 (10 diam)	......	10.7	.....	....	....	[26]
			-31	....	....	....	......	11.7	.....	....		
			-85	....	....	....	......	13.2	.....	....		
3048....	Mn 1.89, Fe 0.02, Cu 0.01, Si 0.004.	Sheet, 1/16 in.	68	13.1 (0.2%)	26.5	3.9	......	....	.....	[a]0.54	....	[26]
			-31	....	....	....	......	....	.....	[a]0.53		
			-85	....	....	....	......	....	.....	[a]0.47		

MAGNESIUM-ZINC ALLOY

3049....	Zn 1.0, Mn 1.5, Al 0.02, Fe 0.02.	Rod, 1/2 in. square, extruded at 750°F.	Room	33.0	44.0	15	30-38	....	R_E 71	9	Impact specimen, Charpy bar with Izod notch.	[25]
			-40	....	....	....	......	....	R_E 72	6.5		
			-105	45.0	51.5	12	22	....	R_E 78	4.5-5.5		

[a] Notch impact value, m-kg/cm^2.
[b] Modulus of elasticity, 6,400 kips/in.^{2} (room); 6,300 kips/in.^{2} (-40°F).

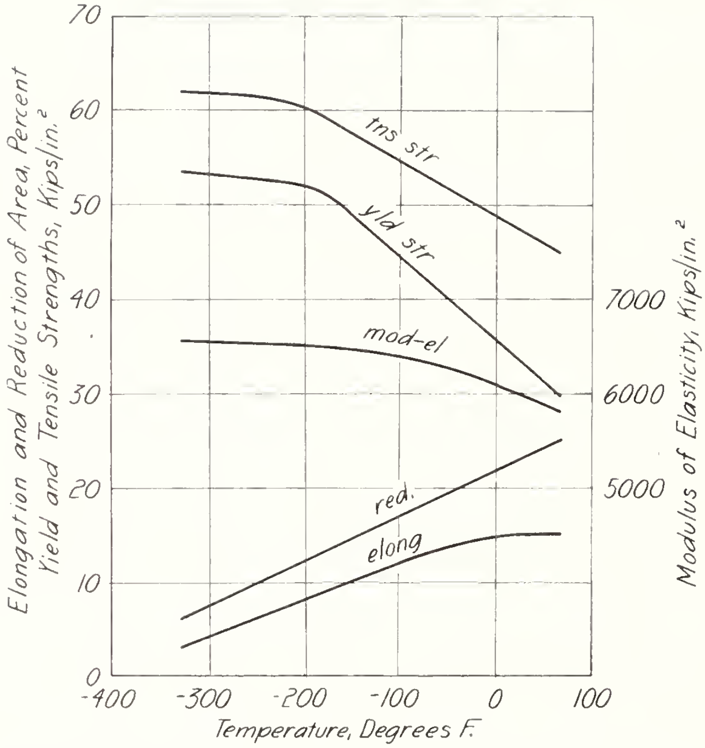


FIGURE 158.—*Tensile properties of a wrought magnesium-aluminum-zinc alloy at low temperatures (Beck [463]).*

(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: 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	Reference
	Percent		$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	
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 390°C	24.9	25.6	26.4	27.2				[478]
3053	Al 4.36, Fe 0.018, Cu 0.007, Si 0.004	Extruded at 350°C	25.5	25.8	26.9	27.8				[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				[478]
3055	Al 10.35, Fe 0.040, Cu 0.016, Si 0.016	...do	24.9	25.9	27.2	[c]28.3				[478]
3056[d]	Al 14		24.4	24.9	26.4	27.9	28.2			[479]
3057[d]	Al 30		22.9	23.7	25.1	26.6	28.1			[479]
3058[d]	Al 43		21.0	21.8	23.5	25.4	27.7			[479]
3059[d]	Al 4, Cd 1, Sn 1, Zn 1		24.2	25.0	26.3	27.6				[479]
3060[d]	Al 5, Cd 3, Zn 3, Mn 0.4		24.6	25.4	27.2	28.4				[479]
3061[d]	Al 8.5, Cu 2, Cd 1, Zn 0.5, Mn 0.15		24.8	25.4	26.6	27.7				[479]
3062	Al 4, Zn 3	Sand-cast		26.2	27.5	28.0				[463]
3063	Al 6, Zn 3	...do		26.4	27.6	28.3				[463]
3064	Al 8.5, Zn 0.5	...do		26.8	28.1	28.7				[463]
3065[d]	Cd 2		24.1	24.9	26.3	27.5				[479]
3066[d]	Cd 6		24.2	25.0	26.4	27.5				[479]
3067[d]	Cu 2		25.0	25.4	26.7	27.9	28.9			[479]
3068[d]	Cu 6		24.8	25.2	26.4	27.6	28.6			[479]
3069[d]	Cu 10		23.7	24.7	26.1	27.3	28.4			[479]
3070[d]	Cu 4, Al 2, Cd 2, Mn 0.2		24.0	24.7	26.1	27.4				[479]
3071	Mn 0.91, Fe 0.020, Al 0.01, Si 0.004, Cu 0.003	Cast at 670°C	26.0	26.3	27.2	27.9				[478]
3072[d]	Ni 2		24.0	24.7	26.4	27.6				[479]
3073[d]	Ni 6		24.0	24.6	25.9	26.9				[479]
3074	Si 1	Sand-cast		26.1	26.9	27.6				[463]
3075	Si 2	Cast		25.2						[463]
3076	Si 6	...do		23.7						[463]
3077	Si 10	...do		22.6						[463]
3078[d]	Ag 2		24.4	25.1	26.4	27.8				[479]
3079[d]	Ag 6		24.2	24.9	26.1	27.4				[479]
3080[e]	Sn 4.7	Annealed	25.0	25.1	25.8	25.9	26.0	26.0	[f]26.6	[480]
3081[e]	Sn 9.1	...do	26.2	25.5	26.1	26.1	25.7	24.4	[f]24.5	[480]
3082[e]	Sn 13.1	...do	24.4	24.0	24.8	24.9	24.8	23.2	[f]22.6	[480]
3083[e]	Sn 20.4	...do	25.2	24.3	24.8	24.7	24.4	22.8	[f]21.8	[480]
3084[e]	Sn 35.2	...do	22.1	22.6	22.8	22.5	21.6	21.1	[f]20.8	[480]
3085[e]	Sn 46.3	...do	21.2	21.1	21.3	21.3	20.7	20.1	[f]19.8	[480]
3086[d]	Zn 2		24.7	25.5	26.9	28.2				[479]
3087[d]	Zn 4, Cu 0.5		25.0	25.8	27.1	28.1				[479]
3088[d]	Zn 6		24.7	25.2	26.7	27.8				[479]
3089	Zn 12	Cast and h-t		26.0						[463]
3090	Zn 15	...do		25.7						[463]
3091[g]	Zn 20			29.5						[481]
3092[g]	Zn 50			30.2						[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 40.—*Magnesium and magnesium alloys, electrical and thermal properties*

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal conductivity	Reference
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10^{-4}*	*Watts cm^{-1} $°C^{-1}$*	
3093	Mg				10 (20°C) 50 (25°C) 15 (100°C) 35 (500°C) 100 (600°C)	1.57 (18°C)	[464]
3094	...do		44.1 (0°C) 39.9 (18°C) 31.0 (100°C) 23.7 (203°C) 16.3 (325°C) 13.1 (456°C)	3.91 (0°C) 4.33 (18°C) 5.56 (100°C) 7.27 (203°C) 10.6 (326°C) 13.2 (456°C)		1.72 (0°C) 1.60 (18°C) 1.67 (100°C) 1.63 (203°C) 1.29 (326°C) 1.31 (456°C)	[482]
3095	Commercial Mg	Cast	38.4-39.5 (20°C)	4.36-4.49 (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 4, Zn 3	Sand-cast	16.1-16.4	10.5-10.7	14.7-15.4 (0°-100°C)	0.94	[463]
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 190°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) .59 (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	...	26.3 (20°C)	6.54 (20°C)	...	...	[463]
3115	Pb 9.9	...	15.0 (20°C)	11.5 (20°C)	...	...	[463]
3116	Mn 2.64	Rod, 9/16 in. diam, hot-forged	35.2 (20°C) 31.9 (50°C) 24.1 (150°C) 19.4 (250°C)	4.9 (20°C) 5.4 (50°C) 7.15 (150°C) 8.9 (250°C)	...	... 1.38 (50°C) 1.42 (150°C) 1.42 (250°C)	[482]
3117	Mn 3.5	Die-cast	...	...	...	1.02	[463]
3118	Ni 2	Vacuum ann	...	...	...	1.36	[463]
3119	Ni 5.36, Ce 2.65	Rod, 9/16 in. diam, hot-forged	31.9 (20°C) 29.2 (50°C) 22.4 (150°C) 17.8 (250°C)	5.4 (20°C) 5.9 (50°C) 7.7 (150°C) 9.7 (250°C)	...	... 1.30 (50°C) 1.30 (150°C) 1.30 (250°C)	[482]
3120	Ni 5.56	...do	36.7 (20°C) 33.2 (50°C) 24.6 (150°C) 19.7 (250°C)	4.7 (20°C) 5.2 (50°C) 7.0 (150°C) 8.75 (250°C)	...	... 1.42 (50°C) 1.42 (150°C) 1.46 (250°C)	[482]
3121	Si 1	Sand-cast	33.2-36.3 (20°C)	4.75-5.20 (20°C)	32.7-41.2 (0°-100°C)	1.52	[463]
3122	Si 1.25	...	35.0 (20°C)	4.93 (20°C)	...	...	[463]
3123	Si 3.7	...	31.0 (20°C)	5.56 (20°C)	...	...	[463]
3124	Ag 2.2	Vacuum ann	...	...	...	1.31	[463]
3125	Ag 2.5	...	35.0 (20°C)	4.93 (20°C)	...	...	[463]
3126	Ag 6	Vacuum ann	...	...	...	1.15	[463]
3127	Ag 7.7	...	29.7 (20°C)	5.81 (20°C)	...	...	[463]
3128	Sn 2.2	Vacuum ann	...	...	...	1.06	[463]
3129	Sn 6.4	...do	...	...	...	0.74	[463]
3130	Zn 2.1	...do	...	...	...	1.25	[463]
3131	Zn 2.2	...	32.2 (20°C)	5.35 (20°C)	...	...	[463]
3132	Zn 6.1	Vacuum ann	...	...	...	1.09	[463]
3133	Zn 6.2	...	26.2 (20°C)	6.58 (20°C)	...	...	[463]
3134	Zn 9.0	...	24.3 (20°C)	7.10 (20°C)	...	...	[463]

X. NICKEL AND NICKEL ALLOYS

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														
....	....	B160-41T...	....	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.
QQ-N-281....	A	B164-41T...	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.
QQ-N-281....	B	B164-41T...	B	"R" monel.........	67	30	1.7	1.1	.1	.05	.035	....	....	3198, 3199, 3200.
QQ-N-286....	....	....	....	"K" monel.........	66	29	0.9	0.85	.15	.5	.005	....	2.75	3195, 3196, 3197, 3288, 3330, 3331; figure 171.
....	....	....	....	"KR" monel........	66	29	.9	.85	.3	.5	.005	....	2.75	3256.
....	....	B166-41T...	....	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].25	[b]1.0	[b].030	20	....	3168, 3169, 3170, 3236, [d]3250, 3269, 3271, 3325 and 3326; figures 168 and 169.
....	....	B83-41.....	....	Resistance alloy...	[c]57	....	rem	[b]3.0	[b].25	[b]1.0	[b].030	16	....	[d]3249, 3336, 3340, 3341.
....	....	....	....	Alumel[e]...........	94	....	0.5	2.5	....	1.0	....	....	2.0	3312 and 3313.
....	....	....	....	Chromel P[e]........	90	....	....	....	....	....	....	10	....	3157, 3266, 3318, 3319.
....	....	....	....	Constantan[e].......	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].25	[b]1.0	[b].030	16	....	[d]3208, [d]3268.

[a] Includes small amount of cobalt.
[b] Maximum.
[c] Minimum.
[d] Approximate composition.
[e] Thermocouple 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 (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 NICKEL (SEE ALSO FIGS. 159 TO 162 INCLUSIVE)													
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
3135..	Ni 99.99.........	Unfused 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	....	107	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	....	177	204	Comp yld str (0.01%)....44.8 kips/in.².... Comp yld str (0.2%).....58.4 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	....	110	....	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.)	....	....	R_B 45	....	....	[483]
3140..	Ni + Co 99.4......	Wrought..............	30,000	....	....	....	....	....	....	....	....	Mod-el (shear)..........11,000 kips/in.².. Specific gravity........8.85.	[486]
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	....	R_B 67	....	Mod-el (shear)..........11,300 kips/in.².. Poisson's ratio.........0.359.	[131]
3142..	...do............	Rod, ann 4 hr at 1,400°F.	31,100	19.7	26.8 (yld pnt)	76.8	48 (2 in.)	76	....	R_B 60	....	Mod-el (shear)..........11,000 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	10 (2 in.)	....	25.0 (10^8)	R_B 55	....	....	[20]
3144..	...do............	Sheet, 0.020 in., rolled (37% red.).	27,000	51.5	....	114	2.3 (2 in.)	....	39.5 (10^8)	R_B 95	....	....	[20]
3145..	...do............	Sheet, 0.020 in., rolled (60% red.).	30,300	52.0	....	122	2.0 (2 in.)	....	40.5 (10^8)	R_B 100	....	....	[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.	....	69.0	104 (0.01% perm)	166	14 (2 in.)	22	40.0	302	....	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	....	174	Iz 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)..........11,000 kips/in.^{2}.. Poisson's ratio.........0.31.	[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; ann 2 hr at 1,650°F, slowly cooled.	30,000	20.2	32.9 (0.01% offset)	81.8	38 (4 $\sqrt{area}$)	....	....	....	....	....	[24]
3152..	Al 1.78, Mn 0.26, C 0.17, Fe 0.07, Si 0.05.	...do..................	30,100	13.4	26.7 (0.01% offset)	87.6	43 (4 $\sqrt{area}$)	....	....	....	....	....	[24]

NICKEL-BERYLLIUM ALLOYS

3153..	Be 2.0...........	Quenched.............	24,900	....	52.0	114	38 (2 in.)	....	....	140	....	....	[111]
3154..	...do............	Quenched; aged 5 hr at 895°F.	26,000	....	142	191	8.4 (2 in.)	....	....	365	....	....	[111]
3155..	...do............	Cold-rolled (50% red.)	25,600	....	144	179	1.1 (2 in.)	....	....	350	....	....	[111]
3156..	...do............	Cold-rolled; h-t......	27,000	....	238	270	8.8 (2 in.)	....	....	480	....	....	[111]

NICKEL-CHROMIUM ALLOYS (SEE ALSO FIG. 163)

3157..	Chromel P: Cr 10..	Wrought..............	....	....	....	80	30	....	....	....	....	....	[2]
3158..	Ni 80, Cr 13, Fe rem.	Sheet, ann...........	31,000	....	....	78.4	....	....	....	....	....	Shear str..............56.0 kips/in.^{2}.... Mod-el (shear)..........11,000 kips/in.^{2} Poisson's ratio.........0.29.	[489]
3159..	...do............	Sheet, half-hard......	31,000	....	....	98.6	....	....	....	....	....	Shear str..............67.2 kips/in.^{2}.... Mod-el (shear)..........11,000 kips/in.^{2} Poisson's ratio.........0.29.	[489]
3160..	...do............	Sheet, hard..........	31,000	....	....	152	....	....	....	....	....	Shear str..............82.9 kips/in.^{2}.... Mod-el (shear)..........11,000 kips/in.^{2} Poisson's ratio.........0.29.	[489]
3161..	...do............	Rod, 1/2 to 1 in. diam, hot-rolled.	....	....	....	96	....	....	43 (10^8)	....	....	....	[183]
3162..	...do............	Rod, 1/2 to 1 in. diam, cold-drawn.	....	....	....	110	....	....	49 (10^8)	....	....	....	[183]
3163..	Cr 13.01, Fe 5.45, Si 0.17, Mn 0.11, Cu 0.10, C 0.06, S 0.008.	Rod, 1 in. diam, hot-rolled.	....	....	38.2 (0.01% offset) 47.0 (0.2% offset)	91.2	42 (2 in.)	66	....	159	191	Comp yld str (0.01%)....30.6 kips/in.^{2}.... Comp yld str (0.2%).....42.0 kips/in.^{2}	[185]
3164..	...do............	Rod, 7/8 in. diam, cold-drawn (24% red.); stress-relief ann 3 hr at 575°F.	....	....	98.6 (0.01% offset) 113 (0.2% offset)	122	19 (2 in.)	62	....	210	151	Comp yld str (0.01%)....90.0 kips/in.^{2}.... Comp yld str (0.2%).....105 kips/in.^{2}	[185]
3165..	...do............	Rod, 7/8 in. diam, cold-drawn; ann 3 hr at 1,750°F.	....	....	28.6 (0.01% offset) 33.0 (0.2% offset)	93.2	42 (2 in.)	68	....	136	230	Comp yld str (0.01%)....22.6 kips/in.^{2}.... Comp yld str (0.2%).....28.4 kips/in.^{2}	[485]
3166.	Cr 13.6, Fe 5.7, Mn 0.12, C 0.04.	Annealed.	....	....	41.3 (0.1%)	102	40 (2 in.)	67	47.0 (10^8)	178	....	....	[17]
3167..	.do............	Cold-drawn.	....	....	172 (0.1%)	178	7 (2 in.)	27	53.0 ($2 \cdot 10^8$)	340	....	....	[17]

TABLE 42.—*Nickel and nickel alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					NICKEL-CHROMIUM ALLOYS—Continued								
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
3168..	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	41 ($4\sqrt{area}$)	......	....	....	....	....	[24]
3169..	Cr 20........	Wrought........	31,000	....	63.0 (yld pnt)	110	30 (10 in.)	55	....	....	....	Specific gravity........8.4 Melting point........2,552°F.	[192]
3170..	...do........	Rolled, ann........	31,700	49.3	....	112	40 ($4\sqrt{area}$)	55	33.6	225	....	....	[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.)	......	....	190	....	Mod-el (shear)........9,000 kips/in.².. Melting point........2,375°F. Specific gravity........8.31.	[483]
					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.)	60	....	....	....	....	[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 7.02, Ti 2.19.	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 9.46, Fe 8.4, Ti 2.4.	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........	....	....	....	88.3	29 (2 in.)	57	29.0 (10^9)	....	....	....	[38]
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	124	....	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)	88.8	49 (2 in.)	70	37.8	109	....	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	....	145	....	Comp yld str (0.2%)......38 kips/in.².....	[483]
3181..	...do........	Cold-drawn; stress-relief ann at 525°F.	....	....	87 (0.2% offset)	97	27 (2 in.)	56	....	200	....	Comp yld str (0.2%)......81 kips/in.².....	[483]

3182..	...do............	Cold-drawn; ann 3 hr at 1,450°F, f-c.	....	....	33 (0.2% offset)	78	44 (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 0.38, 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..	Rolled; w-q from 1,875°F	....	33.9	....	62.6	17	38	....	130	....	....	[494]
3186..	...do............	Rolled; 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..	....	....	....	88.3	- 38 (2 in.)	....	26.8 (10^8)	....	....	....	[20]
3188..	...do............	Sheet, 0.020 in., h-t..	27,700	74.0	....	153	11 (2 in.)	....	37.0 (10^8)	R_G 102	....	....	[20]
3189..	Cu 29.37, Si 1.85, Fe 0.55.	Sheet, 0.018 in.......	29,300	48.5	....	144	2.7 (2 in.)	....	37.0 (10^8)	R_G 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 (10^8)	R_G 25	....	....	[20]
3192..	...do............	Sheet, 0.020 in., rolled (44% red.).	27,300	45.6	....	116	3.0 (2 in.)	....	39.5 (10^8)	R_G 79	....	....	[20]
3193..	...do............	Sheet, 0.020 in., rolled (56% red.).	26,400	58.2	....	123	1.7 (2 in.)	....	37.8 (10^8)	R_B 82	....	....	[20]
3194..	Cu 30.0, Si 4.0, 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 0.005.	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%)....34.0 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	[485]
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 0.041, 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	[485]
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	44 (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 4.—*Nickel and nickel alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					NICKEL-COPPER ALLOYS—Continued								
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*Ft-lb*		
3201..	Cu 31.31, Mn 0.90, Fe 0.83, C 0.19, Si 0.04, S 0.007.	Rod, 1 in. diam, hot-rolled.	....	....	36.6 (0.01% offset) 40.6 (0.2% offset)	83.8	40 (2 in.)	68	....	115	232	Comp yld str (0.01%)....33.0 kips/in.².... Comp yld str (0.2%).....38.0 kips/in.²	[485]
3202..	...do............	Rod, 7/8 in. diam. cold-drawn (21% red.); stress-relief ann 3 hr at 575°F.	....	....	75.0 (0.01% offset) 86.6 (0.2% offset)	97.2	27 (2 in.)	66	....	199	151	Comp yld str (0.01%)....58.0 kips/in.².... Comp yld str (0.2%).....80.8 kips/in.²	[485]
3203..	...do............	Rod, 7/8 in. diam, cold-drawn; ann 3 hr at 1,150°F.	....	....	27.6 (0.01% offset) 33.4 (0.2% offset)	78.1	44 (2 in.)	56	....	123	200	Comp yld str (0.01%)....19.2 kips/in.².... Comp yld str (0.2%).....28.2 kips/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	47 (2 in.)	78	26.5	83	....	Shear str...............47.5 kips/in.²....	[93]
3205..	...do............	Hot-rolled; ann 1 hr at 1,500°F, f-c.	....	14.5	20.3 (0.01% perm)	62.4	50 (2 in.)	75	24.0	83	....	Shear str...............47.1 kips/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 pnt)	55.8	46 (2 in.)	79	....	R_B 58	....	Mod-el (shear)..........9,700 kips/in.²... Poisson's ratio.........0.357.	[131]
3207..	...do............	Rod, 1 in. diam, ann 4 hr at 1,400°F.	26,800	19.2	25.6 (yld pnt)	64.2	46 (2 in.)	79	....	R_B 52	....	Mod-el (shear)..........9,400 kips/in.²... Poisson's ratio.........0.357.	[131]
					NICKEL-IRON ALLOYS								
3208..	Ni 60, Cr 12, Fe rem.	Cast.................	....	47.0	....	60.0	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 pnt)	111	33	47	....	185	Iz 50	....	[287]
3210..	Ni 60, Cr 15, Mo 7, Be 0.6-1.0, Fe rem.	Quenched.............	22,100	....	59.4 (yld pnt)	125	30 (4 in.)	......	....	195	....	Specific gravity........8.3...............	[490]
3211..	...do............	Quenched, h-t.........	22,900	....	70.1 (yld pnt)	132	23 (4 in.)	......	....	320	....	....	[490]
3212..	...do............	Hard-rolled..........	24,000	....	199 (yld pnt)	213	2.0 (4 in.)	......	....	320	....	....	[490]
3213..	...do............	Hard-rolled; h-t......	26,300	....	213 (yld pnt)	263	6.0 (4 in.)	......	....	430	....	....	[490]
					NICKEL-MANGANESE ALLOYS (SEE ALSO FIG. 161)								
3214..	Mn 1.89, Fe 0.52, Cu 0.18, C 0.11, Si 0.05, S 0.005.	Rod, hot-rolled......	31,800	25.5	34.4 (yld pnt)	81.8	46 (2 in.)	61	....	R_B 69	....	Mod-el (shear)..........11,100 kips/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 pnt)	80.7	50 (2 in.)	74	....	R_B 63	....	Mod-el (shear)..........11,400 kips/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.	Rod, hot-rolled......	32,300	31.4	38.6	86.5	40	53	....	R_B 77	....	Mod-el (shear)..........10,600 kips/in.^{2}.. Poisson's ratio.........0.339.	[131]
3217..	...do............	Rod, ann 4 hr at 1,400°F.	31,500	25.8	32.6	85.8	49	72	....	R_B 68	....	Mod-el (shear)..........10,900 kips/in.^{2}.. Poisson's ratio.........0.339.	[131]
3218..	Mn 15.00, Fe 0.25, Si 0.20, C 0.12, Cu 0.10, S 0.005.	Rod, 1 in. diam, hot-rolled.	....	....	38.0 (yld pnt)	95.0	38 (2 in.)	60	....	155	....	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.)	11-19	....	175-215	....	Specific gravity........8.94..............	[497]
3220..	Mo 17, Cr 14, Fe 6, W 5.	...do................	....	....	42-47	55-79	3-11	5-15	....	220	....	Specific gravity........8.94.............. Melting range...........2,318°-2,381°F.	[491]
3221..	Mo 20, Fe 20......	...do................	27,000	....	42-45 (yld pnt)	69-78	8-12 (2 in.)	16-18	....	155-200	Iz 25-35	Specific gravity........8.80..............	[497]
3222..	...do............	Rolled; ann..........	27,000	....	47-52 (yld pnt)	110-120	40-48 (2 in.)	40-54	....	200-215	Iz 62-77	Erichsen................10-11 mm..........	[497]
3223..	Mo 28, Fe 7 (Electrolytic Ni and Fe powders, -200 mesh).	Mixed powders; compacted at 30 tons/in^2, sintered 24 hr at 2,280°F in hydrogen.	....	....	....	87.0	20	12	....	R_B 68	....	Density.................8.16 g/cm^3........	[289]
3224..	Mo 28, Fe 7 (Reduced oxide powders, -325 mesh).	...do................	....	....	....	98.6	0.01	6.5	....	R_B 102	....	Density.................9.2 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............	Rolled; ann..........	30,800	....	60-65 (yld pnt)	130-140	40-45 (2 in.)	40-15	....	210-235	Iz 68-78	Erichsen................10-11 mm..........	[497]

NICKEL-RHODIUM ALLOY

3227..	Rh 43............	Hard.................	....	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, <0.01.	Sand-cast............	30,000	....	21.0 (0.2% offset)	55.0	22 (2 in.)	....	....	120	60	Specific gravity........8.85.............. Melting range...........2,550°-2,650°F.	[500]
3230..	Si 10, Cu 3.......	Cast.................	28,800	....	....	36-40.5	0 (2 in.)	0	....	R_C 50-55	....	Specific gravity........7.80..............	[498]

NICKEL-TANTALUM ALLOYS

3231..	Ta 0.97, Fe 0.42..	Rod, 1 in. square, ann 1 hr at 1,740°F, f-c.	....	14.0	26.2 (0.2% offset)	70.8	50 (2 in.)	....	....	....	....	....	[24]
3232..	Ta 5.14, Fe 0.95..	...do................	....	24.0	34.3 (0.2% offset)	87.1	47 (2 in.)	....	....	....	....	....	[24]

NICKEL-ZIRCONIUM ALLOY

3233..	Zr 1.31, Fe 0.04..	Rod, 1 in. square, ann 1 hr at 1,740°F, f-c.	....	13.0	27.6 (0.2% offset)	79.3	36 (2 in.)	....	....	....	....	....	[24]

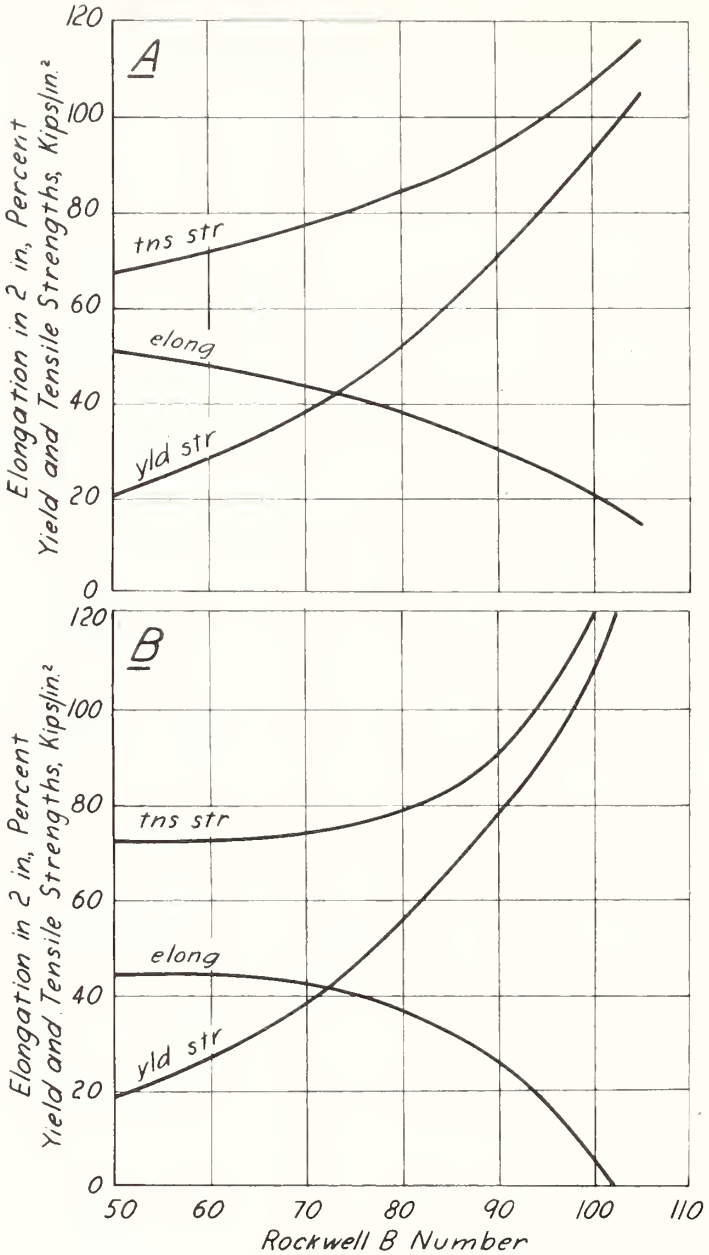


FIGURE 159.—*Relation between Rockwell number and tensile properties for commercially pure nickel [687]).*

(Yield strength, 0.2%)

A, Rod, hot-rolled and cold-drawn; B, sheet and strip, cold-rolled.

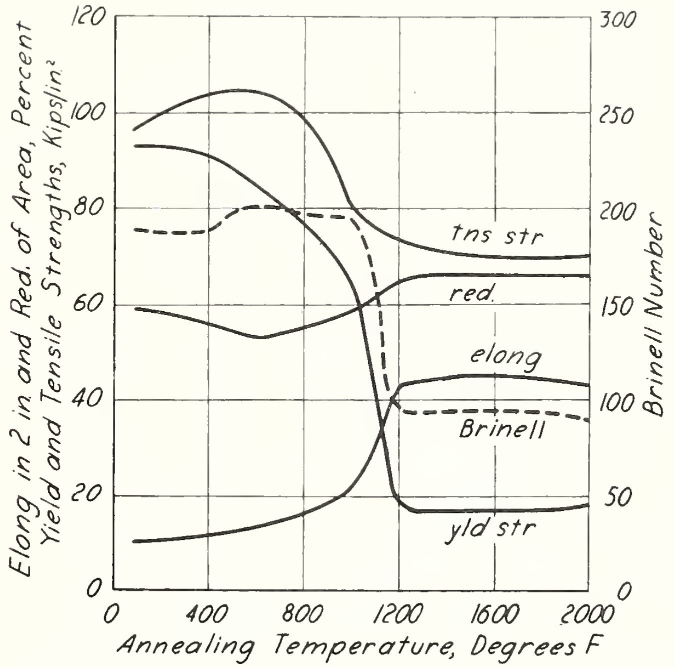


FIGURE 160.—*Effect of annealing on the tensile properties and hardness of cold-drawn nickel (Mochel [487]).*

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.

