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DEPARTMENT OF COMMERCE

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S. W. STRATTON, DIRECTOR

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METALLOGRAPHIC TESTING

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METALLOGRAPHIC TESTING

ABSTRACT.

In the modern testing of metals a mere determination of their properties, in general is not sufficient. It is necessary that the underlying conditions which determine these properties be understood; it is the study of these fundamental conditions, structure, constitution, and treatment of metals and alloys that makes up the subject of metallography. The principal conditions which affect the mechanical and other common properties of any metal or alloy are as follows: Conditions of melting and casting, mechanical working received, thermal treatment, and structural features. The circular discusses briefly the different lines of metallographic testing carried out by the Bureau of Standards under the following headings: Microscopy and structure of metals, thermal analysis and heat treatment, mechanical working of metals, chemical metallurgy, and melting of metals. These headings correspond to the different sections into which the division of metallurgy is subdivided to assist in carrying out the work of a physical metallurgical—that is, metallographic—nature.

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I. INTRODUCTION

It is now very generally recognized that for a complete working knowledge of the properties of metals and alloys the information gained by metallographic methods of examination is very necessary in addition to the results of the usual mechanical tests and chemical analysis. Indeed, such investigations are often imperative and in numerous instances have proved to be a means of

solving difficulties which were inexplicable by the older methods of testing alone. The method is not to be considered as a panacea, however, nor in any way as replacing the older testing methods, but rather as a valuable supplement to them and as an additional means of testing. It is the purpose of this circular to describe very briefly the investigations and tests of a metallographic nature for which the Bureau of Standards is equipped and to mention the conditions under which such tests are made.

All tests and investigations of a metallurgical nature made by the Bureau of Standards start with the metal as such. Those phases of the general subject of metallurgy such as ore dressing, smelting, and similar stages in the production of metals do not fall within the field of investigation covered by this Bureau.

In the study of metals a mere determination of their properties is not sufficient. It is necessary that the underlying conditions which determine these properties be understood, and it is the study of these fundamental conditions, structure, constitution, and treatment of metals and alloys which constitutes the subject of metallography. By some this term is used to refer only to the microscopic study of metals, but by the Bureau of Standards it is used in the wider sense given above. Thus it becomes almost synonymous with the term "physical metallurgy," which concerns itself with the nature of metals and alloys, their properties and behavior.

II. TYPES OF EXAMINATIONS AND INVESTIGATIONS

For a proper and thorough understanding of any metal or alloy and its characteristics a series of examinations is usually necessary, including chemical, mechanical, metallographic (thermal, microscopic, etc.), as well as others in special cases. In general, chemical analyses will be made by this Bureau for individuals only in very special cases of dispute, or when some question of very considerable scientific or technical importance is involved. Mechanical testing is not discussed in this circular; for details concerning this, Circular 45, *The Testing of Materials*, should be consulted.

The principal conditions which affect the mechanical and other common properties of any given metal or alloy are as follows: Conditions of melting and casting of the material, mechanical working received, heat treatment, structural features of the material, and chemical influences. Most of the tests which the Bureau is called upon to make in connection with the physical metallurgy of metals are, with few exceptions, of a special nature,

each one involving considerable investigation. The Bureau is equipped for studying in detail the methods of preparation of metals and alloys, the means for shaping such materials by suitable mechanical working and the characteristics of the resulting products, together with such related subjects which have a direct bearing upon the different processes.

For convenience in carrying out tests and investigations, the metallurgical division has been divided into sections corresponding to the principal determining factors of the properties of metals. Practically every investigation, however, requires work in more than one of these fields.

1. MICROSCOPY AND STRUCTURE OF METALS

This subject has been discussed at a very considerable length in Circular 113, *The Structure and Related Properties of Metals*. Some of the purposes for which this type of examination is made are: As a supplement to chemical analysis by the identification of unknown alloys and of metallographic constituents of an alloy and by the determination of the homogeneity of any metallic product; investigation of the previous heat treatment and mechanical working of metals, either for the purpose of duplication or for explaining certain observed properties; examination for evidence bearing on the causes of the service failure of metals; determination of suitable metallographic methods for properly revealing the structure; relation of the structure of