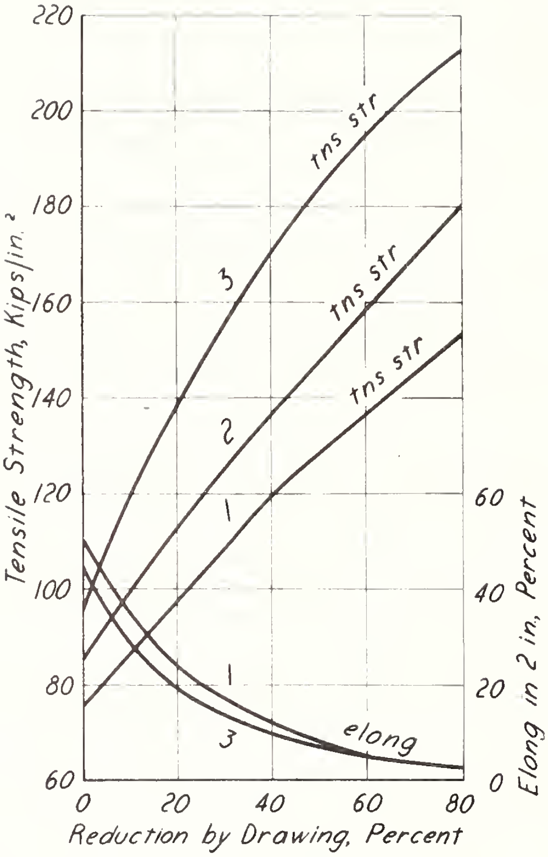


FIGURE 161.—*Effect of cold-drawing on the tensile properties of nickel and nickel-manganese alloys (Mudge [496]).*

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%.

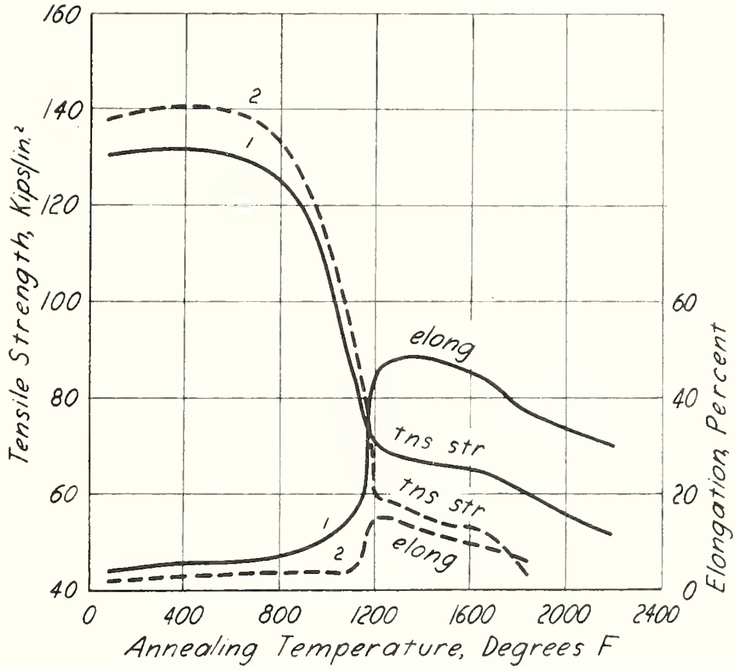


FIGURE 162.—*Effect of annealing on the tensile properties of hard-drawn commercial nickel wire (Ransley and Smithells [688]).*

(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.

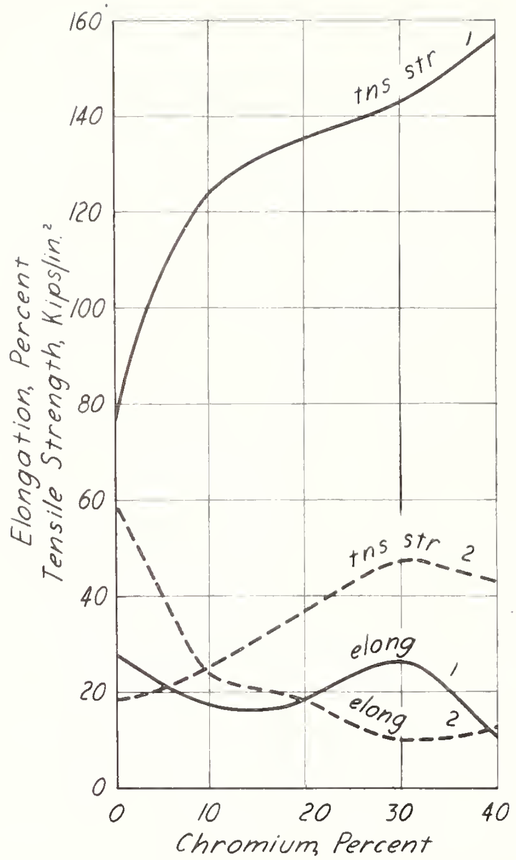


FIGURE 163.—*Tensile properties of wrought nickel-chromium alloys at normal and high temperatures (Jenkins, Tapsell, Austin, and Rees [689]).*

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.

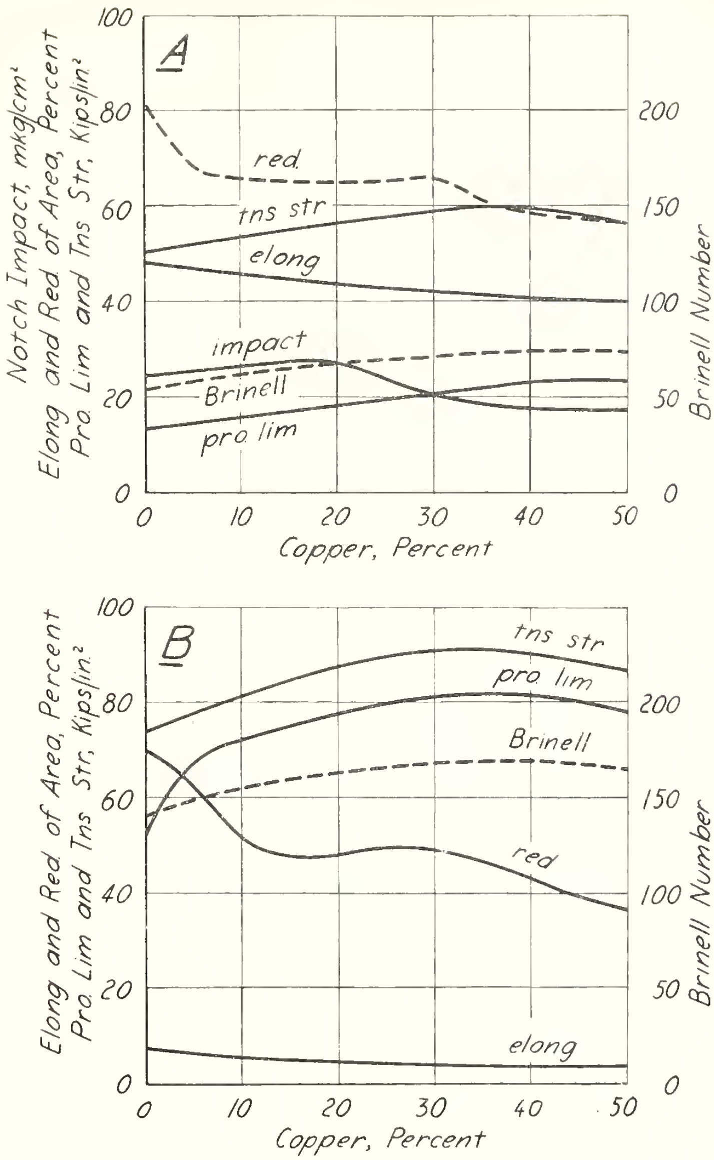


FIGURE 164.—*Tensile properties, impact value, and hardness of wrought nickel-copper alloys (Broniewski and Kulesza [648]).*

(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.

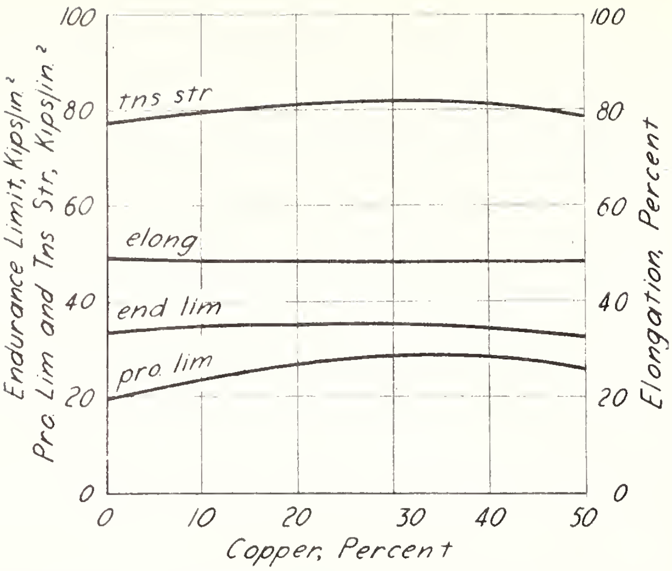


FIGURE 165.—*Tensile properties and endurance limit of wrought, annealed commercial nickel-copper alloys (Wise [649]).*

(Endurance limit at 10^8 cycles)

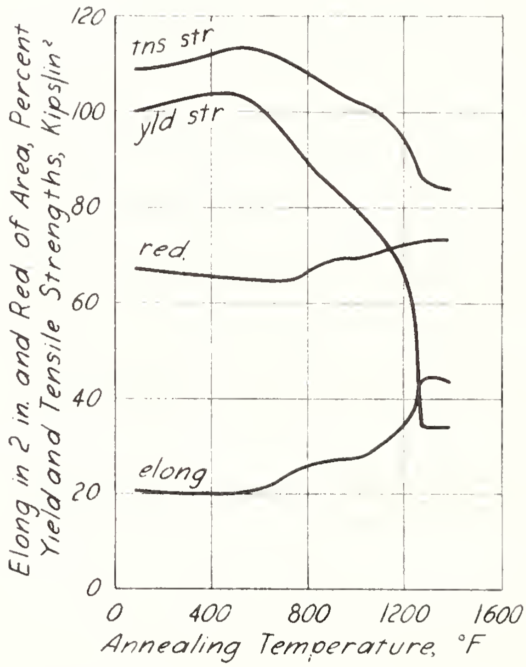


FIGURE 166.—*Effect of annealing on the tensile properties of a cold-drawn nickel-copper alloy (Mudge [691]).*

(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 R_B, R_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: "Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Hardness number	Creep properties: Stress (kips/in.^{2}) for designated creep rate per 1,000 hours: 0.01%	0.1%	1.0%	Duration	Reference
	Percent		°F	*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Percent*	*Percent*					*Hours*	
3234....	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	....	....	....	....	[63]
			300	25.8	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	
			1,400	....	31.5 (yld pnt)	58.7	20 (2 in.)	29	....	....	....	3.0 (0.67%)	250	
			1,600	....	17.0 (yld pnt)	29.8	22 (2 in.)	35	....	....	....	....	....	
3236....	Cr 20....................	Rod, 3/16 in. diam, wrought; 1/4 hr at 1,740°F in hydrogen, a-c.	1,112	....	....	....	....	....	....	....	9.0	....	250	[363]
3237....	Co 17, Fe 7.5, Ti 2.5....	...do............................	1,112	....	....	....	....	....	....	....	8.0 (0.08%)	....	250	[363]
3238....	Co 25, Cr 19, Fe 7.5, Ti 2.5.	...do............................	1,472	....	....	....	....	....	....	....	2.25 (0.5%)	....	250	[363]
3239....	Co 25, 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	....	....	....	....	....	....	6.0 (0.02%)	8.0 (0.09%)	....	250	[363]
3241....	Cu 28.46, Fe 1.24, Mn 0.34, C 0.18, Si 0.10, S 0.007.	Wrought..........................	Room	....	122	128	12 (2 in.)	64	R_B 102	....	....	....	....	[501]
			700	....	....	....	....	....	....	75	....	....	....	
			800	....	....	....	....	....	....	12	30	50.0	....	
			900	....	....	....	....	....	....	....	10	23	....	
			1,000	....	....	....	....	....	....	....	3.7	10	....	
			1,100	....	....	....	....	....	....	....	1.3	4.8	....	
			1,300	....	....	....	....	....	....	....	0.45	2.2	....	

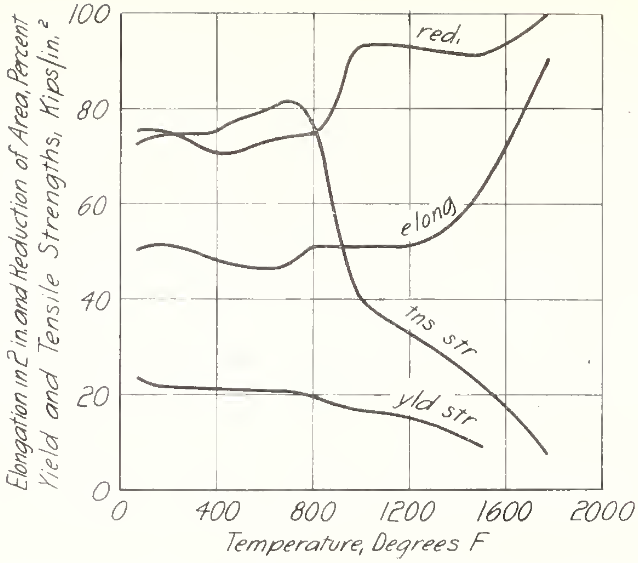


FIGURE 167.—*Short-time tensile properties of hot-rolled annealed nickel at high temperatures (Geiger [486]).*

(Yield strength, 0.2% offset)

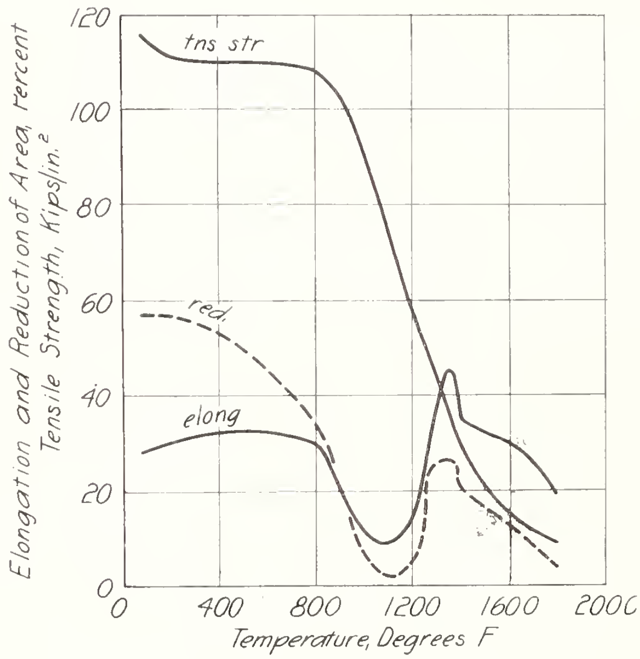


FIGURE 168.—*Short-time tensile properties of a nickel-chromium alloy at high temperatures (Quier [692]).*

(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.

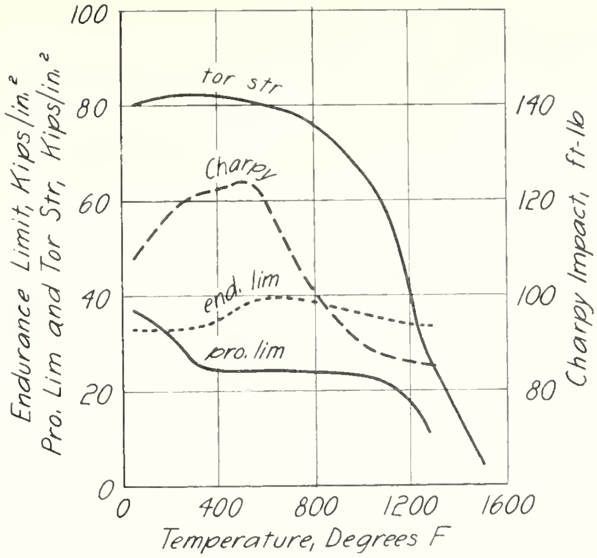


FIGURE 169.—*Torsional properties, impact value, and endurance limit of a nickel-chromium alloy at high temperatures (Pilling and Worthington, [693]).*

Cr 19.04%, Fe 0.88%, Si 0.10%, C 0.09%, S 0.012%. Rolled.

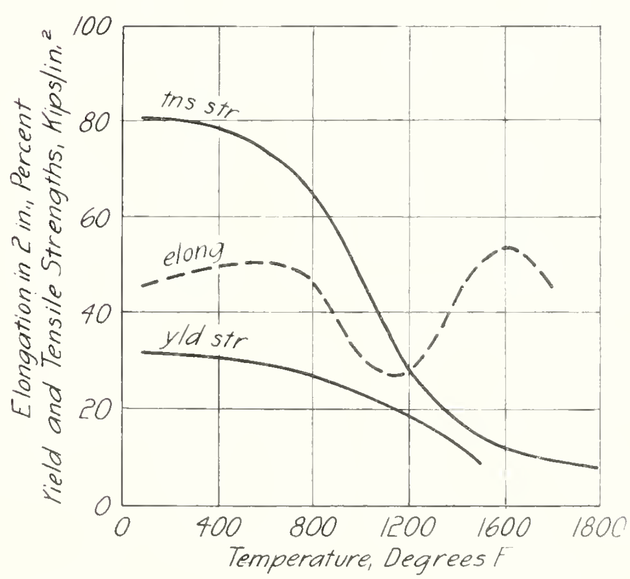


FIGURE 170.—*Short-time tensile properties of a hot-rolled nickel-copper alloy at high temperatures [483]).*

(Yield strength, 0.2% offset)

Cu 30%, Fe 1.4%, Mn 1.0%, C 0.15%, Si 0.10%, S 0.01%.

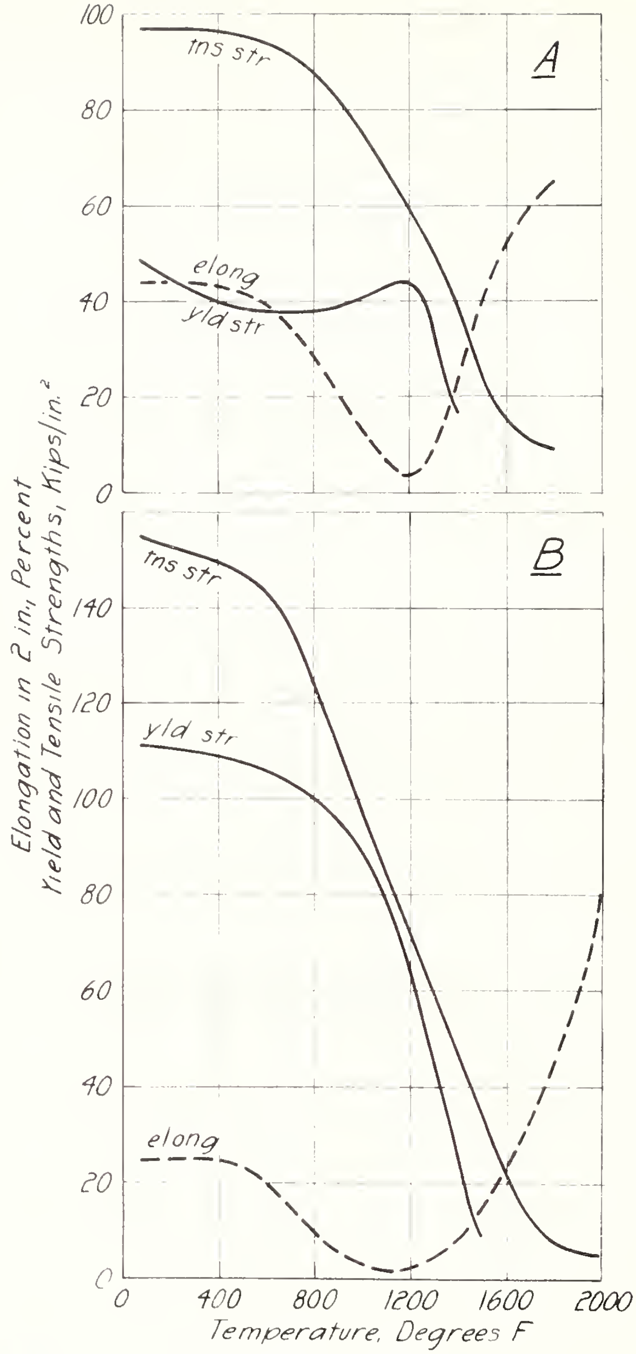


FIGURE 171.—*Short-time tensile properties of a nickel-copper-aluminum alloy at high temperatures* [483].

(Yield strength, 0.2% offset)

Cu 29%, Al 2.75%, Fe 0.9%, Si 0.5%, Mn 0.4%, C 0.15%, S 0.005%.

A, Hot-rolled; B, hot-rolled and age-hardened.

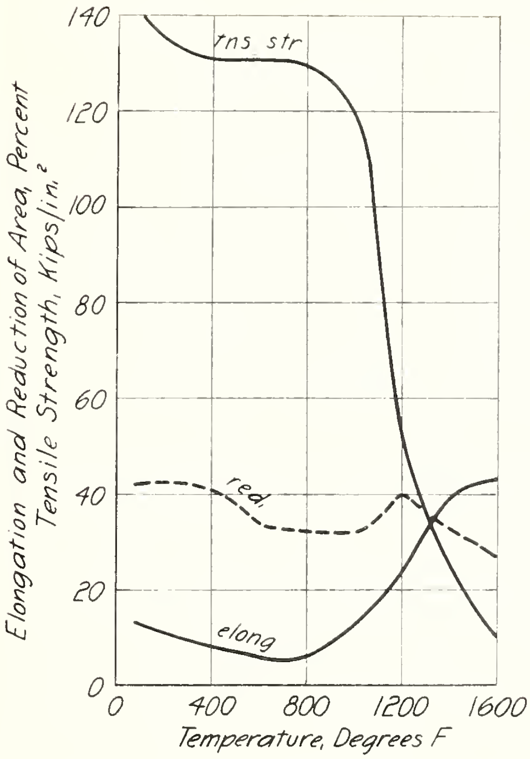


FIGURE 172.—*Short-time tensile properties of a nickel-iron-chromium alloy at high temperatures (Quier [692]).*

(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.

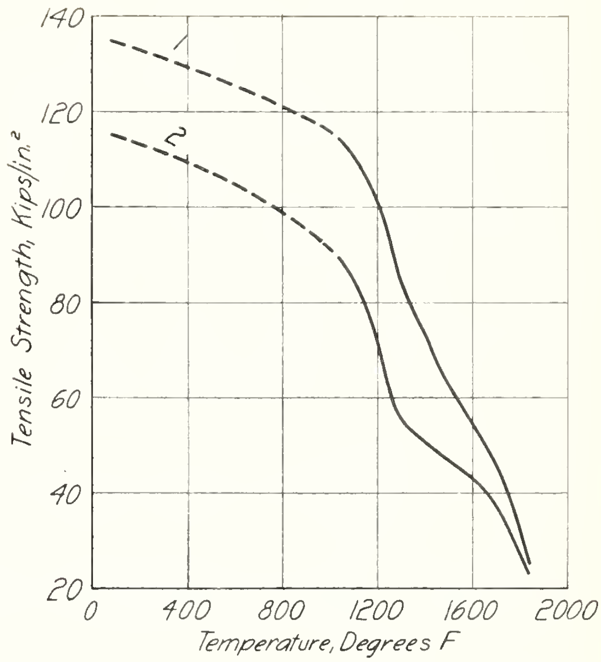


FIGURE 173.—*Short-time tensile strengths of nickel-molybdenum-iron alloys at high temperatures (Field [497]).*

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: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Hardness number	Impact value	Remarks	Reference
	Percent		°F	Kips/in.²	Kips/in.²	Percent	Percent		ft-lb		
PURE AND COMMERCIAL NICKEL											
3242....	Fe 0.15....	Cold-drawn (93% red.)....	77	......	133	1.1 (2 in.)	58	......	......	......	[65]
			-301	......	155	3.1 (2 in.)	54	......	......		
3243....	Si 0.23, Co 0.14, Fe 0.10, Mg 0.26 (0.026?), S 0.005.	Rod, 1 in. diam, rolled; ann....	Room	24.6	65.5	42 (2 in.)	78	......	Iz 89	Tensile specimen 0.25 in. diam; impact specimen 10 x 10 mm with three 45° notches.	[64]
			-40	25.3	71.7	45 (2 in.)	72	......	Iz 90		
			-112	27.6	76.4	43 (2 in.)	73	......	Iz 92		
			-184	25.9	80.6	45 (2 in.)	77	......	Iz 93		
			-292	27.9	97.9	53 (2 in.)	74	......	Iz 98		
3244....	Mn 0.24, C 0.14, Fe 0.10, Cu 0.03, Si 0.03.	Rod, 5/8 in. diam, cold-drawn...	Room	97.0	103	16	68	R_C 20	199-222	......	[25]
			-40	......	......	......	......	R_C 22	205-223		
			-105	102	112	22	61	R_C 22	202-223		
3245....	Mn 0.38, C 0.07....	Forged....	Room	91.2 (yld pnt)	105	12 (10 diam)	71	208	......	......	[56]
			-423	117 (yld pnt)	144	22 (10 diam)	64	......	......		
3246....	Fe 0.28, Cu 0.20, Mn 0.11, C 0.09.	Wrought....	59	......	65.0	43 (10 diam)	......	......	......	......	[66]
			-296	......	103	51 (10 diam)	......	......	......		
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.	Room	36.0	94.0	37	65	R_B 82	130	......	[25]
			-40	......	......	......	......	R_B 86	135		
			-105	42.5	106	40	64	R_B 87	133		
3248....	...do....	Rod, 5/8 in. diam, cold-drawn, tempered at 525°F.	Room	147	152	7	49	R_C 31	47-58	......	[25]
			-40	......	......	......	......	R_C 34	47-71		
			-105	155	164	10	51	R_C 36	33-63		
3249....	Ni 59.3, Cr 14.40, Mn 2.41, C 0.46, Si 0.21, Fe rem.	Forged....	Room	113 (yld pnt)	122	22 (10 diam)	58	230	......	......	[66]
			-423	135 (yld pnt)	174	28 (10 diam)	40	......	......		
3250....	Cr 18.9, Mn 1.41, C 0.31, Si 0.20....	Water-quenched from 1,830°F....	Room	103 (yld pnt)	133	28 (10 diam)	52	236	......	......	[66]
			-423	139 (yld pnt)	188	34 (10 diam)	50	......	......		

NICKEL-COPPER ALLOYS

3251....	Cu 28.85, Fe 1.78, Mn 0.99, C 0.08, Si 0.01.	Cold-drawn......................	Room	....	93.3	33 (2 in.)	72	208	62	....	[65]
			-40	....	103	38 (2 in.)	71	218	62		
			-112	....	....	....	....	[a]227	63		
3252....	Cu 28.86, Mn 0.28........................	Rod, 1 in. diam, rolled; ann....	Room	20.9	70.8	41 (2 in.)	75	......	Iz 90	Tensile specimen, 0.25 in. diam; impact specimen 10 x 10 mm with three 45° notches.	[64]
			-40	24.9	80.0	47 (2 in.)	76	......	Iz 93		
			-112	27.1	85.3	40 (2 in.)	74	......	Iz 90		
			-184	28.6	91.6	41 (2 in.)	74	......	Iz 93		
			-292	29.6	113	51 (2 in.)	72	......	Iz 97		
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	94.0	104	18	71	R_c 19	170-190	....	[25]
			-40	....	....	....	....	R_c 22	180-205		
			-105	100	118	22	70	R_c 25	170-190		
3254....	Cu 29.4, Fe 1.95, Si 1.43, C 0.13.........	Cast............................	Room	36.3 (0.1%)	80.0	28 (2 in.)	34	135	74	Impact specimen, Charpy bar with Izod notch.	[502]
			-310	....	....	....	....	......	90		
3255....	Cu 29.4, Si 2.69, Fe 1.50, C 0.14.........	...do...........................	Room	54.7 (0.1%)	88.9	15 (2 in.)	28	190	44	...do..........................	[502]
			-310	....	....	....	....	......	47		
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	126	157	15	37	R_c 33	27	....	[25]
			-40	....	....	....	....	R_c 35	28		
			-105	134	172	17	41	R_c 36	28		
3257[b]...	Cu 30, Fe 1.4, Mn 1.0, C 0.15, Si 0.1.....	Cold-drawn......................	Room	....	....	....	....	......	135	....	[502]
			-20	....	....	....	....	......	136		

NICKEL-IRON ALLOYS

3258....	Fe 15.4, Cr 15.1, Mo 7.18, Mn 1.78........	....	68	49.3	110	40 (5 diam)	65	156	[c]28	....	[370]
			-297	....	....	....	....	206	[c]26		
			-423	....	....	....	....	......	[c]22		
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	115	130	....	43	267	22	....	[25]
			-300	....	....	....	....	......	22		
3260....	...do....................................	Bar, 1 1/8 in. square, forged; a-c from 1,700°F.	Room	36	88.5	40	51	149	42	....	[25]
			-300	....	....	....	....	......	58		
3261....	...do....................................	Bar, 1 1/8 in. square, forged; w-q from 2,050°F.	Room	36.5	92.5	40	58	133	54	....	[25]
			-300	....	....	....	....	......	43		
3262....	Ni 57.5, Mn 1.31, C 0.34, Si 0.14, Fe rem	Forged..........................	Room	72.4 (yld pnt)	107	32 (10 diam)	60	177	....	....	[66]
			-423	107 (yld pnt)	164	36 (10 diam)	54	......	....		

[a] -103°F.
[b] Endurance limit (6×10^7 cycles): Room, 35.7 kips/in.^{2}; -40°F, 38.4 kips/in.^{2} Modulus of elasticity: 75°F, 25,500 kips/in.^{2}; -50°F, 25,800 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.^{2}

TABLE 45.—*Nickel and nickel alloys, thermal expansion*

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade: 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	Reference
	Percent		$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	
3263[a]..	Fe 0.03, Co 0.016, Cu 0.006, Si 0.006, C 0.005, S 0.004.	Cold-swaged and ann..........	......	......	......	13.3	13.9	14.4	15.1	15.2	15.5	15.8	16.0	16.3	......	[503]
3264[b]..	C 0.05, Fe 0.03, SiO_2 0.011, Al 0.0043, Mg 0.0035, Mn <0.001, Cu 0.0005.	Annealed......................	9.8 (-192° to 0°C)	11.4	12.8	13.1	13.7	14.4	15.0	......	......	......	......	......	......	[68]
3265...	Be 1.8-2.0..................	Rod or strip..................	......	......	......	13.1	13.9	......	......	......	......	......	......	......	......	[110]
3266[b]..	Cr 10.......................	......	......	......	13.2	13.4	13.8	14.2	14.6	15.0	15.5	15.9	16.4	16.9	17.4	[196]
3267...	Cr 14, Fe 6.................	Wrought......................	......	......	......	[b] 12.6	......	......	......	......	......	......	......	......	......	[375]
3268...	Cr 16.3, Fe 6.6, Mn 3.23, Si 2.51, C 0.94, Al <0.1, Cu <0.1.	Sand-cast at 1,480°C..........	......	......	......	13.6	13.8	14.0	14.3	14.6	15.0	15.2	15.3	15.6	......	[713]
3269...	Ni 65, Cr 18, Fe rem........	Cast.........................	......	......	......	[b] 16.2	......	......	......	......	......	......	......	......	......	[69]
3270...	Cr 19.3, Mn 2.50, Fe 0.65, Si 0.12, C 0.08, Al <0.1, Cu <0.1.	Hot-rolled and slowly cooled..	......	......	......	13.6	14.0	14.3	14.5	15.1	15.6	16.1	16.5	17.0	17.6	[713]
3271...	Cr 20.40, Mn 1.92, Fe 0.40, Si 0.26, C 0.12, Cu 0.10.	Hot-rolled....................	......	......	......	13.0	13.3	13.3	13.9	14.7	15.3	15.8	16.2	16.7	17.2	[713]
3272...	Cr 23, Cu 8, Mo 4, W 2, Mn 1.	Cast.........................	......	......	......	[b] 14.0	......	......	......	......	......	......	......	......	......	[375]
3273...	Ni 60, Cr 25, Cu 8, Fe rem..	...do.........................	......	......	......	[b] 13.5	......	......	......	......	......	......	......	......	......	[69]
3274...	Co 10.......................	Rod, 0.2 in. diam, cast; 1 hr at 1,000°C in hydrogen, slowly cooled.	......	......	......	[c] 13.1	......	......	......	......	......	......	......	......	......	[504]
3275...	Co 10, Fe 10................	...do.........................	......	......	......	[c] 12.8	......	......	......	......	......	......	......	......	......	[504]
3276[b]..	Co 19.50, Fe 7.60, Ti 2.86, Si 0.30, Mn 0.14, Cu 0.04.	Hot-rolled....................	......	......	......	10.8	11.3	11.9	12.5	13.1	13.7	14.3	......	......	......	[69]
3277...	Co 19.9, Fe 10.1............	Rod, 0.2 in. diam, cast; 1 hr at 1,000°C in hydrogen, slowly cooled.	......	......	......	[c] 12.6	......	......	......	......	......	......	......	......	......	[504]
3278...	Co 19.9, Fe 30.1............	...do.........................	......	......	......	[c] 12.2	......	......	......	......	......	......	......	......	......	[504]
3279[d]..	Co 24.86, Cr 18.74, Fe 7.02, Ti 2.19.	Bar, hot-rolled and h-t.......	......	......	......	......	14.0	14.4	14.8	15.1	16.2	......	......	......	......	[524]
3280...	Co 29.9, Fe 10.1............	Rod, 0.2 in. diam, cast; 1 hr at 1,000°C in hydrogen, slowly cooled.	......	......	......	[c] 12.4	......	......	......	......	......	......	......	......	......	[504]
3281...	Co 29.9, Fe 20.1............	...do.........................	......	......	......	[c] 12.2	......	......	......	......	......	......	......	......	......	[504]
3282...	Co 30.......................	...do.........................	......	......	......	[c] 12.8	......	......	......	......	......	......	......	......	......	[504]
3283...	Co 50.......................	...do.........................	......	......	......	[c] 12.6	......	......	......	......	......	......	......	......	......	[504]
3284...	Ni 88.92, Fe 0.30, Mn 0.03, Cu rem.	Rod, 0.32 in. diam, hot-forged; ann 3 hr at 850°C in vacuum.	10.5 (-182° to 0°C) 12.6 (-40° to 0°C)	[b] 11.9	......	......	......	......	......	......	......	......	......	......	......	[201]
3285...	Ni 78.99, Fe 0.33, Mn 0.04, Cu rem.	...do.........................	10.8 (-182° to 0°C) 12.7 (-40° to 0°C)	[b] 12.1	......	......	......	......	......	......	......	......	......	......	......	[201]
3286...	Cu 25, Sn 9, Fe 3.5, Mn 0.75, Si 0.75.	......	......	......	......	......	[e] 14.1	......	[f] 14.8	16.0	......	......	......	......	......	[723]
3287[c]..	Cu 26.96, Fe 2.70, Mn 2.35, Si 0.54, C 0.15.	Cast.........................	......	......	......	16.5	16.6	16.8	17.0	17.2	......	......	......	......	......	[69]
3288[a]..	Cu 29, Al 2.75, Fe 0.90, Mn 0.40, Si 0.25, C 0.15, S 0.005.	......	......	......	......	11	......	15	......	......	16	......	......	......	......	[505]
3289[a]..	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..	......	......	......	14.2	14.6	14.9	15.4	15.7	16.1	......	......	......	......	[505]
3290...	Cu 29.66, Fe 1.30, Mn 1.07, C 0.14, Si 0.06, S 0.005.	Wrought and ann...............	12.2 (-170° to 25°C) 13.0 (-75° to 25°C) 13.2 (-20° to 25°C)	......	......	......	......	......	......	......	......	......	......	......	......	[502]

3291...	Cu 30, Si 4, Fe 2, Mn 0.5, C 0.1, S 0.015.	Cast				12.3			[g] 15.1							[495]
3292...	Ni 68.86, Fe 0.21, Mn 0.05, Cu rem.	Rod, 0.32 in. diam, hot-forged; ann 3 hr at 850°C in vacuum.	11.1 (-182° to 0°C) 13.0 (-40° to 0°C)	[b] 12.3												[201]
3293[a]..	Cu 32.46, Pb 2.22, Fe 2.21, Mn 2.00, Si 0.87, C 0.15, S 0.035.	Rod, 3/8 in. square, cast; 1 hr at 900°C.				14.3	14.7	15.1	15.5	16.0	16.5					[506]
3294...	Ni 59.35, Fe 0.07, Mn 0.04, Cu rem.	Rod, 0.32 in. diam, hot-forged; ann 3 hr at 850°C in vacuum.	11.5 (-182° to 0°C) 13.3 (-40° to 0°C)	[b] 12.8												[201]
3295...	Cu 40, Mn 15	Rod, cold-worked; quenched from 900°C.				13.6										[507]
3296...	Fe 18.1, Cr 15.9, Mn 2.11, Si 0.78, C 0.08, P 0.013.	Hot-rolled			[h] 13.2	13.4	14.0	14.4	14.8	15.2	15.7	16.0	16.3	16.8	17.0	[713]
3297...	Fe 20	Rod, 0.2 in. diam, cast; 1 hr at 1,000°C in hydrogen, slowly cooled.				[c] 12.8										[504]
3298...	Fe 20.1, Co 19.9	...do				[c] 12.6										[504]
3299...	Ni 61.00, Cr 15.70, C 0.95, Cu 0.78, Si 0.69, Mn 0.62, Fe rem.	Cast at 1,510°C			[h] 12.2	12.3	12.7	13.3	13.7	14.1	14.5	14.7				[713]
3300[b]..	Fe 30, Cr 10					11.5	12.3	12.8	13.4	13.9	14.4	15.0	15.5	15.9	16.4	[274]
3301...	Ni 67.98, Si 0.05, Fe rem...	Rod, 1/4 in., hot-rolled; 1 hr at 800°C, slowly cooled.													15.4	[385]
3302...	Ni 57.81, Mn 0.25, Si 0.05, Fe rem.	...do													14.5	[385]
3303...	Fe 48					8.8	9.2	9.3	9.3	9.5	10.3	11.1				[508]
3304[a]..	Mn 4.92, Fe 0.46, Cu 0.14, C 0.12, Si 0.10, S 0.030.	Hot-rolled; 1 hr at 870°C				13.3	13.8	14.4	14.8	15.2	15.6					[506]
3305[b]..	Mo 17, Cr 15, Fe 8					11.3									15.3	[497]
3306[b]..	Mo 20, Fe 20					11.0									15.4	[497]
3307[b]..	Mo 30, Fe 5					10.0									14.6	[497]

[a] Base temperature 25° instead of 20°C.
[b] Base temperature 0° instead of 20°C.
[c] 30° to 100°C.
[d] Base temperature 50° instead of 20°C.
[e] 20° to 180°C.
[f] 20° to 350°C.
[g] 20° to 450°C.
[h] 20° to 60°C.

TABLE 46.—*Nickel and nickel alloys, electrical and thermal properties*

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal conductivity	Reference
	Percent		*Percent IACS*	*Microhm cm*	*per °C x 10⁻⁴*	*Watts cm⁻¹ °C⁻¹*	
3308	Ni 99.99		28.1 (0°C) 25.2 (20°C) 16.7 (100°C)	6.141 (0°C) 6.844 (20°C) 10.327 (100°C)	63.6 (20°-100°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)				0.89 (40°C) .83 (100°C) .73 (200°C) .64 (300°C) .59 (400°C) .62 (500°C)	[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				.69 (20°C) .65 (100°C) .55 (300°C) .55 (500°C) .57 (600°C)	[402]
3312	Alumel: Al 2, Mn 2, Si 1	Bar, 1 5/8 in. square, hot-rolled				.30 (100°C) .32 (200°C) .35 (300°C) .41 (500°C)	[402]
3313	...do		6.1 (0°C) 5.0 (100°C) 4.3 (200°C) 3.8 (400°C) 3.4 (600°C) 3.1 (800°C) 2.9 (1,000°C) 2.6 (1,200°C)	28.1 (0°C) 34.8 (100°C) 40.1 (200°C) 46.0 (400°C) 51.0 (600°C) 55.7 (800°C) 60.4 (1,000°C) 65.1 (1,200°C)			[512]
3314	Be 1.8-2.0	Strip, soft ann	5.1	33.7			[110]
3315	...do	Strip, ann, h-t	8.1	21.3			[110]
3316	...do	Strip, cold-rolled	5.4	31.9			[110]
3317	...do	Strip, cold-rolled, h-t	8.9	19.3			[110]
3318	Chromel P: Cr 10	Bar, 1 5/8 in. square, hot-rolled				.19 (100°C) .27 (500°C)	[402]
3319	...do		2.5 (0°C) 2.3 (200°C) 2.1 (400°C) 2.0 (500°C) 1.9 (700°C) 1.8 (900°C) 1.7 (1,200°C)	70.0 (0°C) 76.0 (200°C) 83.1 (400°C) 85.5 (500°C) 89.3 (700°C) 93.4 (900°C) 100.1 (1,200°C)			[512]
3320	Cr 12.97, Fe 6.31, Mn 0.24, Cu 0.18, Si 0.15, C 0.067.	Rolled and ann				.15 (100°C) .19 (400°C)	[210]
3321	Ni 82.25, Cr 12.98, Mn 0.88, Si 0.75, C 0.09, Fe rem.	Rod, 1 in. diam, rolled				.18 (30°C) .19 (200°C) .28 (800°C) .36 (1,200°C)	[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)		.13 (15°C)	[383]
3323	Cr 15		1.8	95	3 (0°-200°C) 0.66 (200°-1,100°C)		[509]

3324	Ni 75.15, Cr 19.93, Mn 1.81, Si 1.13, C 0.04, Fe rem.	Rod, 1 in. diam, rolled	...	...	...	.15 (30°C) .18 (200°C) .26 (800°C) .33 (1,100°C)	[395]
3325	Cr 20	Rod, 3/4 in. diam, hot-rolled	...	...	...	.14 (100°C) .17 (300°C) .21 (500°C)	[402]
3326	...do	...	1.6 (0°C) 1.5 (200°C) 1.5 (400°C) 1.5 (500°C) 1.5 (700°C) 1.5 (800°C) 1.5 (1,100°C)	107.6 (0°C) 112.0 (200°C) 114.9 (400°C) 115.5 (500°C) 114.8 (700°C) 114.7 (800°C) 116.5 (1,100°C)	...	...	[512]
3327	Cr 20, Fe 10	...	1.6	108	2 (0°-200°C)	...	[509]
3328	Ni 45, Co 25, Mo 7, Fe rem.	Annealed	2.2	80	...	...	[396]
3329	Cu 28.32, Si 3.37, Fe 2.15, Mn 1.74, C 0.38	Cast	...	...	...	.20 (100°C) .27 (400°C)	[210]
3330	Cu 29.0, Al 2.75, Fe 0.90, Mn 0.40, Si 0.25, C 0.15, S 0.005.	Hot-rolled; quenched	2.8 (23°C)	62.8 (23°C)	1.9 (23°-100°C)	.18 (0°-100°C)	[505]
3331	...do	Heat-treated	2.8 (23°C)	62.0 (23°C)	1.9 (23°-100°C)	.18 (0°-100°C)	[505]
3332	Cu 30, Fe 1.4, Mn 1.0, C 0.15, Si 0.1	...	4.1 (0°C)	42.5 (0°C)	...	.3 (0°-100°C)	[510]
3333	Cu 37.86, Sn 9.91, Zn 0.86	Cast	...	...	...	.21 (100°C) .28 (400°C)	[210]
3334	Fe 17.7, Cr 3.8	...	2.7	65	...	...	[396]
3335	Fe 17.7, Mo 3.8	...	3.1	55	...	...	[396]
3336	Ni 62.85, Cr 16.95, Mn 1.00, Si 0.51, C 0.12, Fe rem.	Rod, 1 in., rolled	...	...	...	.18 (30°C) .19 (200°C) .24 (500°C) .30 (800°C) .39 (1,100°C)	[395]
3337	Fe 20, Cr 15	...	1.6	106	2.02 (20°-500°C)	...	[511]
3338	Fe 21.5	Quenched	11	16	...	...	[396]
3339	Fe 22.5, Co 7.5	Annealed	11	16	...	...	[396]
3340	Fe 23, Cr 16	Rod, 3/4 in. diam, hot-rolled	...	...	...	.13 (100°C) .19 (500°C)	[402]
3341	...do	...	1.5 (0°C) 1.5 (200°C) 1.4 (400°C) 1.4 (500°C) 1.4 (700°C) 1.4 (800°C) 1.3 (1,000°C)	111.6 (0°C) 117.0 (200°C) 121.9 (400°C) 123.7 (500°C) 124.9 (700°C) 125.8 (800°C) 128.2 (1,000°C)	...	...	[512]
3342	Ni 62.0, Cr 13.0, Mn 1.40, Si 0.45, C 0.10, Fe rem.	Air-cooled from 1,050°C	1.6 (15°C) 1.6 (1,000°C)	105 (15°C) 110 (1,000°C)	...	.13 (15°C) .29 (1,000°C)	[383]
3343	Fe 24.9	...	...	...	...	.29 (20°-100°C)	[337]
3344	Fe 30, Co 25	Annealed	9.1	19	...	...	[396]
3345	Mn 4.65, Fe 0.20, Cu 0.10, Si 0.10, C 0.10, S 0.005.	...	8.6	20.0	36 (20°-100°C) 24 (20°-1,000°C)	...	[496]
3346	Si 1.25, Fe 0.50, Mn 0.50, C 0.25, Mg 0.1, S <0.01.	Cast	7.8 (20°C)	22.2 (20°C)	...	.59 (25°C)	[500]

XI. TIN AND TIN ALLOYS

TABLE 47.—*Classification of tin 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		SAE	Sn	Pb	Sb	Cu	
Spec.	Grade	Spec.	Alloy						
TIN									
QQ-T-371	A	...	...	...	99.75	...	...	...	2831, 3347 to 3353, inclusive; 3412, 3431, 3441, 3442.
QQ-T-371	B	...	...	...	98.00	[a]1.50	[a]1.50	...	3354, 3355, 3385, 3386, 3413.
BEARING ALLOYS (BABBITTS)									
QQ-M-161	1	B23-26	1	10	91	[a]0.35	4.5	4.5	3360, 3424.
QQ-M-161	2	B23-26	2	110	89	[a].35	7.5	3.5	2770, 3365, 3426.
...	...	...	...	11	87	[a].35	7	6	3362.
QQ-M-161	3	B23-26	3	...	83.33	[a].35	8.33	8.33	2771, 3368.
...	...	B23-26	4	...	75	10	12	3	3372.
...	...	B23-26	5	...	65	18	15	2	3388.
DIE-CASTING ALLOYS									
...	...	B102-39T	1	...	91	[a]0.35	4.5	4.5	...
...	...	B102-39T	2	...	82	[a].35	13	5	...
...	...	B102-39T	3	...	65	18	15	2	...
SOFT-SOLDERS									
QQ-S-571a	F	B32-40T	...	...	70	30	...	...	3433.
...	...	B32-40T	...	...	65	35	...	...	3389, 3451.
...	...	B32-40T	...	...	63	37	...	...	2836, 3391, 3392, 3429.
QQ-S-571a	H	B32-40T	...	...	60	40	...	...	...
...	...	B32-40T	...	...	55	45	...	...	3434.

[a] Maximum.

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. 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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	PURE AND COMMERCIAL TIN												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
3347..	"Banca" tin: Sn 99.95..	Sheet, 0.04 in., 2 days at r-t.										Erichsen............14.0 mm	[515]
3348..	Sn 99.9+		5,900			2.0				5		Poisson's ratio.....0.33	[513]
3349..	"Straits" tin	Sheet, 0.040 in., ann 1 hr at 370°F.			1.3 (0.2% offset)	2.2	45 (2 in.)			V 7.2			[129]
3350..	...do	Sheet, 0.040 in., cold-rolled (30% red.).			2.0 (0.2% offset)	2.8	35 (2 in.)			V 8.4			[129]
3351..	"Pure" tin	Foil, 0.0016 in.				2.0	6.5						[511]
3352..	Tin											Mod-el (shear)......2,190-2,190 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	[144]
	TIN-ANTIMONY ALLOYS (SEE ALSO FIG. 174)												
3354..	Sb 0.5	Sheet, 0.04 in., aged 2 days at r-t.										Erichsen............13.7 mm	[515]
3355..	Sb 1.0	...do										Erichsen............11.6 mm	[515]
3356..	Sb 2.98	Cast				[a]4.6	10 (4 in.)				Iz 18	Shear str[a]..........1.6 kips/in.²	[144]
3357..	Sb 3.59, Cu 3.4, Ni 0.08, 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 Comp str...........23.9 kips/in.²	[432]
3358..	Sb 4, Cu 2	...do								15		Comp yld pnt........7.4 kips/in.² Comp str (25%)......10.9 kips/in.²	[516]
3359..	Sb 4, Cu 3.5, Cd 1.0, Pb 0.04.	...do				10.0				25			[516]
3360..	Sb 4.52, Cu 1.56	...do								17		Comp yld str (0.125%)..4.4 kips/in.² Comp str (25%)......12.8 kips/in.² Specific gravity....7.34. Melting point.......433°F.	[516]
3361..	Sb 5.17	...do				[a]5.9	38 (4 in.)				Iz 20	Shear str[a]..........6.0 kips/in.²	[144]
3362..	Sb 6.87, Cu 5.69, 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		Comp yld str (0.2%)..7.7 kips/in.² Comp str............25.6 kips/in.²	[432]
3363..	Britannia metal: Sb 7, Cu 2.	Sheet, 0.241 in., cold-rolled.				7.6	50 (2 in.)			8.0			[517]
3364..	...do	Sheet, 0.241 in., cold-rolled; 1 hr at 400°F, a-c.				8.6	40 (2 in.)			9.5			[517]

3365..	Sb 7.4, Cu 3.1, Pb 0.03.	Cast..................	....	....	....	....	....	......	....	21	......	Comp yld str (0.125%)......5.1 kips/in.^{2}... Comp str..................11.9 kips/in.^{2} Specific gravity..........7.39. Melting range.............466°-669°F.	[516]
3366..	Sb 8, Cu 2...........	...do.................	....	....	....	....	....	......	....	22	......	Comp yld pnt...............9.9 kips/in.^{2}... Comp str (25%)............15.2 kips/in.^{2}	[516]
3367..	Sb 8, Cu 3.5, Cd 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%)............17.6 kips/in.^{2} Specific gravity..........7.46. Melting range.............464°-792°F.	[516]
3369..	Sb 9.88, Cu 4.21, Pb 0.33, 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 9.88, Pb 0.19, Fe 0.08.	Cast..................	8,500	....	9.8 (0.2%)	10.7	0.6 (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 11.44, Cu 7.11, Pb 0.67, Fe 0.04, As 0.02.	...do.................	8,200	....	9.5 (0.2%)	11.8	0.6 (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. Melting range.............363°-583°F.	[516]
3373..	Sb 13.60, Pb 10.28, Cu 5.18, As 0.20, Fe 0.1, Ni 0.02.	...do.................	6,800	....	9.7 (0.2%)	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.	....	....	....	....	....	......	....	......	......	Erichsen..................11.3 mm.........	[515]
3375..	As 0.5...............	...do.................	....	....	....	....	....	......	....	......	......	Erichsen..................10.4 mm.........	[515]
3376..	Be 0.2...............	...do.................	....	....	....	....	....	......	....	......	......	Erichsen..................11.2 mm.........	[515]

TIN-BISMUTH ALLOYS (SEE ALSO FIG. 175)

3377..	Bi 0.056.............	Cast from 480°F into mold at 355°F.	....	....	1.5 (yld pnt)	2.4	....	100	....	1.6	......	Comp yld pnt..............2.2 kips/in.^{2}...	[518]
3378..	Bi 0.5...............	Sheet, 0.04 in., aged 2 days at r-t.	....	....	....	....	....	......	....	......	......	Erichsen..................12.9 mm.........	[515]
3379..	Bi 1.0...............	...do.................	....	....	....	....	....	......	....	......	......	Erichsen..................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 pnt)	3.5	....	98	....	5.3	......	Comp yld pnt..............2.5 kips/in.^{2}...	[518]
3381..	Cu 1.0...............	Sheet, 0.1 in., cold-rolled; aged 2 months at r-t.	....	....	....	7.1	31 (2 in.)	......	....	......	......	....	[519]
3382..	Cu 8, Sb 4...........	Cast..................	....	....	....	....	....	......	....	21	......	Comp yld pnt..............10.8 kips/in.^{2}... Comp str (25%)............13.5 kips/in.^{2}	[516]

[a] Free-head speed 0.1 in./minute.

TABLE 48.—*Tin and tin alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
TIN-GERMANIUM ALLOY													
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
3383..	Ge 0.35...............	Sheet, 0.04 in., aged 2 days at r-t.	....	....	....	....	....	....	....	......	......	Erichsen....................10.9 mm........	[515]
TIN-IRON ALLOYS (SEE FIG. 177)													
TIN-LEAD ALLOYS													
3384..	Pb 0.253.............	Cast from 480°F into mold at 355°F.	....	....	2.4 (yld pnt)	3.9	....	95	....	6.7	......	Comp yld pnt................3.2 kips/in.²..	[518]
3385..	Pb 0.5...............	Sheet, 0.04 in., aged 2 days at r-t.	....	....	....	....	....	....	....	......	......	Erichsen....................13.6 mm........	[515]
3386..	Pb 1.0................	...do..................	....	....	....	....	....	....	....	......	......	Erichsen....................14.2 mm........	[515]
3387..	Pb 5.0, Sb 0.5........	....	....	....	....	....	....	....	....	......	......	Melting range..............361°-432°F.....	[520]
3388..	Pb 18.2, Sb 14.1, Cu 2.0.	Cast..................	....	....	....	....	....	....	....	22	......	Comp yld str (0.125%).......5.0 kips/in.².. Comp str (25%)..............15.0 kips/in.² Specific gravity...........7.75. Melting range..............358°-565°F.	[516]
3389..	Pb 35.1, Sb 0.98......	...do..................	....	....	....	[a]8.7	20 (4 in.)	....	....	......	Iz 15	Shear str[a]..................6.4 kips/in.²..	[444]
3390..	Pb 36.7, Sb 3.4.......	...do..................	....	....	....	[a]10.1	18 (4 in.)	....	....	......	Iz 12	Shear str[a]..................6.9 kips/in.²..	[444]
3391..	Pb 37.................	...do..................	....	....	....	7.5	32 (4 in.)	....	....	14	Iz 15	Shear str..................6.2 kips/in.².. Specific gravity...........8.42. Melting point..............361°F.	[445]
3392..	Sn 63, Sb 0.12, Bi 0.010, Cu 0.002, Ag 0.0009, Pb rem.	Annealed 16 hr at 212°F.	....	....	....	[b]7.5	30 (2 in.)	....	....	......	14	Shear str..................6.1 kips/in.²..	[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., ann 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	....	....	....	....	....	....	....	....	....	....	Melting range 860°-1,060°F	[184]
3403..	Ag 40, Cu 14, Zn 6	....	....	....	....	....	....	....	....	....	....	Melting range 690°-800°F	[184]

TIN-ZINC ALLOYS

3404..	Zn 0.24	Cast from 480°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, Ni 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 13, 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.

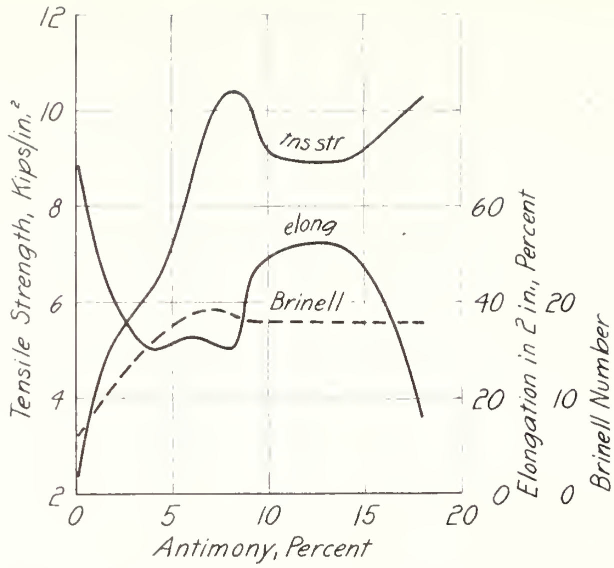


FIGURE 174.—*Tensile properties and hardness of tin-antimony alloys (Hanson and Pell-Walpole [696]).*

(Rate of strain, 0.1 (in./in.)/minute)

Rolled (80% red.) and aged 1 month at room temperature.

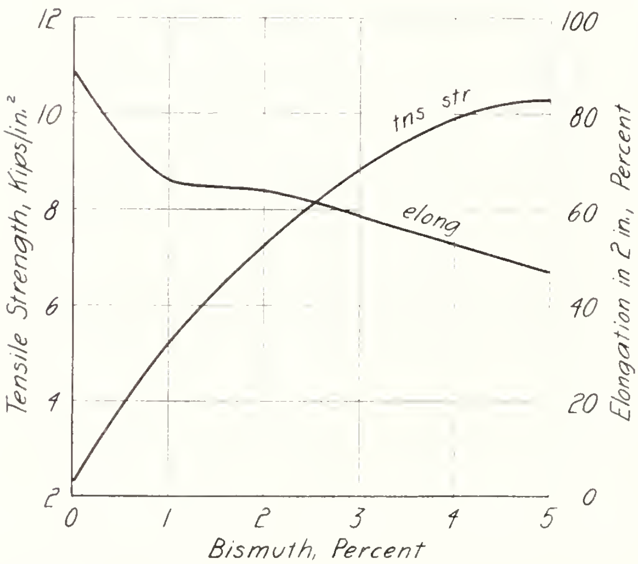


FIGURE 175.—*Tensile properties of tin-bismuth alloys (Hanson and Sandford [697]).*

(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.

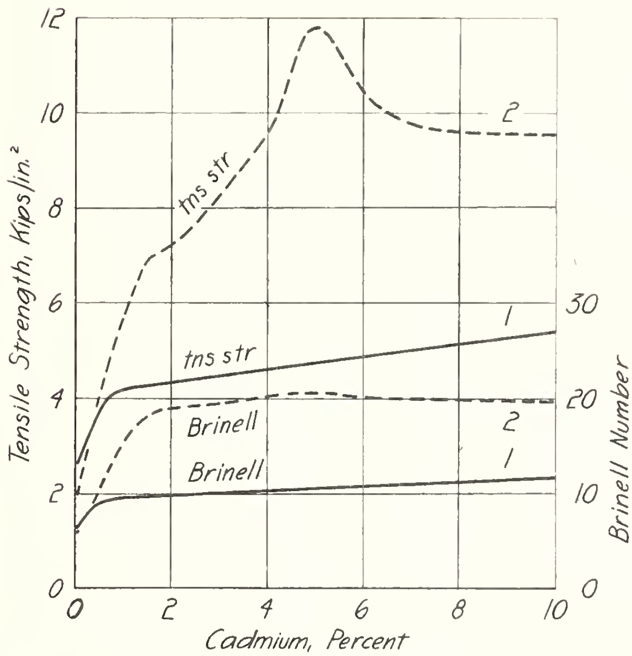


FIGURE 176.—*Tensile strength and hardness of tin-cadmium alloys (Hanson and Pell-Walpole [698]).*

(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.

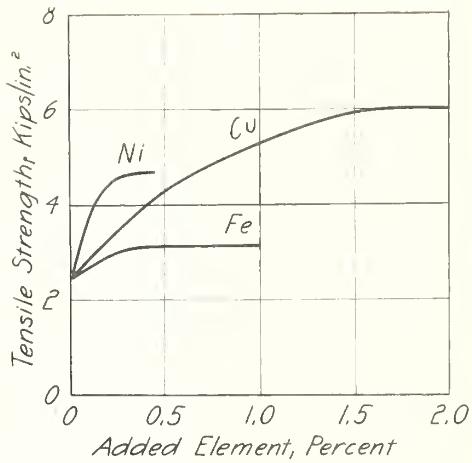


FIGURE 177.—*Effect of various elements on the tensile strength of tin (Hanson, Sandford, and Stevens [699]).*

(Rate of strain, 1 5/32 in./minute)

Strip, 0.1 in., cold-rolled (80% red.) and aged 15 days at room temperature.

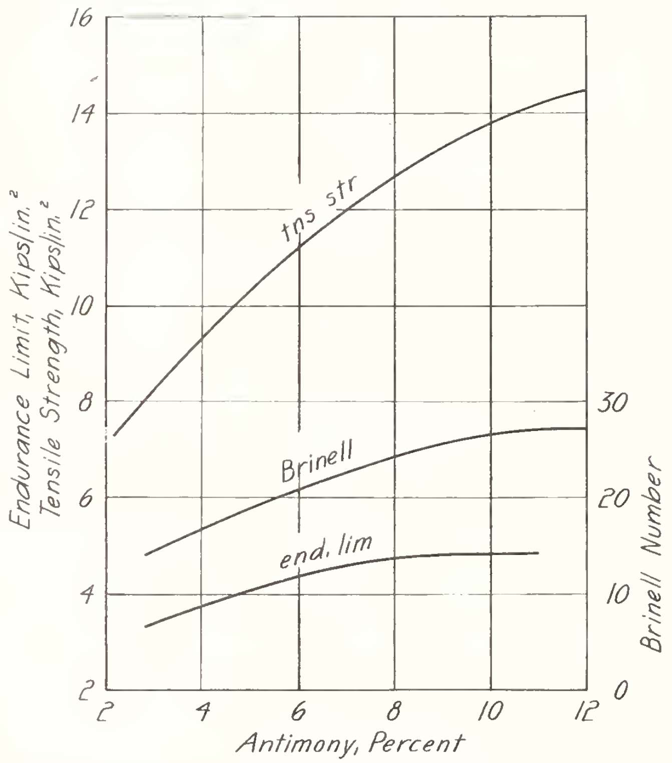


FIGURE 178.—*Effect of antimony on the tensile strength, hardness, and endurance limit of a tin-copper alloy (McNaughton [700]).*

(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	
	Percent		*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	930	[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	29	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. 134]

Serial number	Composition	Condition	Temperature	Short time properties: Tensile strength[a]	Short time properties: Elongation[b]	Short time properties: Reduction of area	Creep properties: Stress (kips/in.^{2}) for designated creep rate per 1,000 hours: 0.1%	Creep properties: Stress (kips/in.^{2}) for designated creep rate per 1,000 hours: 1.0%	Creep properties: Duration	Reference
	Percent		°F	*Kips/in.*^{2}	*Percent*	*Percent*	0.1%	1.0%	*Hours*	
3424	Sb 3.78, Cu 3.55, Pb 0.30, Fe 0.04, As 0.03.	Rod, 6 × 1/2 × 1/8 in., chill-cast from 840°F	64	3.5	20	24	...	...	...	[522]
			122	8.1	26	34	...	...	...	
			212	5.3	25	35	...	...	...	
			302	3.8	32	38	...	...	...	
			347	2.7	36	41	...	...	...	
3425	Above + Cd 1.0	Rod, 6 × 1/2 × 1/8 in., chill-cast from 1,020°F	61	14.4	8.5	10	...	...	...	[522]
			122	11.0	16	19	...	...	...	
			212	7.7	20	26	...	...	...	
			302	4.3	45	40	...	...	...	
			347	3.0	63	69	...	...	...	
3426	Sb 7.14, Cu 3.21, Pb 0.47, Fe 0.03	Rod, 6 × 1/2 × 1/8 in., chill-cast from 750°F	68	11.2	18	25	...	...	...	[522]
			122	9.2	24	27	...	...	...	
			212	6.5	23	28	...	...	...	
			302	4.0	32	38	...	...	...	
			347	2.9	38	44	...	...	...	
3427	Sb 9.88, Cu 4.21, Pb 0.33, Fe 0.05, As 0.03.	Rod, 6 × 1/2 × 1/8 in., chill-cast from 840°F	64	13.2	13	17	...	...	...	[522]
			122	11.1	17	25	...	...	...	
			212	8.1	23	26	...	...	...	
			302	4.9	33	43	...	...	...	
			347	3.1	52	61	...	...	...	
3428	Above + Cd 1.0	Rod, 6 × 1/2 × 1/8 in., chill-cast from 1,020°F	64	16.2	8	10	...	...	...	[522]
			122	13.2	13	14	...	...	...	
			212	8.0	23	28	...	...	...	
			302	5.0	29	35	...	...	...	
			347	4.0	45	42	...	...	...	
3429	Sn 62.2, Pb rem	Chill-cast	Room	...	...	...	0.21	0.41	4,800	[449]
			175	...	...	...	.068 (0.42%)	...	4,800	
3430	Sn 55.0, Sb 3.6, Pb rem	...do	Room	...	...	...	0.35	0.58	4,800	[449]
			175	...	...	...	.125 (0.42%)	...	4,800	

[a] Rate of strain 0.013 in./minute.

[b] Gage length = $4\sqrt{\text{area}}$.

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	
	Percent		$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	
3431[a]	"Pure" tin	Rod, annealed	23.2	23.8	24.2	....	....	....	[480]
3432	Pb 8.72	....	....	[b]20.6	....	....	....	....	[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	16.1	16.1	16.8	[480]
3440	Mg 45.0	...do	19.8	20.0	20.1	19.8	19.7	19.7	[480]

[a]Gruneisen [720] reports values 22.6×10^{-6} (-183° to 16°C) and 27.0×10^{-6} (19° to 100°C).

[b]15° to 110°C.

TABLE 52.—*Tin and tin alloys, electrical and thermal properties*

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal conductivity	Reference
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10⁻⁴*	*Watts cm⁻¹ °C⁻¹*	
3441	"Pure" tin		50.7 (-183°C)	3.40 (-183°C)		0.82 (-170°C)	[513]
			19.7 (-78°C)	8.77 (-78°C)		.64 (0°C)	
			13.2 (0°C)	13.1 (0°C)		.64 (15°C)	
			15.0 (20°C)	11.5 (20°C)		.59 (100°C)	
			9.47 (91.45°C)	18.2 (91.45°C)		.61 (200°C)	
			7.29 (176°C)	23.6 (176°C)			
			7.84 (225°C)	22.0 (225°C)			
3442	...do	Cast; ann	15.82 (0°C)	10.90 (0°C)	15.67 (0°-100°C)		[220]
3443	Sb 2.975	Cast	12.1	14.2			[444]
3444	Sb 6.2	...do	10.4	16.6			[444]
3445	Cu 35.30	Cast; ann	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)	3.55 (-190.6°C)	[a]37.0 (19.5° to -190.6°C)		[457]
			14.1 (0°C)	12.2 (0°C)			
			13.2 (19.5°C)	13.1 (19.5°C)			
3450	In 8.05		25.7 (-190.9°C)	6.71 (-190.9°C)	[a]29.3 (21.0° to -190.9°C)		[457]
			11.3 (0°C)	15.2 (0°C)			
			10.7 (21.0°C)	16.1 (21.0°C)			
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; ann	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

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									
Spec.	Grade	Spec.	Grade			Pb	Fe	Cd	Al	Pb + Fe + Cd	Cu	Mg	Sn	
SLAB ZINC (SPELTER)														
QQ-Z-351a....	A-1	B6-37.....	1a	.....	Special high grade..	0.007	0.005	0.005	None	0.010	....	....	....	3459, 3569, 3580.
QQ-Z-351a....	A	B6-37.....	1	.....	High grade..........	.07	.02	.07	...do.....	.10	....	....	....	[a]3583, [a]3584, 3585; figures 180, 185.
QQ-Z-351a....	B	B6-37.....	2	.....	Intermediate........	.20	.03	.50	...do.....	.50	....	....	....	[a] 3463; figure 180.
QQ-Z-351a....	C	B6-37.....	3	.....	Brass special.......	.60	.03	.50	...do.....	1.0	....	....	....	Figure 180.
QQ-Z-351a....	D	B6-37.....	4	.....	Selected...........	.80	.04	.75	...do.....	1.25	....	....	....	[a]3467, [a]3468, [a]3469.
QQ-Z-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...	XXIII	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.

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_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: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	PURE AND COMMERCIAL ZINC (SEE ALSO FIGS. 179 AND 180)												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
3459..	Cd 0.003, Fe 0.003, Pb 0.001.	Cast from 805°F..........	....	....	....	4.0	2.0 (2 in.)	....	....	31	......	....	[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.	....	....	[a]4.0	[b]20.8	49 (2 in.)	....	....	......	......	....	[527]
3462..	...do..............	Sheet, soft; tested perpendicular to rolling direction.	....	....	[a]6.3	[c]26.2	36 (2 in.)	....	....	......	......	....	[527]
3463..	Pb 0.15, Cd 0.11, Fe 0.017.	Sheet, 0.0185 in., rolled.	....	....	....	[d]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..	....	....	....	[d]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.	....	....	[a]5.2	[e]22.2	35 (2 in.)	....	....	......	......	....	[527]
3466..	...do..............	Sheet, soft; tested perpendicular to rolling direction.	....	....	[a]10.2	[f]30.9	22 (2 in.)	....	....	......	......	....	[527]
3467..	Pb 0.8, Cd 0.15.....	Sheet, soft; tested parallel to rolling direction.	....	....	[a]5.8	[g]21.2	43 (2 in.)	....	....	......	......	....	[527]
3468..	...do..............	Sheet, soft; tested perpendicular to rolling direction.	....	....	[a]10.5	[h]29.5	14 (2 in.)	....	....	......	......	....	[527]
3469..	Pb 0.80, Cd 0.09, Fe 0.017.	Sheet, 0.0173 in., rolled.	....	....	....	[d]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...	12,800	5.2	....	[i]23.8	12 (8 in.)	....	....	......	......	....	[526]
3472..	...do..............	Sheet, 0.10 in., rolled...	10,600	3.6	....	[i]22.3	19 (8 in.)	....	....	......	......	....	[526]

[a]Johnson'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.)
[b]Rate of strain: 0.00118 (in./in.)/minute below Johnson's limit; 0.650 (in./in.)/minute at rupture.
[c]Rate of strain: 0.0010 (in./in.)/minute below Johnson's limit; 0.750 (in./in.)/minute at rupture.
[d]Rate of strain: 0.25 in./minute.
[e]Rate of strain: 0.00112 (in./in.)/minute below Johnson's limit; 0.60 (in./in.)/minute at rupture.
[f]Rate of strain: 0.000823 (in./in.)/minute below Johnson's limit; 0.70 (in./in.)/minute at rupture.
[g]Rate of strain: 0.00107 (in./in.)/minute below Johnson's limit; 0.65 (in./in.)/minute at rupture.
[h]Rate of strain: 0.00095 (in./in.)/minute below Johnson's limit; 0.75 (in./in.)/minute at rupture.
[i]Rate of strain: 0.5 in./minute.

TABLE 54—*Zinc and zinc alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
						PURE AND COMMERCIAL ZINC—Continued							
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
3473..	Zinc...............	Sheet, 0.018 in., rolled..	10,500	5.8	....	[I]25.5	....	....	....	......	......	....	[526]
3474..	...do..............	Sheet, 0.006 in., rolled..	14,800	5.1	....	[I]26.5	6.5 (8 in.)	....	....	......	......	....	[526]
						ZINC-ALUMINUM ALLOYS (SEE ALSO FIG. 181)							
3475..	Al 3, Cu 3.........	Sheet, cold-rolled to 0.039 in. (67% red.).	....	....	....	51.2	22	....	....	......	......	Bend No. (0.12-in. radius)....................36.............	[529]
3476..	Al 4...............	Sand-cast from 840°F......	....	....	14.1 (0.2%)	26.3	3.6	....	....	63	[J]153	....	[530]
3477..	...do..............	Cast from 840°F into mold at 390°F.	....	....	15.6 (0.2%)	28.3	2.0	....	....	66	[J]215	....	[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	[J]82	....	[530]
3480..	...do..............	Cast from 860°F into mold at 390°F.	....	....	17.4 (0.2%)	29.2	0.5	....	....	91	[J]89	....	[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 895°F......	....	....	17.1 (0.2%)	17.4	<0.5	....	....	87	[J]85	....	[530]
3483..	...do..............	Cast from 895°F into mold at 390°F.	....	....	17.6 (0.2%)	27.0	<.5	....	....	88	[J]98	....	[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 0.02-0.08.	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.	....	....	....	[K]47.6	....	....	8.2 (10^8)	......	......	....	[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	[J]102	....	[530]

3491..	...do	Cast from 895°F into mold at 390°F.	...	...	19.9 (0.2%)	35.1	0.8	...	...	113	[j]286	...	[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	[j]67	...	[530]
3494..	...do	Cast from 895°F into mold at 390°F.	...	...	19.5 (0.2%)	30.1	<.5	...	...	114	[j]81	...	[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.	...	...	...	[k]52.1	...	...	8.5 (10^8)	...	...	...	[533]
3498..	Al 4, Li 0.03	Sand-cast from 860°F	...	...	...	11.8	<0.5	...	...	76	[j]114	...	[530]
3499..	...do	Cast from 860°F into mold at 390°F.	...	...	16.8 (0.2%)	24.1	<.5	...	...	79	[j]96	...	[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	[j]101	...	[530]
3503..	...do	Cast from 840°F into mold at 390°F.	...	...	18.3 (0.2%)	31.9	.5	...	...	81	[j]74	...	[530]
3504..	...do	Sheet, rolled	...	...	19.6 (0.2%)	50.2	2	...	...	76	...	...	[530]
3505..	...do	Die-cast; aged 6 months at r-t.	...	...	...	[k]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	[j]86	...	[530]
3507..	...do	Cast from 860°F into mold at 390°F.	...	...	17.8 (0.2%)	24.9	<0.5	...	...	87	[j]96	...	[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	[529]
3512..	Al 7, Cu 4	...do	...	...	...	45.5	40	...	...	...	...	Bend No. (0.12-in. radius)....34	[529]
3513..	Al 7, Cu 4, Mg 0.03.	...do	...	...	...	59.7	30	...	...	...	...	Bend No. (0.12-in. radius)....10	[529]

[i]Rate of strain: 0.5 in./minute. [j]Impact value, cm-kg/cm.² [k]As die-cast.

TABLE 54.—*Zinc and zinc alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
						ZINC-ALUMINUM ALLOYS—Continued							
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
3514..	Al 9-11, Cu 1.8-2.0, Mg 0.02-0.05.	Extruded				68	7	55		105	½		[534]
3515..	Al 10	Sheet, rolled				26	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 0.004.	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)	41					[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.				^{m}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.				^{m}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.				^{m}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.				^{m}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.				^{m}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.				^{m}30.0	82 (1.25 in.)	74					[539]

ZINC-COPPER ALLOYS (SEE ALSO FIGS. 182 AND 183)

3531..	Cu 1.0, Pb 0.084, Fe 0.015, Cd 0.0049.	Sheet, 0.018 in., rolled..	....	....	....	[d] 31.3	33 (2 in.)	....	....	S 20	......	Dynamic ductility............0.285 in........ Temper........................60%.	[528]
3532..	Cu 1.0, Pb 0.09, Fe 0.011, Cd 0.0013, Mg 0.0036.	...do.....................	....	....	....	[d] 29.8	26 (2 in.)	....	....	S 19	......	Dynamic ductility............0.250 in........ Temper........................62%.	[528]
3533..	Cu 1.0, Mg 0.01.....	Sheet, 0.040 in., soft....	....	....	....	27	35	....	....	R_F 72	......	Dynamic ductility............0.38 in......... Temper........................37%.	[537]
3534..	...do...............	Sheet, 0.040 in., rolled (50% red.).	....	....	....	46	23	....	....	R_F 93	......	Dynamic ductility............0.34 in......... Temper........................52%.	[537]
3535..	Cu 1.1, Pb 0.077, Fe 0.012, Cd 0.0047.	Sheet, 0.018 in., rolled..	....	....	....	[d] 34.0	56 (2 in.)	....	....	S 18	......	Dynamic ductility............0.300 in........ Temper........................44%.	[528]
3536..	Cu 1.1, Pb 0.09, Fe 0.012, Mg 0.0057, Cd 0.0046.	...do.....................	....	....	....	[d] 36.7	22 (2 in.)	....	....	S 21	......	Dynamic ductility............0.240 in........ Temper........................67%.	[528]
3537..	Cu 3, Al 1..........	Sheet, cold-rolled to 0.039 in. (67% red.).	....	....	....	48.4	24	....	....	......	......	Bend No. (0.12-in. radius)....80.............	[529]
3538..	Cu 3.7-4.0, Bi 0.25-0.40, Mn 0.25-0.40, Al 0.2-0.3, Fe 0.1-0.3, Mg <0.005.	Extruded.................	....	....	....	51	18	25	....	93	......	....	[534]
3539..	Cu 3.7-4, Bi 0.1-0.15, Mn 0.1-0.2, Al 0.05-0.2, Pb 0.06-0.08, Tl 0.02-0.05.	...do.....................	....	38-40	....	44-45	8-16 (10 diam)	....	....	......	......	....	[538]
3540..	...do...............	Rod, 1/2 in. diam, extruded and drawn.	....	....	....	45-47	20-25 (10 diam)	30-35	....	85-95	[l] 10-12	....	[538]
3541..	Cu 4-5, Al 0.2-0.25..	Extruded.................	....	....	....	47	30	60	....	88	......	....	[534]
3542..	Cu 4.8, Al 0.2......	Sheet, rolled............	....	....	....	36	75	....	....	......	......	Bend No......................32............. Erichsen.....................18 mm.	[534]
3543..	Cu 5, Al 1..........	Sheet, cold-rolled to 0.039 in. (67% red.).	....	....	....	42.7	45	....	....	......	......	Bend No. (0.12-in. radius)....80.............	[529]
3544..	Cu 5, Al 3..........	...do.....................	....	....	....	46.9	40	....	....	......	......	Bend No. (0.12-in. radius)....34.............	[529]

[d] Rate of strain: 0.25 in./minute. [l] Impact value, cm-kg/mm.^{2} [m] Rate of strain: 6%/minute.

TABLE 54.—*Zinc and zinc alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					ZINC-MANGANESE-COPPER ALLOY								
	Percent		*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*	*Kips/in.*^{2}		*ft-lb*		
3545..	Mn 20, Cu 10........	Cast......................	....	....	....	75.0	....	....	....	R_C 7	......	....	[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.................	....	....	....	[n]9.7	....	....	....	52	......	Transverse deflection (3-in. span).................0.18 in......... Mod rupture...................52.7 kips/in.^{2}	[526]
3550..	Sn 30, Ag 20........	....	....	....	....	....	....	....	....	......	......	Melting range 650°-970°F......................	[184]

[n]Rate of strain: 0.266 in./minute.

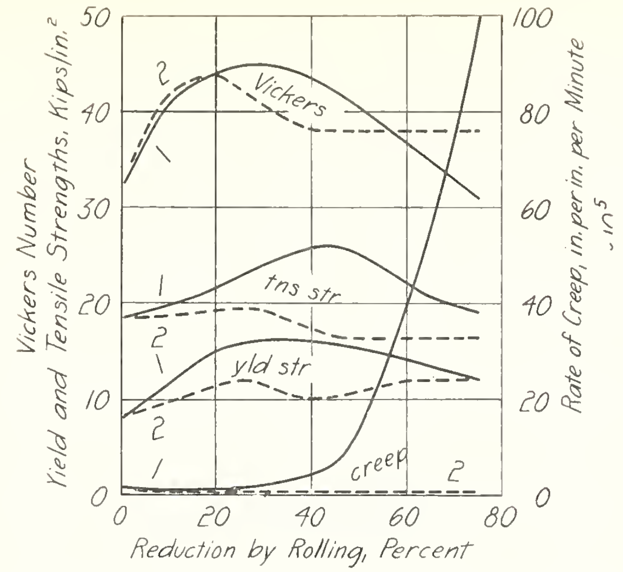


FIGURE 179.—*Effect of cold-rolling on the tensile properties and hardness of electrolytic zinc (Chadwick [701]).*

(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.

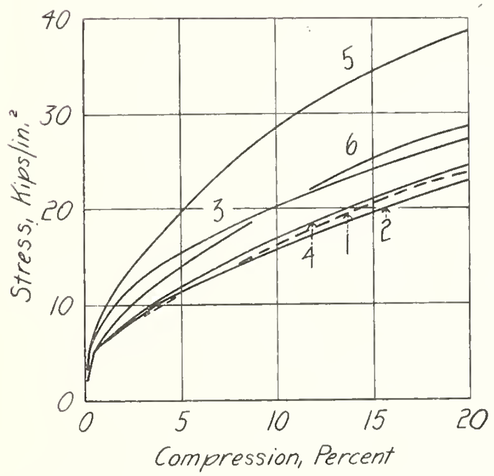


FIGURE 180.—*Compressive strength of cast zinc (Rigg and Williams [702]).*

(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%.

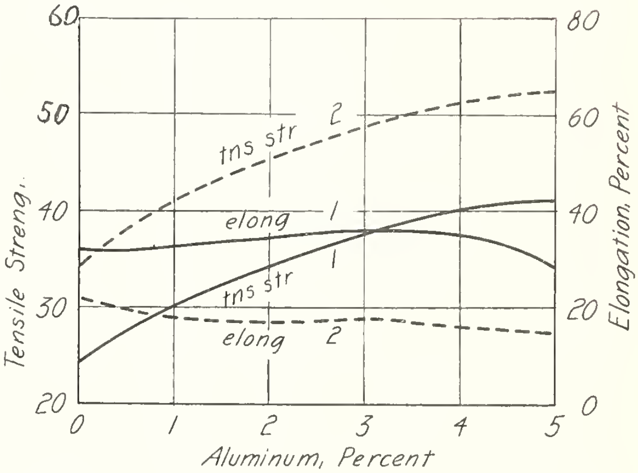


FIGURE 181.—*Tensile properties of zinc-aluminum alloys (Bayer [529]).*

Sheet, 0.04 in., cold-rolled (67% red.).

Curves: 1, parallel to rolling direction; 2, perpendicular to rolling direction.

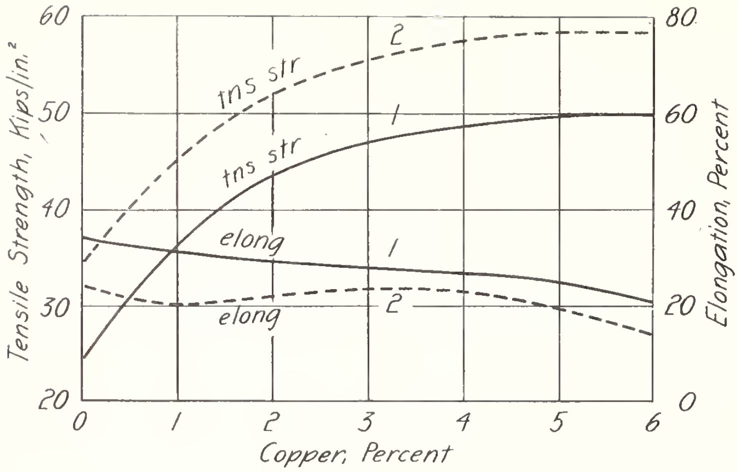


FIGURE 182.—*Tensile properties of zinc-copper alloys (Bayer [529]).*

Sheet, 0.04 in., cold-rolled (67% red.).

Curves: 1, parallel to rolling direction; 2, perpendicular to rolling direction.

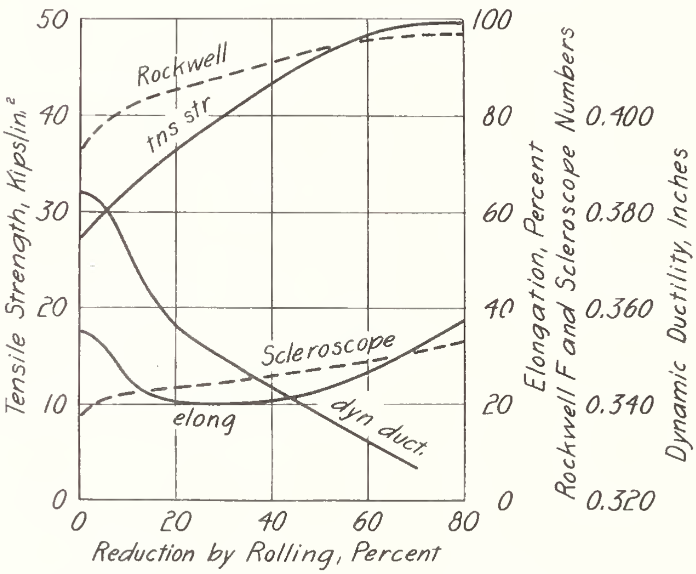
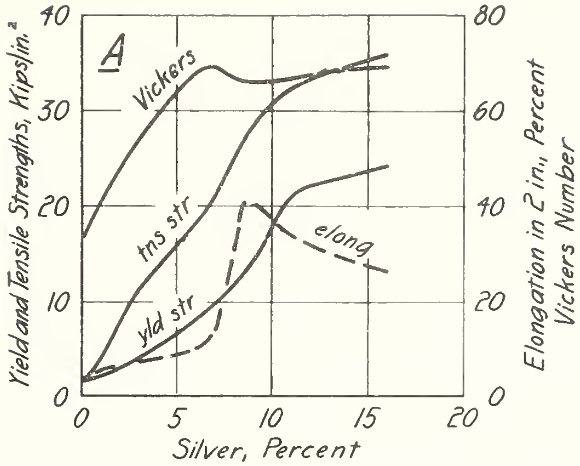


FIGURE 183.—*Effect of cold-rolling on the tensile properties, hardness, and dynamic ductility of a zinc-copper-magnesium alloy (Kelton and Edmunds [537]).*

Cu 1.0%, Mg 0.01%. Sheet, 0.040 in.



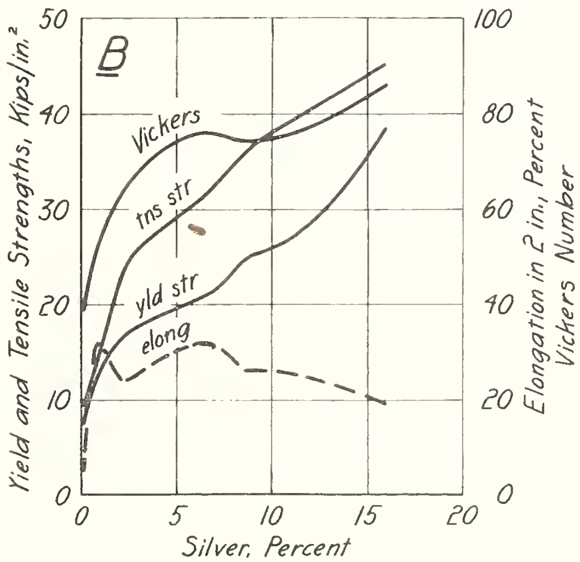


FIGURE 184.—*Tensile properties and hardness of zinc-silver alloys (Addicks [129]).*

(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			Remarks	Reference
	Percent		°F	0.01%	0.1%	1.0%		
3551	Pb 0.05, Cd 0.002	Rolled, soft	68 104 140	6.5	8.4 6.8	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 14.1	Tested perpendicular to rolling direction	[527]
3557	...do	Rolled, medium hard	68 104 140	6.6 5.0	9.1 6.8 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 44%	[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]

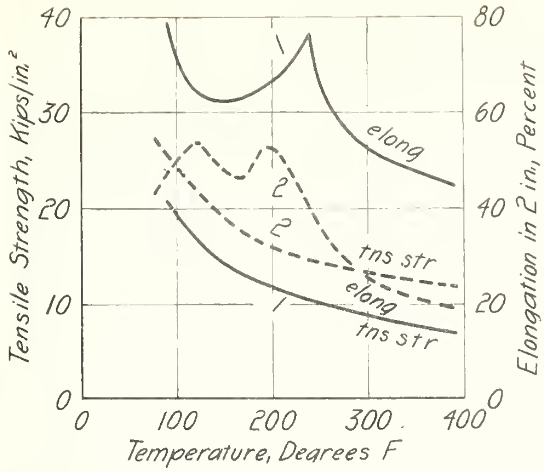


FIGURE 185.—*Short-time tensile properties of zinc at high temperatures (Anderson [703]).*

(Rate of strain, 0.285 in./minute)

Pb 0.065%, Fe 0.01%.

Curves: 1, with grain; 2, across grain.

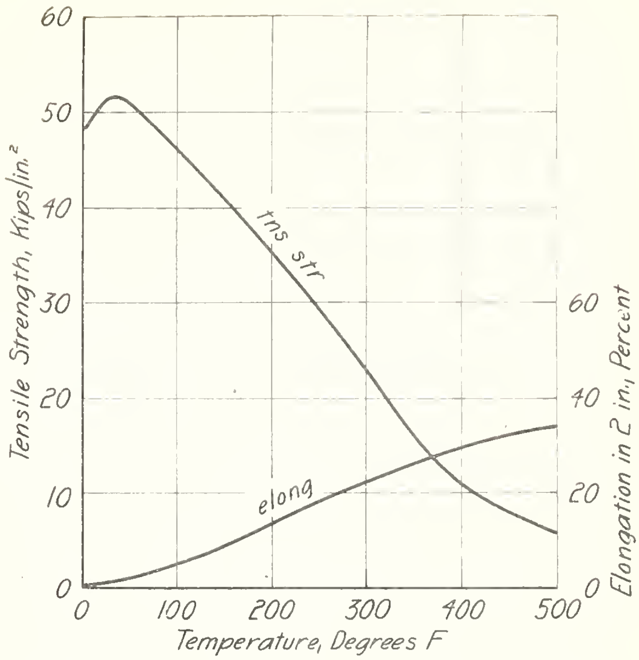


FIGURE 186.—*Short-time tensile properties of a die-cast zinc-aluminum-copper-magnesium alloy at various temperatures (Anderson [703]).*

(Rate of strain, 0.02 in./minute)

Al 4.67%, Cu 2.89%, Mg 0.09%, Fe 0.015%.

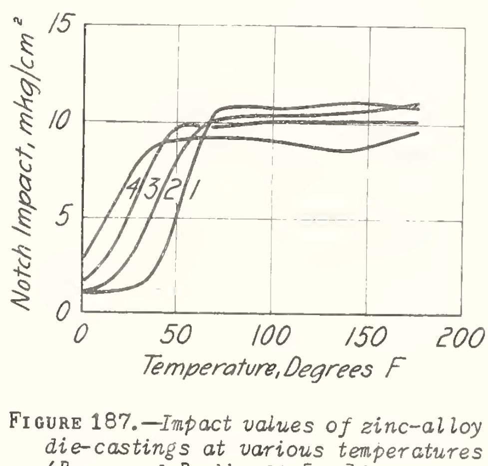


FIGURE 187.—*Impact values of zinc-alloy die-castings at various temperatures (Bayer and Burkhardt [536])*

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. 186 and 187]

Serial number	Composition	Condition	Temperature of test	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Tensile properties: Charpy impact value	Reference
	Percent		°F	*Kips/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	....	

[a]Notch 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	20° to 200°C	20° to 300°C	
	Percent		$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	
3569[a]	Cd 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]
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	....	32.0	37.2	[b]40.7	[707]
3573	Al 12.5	Rod, 1/4 in. diam	26.4	29.1	[c]38.7	[543]
3574	Al 22.57, Fe 0.11, Cu 0.05, Si 0.05	....	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	....	23.2	....	....	[481]
3577[d]	Mg 10	....	24.0	....	....	[481]
3578[d]	Mg 17	....	33.2	....	....	[481]
3579[d]	Mg 30	....	31.5	....	....	[481]

[a]Coefficient 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).

[b]20° to 250°C.

[c]20° to 290°C.

[d]Base temperature 40° instead of 20°C.

TABLE 58.—*Zinc and zinc alloys, electrical and thermal properties*

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal conductivity	Reference
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10⁻⁴*	*Watts cm⁻¹ °C⁻¹*	
3580	Zn 99.993	Cast	...	...	...	1.27 (-100°C); 1.09 (0°C); 0.99 (100°C)	[544]
3581	Zinc (spectrographically pure)	Wire, 0.07 in., swaged	29.1 (20°C)	5.916 (20°C)	...	...	[544]
3582	...do	Wire, 0.0089 in., drawn (87% red.)	...	...	41.9 (0°-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	...	...	...	1.12 (100°C); 1.08 (200°C); 1.05 (300°C)	[402]
3586	Al 3.5-4.3, Mg 0.03-0.08	Die-cast	27 (25°C)	6.4 (25°C)	...	1.1 (25°-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°-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°-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]

[a]Parallel to the vertical axis of the crystal.
[b]Perpendicular to the vertical axis of the crystal.

XIII. MISCELLANEOUS METALS AND ALLOYS

TABLE 59.—*Classification of some miscellaneous metals and alloys (1942)*

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

Designation: Government Spec	Government Alloy	ASTM Spec	ASTM Alloy	SAE	Commercial name	Ag	Cu	Zn	Cd	Au	Other	Serial numbers of corresponding alloys in the tables
CADMIUM-BASE BEARING ALLOYS												
				18					98.5		Ni 1.5	3619, 3919.
				180		1.0	0.75		98.25			
GOLD												
CS-67-38[a]					Fine (24 carat)					99.9+		3641 to 3645, inclusive; 3927, 3957, 3958, 4019, 4020.
					18 carat					75		3651, 3663, 3682, 3685, 3709, 3716.
					16 carat					66.67		3654, 3668, 3960, 3961.
					14 carat					58.33		3657, 3661, 3662, 3665, 3666, 3667, 3683, 3695 to 3698, inclusive.
					12 carat					50		3660, 3679, 3680, 4041, 4050, 4051.
					10 carat					41.66		3670, 3671, 3672, 3674.
SILVER												
					Fine	99.9+						3798 to 3804, inclusive; 3929, 3984, 3985, 4140, 4141, 4142; figures 195 and 206.
Congress statutes at large, 260[b]					Sterling	92.5	7.5					3814, 3815, 3816; figures 195 and 206.
Do					Coin	90	10					Figure 206.
SILVER SOLDERS (HARD SOLDERS)												
		B73-29	8			80	16	4				3819, 3909.
		B73-29	7			70	20	10				3908.
QQ-S-561c[c]	2	B73-29	6			65	20	15				3820, 3907.
		B73-29	5			50	34	16				3824, 3905.
47S13c[d]					"Easy-Flo"	50	15.5	16.5	18			3906.
QQ-S-561c[c]	1	B73-29	4			45	30	25				3904.
		B73-29	3			20	45	30	5			1057 (copper section), 3903.
QQ-S-561c[c]	0	B73-29	2			20	45	35				1058 (copper section), 3902.
47S13c[d]					"Sil-Fos"	15	80				P 5	3901.
		B73-29	1			10	52	38				1059 (copper section), 3900.

[a]National Bureau of Standards.
[b]See "Standards and Specifications for Metals and Metal Products," Misc. Pub. BS 120 (1933).
[c]Federal.
[d]Navy.

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 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: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
						ANTIMONY							
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
3598..	Antimony..........		11,300									Specific gravity........6.62	[546]
3599..	Sb 99.45..........	Wire, 0.0091 in. diam..	11,300			1.5						Mod-el (shear)..........2,900 kips/in.²	[303]
3600..	Antimony (vacuum distilled).	Cast; ann at 1,100°F in vacuum.	7,800										[450]
						BERYLLIUM AND BERYLLIUM ALLOYS							
3601..	Be 99.962........									98		Density................1.816 g/cm³ at 64.4°F..	[517]
3602..	Be 99.5..........	Chill-cast............	42,600			17.0	0			97			[548]
3603..	...do............	Rod, 3/8 in. diam, forged at 1,800°-1,650°F (77% red.).	40,000	9.4		29.8	0 (4 diam)	0				Comp yld str (0.2%).....35.3 kips/in.² Shear str...............38.6 kips/in.² Specific gravity........1.844.	[548]
3604..	...do............	Rod, 3/8 in. diam, forged; ann at 1,830°F in hydrogen.	36,800	8.7	23.4 (0.2% offset)	27.0	0 (4 diam)	0					[548]
3605..	Al 28............	Chill-cast............	29,000		19.0 (yld pnt)	25.0	3.0 (2 in.)			86		Specific gravity........2.03	[548]
3606..	Be 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)..........1,800 kips/in.² Poisson's ratio.........0.33.	[88]
3608..	...do............		4,600									Specific gravity........9.80	[516]
3609..	Pb 26.7, Sn 13.3, Cd 10.	Cast..................				[a]6.0	140 (2 in.)			9.2		Melting point...........158°F	[427]
3610..	Pb 26.7, Sn 13.3, Cd 10, Hg 10.	...do.................				[a]6.0	89 (2 in.)			8.9		Melting point...........151°F	[427]
3611..	...do............	Cast; aged 6 weeks at r-t.				[a]6.0	42 (2 in.)			10			[427]
3612..	Bi 51.8, Pb rem...					[a]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.				[b]10.3	50			21-23		Specific gravity........8.65	[550]
3614..	...do............	Rod, rolled from 1 1/2 in. to 1/2 in., aged 21 days at r-t.				[b]13.7	126 (1.25 in.)					Specific gravity........8.65	[550]

3615..	...do............	Sheet, rolled from 1 1/2 in. to 1/4 in., aged 4 1/2 hr at r-t.	....	....	....	[b]12.3	92 (2 in.)	......	....	....	......	....	[550]
3616..	Cadmium..........	....	7,100-10,000	....	....	....	....	......	....	....	......	Mod-el (shear)..........1,400-3,600 kips/in.^{2}.. Poisson's ratio.........0.30.	[303]
3617..	Cu 1.5, Mg 0.95...	Cast..................	8,000	....	7.8 (0.02%) 14.0 (0.2%)	22.3	8.8 (10 diam)	12	5.4	42	......	Comp yld str (0.2%).....14.4 kips/in.^{2}......... Compressive str.........67.7 kips/in.^{2}	[432]
3618..	Cu 1.94, Ag 0.48..	...do.................	9,200	....	7.4 (0.02%) 13.5 (0.2%)	20.5	7.4 (10 diam)	12	....	29	......	Comp yld str (0.2%).....15.2 kips/in.^{2}......... Compressive str.........40.1 kips/in.^{2}	[432]
3619..	Ni 1.3...........	....	....	....	11.7	[c]16.4	19 (2 in.)	43	3.8 (2×10^7)	33	......	Comp str (50%)..........27 kips/in.^{2}........... Melting range...........604°-743°F.	[551]
3620..	Ni 3.0...........	....	....	....	16.8	[c]22.9	6 (2 in.)	6	....	48	......	Comp str (50%)..........38 kips/in.^{2}........... Melting range...........604°-855°F.	[551]
3621..	Ag 5.............	Rod, 1/4 in..........	....	....	....	16.4	31 (2 in.)	81	....	....	......	....	[129]
3622..	Zn 5.0...........	Rod, 1 in. diam, chill-cast from 660°F; aged one month at r-t.	....	....	....	[b]13.1	6.5 (1.25 in.)	3	....	32	......	Specific gravity........8.55...................	[539]
3623..	Zn 12.5..........	...do.................	....	....	....	[b]22.6	40 (1.25 in.)	53	....	42	......	....	[539]
3624..	Zn 25.0..........	...do.................	....	....	....	[b]20.2	52 (1.25 in.)	45	....	34	......	....	[539]
						CALCIUM; CERIUM; CHROMIUM							
3625..	Ca 99.3, Si 0.14, Fe 0.02.	Distilled.............	2,900-3,700	1.5	....	6.3	53	62	....	13	[d]3.1	Shear str...............6.1 kips/in.^{2}.......... Specific gravity........1.54.	[552]
3626..	Ca 98.5, Cl 0.85, Fe 0.29, Si 0.07.	Electrolytic..........	3,700	3.1	....	7.2	30	37	....	14	[d]3.5	Shear str...............6.4 kips/in.^{2}..........	[552]
3627..	Calcium..........	Extruded..............	....	5.6	....	8.1	61	68	....	17	......	....	[552]
3628..	...do............	....	2,800	....	....	....	....	......	....	....	......	....	[553]
3629..	Cerium...........	Rolled................	....	....	....	12.9	....	......	....	42	......	....	[554]
3630..	Misch metal: Ce 50-70, Fe 1-5, La, Nd, Pr.	....	....	....	....	....	....	......	....	....	......	Melting point...........1,380°F................	[554]
3631..	Chromium.........	....	....	....	....	....	....	......	....	108	......	....	[555]
						COBALT AND COBALT ALLOYS							
3632..	Co 99.73.........	Cast..................	....	....	....	34.4	....	......	....	....	......	Compressive str.........122 kips/in.^{2}.......... Specific gravity........8.77.	[556]
3633..	Fe 1.4, Ni 1.1, C 0.24.	Cast; ann 2 hr at 1,650°F.	29,600	....	....	....	....	......	....	....	......	Mod-el (shear)..........11,100 kips/in.^{2}.......	[237]
3634..	Co >55, Cr <33, W <6.	Cast..................	30,400	....	....	105	1.0 (2 in.)	......	....	....	......	Compressive str.........220 kips/in.^{2}.......... Specific gravity........8.38. Melting point...........2,327°F.	[557]
3635..	...do............	Forged................	....	....	....	130	2.0 (2 in.)	......	....	....	......	Compressive str.........259 kips/in.^{2}..........	[557]
3636..	Co 45-55, Cr 30-35, W 12-17.	Cast..................	35,400	....	....	65.0	0 (2 in.)	......	....	R_c 61	......	Specific gravity........8.76................... Melting point...........2,318°F.	[557]

[a]Rate of strain 0.5 in./minute (free cross-head speed). [b]Rate of strain 6 percent/minute. [c]Rate of strain 0.05 (in./in.)/minute. [d]Notch impact value m-kg/cm.^{2}

TABLE 60.—*Miscellaneous metals and alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
						COBALT AND COBALT ALLOYS—Continued							
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
3637..	Co >47, Cr <34, W <10.	Cast..................	....	....	....	76.0	0 (2 in.)	......	....	....	......	Compressive str.........143 kips/in.².......... Specific gravity........8.40. Melting point...........2,306°F.	[557]
3638..	Co >43, Cr <34, W <14.	...do..................	35,000	....	....	47.0	0 (2 in.)	......	....	....	......	Compressive str.........256 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 0.003, Ni 0.002.	....	....	....	....	2.8-5.4	2-40	......	....	....	......	....	[558]
						GOLD							
3641..	Au 999⁺ fine (parts per thousand).	Rod, 0.8 in. diam, rolled; ann 10 min at 930°F, strained 5%.	10,300	2.9	8.1 (0.01%)	ᶜ17.9	65 (2 in.)	87	....	....	......	....	[559]
3642..	Gold.............	....	....	....	....	....	....	......	....	....	......	Mod-el (shear)..........4,100-5,600 kips/in.².. Poisson's ratio.........0.42.	[88]
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 (10⁷)	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°-1,686°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...........1,749°-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 1,290°F.	13,000	21.0	....	55.0	29 (8 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°-1,486°F.........	[561]

3652..	Cu 12.3, Cd 7.9, Ag 7.2, Zn 1.7.	....	....	40.1	....	55.7	51 (2 in.)	......	....	73	......	Melting range..........1,398°-1,423°F.........	[561]
3653..	Cu 12.5, Ag 4.2...	Strip, 3/8 in., ann 1/3 hr at 1,365°F.	....	40.7	....	62.7	43	......	....	....	......	Melting range..........1,654°-1,692°F......... Color..................orange-yellow.	[563]
3654..	Cu 15.4, Cd 8.5, Ag 7.5, Zn 1.9.	....	....	47.1	....	72.5	45 (2 in.)	......	....	101	......	Melting range..........1,330°-1,400°F.........	[561]
3655..	Cu 15.6, Ag 6.0, Pt 2.78, Zn 2.38, Ni 1.98.	Rod, 1/8 in. diam, cast; w-q from 1,290°F.	13,000	53.5	....	69.0	4 (3 in.)	......	....	....	......	Melting range..........1,620°-1,805°F.........	[560]
3656..	...do............	Rod, 1/8 in. diam, cast; f-c from 840° to 480°F in 1/2 hr.	14,000	94.5	....	108	....	......	....	....	......	....	[560]
3657..	Cu 17.95, Ni 17.60, Zn 6.0, Mn 0.4.	Sheet, 0.050 in., rolled (50% red.); 1/2 hr at 1,290°F, a-c.	....	....	64.0 (yld pnt)	103	44 (2 in.)	......	....	....	......	Color..................white..................	[564]
3658..	Cu 18.9, Ag 13.9, Ni 2.57, Zn 1.92.	Rod, 1/8 in. diam, cast; w-q from 1,290°F.	13,000	46.0	....	70.0	10 (3 in.)	......	....	....	......	Melting range..........1,510°-1,600°F.........	[560]
3659..	...do............	Rod, 1/8 in. diam, cast; f-c from 840° to 480°F in 1/2 hr.	13,000	73.0	....	103	1 (3 in.)	......	....	....	......	....	[560]
3660..	Cu 21.9, Ni 18.0, Zn 10.0, Mn 0.1.	Sheet, 0.050 in., rolled (50% red.); ann 1/2 hr at 1,200°F, a-c.	....	....	63.8 (yld pnt)	105	41 (2 in.)	......	....	....	......	Color..................white..................	[564]
3661..	Cu 24.66, Ni 17.04	Sheet, 0.045 in., rolled (50% red.); ann 1/3 hr at 1,300°F, a-c.	....	....	77.2 (yld pnt)	113	15 (1.25 in.)	15	....	R_B 97	......	Melting point..........1,920°F............... Color..................white.	[565]
3662..	Cu 24.86, Zn 16.84	...do.................	....	....	50.0 (yld pnt)	70.0	28 (1.25 in.)	26	....	R_B 78	......	Melting point..........1,530°F............... Color..................brass-yellow.	[565]
3663..	Cu 24............	Quenched from 1,470°F..	15,300	....	....	....	....	......	....	....	......	....	[55]
3664..	...do............	Quenched from 1,470°F, aged 20 hr at 570°-750°F.	13,700	....	....	....	....	......	....	....	......	....	[55]
3665..	Cu 25.22, Ni 8.59, Zn 7.89.	Sheet, 0.045 in., rolled (50% red.); ann 1/3 hr at 1,300°F, a-c.	....	....	45.6 (yld pnt)	87.2	50 (1.25 in.)	38	....	R_B 83	......	Melting point..........1,745°F............... Color..................white.	[565]
3666..	Cu 26.43, Ag 11.03, Zn 2.21, Ni 2.00.	Sheet, 0.050 in., rolled (50% red.); 1/2 hr at 1,290°F, w-q.	....	....	54.2 (yld pnt)	79.3	50 (2 in.)	......	....	....	......	Color..................yellow.................	[564]
3667..	Cu 26.94, Ni 7.42, Ag 7.34.	Sheet, 0.045 in., rolled (50% red.); ann 1/3 hr at 1,300°F, a-c.	....	....	86.1 (yld pnt)	110	18 (1.25 in.)	16	....	R_B 100	......	Melting point..........1,750°F............... Color..................yellow-white.	[565]
3668..	Cu 28.5, Ag 4.8...	Strip, 3/8 in., ann 1/3 hr at 1,365°F.	....	40.4	....	65.7	49	......	....	....	......	Melting range..........1,638°-1,652°F......... Color..................orange-yellow.	[563]
3669..	Cu 31.98, Zn 15.38, Ag 12.3, Ni 1.84.	Sheet, 1/2 hr at 1,290°F, w-q.	....	....	34.1 (yld pnt)	59.1	62 (2 in.)	......	....	....	......	Color..................green..................	[564]
3670..	Cu 34.8, Zn 23.59	Sheet, 0.045 in., rolled (50% red.); ann 1/3 hr at 1,300°F, a-c.	....	....	28.4 (yld pnt)	45.6	60 (1.25 in.)	42	....	R_B 18	......	Melting point..........1,570°F............... Color..................brass-yellow.	[566]
3671..	Cu 34.9, Ni 12.14, Ag 11.11.	Sheet, 0.045 in., rolled (50% red.); ann 1/3 hr at 1,300°F, a-c.	....	....	70.0 (yld pnt)	90.4	19 (1.25 in.)	20	....	R_B 94	......	Melting point..........1,815°F............... Color..................white.	[566]
3672..	Cu 35.15, Zn 11.73, Ag 11.50.	...do.................	....	....	32.0 (yld pnt)	53.5	60 (1.25 in.)	44	....	R_B 58	......	Melting point..........1,550°F............... Color..................yellow.	[566]
3673..	Cu 35.45, Ni 6.25..	Sheet, 0.045 in., rolled (50% red.); ann 1/3 hr at 1,300°F, a-c.	....	....	42.1 (yld pnt)	80.0	50 (1.25 in.)	37	....	R_B 76	......	Melting point..........1,820°F............... Color..................light-pink.	[565]

TABLE 60.—*Miscellaneous metals and alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
					GOLD-COPPER ALLOYS—Continued								
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
3674..	Cu 35.54, Ni 23.85	Sheet, 0.045 in., rolled (50% red.); ann 1/3 hr at 1,300°F, a-c.	....	....	104 (yld pnt)	111	19 (1.25 in.)	18	....	R_B 100	......	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, aged 1/2 hr at 615°F.	....	....	110 (yld pnt)	117	6.5 (2 in.)	......	....	....	......	Color.....yellow.....	[564]
3679..	Cu 49.....	Quenched from 1,470°F..	16,800	....	....	....	....	......	....	....	......	....	[55]
3680..	...do.....	Quenched from 1,470°F, aged 20 hr at 570°-750°F.	18,100	....	....	....	....	......	....	....	......	....	[55]
					GOLO-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.....	....	17,100	....	....	....	....	......	....	....	......	Modulus (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..	Pd 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.................2,570°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	24 (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-q from 1,290°F.	13,000	50.0	....	61.5	1 (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	12 (8 in.)	......	....	....	......	Melting point.................1,870°F..........	[560]
3694..	...do...........	Strip, 0.006 in., f-c from 840° to 480°F in 1/2 hr.	18,000	116	....	157	4.6 (8 in.)	......	....	....	......	....	[560]
3695..	Pt 15.2, Ag 15.0, Cu 8.8, Ni 1.3.	Wire, 0.035 in. diam, w-q from 1,290°F.	16,000	63.0	....	102	10 (8 in.)	......	....	....	......	Melting point.................1,750°F..........	[560]
3696..	...do...........	Wire, 0.035 in. diam, f-c from 840° to 480°F in 1/2 hr.	17,000	76.0	....	123	6.8 (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	9.6 (8 in.)	......	....	....	......	Melting point.................1,850°F..........	[560]
3698..	...do...........	Wire, 0.035 in. diam, f-c from 840° to 480°F in 1/2 hr.	19,000	133	....	175	4.6 (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.	....	68.1	....	124	18 (8 in.)	......	....	....	......	....	[568]
3700..	...do...........	Wire, 0.040 in. diam, quenched from 1,650°F, aged 1/4 hr at 840°F.	....	113	....	174	0.9 (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	9.9 (8 in.)	......	....	....	......	Melting point.................1,950°F..........	[560]
3702..	...do...........	Strip, 0.006 in., f-c from 840° to 480°F in 1/2 hr.	15,000	44.0	....	90.0	11 (8 in.)	......	....	....	......	....	[560]
						GOLD-SILVER ALLOYS							
3703..	Ag 4.6, Cu 3.7....	Rod, 1/8 in. diam, cast	....	11.0	....	34.5	20 (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-q from 1,290°F.	13,000	25.0	....	59.0	19 (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	18 (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	18 (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	7 (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 1/2 hr.	12,000	61.5	....	70.0	....	......	....	....	......	....	[560]

TABLE 60.—*Miscellaneous metals and alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	GOLD-SILVER ALLOYS—Continued												
	Percent		*Kips/in.*²	*Kips/in.*²	*Kips/in.*²	*Kips/in.*²	*Percent*	*Percent*	*Kips/in.*²		*ft-lb*		
3709..	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)	71.8	26 (1 in.)	......	28.5 (10^7)	115	......	....	[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°-1,445°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..	Indium: In 99.9..	Rod, 3/8 in. diam, cast	....	....	....	0.43	....	99	....	ᵉV 1.0	......	....	[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[f]..	Electro manganese	Cold-worked........	23,000	....	....	120	....	......	....	....	......	Specific gravity........7.20........	[571]
3724[f]..	...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	Rod, 1/2 in. diam, quenched from 1,470°F.				67	44 (1.25 in.)	70		R_B 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_B 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 10.2	[52]
3739..	...do		41,200										[575]
3740..	Osmium	Cast								V 350		Specific gravity 22.48	[576]
						PALLADIUM AND PALLADIUM ALLOYS (SEE ALSO FIGS. 188 AND 189)							
3741..	Palladium	Hard	17,000			47.0				109		Specific gravity 12.0	[570]
3742..	...do	Annealed	13,800			20.0				46			[570]
3743..	...do	Wire	18,300									Mod-el (shear) 6,700 kips/in.^{2} Poisson's ratio 0.39.	[303]
3744..	...do	Wire, 0.05 in. diam, hard (50% red.).		31.8		46.8	1.5 (2 in.)	92		109		Specific gravity 12.16	[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 570°-750°F.	16,600										[55]
3748..	Au 10	Annealed at 1,470°F.				34.0							[499]
3749..	...do	Cold-worked (66% red.).				57.0							[499]
3750..	Pt 25	Hard								150			[570]
3751..	...do	Annealed				43.0				80		Erichsen 11.5 mm	[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 4, 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: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
PLATINUM AND PLATINUM ALLOYS (SEE ALSO FIGS. 190 TO 194, INCLUSIVE)													
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
3756	Pt 99.9+	Wire, 0.05 in. diam, cold-drawn (50% red.).	....	27.0	....	36.0	2.5 (2 in.)	95	....	....	......	....	[577]
3757	...do	Wire, 0.05 in. diam, ann 5 min at 1,650°-1,830°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.	[570]
3760	...do	....	22,700-24,900	....	....	....	....	......	....	....	......	Mod-el (shear).......8,500-10,000 kips/in.². Poisson's ratio.......0.38.	[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..	Pd 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°-2,010°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%)	[c]21.5	65 (2 in.)	92	...	...	...	...	...	[559]
3799..	Ag, 999 fine (parts per thousand).	Sheet, 0.032 in., rolled (50% red.).	...	...	44.3 (yld 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 (yld 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........0.392. Specific gravity.......10.43.	[579]
3802..	...do	Annealed	10,600	...	...	...	...	...	...	...	...	...	Mod-el (shear).........3,900 kips/in.^{2} Poisson's ratio........0.369. Specific gravity.......10.49.	[579]

[c]Rate of strain 0.05 (in./in.)/minute.

TABLE 60.—*Miscellaneous metals and alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	Tensile properties: "Proportional limit"	Tensile properties: Yield strength	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	SILVER AND SILVER ALLOYS—Continued												
	Percent		*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Kips/in.^{2}*	*Percent*	*Percent*	*Kips/in.^{2}*		*ft-lb*		
3803..	Silver	Chill-cast	...	2.0	4.7 (yld pnt)	15.4	60 (2 in.)	67	...	42	...	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	...	34	...	Compressive str (40%) ... 48.1 kips/in.^{2}	[303]
3805..	Ag 94.7, Al rem	Sheet, 0.064 in, ann 1/2 hr at 1,200°F.	...	...	...	41.0	70 (1/2 in.)	...	...	^{g}62	...	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, ann 1 hr at 1,290°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, ann 1 hr at 1,290°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	...	...	...	...	Melting range ... 1,103°-1,166°F.	[581]
3811..	Cr 0.14	Sheet, 0.064 in., ann 1/2 hr at 1,200°F.	...	...	...	27.5	48 (1/2 in.)	...	...	^{g}49	...	Specific gravity ... 10.48	[580]
3812..	Cr 0.77	...do	...	...	...	28.5	41 (1/2 in.)	...	...	^{g}53	...	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	17	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	14	Compressive str (40%) ... 71.0 kips/in.^{2}	[303]
3817..	Ag 92.1, Cu rem	Sheet, 0.064 in., ann 1/2 hr at 1,200°F.	...	...	...	44.0	46 (1/2 in.)	...	...	^{g}76	...	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}	[16]
3819..	Cu 16, Zn 4	Cast	...	...	...	50.1	16 (2 in.)	...	...	...	...	Specific gravity ... 10.05	[184]
3820..	Cu 20, Zn 15	...do	...	...	...	64.8	34 (2 in.)	...	...	...	...	Specific gravity ... 9.60	[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]

3824..	Cu 32.5, Zn 17.5..	...do				55.5	9.0 (2 in.)						[184]
3825..	Cu 36, Zn 24	...do				57.8	6.2 (2 in.)					Specific gravity 9.11	[184]
3826..	Cu 36-38, Zn 18.5-20.5.	...do			42.6	49.3	12					Melting range 1,292°-1,427°F.	[581]
3827..	Pb 0.02	Chill-cast								24		Shear str 13.7 kips/in.^{2}	[582]
3828..	Pb 0.98	...do								29		Shear str 14.6 kips/in.^{2}	[582]
3829..	Pb 2.96	...do								34		Shear str 14.5 kips/in.^{2}	[582]
3830..	Pb 4.68	...do								34		Shear str 14.5 kips/in.^{2}	[582]
3831..	Mg 1.19, Si 0.79, Ni 0.05.	Sheet, ann 1 hr at 1,110°F.			11.4 (0.2% offset)	26.2	27 (2 in.)			V 46			[129]
3832..	...do	Sheet, 0.040 in., cold-rolled (30% red.).			37.4 (0.2% offset)	40.0	4 (2 in.)			V 94			[129]
3833..	Ag 97.5, Mn rem...	Sheet, 0.064 in., ann 1/2 hr at 1,200°F.				25.5	44 (1/2 in.)			[g]51		Specific gravity 10.30 Melting point 1,760°F.	[580]
3834..	Ag 95.3, Mn rem...	...do				28.0	45 (1/2 in.)			[g]54		Specific gravity 10.10 Melting point 1,760°F.	[580]
3835..	Mn 7.65, Si 0.90..	Sheet, ann 1 hr at 1,110°F.			10.2 (0.2% offset)	23.2	19 (2 in.)			V 50			[129]
3836..	...do	Sheet, 0.040 in., cold-rolled (30% red.).			30.8 (0.2% offset)	31.9	2 (2 in.)			V 83			[129]
3837..	Mn 15.97, Si 0.43..	...do			45.2 (0.2% offset)	45.9	2 (2 in.)			V 106			[129]
3838..	Ni 0.10	Sheet, ann 1 hr at 1,290°-1,400°F.			11.8 (0.2% offset)	23.2	26 (2 in.)			V 41			[129]
3839..	...do	Sheet, 0.040 in., cold-rolled (30% red.).			32.4 (0.2% offset)	34.8	4 (2 in.)			V 81			[129]
3840..	Ni 0.6	Sheet, ann 1 hr at 1,290°-1,400°F.			8.8 (0.2% offset)	26.6	12 (2 in.)			V 46			[129]
3841..	...do	Sheet, 0.032 in., cold-rolled (50% red.).			41.0 (0.2% offset)	43.5	6 (2 in.)			V 92			[129]
3842..	Ag 98.1, Ni rem...	Sheet, 0.064 in., ann 1/2 hr at 1,200°F.				30.0	46 (1/2 in.)			[g]59		Specific gravity 10.47 Melting point 1,760°F.	[580]
3843..	Si 0.87, Ni 0.07..	Sheet, ann 1 hr at 1,110°F.			10.5 (0.2% offset)	25.8	36 (2 in.)			V 43			[129]
3844..	...do	Sheet, 0.040 in., cold-rolled (30% red.).			38.5 (0.2% offset)	40.7	3 (2 in.)			V 90			[129]
					TANTALUM; TELLURIUM; THORIUM; TITANIUM								
3845..	Tantalum		27,000							45-350		Specific gravity 16.6	[52]
3846..	...do	Wire, hard-drawn				50-170	1-2						[52]
3847..	...do	Wire, annealed				50	25-40						[52]
3848..	W 12, Ni 8, TaC rem.	Cemented								R_A 88		Mod rupture 250 kips/in.^{2}	[583]
3849..	Tellurium	Wire, 0.0091 in. diam..	6,000			1.6						Mod-el (shear) 2,200 kips/in.^{2}	[303]
3850..	...do											Specific gravity 6.24	[546]
3851..	Thorium (Ca reduced).	Rod, sintered and swaged.								R_B 43		Specific gravity 11.32	[584]

[g]Reported in the literature as "Baby Brinell" number.

TABLE 60.—*Miscellaneous metals and alloys, normal-temperature properties*—Continued

Serial number	Composition	Condition	Tensile properties: Modulus of elasticity	"Proportional limit"	Yield strength	Tensile strength	Elongation	Reduction of area	Endurance limit	Hardness number	Impact value	Miscellaneous	Reference
	TANTALUM; TELLURIUM; THORIUM; TITANIUM—Continued												
	Percent		*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*	*Kips/in.²*		*ft-lb*		
3852..	Thorium	Wire				80.0						Specific gravity......11.3-11.7	[554]
3853..	Titanium	Wire, 0.01 in. diam	12,100									Specific gravity......4.5	[585]
3854..	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			[588]
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	49,500-53,000									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 Specific gravity......15.04.	[583]
3864..	Co 6, WC rem	...do								R_A 91		Compressive str.......680-730 kips/in.² Mod rupture...........205 kips/in.² Specific gravity......14.82.	[583]
3865..	Co 9, WC rem	...do								R_A 90		Mod rupture...........250 kips/in.² Specific gravity......14.56.	[583]
3866..	Co 13, WC rem	...do	79,000							R_A 88		Compressive str.......540 kips/in.² Mod rupture...........300 kips/in.² Mod-el (shear)........17,200 kips/in.² Specific gravity......14.10.	[583]
3867..	Co 20, WC rem	...do								V 755		Specific gravity......12.54	[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 pnt)	89.6	4 (1 in.)			290		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, ann 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]

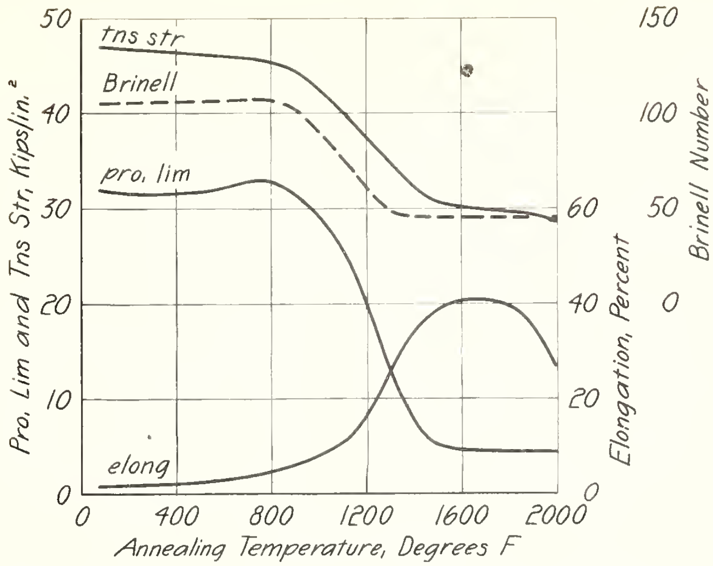


FIGURE 188.—*Effect of annealing on the tensile properties and hardness of hard-drawn palladium (Vines [499]).*

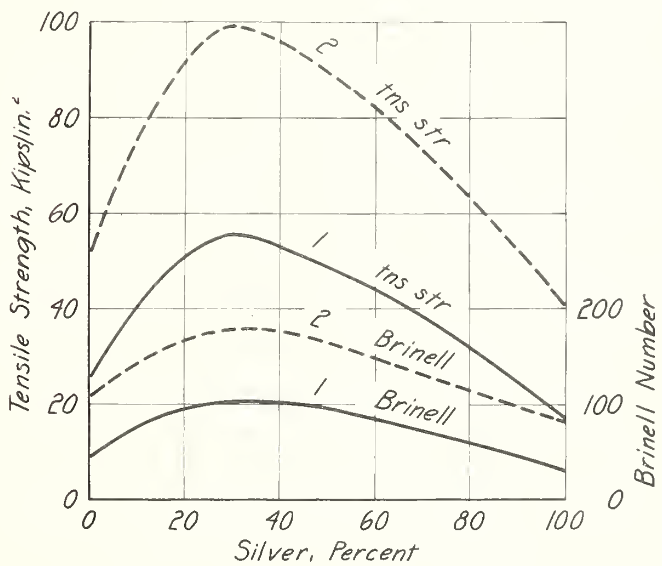


FIGURE 189.—*Tensile strength and hardness of palladium-silver alloys (Vines [499]).*

Curves: 1, annealed; 2, hard.

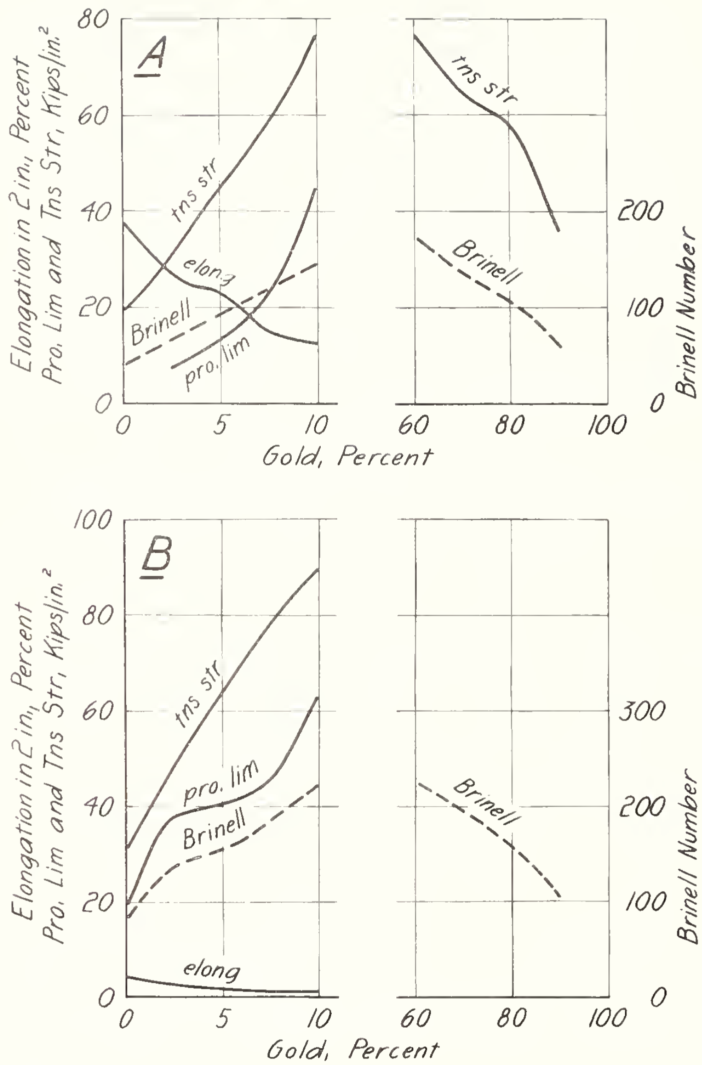


FIGURE 190.—*Tensile properties and hardness of platinum-gold alloys (Vines [499]).*

A, Annealed; B, hard-rolled (50% red.).

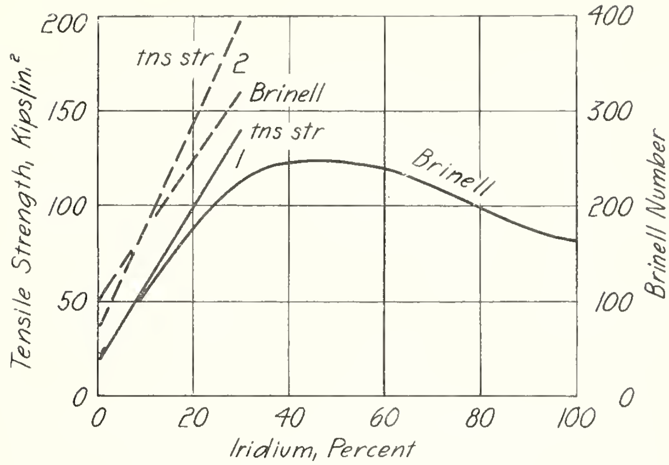


FIGURE 191.—*Tensile strength and hardness of platinum-iridium alloys (Vines [499]).*

Curves: 1, annealed; 2, hard.

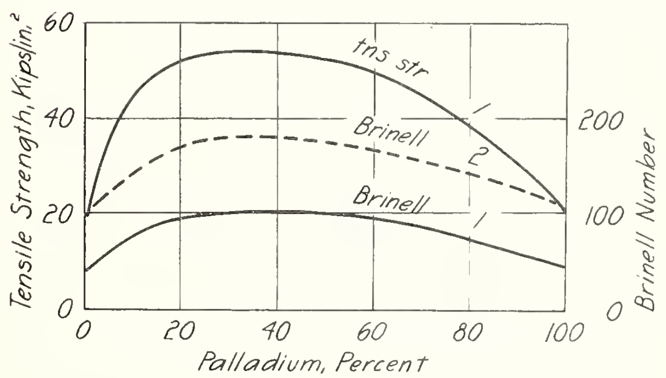


FIGURE 192.—*Tensile strength and hardness of platinum-palladium alloys (Vines [499]).*

Curves: 1, annealed; 2, hard.

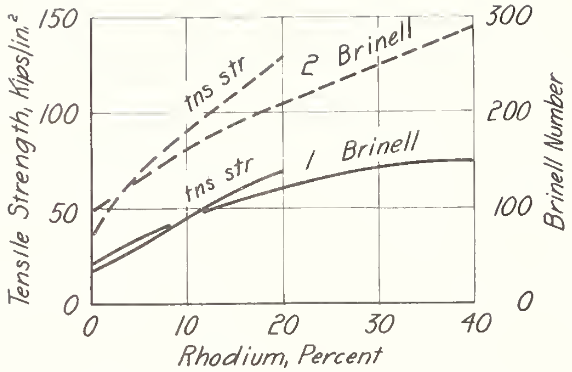


FIGURE 193.—*Tensile strength and hardness of platinum-rhodium alloys (Vines [499]).*

Curves: 1, annealed; 2, hard.

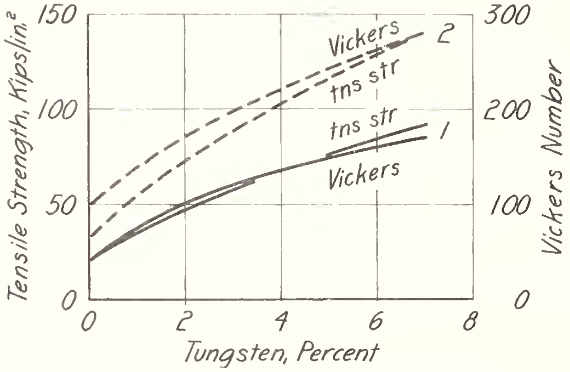


FIGURE 194.—*Tensile strength and hardness of platinum-tungsten alloys (Vines [499]).*

Curves: 1, wire or sheet annealed 5 minutes at 2,190°F; 2, wire or sheet, cold-worked (50% red.).

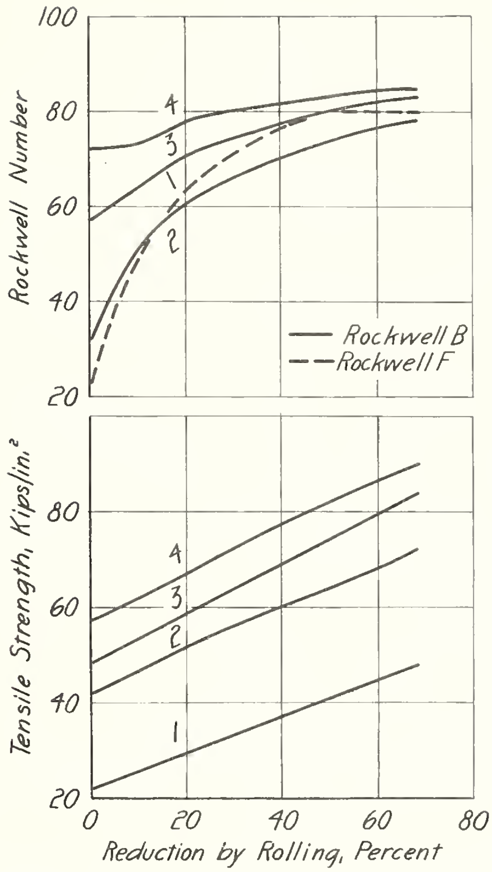


FIGURE 195.—*Effect of cold-rolling on the tensile strength and hardness of annealed silver and silver-copper alloys (Leach and Christie [704]).*

Curves: 1, Fine silver; 2, Sterling silver, Cu 7.5%; 3, 800 fine, Cu 20%; 4, 720 fine, Cu 28%.

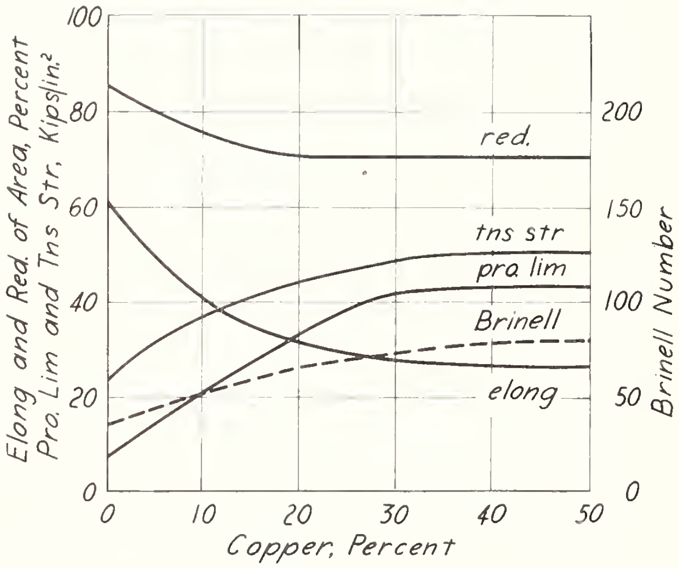


FIGURE 196.—*Tensile properties and hardness of wrought silver-copper alloys (Broniewski [651]).*

(Elongation in 10 diam)

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

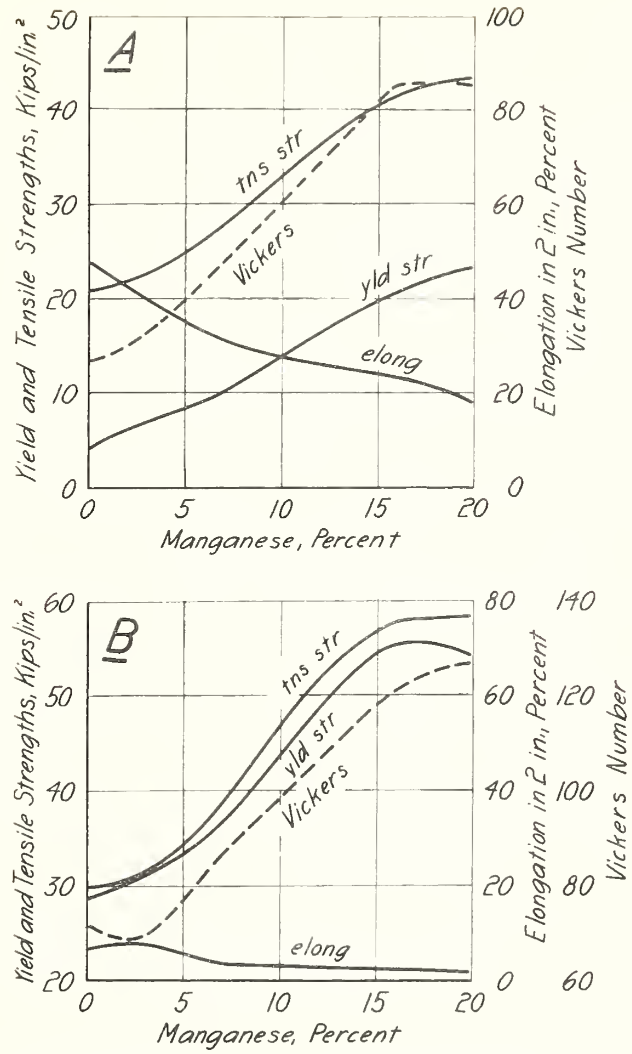


FIGURE 197.—*Tensile properties and hardness of silver-manganese alloys (Addicks [129]).*

(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.).

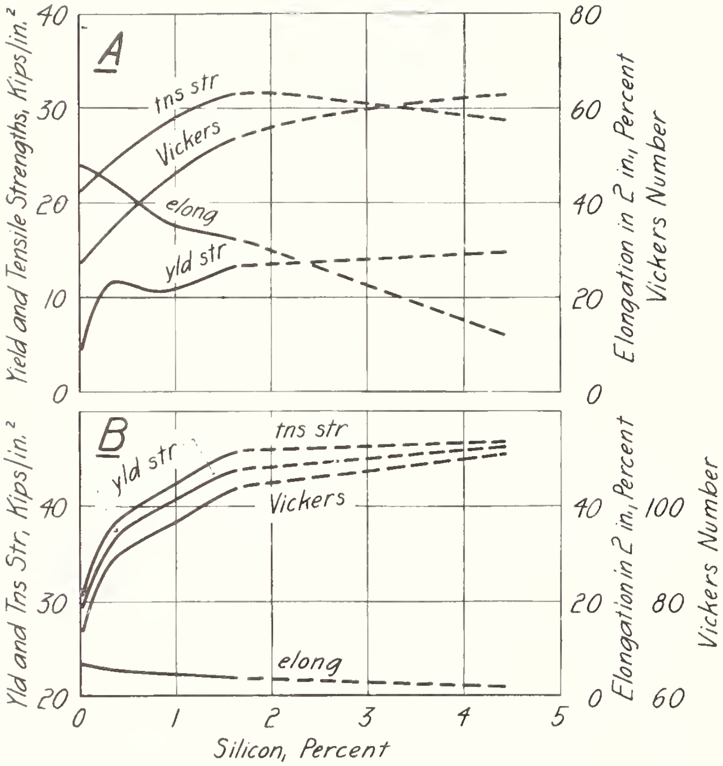


FIGURE 198.—*Tensile properties and hardness of silver-silicon alloys (Addicks [129]).*

(Yield strength, 0.2% offset)

A, Sheet, annealed 1 hour at 1,290°F; B, sheet, 0.040 in., cold-rolled (30% red.).

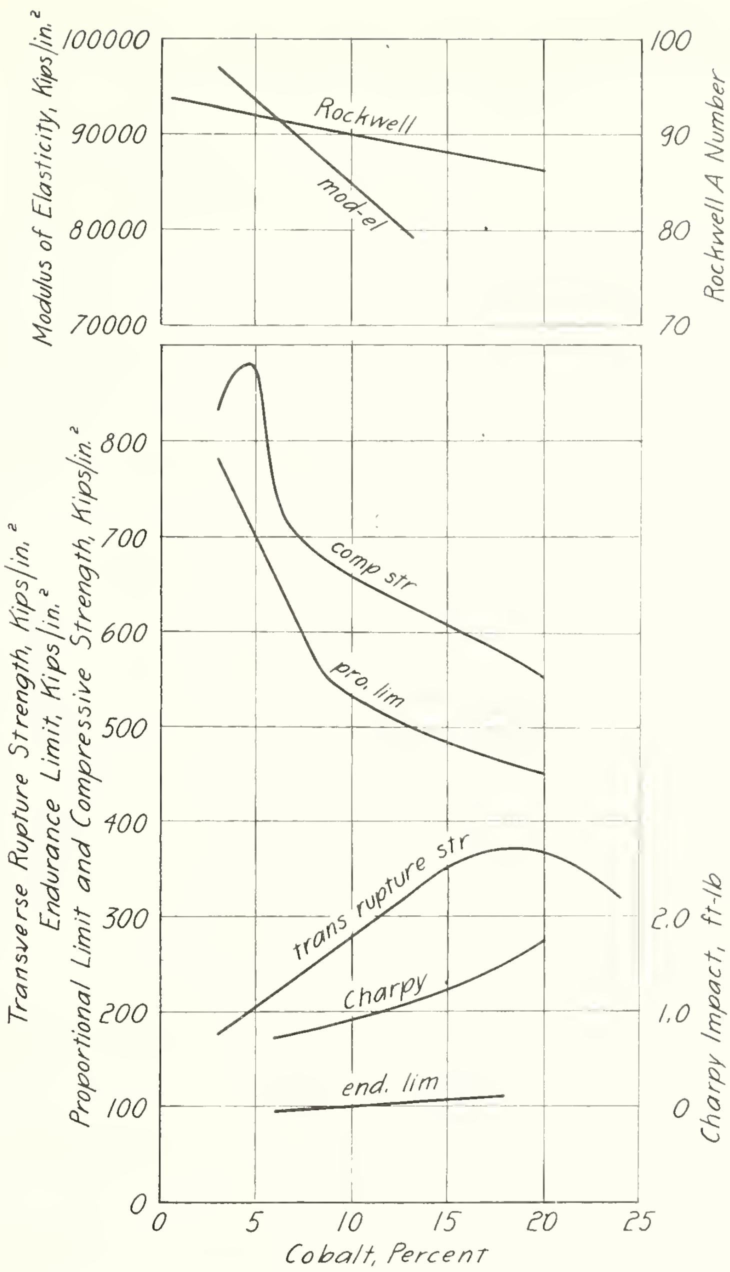


FIGURE 199. — *Effect of cobalt binder on the compressive properties, transverse rupture strength, endurance limit, impact value, and hardness of tungsten carbide (Engle [52]).*

(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	°F	°C
3874	Anatomical alloy	53.5	...	17	19	Hg 10.5	140	60
3875	Wood's alloy[a]	50	12.5	25	12.5	...	154.4	68
3876	Lipowitz's alloy[b]	50.1	10	26.6	13.3	...	154.4	68
3877	Quaternary eutectic alloy	49.5	10.10	27.27	13.13	...	158	70
3878	Fusible teaspoons	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	...	40	...	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	Sb 9	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	40	...	...	...	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 149.9°F (65.5°C).
[b] Melting point also given as 149°F (65°C).
[c] Melting point also given as 205°F (96.5°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	°F	°C	°F	°C	
SILVER SOLDERS												
3900[a]	10	52	38	<0.5	...	...	...	1,600	870	1,510	820	Yellow.
3901	15	80	...	...	5	...	...	1,300	705	1,190	645	...
3902[a]	20	45	35	<0.5	...	...	...	1,500	815	1,430	775	Yellow.
3903[a]	20	45	30	5	...	...	...	1,500	815	1,430	775	Do.
3904[a]	45	30	25	nil	...	...	...	1,370	745	1,250	675	Nearly white.
3905[a]	50	34	16	nil	...	...	...	1,425	775	1,280	695	Do.
3906	50	15.5	16.5	18	...	...	...	1,175	635	1,160	625	...
3907[a]	65	20	15	nil	...	...	...	1,325	720	1,280	695	White.
3908[a]	70	20	10	nil	...	...	...	1,390	755	1,335	725	Do.
3909[a]	80	16	4	nil	...	...	...	1,460	795	1,360	740	Do.
BRAZING ALLOYS												
3910[b]	...	50-53	rem	...	...	...	...	1,620	880	1,595	870	Brass-yellow.
3911[b]	...	52-53	rem	...	...	...	...	1,620	880	1,600	870	Do.
3912	...	rem	45-50	...	...	3-5	...	...	...	1,575	855	Yellow to pale yellow.
3913[c]	...	rem	57-65	...	...	5-9	...	1,440	780	1,385	750	Gray to black.
3914	...	rem	55-59	...	...	...	7-9	...	...	1,600	870	White.
3915	...	47	rem	...	...	...	11	...	...	1,700	925	Do.
3916	...	93	...	...	rem	...	...	1,526	830	1,304	705	Gray.
3917	...	rem	...	...	0.03-0.09	...	...	1,981	1,083	1,981	1,083	Copper-red.

[a] Impurities 0.15 percent maximum.
[b] Lead 0.50 percent maximum, iron 0.10 percent maximum.
[c] Iron 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: Modulus of elasticity	Short time properties: Yield strength	Short time properties: Tensile strength	Short time properties: Elongation	Short time properties: Reduction of area	Short time properties: Hardness number	Creep properties: Stress (kips/in.²) for designated creep rate per 1,000 hours: 0.1%	Creep properties: Stress (kips/in.²) for designated creep rate per 1,000 hours: 1.0%	Creep properties: Duration	Reference
	Percent		°*F*	*Kips/in.²*	*Kips/in.²*	*Kips/in.²*	*Percent*	*Percent*				*Hours*	
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	Room	20,400	13.6 (0.1%)	13.7	0 (2 in.)	...	75	...	...	...	[549]
			500	...	...	10.5	1 (2 in.)	...	...	...	...	...	
3919[a]..	Cadmium-nickel alloy: Ni 1.3	Cast	82	...	11.7	16.4	19 (2 in.)	43	33	...	...	...	[551]
			212	...	...	10.5	36 (2 in.)	52	22	...	...	...	
			392	...	...	3.3	111 (2 in.)	76	6.5	...	...	...	
			572	...	...	0.6	162 (2 in.)	78	1.8	...	...	...	
3920[b]..	Cadmium-nickel alloy: Ni 3.0	...do	82	...	16.8	22.9	6 (2 in.)	6	48	...	...	...	[551]
			212	...	...	14.3	13 (2 in.)	17	28	...	...	...	
			392	...	...	3.3	65 (2 in.)	42	8.3	...	...	...	
			572	...	...	0.7	213 (2 in.)	82	1.9	...	...	...	
3921...	Cadmium-silver-copper alloy: Ag 2, Cu 0.5.	...do	Room	...	...	18.0	50 (2 in.)	...	40	...	...	...	[129]
			212	...	...	12.0	...	...	19	...	...	...	
			300	...	...	8.0	...	...	13	...	...	...	
			400	...	...	4.4	68 (2 in.)	...	8.1	...	...	...	
3922...	Cadmium-silver alloy: Ag 5	Rod, 1/4 in. diam	Room	...	...	16.4	31 (2 in.)	81	...	...	...	...	[129]
			300	...	...	4.4	94 (2 in.)	91	...	...	...	...	
			425	...	...	2.6	94 (2 in.)	68	...	...	...	...	
			500	...	...	1.7	22 (2 in.)	11	...	...	...	...	
3923...	Cobalt-iron-titanium alloy: Co 85, Fe 11.25, Ti 3.75.	Rod, 3/16 in. diam, wrought; ann 1/4 hr at 1,742°F in hydrogen, a-c.	1,112	...	...	...	...	...	...	4.0 (0.16%)	...	250	[363]
			1,292	...	...	...	...	...	...	4.0 (0.58%)	8.0 (0.88%)	250	
			1,472	...	...	...	...	...	...	2.0 (0.43%)	4.0 (1.7%)	250	
3924...	Cobalt-iron-nickel-titanium alloy: Co 69.18, Fe 14.38, Ni 13.20, Ti 2.53.	Bar, w-q from 1,740°F, aged 72 hr at 1,200°F.	Room	...	80.0 (0.2%)	130	30 (2 in.)	53	...	...	...	...	[593]
			1,112	...	72.0 (0.2%)	103	16 (2 in.)	19	...	...	...	...	
3925...	Cobalt-nickel-iron-titanium alloy: Co 51.08, Ni 31.76, Fe 13.31, Ti 2.82.	...do	Room	...	101 (0.2%)	160	26 (2 in.)	36	...	...	...	...	[593]
			1,112	...	93.5 (0.2%)	113	55 (2 in.)	10	...	...	...	...	
3926...	Cobalt-nickel-chromium-iron-titanium alloy: Co 47, Ni 23, Cr 20, Fe 7.5, Ti 2.5.	Rod, 3/16 in. diam, wrought; ann 1/4 hr at 1,742°F in hydrogen, a-c.	1,472	...	...	...	...	...	...	...	2.2 (0.9%)	250	[363]

3927...	Gold	Annealed	59	7,900	...	...	...	...	...	...	...	...	[303]
			212	7,700	...	...	...	...	...	...	...	...	
			392	7,800	...	...	...	...	...	...	...	...	
3928...	Platinum	...do	59	22,100	...	...	...	...	...	...	...	...	[303]
			212	20,200	...	...	...	...	...	...	...	...	
			392	18,400	...	...	...	...	...	...	...	...	
3929...	Silver	...do	59	10,200	...	...	...	...	...	...	...	...	[303]
			212	10,400	...	...	...	...	...	...	...	...	
			392	9,000	...	...	...	...	...	...	...	...	
3930...	Tungsten	Wire, drawn	Room	...	...	420	...	...	...	...	...	...	[587]
			620	...	...	310	...	...	...	...	...	...	
			1,340	...	...	210	...	...	...	...	...	...	

[a]Compressive str (50%): 27 kips/in.^{2} (82°F); 18 kips/in.^{2} (212°F); 7 kips/in.^{2} (392°F). Rate of strain 0.05 (in./in.)/minute for both tension and compression tests.
[b]Compressive str (50%): 38 kips/in.^{2} (82°F); 29 kips/in.^{2} (212°F); 12 kips/in.^{2} (392°F). Rate of strain 0.05 (in./in.)/minute for both tension and compression tests.

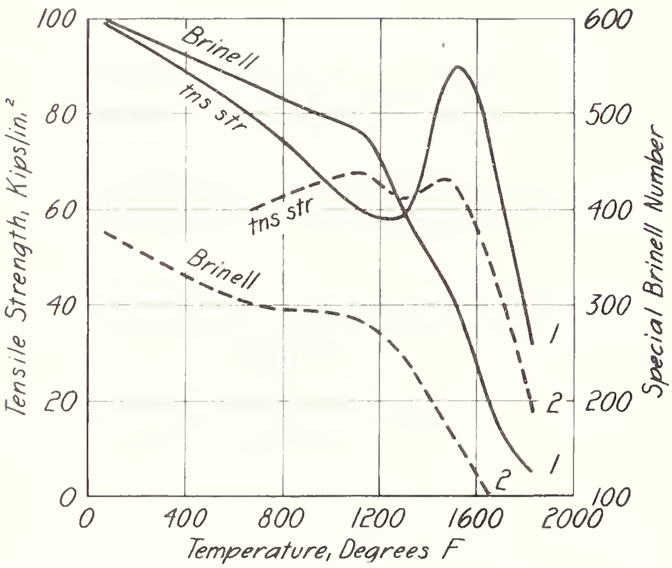


FIGURE 200.—*Short-time tensile strength and hardness of cobalt-chromium-tungsten alloys at high temperatures (Wissler [557]).*

Curves: 1, Co 45-55%, Cr 30-35%, W 12-17%; 2, Co >55%, Cr <33%, W <6%.

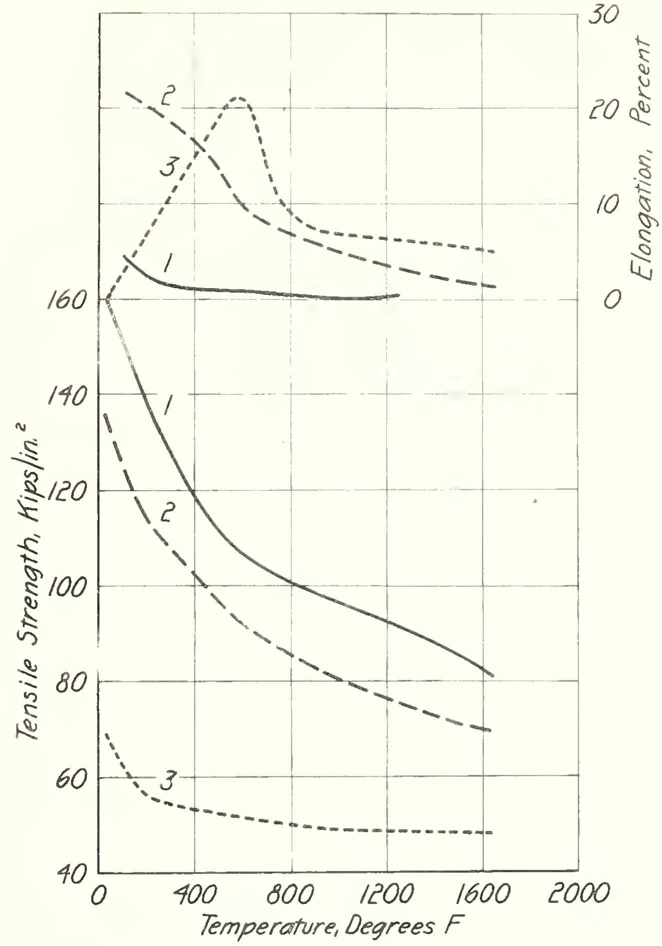


FIGURE 201. —*Short-time tensile properties of molybdenum wire at high temperatures (Highriter [52]).*

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

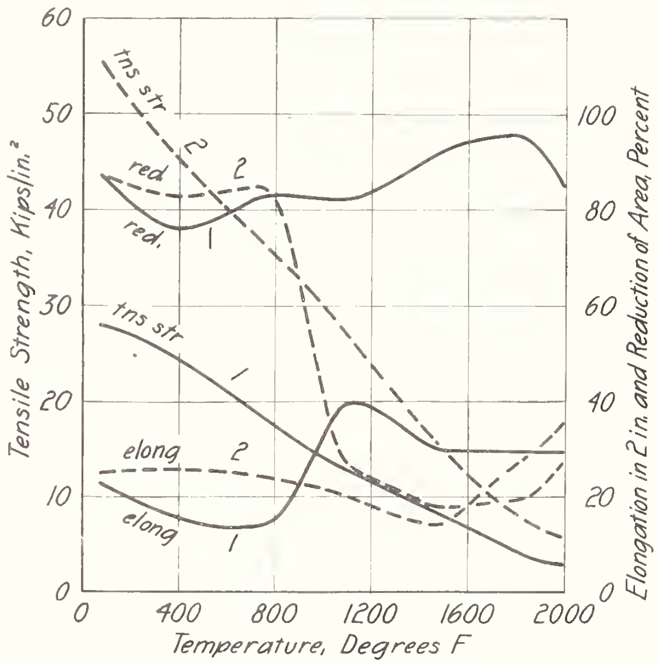


FIGURE 202.—*Short-time tensile properties of palladium and a palladium-rhodium-ruthenium alloy at high temperatures (Wise and Eash [705]).*

(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%.

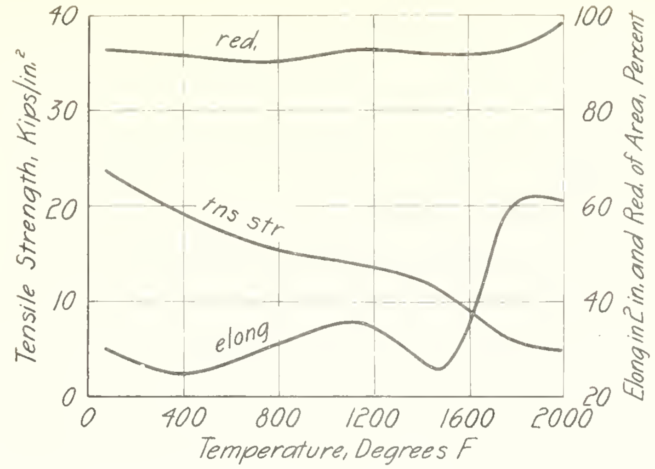


FIGURE 203.—*Short-time tensile properties of platinum at high temperatures (Wise and Eash [705]).*

(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.

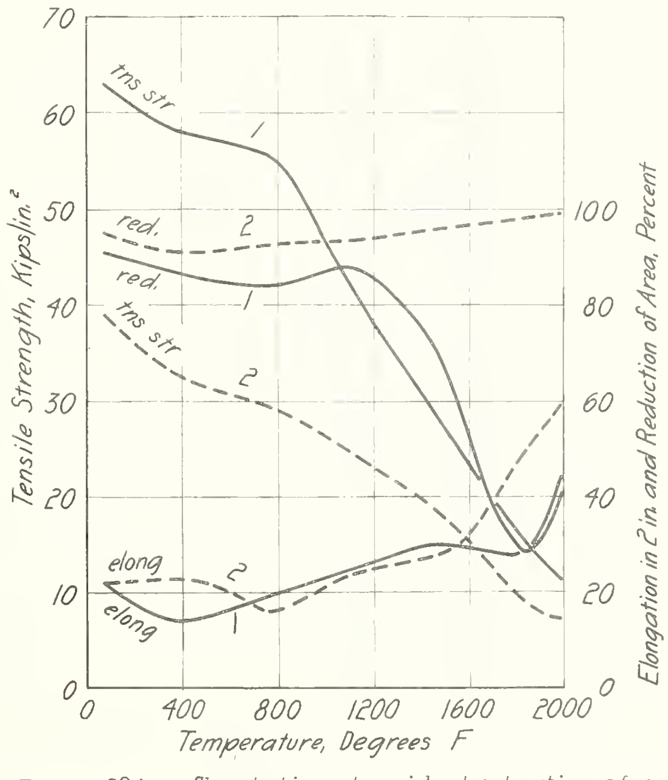


FIGURE 204.—*Short-time tensile properties of a platinum-iridium and a platinum-nickel alloy at high temperatures (Wise and Eash [705]).*

(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%.

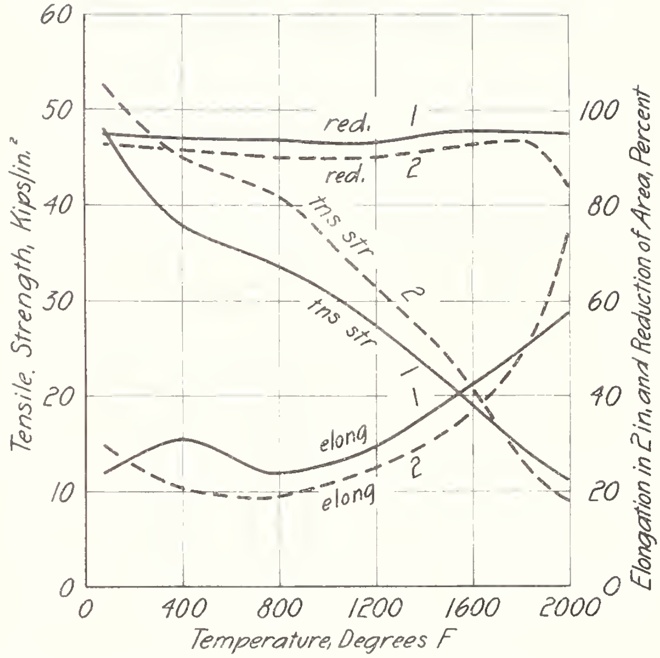


FIGURE 205. — *Short-time tensile properties of a platinum-rhodium and a platinum-palladium-rhodium alloy at high temperatures (Wise and Eash [705]).*

(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%.

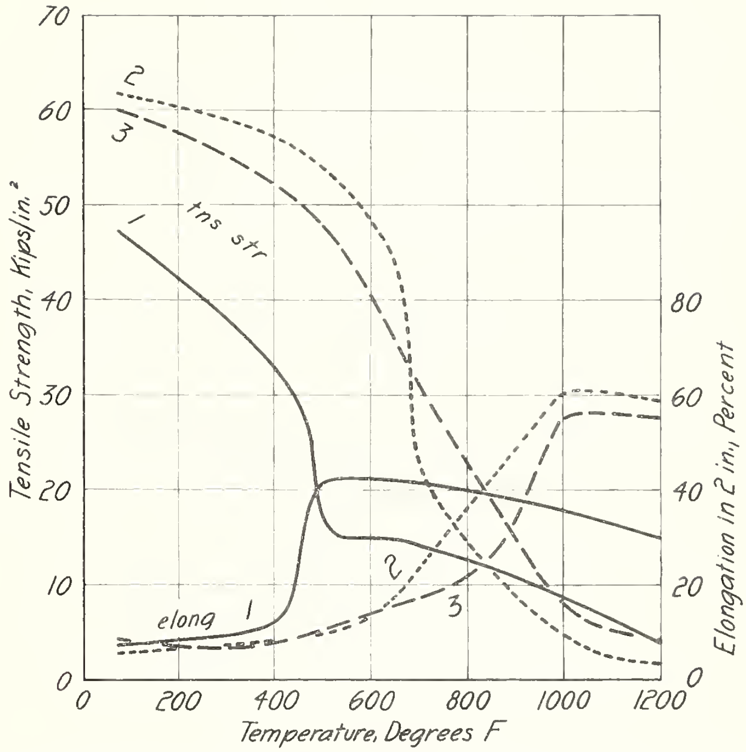


FIGURE 206.— *Short-time tensile properties of silver and silver-copper alloys at high temperatures (Leach [706]).*

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%.

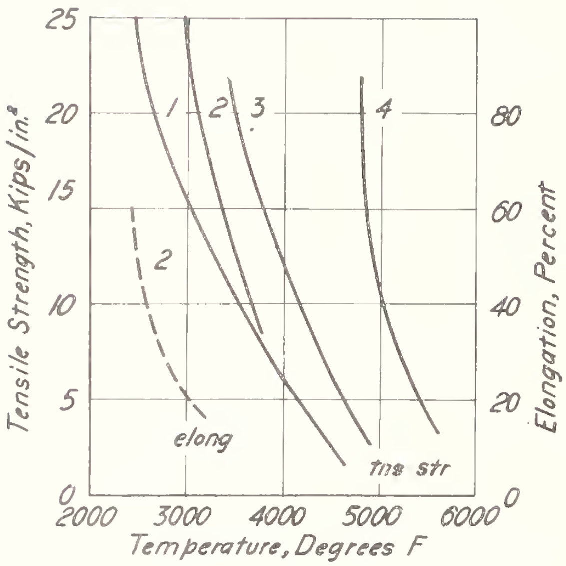


FIGURE 207.—*Short-time tensile properties of tungsten wire at high temperatures (Highriter [52]).*

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%.

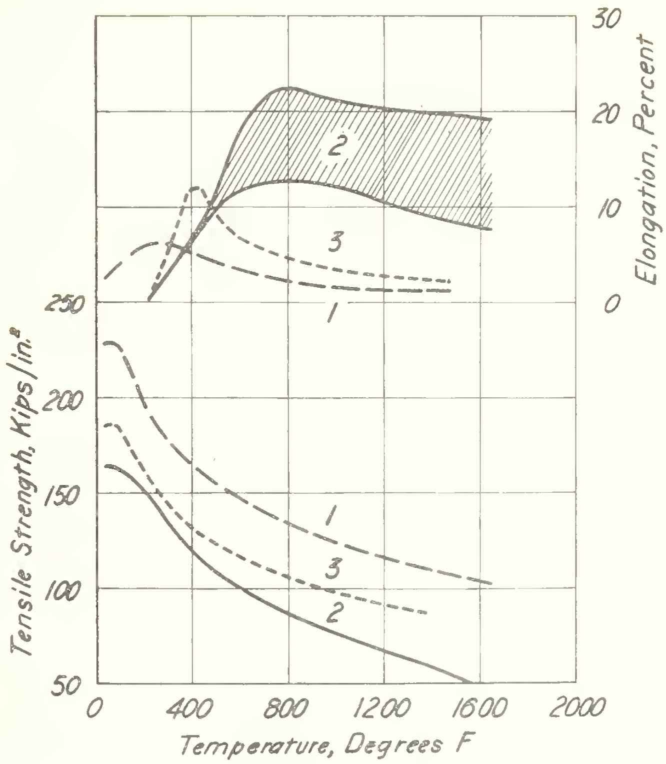


FIGURE 208.—*Short-time tensile properties of tungsten wire containing 0.75 percent ThO_2 at high temperatures (Highriter [52]).*

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.

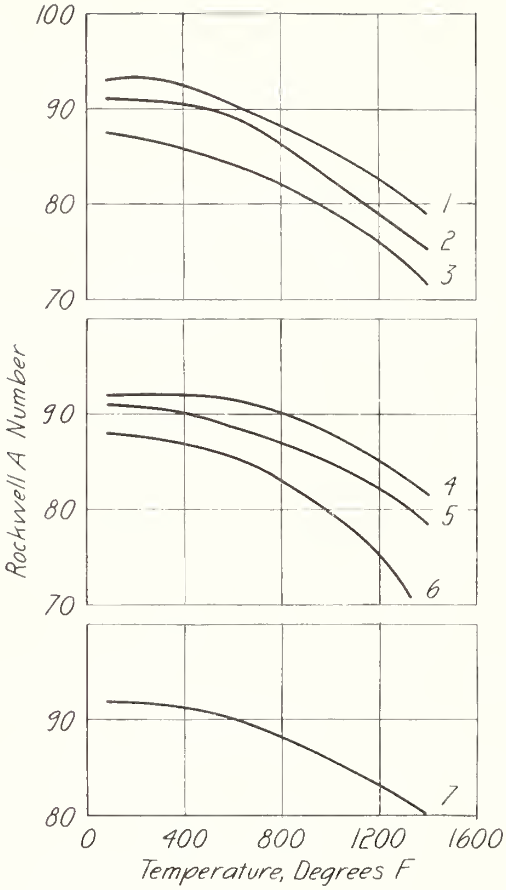


FIGURE 209.—*Hardness of commercial cemented carbide alloys at high temperatures (Engle [52]).*

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	Tensile properties: Modulus of elasticity	Tensile properties: Tensile strength	Tensile properties: Elongation	Tensile properties: Reduction of area	Hardness number[a]	Reference
	Percent		°F	*Kips/in.*^{2}	*Kips/in.*^{2}	*Percent*	*Percent*		
3931	Antimony (vacuum distilled)	Cast; ann at 1,100°F in vacuum	64	7,800	...	...	...	...	[450]
			-319	8,400	...	...	...	...	
3932	Cadmium	...	59	...	10.1	12	...	...	[451]
			-4	...	18.8	9.5	...	...	
			-40	...	26.5	8	...	...	
			-103	...	30.6	5	...	...	
3933	Cobalt	...	68	...	...	...	...	174	[65]
			-305	...	...	...	...	222	
3934	Molybdenum: Mo 99.9	Annealed	77	...	63.0	0	0	...	[65]
			-301	...	96.0	0	0	...	
3935	...do	Drawn at 2,190°-2,370°F	77	...	118	4.7	68	...	[65]
			-301	...	212	0	0	...	
3936	Mercury	Cast	-72	...	0.4	56 (3 1/2 in.)	...	...	[594]
			-202	...	1.5	44 (3 1/2 in.)	...	...	
3937	...do	...do	-319	13,900	...	...	...	...	[55]
3938	Tungsten	Wire, drawn	Room	...	420	...	...	...	[587]
			-301	...	510	...	...	...	

[a]Brinell number.

TABLE 65.—*Miscellaneous metals and alloys, thermal expansion*

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade: 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	Reference
	ANTIMONY; BISMUTH; CADMIUM; CHROMIUM																
	Percent		$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	$\times10^{-6}$	
3939[a]..	Sb 99.8-99.9+ ...	Sand-cast...	...	...	[b]8.5–10.8	8.4–11.0	8.7–11.3	9.2–11.4	9.2–11.5	9.5–11.6	[c]9.7–11.6	...	...	...	...	...	[595]
3940[a]..	Bismuth...	Rod...	13.0 (-183° to 15°C)	...	...	13.4	...	...	...	...	...	...	...	...	...	...	[720]
3941[a]..	Cadmium...	...	29.5 (-180° to 20°C) 30.8 (-20° to 20°C)	30.3	...	31.8	...	...	...	...	...	...	...	...	...	...	[598]
3942[a]..	...do...	...	...	...	...	...	...	[d]38	...	...	...	...	...	...	...	...	[72]
3943[e]..	Cr 98.7-99.3...	Annealed...	...	[f]5.1	...	6.6	7.3	7.9	8.4	8.8	9.1	9.4	...	...	...	...	[599]
3944...	Electro chromium...	Worked and ann at 1,000°C in vacuum.	4.1 (-216° to 0°C) 5.5 (-60° to 0°C) 5.6 (-20° to 0°C)	...	...	...	...	...	...	...	...	...	...	...	...	...	[721]
	COBALT AND COBALT ALLOYS																
3945...	Co 99.2, Fe 0.47, Mn 0.26, Si 0.03, C 0.02.	Rod, 1/4 in. diam, ann at 800°C.	...	...	...	12.6	13.1	13.6	14.0	...	...	...	...	...	...	...	[596]
3946...	Cr 20...	...	...	...	...	14.1	14.6	15.2	15.4	15.5	16.1	...	...	...	...	...	[506]
3947...	Cr 26.54, W 13.88, C 2.60, Ni 0.34.	...	...	...	...	11.7	11.7	11.8	12.0	12.2	12.5	12.7	13.2	[g]13.4	...	...	[382]
3948...	Cr 29.64, W 14.53, C 2.63, Ni 0.28.	...	...	...	...	12.5	12.6	12.8	12.9	13.2	13.4	13.8	14.0	[g]14.0	...	...	[382]
3949...	Cr 35, W 10...	...	...	...	...	11.0	11.7	12.4	12.8	12.9	13.6	...	...	...	...	...	[506]
3950...	Cr 40, W 3, C 2...	Forged...	...	...	...	12.2	12.7	13.2	13.5	13.9	14.6	...	...	...	...	...	[506]
3951...	Fe 20.3, Ni 10...	Rod, 3/16 in. diam, cast; 1 hr at 1,000°C	...	...	...	[h]11.9	...	...	...	...	...	...	...	...	...	...	[504]
3952...	Fe 30.2, Ni 10...	...do...	...	...	...	[h]11.4	...	...	...	...	...	...	...	...	...	...	[504]
3953...	Fe 40.7...	...do...	...	...	...	[h]9.6	...	...	...	...	...	...	...	...	...	...	[504]
3954...	Ni 5...	...do...	...	...	...	[h]12.3	...	...	...	...	...	...	...	...	...	...	[504]
	COLUMBIUM; GALLIUM																
3955[e]..	Sn 0.93, Fe 0.26, Cb rem.	Annealed...	...	[f]6.9	[i]7.2	7.2	7.4	7.5	...	...	...	...	...	...	...	...	[597]
3956...	In 0.15, Zn 0.10, Pb 0.01, Ga rem.	Heat-treated (solid)..	[j]53 (-78° to 18°C)	...	...	...	...	...	...	...	...	...	...	...	...	...	[602]
	GOLD AND GOLD ALLOYS																
3957[e]..	Au 99.99+ ...	Annealed...	13.0 (-185° to 0°C) 14.0 (-50° to 0°C)	13.7	14.1	14.1	14.3	14.6	14.9	15.2	15.5	15.7	...	...	...	...	[68]
3958[e]..	Gold (spectrographically pure).	1 hr at 950°C, slowly cooled.	...	...	[k]14.2	14.3	14.5	14.7	15.0	15.2	15.5	15.8	16.1	16.5	[l]16.6	...	[196]
3959...	Cu 8.33...	...	...	...	...	[m]14.6	...	...	...	...	...	...	...	...	...	...	[72]

3960...	Cu 33..............	....	....	......	......	n15.5	......	......	.....	.....	.....	.....	.....	.....	....	....	[456]
3961...	Pt 33..............	....	....	......	......	n15.2	......	......	.....	.....	.....	.....	.....	.....	....	....	[456]

INDIUM; IRIDIUM; LITHIUM

3962...	Indium............	....	....	......	......	o24.8	......	......	.....	.....	.....	.....	.....	.....	....	....	[72]
3963p..	Iridium............	....	6.0 (-150° to 50°C) 6.4 (-50° to 50°C)	......	......	......	q6.9	7.1	.....	.....	.....	.....	7.6	.....	....	....	[72]
3964e..	...do..............	....	....	......	......	6.8	6.9	7.0	7.2	7.2	7.3	7.4	7.6	7.8	7.8	....	[499]
3965...	Lithium............	....	....	......	......	......	r60.0	......	.....	.....	.....	.....	.....	.....	....	....	[604]

MANGANESE AND MANGANESE ALLOYS

3966s..	P 0.003, Si 0.002..	Vacuum distilled, quenched from 1,100°C.	20.2 (-183° to 0°C) 23.3 (-60° to 0°C) 24.1 (-20° to 0°C)	f22.5	t24.9	......	......	......	.....	.....	.....	.....	.....	.....	....	....	[721]
3967e..	Manganese..........	....	15.9 (-190° to 0°C) 20.1 (-78° to 0°C)	......	......	22.8	24.0	25.2	.....	.....	.....	.....	.....	.....	....	....	[605]
3968...	Cu 20, Ni 15.......	Rod, 1/4 in. diam, quenched from 900°C.	....	......	......	22.4	......	......	.....	.....	.....	.....	.....	.....	....	....	[507]
3969...	Cu 45, Ni 5........	...do..............	....	......	......	19.1	......	......	.....	.....	.....	.....	.....	.....	....	....	[507]
3970...	Ni 20..............	...do..............	....	......	......	21.4	......	......	.....	.....	.....	.....	.....	.....	....	....	[507]
3971...	Ni 25, Cu 10	...do..............	....	......	......	20.8	......	......	.....	.....	.....	.....	.....	.....	....	....	[507]
3972...	Ni 40, Cu 5........	...do..............	....	......	......	18.3	......	......	.....	.....	.....	.....	.....	.....	....	....	[507]

MOLYBDENUM; PALLADIUM

3973...	Mo 99.95+.........	....	4.2 (-187° to 0°C) 5.1 (-50° to 0°C)	f4.9	u5.4	......	......	......	.....	.....	.....	.....	.....	.....	....	....	[608]
3974e..	Mo 99.85, Fe 0.12, Si 0.015, S 0.002.	Sintered, heated to 1,050°C in H_2, swaged.	4.5 (-142° to 20°C) 4.9 (-50° to 0°C)	f4.6	......	5.2	5.3	5.4	.....	.....	.....	.....	.....	.....	....	....	[600]
3975...	Pd 99.99+.........	....	10.4 (-187° to 0°C) 11.4 (-50° to 0°C)	f11.2	u11.1	......	......	......	.....	.....	.....	.....	.....	.....	....	....	[608]
3976e..	Palladium..........	....	....	......	t11.7	11.1	11.4	11.7	12.0	12.4	12.7	13.0	13.2	13.4	13.6	....	[499]

[a] Values depend on the orientation of the crystals in the polycrystalline material.
[b] 20° to 60°C.
[c] 20° to 550°C.
[d] 0° to 315°C.
[e] Base temperature 0°C instead of 20°C.
[f] -100° to 0°C.
[g] 20° to 850°C.
[h] 30° to 100°C.
[i] 0° to 60°C.
[j] Coefficient of cubical expansion.
[k] 0° to 50°C.
[l] 0° to 950°C.
[m] 0° to 85°C.
[n] 0° to 100°C.
[o] 10° to 90°C.
[p] Base temperature 50°C instead of 20°C.
[q] 50° to 150°C.
[r] 18° to 180°C.
[s] β-manganese. The values of α- and γ-manganese between 0° and 20°C, according to Erfling [603], are 22.3×10^{-6} and 14.8×10^{-6}, respectively. The α-phase is stable up to 742°C, the γ-phase above 1,191°C. The γ→α phase transformation at room temperature, took a month for completion.
[t] 0° to 20°C.
[u] 0° to 25°C.

TABLE 65.—*Miscellaneous metals and alloys, thermal expansion*—Continued

Serial number	Composition	Condition	Coefficient of linear expansion per degree centigrade: 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	Reference
							PLATINUM AND PLATINUM ALLOYS										
	Percent		×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	×10⁻⁶	
3977...	Pt 99.99+		8.1 (-188° to 0°C) 8.9 (-50° to 0°C)	[f]8.7	[u]9.0	[v]9.0											[608]
3978[e]..	Platinum (spectro-graphically pure).	Slowly cooled from 1,000°C.			[k]9.0	9.1	9.2	9.3	9.4	9.6	9.7	9.8	9.9	10.0	10.2		[196]
3979[e]..	Ir 20		7.5 (-190° to 0°C)			8.3	8.5	8.6	8.8	8.9	9.0	9.2	9.3	9.5	9.6	9.9 (0° to 1,200°C) 10.2 (0° to 1,400°C) 10.5 (0° to 1,600°C)	[722]
3980...	Rh 20															8.8 (0° to 1,500°C)	[72]
							RHODIUM; SELENIUM										
3981[e]..	Rhodium				[k]8.0	8.5	9.0	9.3	9.6	9.8	10.0	10.1	10.3	10.6	10.8	11.2 (0° to 1,200°C) 11.8 (0° to 1,400°C) 12.1 (0° to 1,500°C)	[610]
3982...	Rhodium, "pure"		6.8 (-195° to 0°C) 8.2 (-20° to 0°C)	[f]7.8													[721]
3983...	Selenium		37.2 (-180° to 0°C)		[w]43.9												[456]
							SILVER AND SILVER ALLOYS										
3984...	Ag 99.999		17.1 (-186° to 0°C) 18.5 (-50° to 0°C)	[f]18.1	[u]19.1												[608]
3985[e]..	Silver (spectro-graphically pure).	Furnace-cooled from 900°C.			[k]19.6	19.6	19.8	20.0	20.3	20.6	21.0	21.4	21.8	22.4			[196]
3986[e]..	Cu 23												[x]18.0				[72]
3987[e]..	Cu 30.36, Zn 20.70, Sn 1.11.	Cast				19.0	19.2	19.6	20.4	21.3							[69]
3988[e]..	Cu 32.33, Zn 9.25, Sn 5.71.	...do				20.0	20.3	20.6	21.0	22.0							[69]
3989[e]..	Pt 33	...do				[n]15.2											[456]
							SODIUM; TANTALUM AND TANTALUM CARBIDE										
3990...	Sodium	Crystal	60.1 (-190° to 0°C) 68.1 (-50° to 0°C)	[f]66.4	[y]68.2												[611]
3991...	Ta 99.9+	Forged	6.8 (-190° to 20°C)	6.4	6.5	6.5	6.6	6.6	6.6	6.6							[612]
3992...	Tantalum carbide															8.2 (20° to 2,650°C)	[200]

TITANIUM; TUNGSTEN AND TUNGSTEN ALLOYS

3993[e]..	Fe 1.11, Si 1.05 C 0.22, Cb 0.2, V 0.17, Mn 0.01, Cu 0.01, Ti rem.	Cast; h-t...........	6.8 (-190° to 20°C) 8.3 (-80° to 20°C)	.....	......	8.8	9.1	9.5	9.7	10.0	10.4	10.7	.....	.....	....	....	[609]
3994[e]..	Mo 0.015, Cu 0.005, As 0.002, W rem.	Rod, 3/16 in. diam..	4.3 (-50° to 0°C)	4.2	[k]4.3	4.3	4.4	4.5	4.5	4.6	.....	.....	.....	.....	....	....	[613]
3995...	Co 5.9, WC rem.....	Rod, 1/4 in. diam, cemented electrically.	....	......	4.5	4.5	4.8	5.0	5.2	.....	.....	.....	.....	.....	....	....	[614]
3996...	Co 12.9, WC rem....	...do................	....	......	5.0	5.2	5.5	5.7	6.0	.....	.....	.....	.....	.....	....	....	[614]
3997[e]..	Cu 40, W rem.......	Prepared from powders	....	......	......	8.0	8.3	8.7	9.1	9.6	10.2	.....	.....	.....	....	....	[52]

ZIRCONIUM

3998...	Zirconium..........	....	5.0 (-195° to 0°C) 5.8 (-20° to 0°C)	[f]5.6	......	......	......	......	.....	.....	.....	.....	.....	.....	....	....	[721]

[e]Base temperature 0°C instead of 20°C.
[f]-100° to 0°C.
[k]0° to 50°C.
[n]0° to 100°C.
[u]0° to 25°C.
[v]0° to 95°C.
[w]The 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: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal conductivity	Reference
	ANTIMONY AND ANTIMONY ALLOYS						
	Percent		*Percent IACS*	*Microhm cm*	*per °C x 10⁻⁴*	*Watts cm⁻¹ °C⁻¹*	
3999	Antimony					0.37 (-190°C) .22 (-80°C) .19 (0°C) .18 (100°C)	[459]
4000	Antimony	Fully ann at 450°C, slowly cooled	4.77 (0°C)	36.12 (0°C)	51.5 (0°-100°C)		[615]
4001	Pb 29.7		3.2 (24.2°C)	53.9 (24.2°C)			[421]
4002	Pb 45.9		3.7 (26.3°C)	46.5 (26.3°C)			[421]
4003	Ag 13.78	Fully ann at 450°C, slowly cooled	4.2 (0°C)	41.3 (0°C)	47.2 (0°-100°C)		[615]
4004	Ag 31.70	...do	3.0 (0°C)	57.0 (0°C)	35.3 (0°-100°C)		[615]
	BERYLLIUM						
4005	Be 99.5	Rod, 3/8 in. diam	115 (-189°C) 53.5 (-77°C) 29.3 (0°C) 9.27 (315°C) 4.42 (700°C)	1.50 (-189°C) 3.22 (-77°C) 5.88 (0°C) 18.60 (315°C) 39.00 (700°C)	3.71 (-190°C) 48.1 (-70°C) 66.7 (20°C) 80.0 (310°C) 119.6 (685°C)	0.97 (-176.2°C) 1.64 (9.4°C) 1.91 (105.2°C) 2.13 (190.4°C)	[616]
4006	...do	Forged at 950°C	43.1	4.00			[110]
	BISMUTH AND BISMUTH ALLOYS						
4007	Pb 0.06, Fe 0.01, Ag 0.01, Bi rem.	Fully ann at 125°C, f-c	1.61 (0°C)	106.80 (0°C)	41.73 (0°-100°C)		[617]
4008	Cd 2.0	...do	1.7 (0°C)	99.4 (0°C)	40.1 (0°-100°C)		[617]
4009	Cd 12.0	...do	2.5 (0°C)	69.4 (0°C)	34.7 (0°-100°C)		[617]
4010	Cd 40.0	...do	5.9 (0°C)	29.2 (0°C)	27.5 (0°-100°C)		[617]
	CADMIUM AND CADMIUM ALLOYS						
4011	Cd 99.9	Fully ann at 125°C, f-c	25.2 (0°C)	6.83 (0°C)	43.00 (0°-100°C)		[617]
4012	Bi 45	...do	8.6 (0°C)	20.2 (0°C)	28.5 (0°-100°C)		[617]
	CALCIUM						
4013	Calcium		50.3 (0°C)	3.43 (0°C)	45.7		[618]
	CHROMIUM						
4014	Electro chromium	Sintered at 1,400°C	12.2 (20°C) 9.85 (100°C) 7.80 (200°C) 4.59 (500°C) 2.48 (1,000°C) 1.50 (1,500°C) 1.18 (1,800°C)	14.1 (20°C) 17.5 (100°C) 22.1 (200°C) 37.6 (500°C) 69.5 (1,000°C) 114.7 (1,500°C) 145.5 (1,800°C)			[479]
	COBALT AND COBALT ALLOYS						
4015	Co 99.91		30.8 (0°C)	5.60 (0°C)	55.1 (0°-100°C)		[460]

4016	Cobalt					0.69 (30°C)	[459]
4017	Cr 3.4		5.4	32.2			[198]
4018	Cr 29.6		2.1	83.5			[198]

GOLD AND GOLO ALLOYS

4019	"Pure" gold		78.7 (0°C)	2.19 (0°C)	36.5 (-80° to 1,000°C)		[460]
4020	...do					2.96 (0°C)	[459]
4021	Cd 3.1					1.24 (0°C) 1.48 (100°C)	[459]
4022	Cd 5.05	Tempered	42.7 (25°C)	4.04 (25°C)	26.2 (25°-100°C)		[460]
4023	Cd 10.6					0.72 (0°C) .80 (100°C)	[459]
4024	Cd 35.44	Tempered	11.2 (25°C)	15.4 (25°C)	13.1 (25°-100°C)		[460]
4025	Cd 49.76	...do	23.3 (25°C)	7.39 (25°C)	63.6 (25°-100°C)		[460]
4026	Co 2.2	Wire, 0.016 in. diam, 18 hr at 140°C	5.4 (25°C)	32 (25°C)	0.00 (30°-40°C)		[619]
4027	Cu 2		36.9 (19.4°C)	4.67 (19.4°C)			[460]
4028	Cu 3.3					1.10 (0°C) 1.35 (100°C)	[459]
4029	Cu 8.2		17.2 (20.3°C)	10.0 (20.3°C)			[460]
4030	Cu 12.2					0.58 (0°C) .69 (100°C)	[459]
4031	Cu 14.5		14.2 (19.6°C)	12.2 (19.6°C)			[460]
4032	Cu 28.9		12.8 (17.8°C)	13.4 (17.8°C)			[460]
4033	Cu 30.7					.59 (0°C) .63 (100°C)	[459]
4034	Cu 43.0		14.0 (20.1°C)	12.3 (20.1°C)			[460]
4035	Pd 10		23.4 (0°C)	7.37 (0°C)	9.7 (0°-160°C)		[460]
4036	...do					.92 (25°C)	[459]
4037	Pd 23	Rod, 0.08 in. diam	13.6 (-183°C) 12.0 (0°C) 9.0 (500°C) 6.9 (977°C)	12.7 (-183°C) 14.3 (0°C) 19.1 (500°C) 24.9 (977°C)			[620]
4038	Pd 31	...do	9.4 (-183°C) 8.3 (0°C) 6.6 (500°C) 6.4 (977°C)	18.4 (-183°C) 20.7 (0°C) 26.2 (500°C) 32.0 (977°C)			[620]
4039	Pd 40				3.1 (0°-100°C)		[499]
4040	Pd 45	Rod, 0.08 in. diam	6.5 (-183°C) 5.8 (0°C) 5.0 (500°C) 4.3 (977°C)	26.6 (-183°C) 29.5 (0°C) 34.6 (500°C) 40.2 (977°C)			[620]
4041	Pd 50		6.3	27.5			[499]
4042	Pt 10					.69 (25°C)	[459]
4043	...do		16.9 (0°C)	10.2 (0°C)	9.8 (0°-160°C)		[460]
4044	Pt 20					.38 (25°C)	[459]
4045	...do		9.6 (0°C)	18.0 (0°C)	5.4 (0°-160°C)		[460]
4046	Pt 30					.28 (25°C)	[459]
4047	...do		8.9 (0°C)	19.3 (0°C)	5.9 (0°-160°C)		[460]
4048	Pt 40					.24 (25°C)	[459]
4049	...do		5.3 (0°C)	32.7 (0°C)	3.7 (0°-160°C)		[460]
4050	Pt 50	Quenched	4.0	43.5			[499]
4051	...do	Slowly cooled from 1,000° to 400°C	8.8	19.6			[499]

TABLE 66.—*Miscellaneous metals and alloys, electrical and thermal properties*—Continued

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal conductivity	Reference
				INDIUM AND INDIUM ALLOYS			
	Percent		*Percent IACS*	*Microhm cm*	*per °C × 10⁻⁴*	*Watts cm⁻¹°C⁻¹*	
4052	Indium		84.5 (-192.0°C) 20.6 (0°C) 19.0 (20.9°C)	2.04 (-192.0°C) 8.37 (0°C) 9.06 (20.9°C)	[a]39.4 (20.9° to -192.0°C)		[157]
4053	...do		6.0 (155°C)	29 (155°C)			[569]
4054	Pb 22.4		15.8 (-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)	[a]20.9 (20.0° to -191.1°C)		[457]
4055	Pb 48.3		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)	[a]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) 14.6 (0°C) 15.3 (20.0°C)	[a]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)	[a]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)	[a]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) ...	4.92 (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 (100°C)	[499]
				MANGANESE ALLOYS			
4060	Cu 4	Quenched	2.2	79			[215]
4061	Cu 5, Ni 5	Rod, 1/4 in. diam, cold-swaged	1.6 (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	.94	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 (927°C) 0.96 (1,127°C) .84 (1,327°C) .66 (1,627°C)	[622]
4078	...do	....	33.3 (0°C)	5.17 (0°C)	....	1.38 (0°C)	[623]
4079	Molybdenum	....	30 (20°C)	5.7 (20°C)	50.0 (0°-140°C)	....	[511]
4080	Osmium	....	18.1 (20°C)	9.5 (20°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)	2.88 (-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) 36.4 (0°-200°C) 34.5 (0°-400°C) 23.6 (0°-1,200°C)	0.67 (0°C) .70 (18°C) .74 (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 (800°C)	100 (800°C)	....	....	[499]
4088	Cu 28	Annealed	3.7	47	....	....	[499]
4089	Cu 40	Aged	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	14.3	....	....	[499]
4092	Ir 10	....	7.4	23.3	....	....	[499]
4093	Ir 20	....	4.3	40	....	....	[499]
4094	Fe 16	Slowly cooled from 950°C	....	....	85.5 (25°-100°C)	....	[499]
4095	Mn 31	....	1.8 (20°C)	96 (20°C)	....	....	[499]
4096	Os 5	....	10.4	16.6	....	....	[499]
4097	Os 10	....	8.6	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)	14 (0°-160°C)	....	[570]

[a]This value is alpha of the general equation, $R_t = R_0\ (1 + \alpha t)$.

TABLE 66.—*Miscellaneous metals and alloys, electrical and thermal properties*—Continued

Serial number	Composition	Condition	Electrical properties: Volume conductivity	Electrical properties: Resistivity	Electrical properties: Temperature coefficient of resistivity	Thermal conductivity	Reference
			PLATINUM AND PLATINUM ALLOYS				
	Percent		*Percent IACS*	*Microhm cm*	*per* °C × 10^{-4}	*Watts* cm^{-1}°C^{-1}	
4103	Pt 99.99+	Annealed	17.6 (0°C) 6.18 (500°C) 4.00 (1,000°C) 3.11 (1,500°C)	9.81 (0°C) 27.88 (500°C) 43.07 (1,000°C) 55.38 (1,500°C)	39.2 (0°–100°C)		[493]
4104	...do				36.18 (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				14.5 (25°–100°C)		[499]
4112	Co 15	Quenched	3.8	15.8			[499]
4113	Co 40	...do	5.1	33.8			[499]
4114	Cu 10	...do	2.9	60	2.3		[499]
4115	Cu 25	...do	1.9	92			[499]
4116	...do	Aged	8.6	20	2.3		[499]
4117	Cu 40	Quenched	2.4	73			[499]
4118	...do	...do			2.7		[499]
4119	Ir 5		9.0 (20°C)	19.1 (20°C)	20 (10°–160°C)		[570]
4120	Ir 20		5.5 (20°C)	31.5 (20°C)	8 (10°–160°C)		[570]
4121	Ir 35		4.8 (20°C)	36 (20°C)	5.8 (0°–100°C)		[499]
4122	Fe 21	Quenched			8 (25°–100°C)		[499]
4123	...do	Slowly cooled			41 (25°–100°C)		[499]
4124	Mo 2.2		5.5 (25°C)	31.5 (25°C)	10.1 (25°–100°C)		[499]
4125	Ni 30	Quenched	4.1	42			[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)		[625]
4133	Rh 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 (309.3°C) 12 (510.7°C)	4.3 (0°C) 6.2 (100°C) 8.2 (199.1°C) 10.4 (309.3°C) 14.9 (510.7°C)	45.7 (0°-100°C)	0.89 (0°C) .88 (17°C) .80 (100°C)	[499]
4138	Pt 18	Wire, ann	21 (20°C)	8.3 (20°C)	26.5 (0°-100°C)	....	[624]
4139	Pt 38	...do	14.6 (20°C)	11.8 (20°C)	19.2 (0°-100°C)	....	[624]

SILVER AND SILVER ALLOYS

4140	Silver	Annealed	114 (0°C)	1.51 (0°C)	40.50 (0°-100°C)	....	[523]
4141	...do	...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	Annealed	15.6 (0°C)	11.05 (0°C)	5.7 (0°-100°C)	....	[460]
4144	Al 8.6	...do	3.7 (0°C)	46.7 (0°C)	4.4 (0°-100°C)	....	[460]
4145	Al 15.7	...do	6.6 (0°C)	26.3 (0°C)	9.2 (0°-100°C)	....	[460]
4146	Al 37.5	...do	17.8 (0°C)	9.71 (0°C)	15.6 (0°-100°C)	....	[460]
4147	Sb 2.00	Fully ann at 800°C, slowly cooled	13.5 (0°C)	12.8 (0°C)	15.3 (0°-100°C)	....	[615]
4148	Sb 27.04	Fully ann at 550°C, slowly cooled	0.96 (0°C)	180 (0°C)	1.70 (0°-100°C)	....	[615]
4149	Cd 5.9	....	....	....	....	1.65 (0°C) 1.92 (100°C)	[459]
4150	Cd 20.5	....	....	....	....	0.80 (0°C) .96 (100°C)	[459]
4151	Cu 5	....	....	....	....	3.52 (62°C)	[459]
4152	Cu 6.2	Annealed	90.1 (25°C)	1.91 (25°C)	37.4 (25°-100°C)	....	[460]
4153	Cu 25	....	....	....	....	3.30 (62°C)	[459]
4154	Cu 40	....	....	....	....	3.11 (62°C)	[459]
4155	Cu 41.8	Annealed	90.1 (25°C)	1.91 (25°C)	38.0 (25°-100°C)	....	[460]
4156	Au 3.51	....	75.3 (0°C)	2.29 (0°C)	26.6 (0°C)	....	[460]
4157	Au 31.3	Annealed	24.8 (0°C)	6.96 (0°C)	9.1 (0°C)	....	[460]
4158	Pb 0.96	....	75.2 (23.4°C)	2.29 (23.4°C)	....	....	[460]
4159	Mg 0.1	....	80.6 (25°C)	2.14 (25°C)	32.1 (25°-100°C)	....	[460]
4160	Mg 2.91	....	27.5 (25°C)	6.28 (25°C)	....	....	[460]
4161	Pd 10	....	28.5 (0°C)	6.05 (0°C)	9.1 (0°-160°C)	....	[460]
4162	...do	....	....	....	....	1.44 (25°C)	[459]
4163	Pt 10	....	....	....	....	1.00 (25°C)	[459]
4164	Pt 10.39	....	18.8	9.18	....	....	[460]
4165	Sn 8.40	2 days at 800°C, slowly cooled	6.9 (0°C)	25.0 (0°C)	3.90 (0°-100°C)	....	[523]

TANTALUM; THALLIUM; TITANIUM; TUNGSTEN; ZIRCONIUM

4166	Tantalum	Filament, h-t and out-gassed	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) 62.4 (1,227°C) 78.9 (1,727°C) 108.7 (2,727°C)	38.2 (0°-100°C)	....	[626]
4157[b]	...do	Annealed	....	....	....	0.54 (0°C) .73 (1,427°C)	[459]
4168	Thallium	....	....	....	....	.39 (50°C) .40 (100°C) .39 (150°C) .44 (200°C)	[459]

[b]The 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							
	Percent		*Percent IACS*	*Microhm cm*	*per* $°C \times 10^{-4}$	*Watts* $cm^{-1}°C^{-1}$	
4169	Titanium		2.2 (0°C)	80 (0°C)	46.9		[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		4.21 (0°C)	41.0 (0°C)	43.8		[627]

XIV. APPENDIX

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
				g/cm³	°C	*cal/g/°C*	*cal/g*	$\times 10^{-6}$	*Watts* cm^{-1} $°C^{-1}$	*Microhm cm*	*Kips/in.²*
Actinium	Ac	89	227	...	[a]1,600	...	...	...	...	...	...
Aluminum	Al	13	26.97	2.70	660.0 ±0.1	0.226	93	22.9	2.18	2.65 (20°C)	10,300
Antimony	Sb	51	121.76	6.62	630.5 ±0.1	.049	38.3	[b] [c]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	[d]814	.082	...	4.7	...	35 (20°C)	...
Barium	Ba	56	137.36	3.5	704 ±20	.068	...	...	...	...	...
Beryllium	Be	4	9.02	1.82	1,280 ±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	.309	...	2	...	1.8×10^{12} (0°C)	...
Bromine	Br	35	79.916	3.12	-7.2 ±0.2	.070	16.2	...	...	...	...
Cadmium	Cd	48	112.41	8.65	320.9 ±0.1	.055	13.2	29.8	.91	6.83 (0°C)	8,000
Calcium	Ca	20	40.08	1.54	850 ±20	.157	...	25	...	3.43 (0°C)	3,000
Carbon (graphite)	C	6	12.010	2.22	3,700 ±100	.165	...	[e]0.6-4.3	.24	1,375 (0°C)	700
Cerium	Ce	58	140.13	6.9	600 ±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	...	$.720 \times 10^{-4}$	...	...
Chromium	Cr	24	52.01	7.14	1,800 ±50	.12	75.6	6.2	.69	14.1 (20°C)	...
Cobalt	Co	27	58.94	8.9	1,490 ±20	.099	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	68	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	29.78 ±0.02	.079	19.2	18	...	53.4 (0°C)	...
Germanium	Ge	32	72.60	5.36	958 ±10	.073	...	...	...	89×10^{3} (0°C)	...
Gold	Au	79	197.2	19.3	1,063.0 ±0.0	.031	16.1	14.2	2.96	2.19 (0°C)	10,300
Hafnium	Hf	72	178.6	11.4	[a]1,700	...	...	...	...	...	...
Helium	He	2	4.003	0.1664×10^{-3}	[f]-271.4 ±0.2	1.25	...	...	13.9×10^{-4}	...	...
Holmium	Ho	67	164.94	...	...	...	...	...	...	...	...
Hydrogen	H	1	1.0080	0.08375×10^{-3}	-259.2 ±0.1	3.415	15.0	...	17.0×10^{-4}	...	...
Illinium	Il	61	146	...	...	...	...	...	...	...	...
Indium	In	49	114.76	7.31	156.4 ±0.1	0.057	...	33	0.24	8.37 (0°C)	...
Iodine	I	53	126.92	4.93	114 ±1	.052	15.8	93	43.5×10^{-4}	1.3×10^{15} (20°C)	...
Iridium	Ir	77	193.1	22.4	2,454 ±3	.032	...	6.5	0.59	5.3 (20°C)	74,700
Iron	Fe	26	55.85	7.87	1,539 ±3	.108	65	11.7	.79	9.71 (20°C)	28,500
Krypton	Kr	36	83.7	3.488×10^{-3}	-157 ±0.5	...	...	...	$.89 \times 10^{-4}$	...	...
Lanthanum	La	57	138.92	6.15	826 ±6	.045	...	...	...	59 (18°C)	...
Lead	Pb	82	207.21	11.34	327.4 ±0.1	.030	6.3	28.7	.35	20.66 (20°C)	2,600
Lithium	Li	3	6.940	0.53	186 ±5	.79	159	66	.71	8.55 (0°C)	...
Lutecium	Lu	71	174.99	...	...	...	...	...	...	...	...
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	1,260 ±20	.107	64.8	23	...	...	23,000
Masurium	Ma	43	98-99.5	...	[a]2,700	...	...	...	...	...	...
Mercury	Hg	80	200.61	13.55	-38.87 ±0.02	.033	2.7	...	0.084	94.1 (0°C)	...
Molybdenum	Mo	42	95.95	10.2	2,625 ±50	.066	...	[e]4.9	1.46	5.17 (0°C)	60,000
Neodymium	Nd	60	144.27	7.05	840 ±40	.045	...	...	...	79 (18°C)	...
Neon	Ne	10	20.183	0.8387×10^{-3}	-248.6 ±0.3	...	...	...	4.57×10^{-4}	...	...
Nickel	Ni	28	58.69	8.9	1,455 ±1	.112	73.8	[e]13.3	0.90	6.84 (20°C)	30,000
Nitrogen	N	7	14.008	1.1649×10^{-3}	-210.0 ±0.3	.247	6.2	...	2.51×10^{-4}	...	...
Osmium	Os	76	190.2	22.48	2,700 ±200	.031	...	6.1	...	9.5 (20°C)	...
Oxygen	O	8	16.0000	1.3318×10^{-3}	-218.8 ±0.3	.218	3.3	...	2.47×10^{-4}	...	...
Palladium	Pd	46	106.7	12.0	1,554 ±1	.059	34.2	11.8	0.70	10.8 (20°C)	17,000

[a]Computed.
[b]Value depends on the crystal orientation in polycrystalline material.
[c]From 20° to 60°C.
[d]At 36 atmospheres.
[e]From 20° to 100°C.
[f]At 30 atmospheres.

TABLE [illegible].—*Some physical properties of the elements*—Continued

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
				g/cm³	*°C*	*cal/g/°C*	*cal/g*	$\times10^{-6}$	*Watts cm⁻¹ °C⁻¹*	*Microhm cm*	*Kips/in.²*
Phosphorus (yellow)	P	15	30.98	1.82	44.1 ±0.1	0.177	5.0	125	...	10^{17} (11°C)	...
Platinum	Pt	78	195.23	21.45	1,773.5 ±1	.032	27.1	8.9	0.69	9.81 (0°C)	22,000
Polonium	Po	84	210	...	[a]600	...	...	...	...	...	...
Potassium	K	19	39.096	0.86	63 ±1	.177	14.5	83	.99	6.15 (0°C)	...
Praseodymium	Pr	59	140.92	6.63	940 ±50	.158	...	...	...	88 (18°C)	...
Protoactinium	Pa	91	231	...	[a]3,000	...	...	...	...	...	...
Radium	Ra	88	226.05	5.0	700	...	...	...	...	...	...
Radon	Rn	86	222	[g]4.40	-71	...	...	...	...	...	...
Rhenium	Re	75	186.31	20	[a]3,000	.035	...	...	...	...	...
Rhodium	Rh	45	102.91	12.44	1,966 ±3	.060	...	[h]8.1	.98	4.3 (0°C)	42,500
Rubidium	Rb	37	85.48	1.53	39 ±1	.080	6.1	90	...	12.5 (20°C)	...
Ruthenium	Ru	44	101.7	12.2	2,500 ±100	.061	...	9.1	...	10 (18°C)	...
Samarium	Sm	62	150.43	7.7	>1,300	...	...	...	...	...	...
Scandium	Sc	21	45.10	2.5	1,200	...	...	...	...	...	...
Selenium	Se	34	78.96	4.81	220 ±5	.084	...	37	...	1.2 (20°C)	...
Silicon	Si	14	28.06	2.4	1,430 ±20	.176	...	2.8–7.3	.84	85×10^3 (20°C)	16,000
Silver	Ag	47	107.880	10.49	960.5 ±0.0	.056	24.3	18.9	4.08	1.62 (20°C)	10,300
Sodium	Na	11	22.997	0.97	97.7 ±0.2	.295	27.5	71	1.35	4.2 (0°C)	...
Strontium	Sr	38	87.63	2.6	770 ±10	...	25	...	...	22.76 (20°C)	...
Sulfur (rhombic)	S	16	32.06	2.07	112.8 ±0.2	.175	9.3	64	26.4×10^{-4}	2×10^{23} (20°C)	...
Tantalum	Ta	73	180.88	16.6	3,000 ±100	.036	...	6.6	0.54	14.6 (18°C)	27,000
Tellurium	Te	52	127.61	6.24	450 ±10	.047	...	16.8	.060	...	6,000
Terbium	Tb	65	159.2	...	327 ±5	...	...	...	...	...	...
Thallium	Tl	81	204.39	11.85	300 ±3	.031	7.2	28	.39	17.65 (0°C)	...
Thorium	Th	90	232.12	11.5	1,800 ±150	.028	...	[c]11.1	...	18.52 (20°C)	...
Thulium	Tm	69	169.4	...	...	...	...	...	...	...	...
Tin	Sn	50	118.70	7.30	231.9 ±0.1	.054	14.4	23	.64	11.5 (20°C)	5,900
Titanium	Ti	22	47.90	4.54	1,820 ±100	.142	...	8.5	...	80 (0°C)	12,100
Tungsten	W	74	183.92	19.3	3,410 ±20	.034	44	4.3	1.99	5.5 (20°C)	50,000
Uranium	U	92	238.07	18.7	<1,850	.028	...	...	...	60 (18°C)	...
Vanadium	V	23	50.95	5.68	1,735 ±50	.115	...	...	...	...	...
Xenon	Xe	54	131.3	5.495×10^{-3}	-112 ±1	...	...	...	5.19×10^{-5}	...	...
Ytterbium	Yb	70	173.04	...	1,800	...	...	...	...	...	...
Yttrium	Y	39	88.92	5.51	1,490 ±200	...	...	...	...	...	...
Zinc	Zn	30	65.38	7.14	419.5 ±0.1	.09	24.1	[b]17–39	1.1	5.92 (20°C)	12,000
Zirconium	Zr	40	91.22	6.4	1,750 ±700	.066	...	5.6	...	41.0 (0°C)	10,700
...	...	85	[a]221	...	[a]250	...	...	...	...	...	...
...	...	87	[a]224	...	[a]23	...	...	...	...	...	...

[a]Computed.
[b]Value depends on the crystal orientation in polycrystalline material.
[c]From 20° to 60°C.
[g]At -62°C.
[h]From 20° to 50°C.

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/cm²	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/cm²	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.
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.

[4] Used in yield strength column.
[5] Used as a prefix.
[6] Used also for reduction in thickness in rolling sheet or for reduction in area in rolling or drawing rod or wire.

[5] Used as a prefix.

3. Conversion Factors

Multiply	By	To obtain
cm	0.03281	ft
cm	.3937	in.
cm³	.3531×10⁻⁴	ft³
cm³	.0610	in.³
ft³	28,317	cm³
ft³	1,728	in.³
in.³	16.387	cm³
in.³	0.5787×10⁻³	ft³
ft	30.48	cm
ft-lb	0.1383	m-kg
g	2.2046×10⁻³	lb
g/cm³	62.43	lb/ft³
g/cm³	0.03613	lb/in.³
in.	2.540	cm.
kg	2.2046×10⁻³	kips
kg	0.984×10⁻³	long tons[7]
kg/mm²	1.4223	kips/in.²
kg/mm²	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/mm²
long tons[7]	1016	kg
long tons[7]	2.24	kips
long tons/in.²[7]	1.5749	kilograms/mm²
m-kg	7.2330	ft-lb
microhm-cm	6.015	ohms/circular-mil-foot
mm	0.03937	in.
lb/ft³	.01602	g/cm³
lb/ft³	.5787×10⁻³	lb/in.³
lb/in.³	27.68	g/cm³
cm²	1.076×10⁻³	ft²
cm²	0.1550	in.²
in.²	6.452	cm²
in.²	6.944×10⁻³	ft²
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:

$$^\circ C = 5/9\ (^\circ F - 32).$$

$$^\circ F = 1.8\,^\circ C + 32.$$

[7] Used in Great Britain for strength values.

Coefficients (thermal expansion, electrical and thermal conductivity):

$$\alpha/^{\circ}C = \alpha/^{\circ}F \times 1.8$$
$$\alpha/^{\circ}F = \alpha/^{\circ}C \times 5/9$$

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 68.—*Temperature interconversion* (°C ⟷ °F) [673]

a.—*Conversion table: degrees centigrade to degrees Fahrenheit*

°C	0	10	20	30	40	50	60	70	80	90
	F	F	F	F	F	F	F	F	F	F
- 200	- 328	- 346	- 364	- 382	- 400	- 418	- 436	- 454	......	......
- 100	- 148	- 166	- 184	- 202	- 220	- 238	- 256	- 274	- 292	- 310
- 0	+ 32	+ 14	- 4	- 22	- 40	- 58	- 76	-94	- 112	- 130
0	32	50	68	86	104	122	140	158	176	194
100	212	230	248	266	284	302	320	338	356	374
200	392	410	428	446	464	482	500	518	536	554
300	572	590	608	626	644	662	680	698	716	734
400	752	770	788	806	824	842	850	878	896	914
500	932	950	968	986	1004	1022	1040	1058	1076	1094
600	1112	1130	1148	1166	1184	1202	1220	1238	1256	1274
700	1292	1310	1328	1346	1364	1382	1400	1418	1436	1454
800	1472	1490	1508	1526	1544	1562	1580	1598	1616	1634
900	1652	1670	1688	1706	1724	1742	1760	1778	1796	1814
1000	1832	1850	1868	1886	1904	1922	1940	1958	1976	1994
1100	2012	2030	2048	2066	2084	2102	2120	2138	2156	2174
1200	2192	2210	2228	2246	2264	2282	2300	2318	2336	2354
1300	2372	2390	2408	2426	2444	2462	2480	2498	2516	2534
1400	2552	2570	2588	2606	2624	2642	2660	2678	2696	2714
1500	2732	2750	2768	2786	2804	2822	2840	2858	2876	2894
1600	2912	2930	2948	2966	2984	3002	3020	3038	3056	3074
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
	F	F	F	F	F	F	F	F	F	F
2000	3632	3650	3668	3686	3704	3722	3740	3758	3776	3794
2100	3812	3830	3848	3866	3884	3902	3920	3938	3956	3974
2200	3992	4010	4028	4046	4064	4082	4100	4118	4136	4154
2300	4172	4190	4208	4226	4244	4262	4280	4298	4316	4334
2400	4352	4370	4388	4406	4424	4442	4460	4478	4496	4514
2500	4532	4550	4568	4586	4604	4622	4640	4658	4676	4694
2600	4712	4730	4748	4766	4784	4802	4820	4838	4856	4874
2700	4892	4910	4928	4946	4964	4982	5000	5018	5036	5054
2800	5072	5090	5108	5126	5144	5162	5180	5198	5216	5234
2900	5252	5270	5288	5306	5324	5342	5360	5378	5396	5414
3000	5432	5450	5468	5486	5504	5522	5540	5558	5576	5594
3100	5612	5630	5648	5666	5684	5702	5720	5738	5756	5774
3200	5792	5810	5828	5846	5864	5882	5900	5918	5936	5954
3300	5972	5990	5008	6026	6044	6062	6080	6098	6116	6134
3400	6152	6170	6188	6206	6224	6242	6260	6278	6296	6314
3500	6332	6350	6368	6386	6404	6422	6440	6458	6476	6494
3600	6512	6530	6548	6566	6584	6602	6620	6638	6656	6674
3700	6692	6710	6728	6746	6764	6782	6800	6818	6836	6854
3800	6872	6890	6908	6926	6944	6962	6980	6998	7016	7034
3900	7052	7070	7088	7105	7124	7142	7160	7178	7196	7214
°C	0	10	20	30	40	50	60	70	80	90

°C	°F
1	1.8
2	3.6
3	5.4
4	7.2
5	9.0
6	10.8
7	12.6
8	14.4
9	16.2
10	18.0

°F	°C
1	0.56
2	1.11
3	1.67
4	2.22
5	2.78
6	3.33
7	3.89
8	4.44
9	5.00
10	5.56
11	6.11
12	6.67
13	7.22
14	7.78
15	8.33
16	8.89
17	9.44
18	10.00

EXAMPLES: 1347 °C = 2444 °F + 12.6 °F = 2456.6 °F. 3367 °F = 1850 °C + 2.78 °C = 1852.78 °C.

TABLE 68.—*Temperature interconversion* (°C ⟷ °F) [673]—Continued

b.—*Conversion table: degrees Fahrenheit to degrees centigrade.* [Single boldface figures indicate recurring decimals]

°F	0	10	20	30	40	50	60	70	80	90
	C	C	C	C	C	C	C	C	C	C
-400	-240.0	-245.5	-251.1	-256.6	-262.2	-267.7	......	......	......	......
-300	-184.4	-190.0	-195.5	-201.1	-206.6	-212.2	-217.7	-223.3	-228.8	-234.4
-200	-128.8	-134.4	-140.0	-145.5	-151.1	-156.6	-162.2	-167.7	-173.3	-178.8
-100	-73.3	-78.8	-84.4	-90.0	-95.5	-101.1	-106.6	-112.2	-117.7	-123.3
-0	-17.7	-23.3	-28.8	-34.4	-40.0	-45.5	-51.1	-56.6	-62.2	-67.7
0	-17.7	-12.2	-6.6	-1.1	+4.4	+10.0	+15.5	+21.1	+26.6	+32.2
100	37.7	43.3	48.8	54.4	60.0	65.5	71.1	76.6	82.2	87.7
200	93.3	98.8	104.4	110.0	115.5	121.1	126.6	132.2	137.7	143.3
300	148.8	154.4	160.0	165.5	171.1	176.6	182.2	187.7	193.3	198.8
400	204.4	210.0	215.5	221.1	226.6	232.2	237.7	243.3	248.8	254.4
500	260.0	265.5	271.1	276.6	282.2	287.7	293.3	298.8	304.4	310.0
600	315.5	321.1	326.6	332.2	337.7	343.3	348.8	354.4	360.0	365.5
700	371.1	376.6	382.2	387.7	393.3	398.8	404.4	410.0	415.5	421.1
800	426.6	432.2	437.7	443.3	448.8	454.4	460.0	465.5	471.1	476.6
900	482.2	487.7	493.3	498.8	504.4	510.0	515.5	521.1	526.6	532.2
1000	537.7	543.3	548.8	554.4	560.0	565.5	571.1	576.6	582.2	587.7
1100	593.3	598.8	604.4	610.0	615.5	621.1	626.6	632.2	637.7	643.3
1200	648.8	654.4	660.0	665.5	671.1	676.6	682.2	687.7	693.3	698.8
1300	704.4	710.0	715.5	721.1	726.6	732.2	737.7	743.3	748.8	754.4
1400	760.0	765.5	771.1	776.6	782.2	787.7	793.3	798.8	804.4	810.0
1500	815.5	821.1	826.6	832.2	837.7	843.3	848.8	854.4	860.0	865.5
1600	871.1	876.6	882.2	887.7	893.3	898.8	904.4	910.0	915.5	921.1
1700	926.6	932.2	937.7	943.3	948.8	954.4	960.0	965.5	971.1	976.6
1800	982.2	987.7	993.3	998.8	1004.4	1010.0	1015.5	1021.1	1026.6	1032.2
1900	1037.7	1043.3	1048.8	1054.4	1060.0	1065.5	1071.1	1076.6	1082.2	1087.7
2000	1093.3	1098.8	1104.4	1110.0	1115.5	1121.1	1126.6	1132.2	1137.7	1143.3
2100	1148.8	1154.4	1160.0	1165.5	1171.1	1176.6	1182.2	1187.7	1193.3	1198.8
2200	1204.4	1210.0	1215.5	1221.1	1226.6	1232.2	1237.7	1243.3	1248.8	1254.4
2300	1260.0	1265.5	1271.1	1276.6	1282.2	1287.7	1293.3	1298.8	1304.4	1310.0
2400	1315.5	1321.1	1326.6	1332.2	1337.7	1343.3	1348.8	1354.4	1360.0	1365.5
2500	1371.1	1376.6	1382.2	1387.7	1393.3	1398.8	1404.4	1410.0	1415.5	1421.1
2600	1426.6	1432.2	1437.7	1443.3	1448.8	1454.4	1460.0	1465.5	1471.1	1476.6
2700	1482.2	1487.7	1493.3	1498.8	1504.4	1510.0	1515.5	1521.1	1526.6	1532.2
2800	1537.7	1543.3	1548.8	1554.4	1560.0	1565.5	1571.1	1576.6	1582.2	1587.7
2900	1593.3	1598.8	1604.4	1610.0	1615.5	1621.1	1626.6	1632.2	1637.7	1643.3
3000	1648.8	1654.4	1660.0	1665.5	1671.1	1676.6	1682.2	1687.7	1693.3	1698.8
3100	1704.4	1710.0	1715.5	1721.1	1726.6	1732.2	1737.7	1743.3	1748.8	1754.4
3200	1760.0	1765.5	1771.1	1776.6	1782.2	1787.7	1793.3	1798.8	1804.4	1810.0
3300	1815.5	1821.1	1826.6	1832.2	1837.7	1843.3	1848.8	1854.4	1860.0	1865.5
3400	1871.1	1876.6	1882.2	1887.7	1893.3	1898.8	1904.4	1910.0	1915.5	1921.1
3500	1926.6	1932.2	1937.7	1943.3	1948.8	1954.4	1960.0	1965.5	1971.1	1976.6
3600	1982.2	1987.7	1993.3	1998.8	2004.4	2010.0	2015.5	2021.1	2026.6	2032.2
3700	2037.7	2043.3	2048.8	2054.4	2060.0	2065.5	2071.1	2076.6	2082.2	2087.7
3800	2093.3	2098.8	2104.4	2110.0	2115.5	2121.1	2126.6	2132.2	2137.7	2143.3
3900	2148.8	2154.4	2160.0	2165.5	2171.1	2176.6	2182.2	2187.7	2193.3	2198.8
°F	0	10	20	30	40	50	60	70	80	90

°F	0	10	20	30	40	50	60	70	80	90
	C	C	C	C	C	C	C	C	C	C
4000	2204.4	2210.0	2215.5	2221.1	2226.6	2232.2	2237.7	2243.3	2248.8	2254.4
4100	2260.0	2265.5	2271.1	2276.6	2282.2	2287.7	2293.3	2298.8	2304.4	2310.0
4200	2315.5	2321.1	2326.6	2332.2	2337.7	2343.3	2348.8	2354.4	2360.0	2365.5
4300	2371.1	2376.6	2382.2	2387.7	2393.3	2398.8	2404.4	2410.0	2415.5	2421.1
4400	2426.6	2432.2	2437.7	2443.3	2448.8	2454.4	2460.0	2465.5	2471.1	2476.6
4500	2482.2	2487.7	2493.3	2498.8	2504.4	2510.0	2515.5	2521.1	2526.6	2532.2
4600	2537.7	2543.3	2548.8	2554.4	2560.0	2565.5	2571.1	2576.6	2582.2	2587.7
4700	2593.3	2598.8	2604.4	2610.0	2615.5	2621.1	2626.6	2632.2	2637.7	2643.3
4800	2648.8	2654.4	2660.0	2665.5	2671.1	2676.6	2682.2	2687.7	2693.3	2698.8
4900	2704.4	2710.0	2715.5	2721.1	2726.6	2732.2	2737.7	2743.3	2748.8	2754.4
5000	2760.0	2765.5	2771.1	2776.6	2782.2	2787.7	2793.3	2798.8	2804.4	2810.0
5100	2815.5	2821.1	2826.6	2832.2	2837.7	2843.3	2848.8	2854.4	2860.0	2865.5
5200	2871.1	2876.6	2882.2	2887.7	2893.3	2898.8	2904.4	2910.0	2915.5	2921.1
5300	2926.6	2932.2	2937.7	2943.3	2948.8	2954.4	2960.0	2965.5	2971.1	2976.6
5400	2982.2	2987.7	2993.3	2998.8	3004.4	3010.0	3015.5	3021.1	3026.6	3032.2
5500	3037.7	3043.3	3048.8	3054.4	3060.0	3065.5	3071.1	3076.6	3082.2	3087.7
5600	3093.3	3098.8	3104.4	3110.0	3115.5	3121.1	3126.6	3132.2	3137.7	3143.3
5700	3148.8	3154.4	3160.0	3165.5	3171.1	3176.6	3182.2	3187.7	3193.3	3198.8
5800	3204.4	3210.0	3215.5	3221.1	3226.6	3232.2	3237.7	3243.3	3248.8	3254.4
5900	3260.0	3265.5	3271.1	3276.6	3282.2	3287.7	3293.3	3298.8	3304.4	3310.0
6000	3315.5	3321.1	3326.6	3332.2	3337.7	3343.3	3348.8	3354.4	3360.0	3365.5
6100	3371.1	3376.6	3382.2	3387.7	3393.3	3398.8	3404.4	3410.0	3415.5	3421.1
6200	3426.6	3432.2	3437.7	3443.3	3448.8	3454.4	3460.0	3465.5	3471.1	3476.6
6300	3482.2	3487.7	3493.3	3498.8	3504.4	3510.0	3515.5	3521.1	3526.6	3532.2
6400	3537.7	3543.3	3548.8	3554.4	3560.0	3565.5	3571.1	3576.6	3582.2	3587.7
6500	3593.3	3598.8	3604.4	3610.0	3615.5	3621.1	3626.6	3632.2	3637.7	3643.3
6600	3648.8	3654.4	3660.0	3665.5	3671.1	3676.6	3682.2	3687.7	3693.3	3698.8
6700	3704.4	3710.0	3715.5	3721.1	3726.6	3732.2	3737.7	3743.3	3748.8	3754.4
6800	3760.0	3765.5	3771.1	3776.6	3782.2	3787.7	3793.3	3798.8	3804.4	3810.0
6900	3815.5	3821.1	3826.6	3832.2	3837.7	3843.3	3848.8	3854.4	3860.0	3865.5
7000	3871.1	3876.6	3882.2	3887.7	3893.3	3898.8	3904.4	3910.0	3915.5	3921.1
7100	3926.6	3932.2	3937.7	3943.3	3948.8	3954.4	3960.0	3965.5	3971.1	3976.6
7200	3982.2	3987.7	3993.3	3998.8	4004.4	4010.0	4015.5	4021.1	4026.6	4032.2
7300	4037.7	4043.3	4048.8	4054.4	4060.0	4065.5	4071.1	4076.6	4082.2	4087.7
7400	4093.3	4098.8	4104.4	4110.0	4115.5	4121.1	4126.6	4132.2	4137.7	4143.3
7500	4148.8	4154.4	4160.0	4165.5	4171.1	4176.6	4182.2	4187.7	4193.3	4198.8
7600	4204.4	4210.0	4215.5	4221.1	4226.6	4232.2	4237.7	4243.3	4248.8	4254.4
7700	4260.0	4265.5	4271.1	4276.6	4282.2	4287.7	4293.3	4298.8	4304.4	4310.0
7800	4315.5	4321.1	4326.6	4332.2	4337.7	4343.3	4348.8	4354.4	4360.0	4365.5
7900	4371.1	4376.6	4382.2	4387.7	4393.3	4398.8	4404.4	4410.0	4415.5	4421.1
°F	0	10	20	30	40	50	60	70	80	90

°F	°C
1	0.5
2	1.1
3	1.6
4	2.2
5	2.7
6	3.3
7	3.8
8	4.4
9	5.0

EXAMPLES: −246.0°F = −151.11°C − 3.33°C = −154.44°C. 3762°F = 2071.1°C + 1.1°C = 2072.2°C. 2423.5°F = 1326.66°C + 1.66°C + 0.27°C = 1328.61°C.

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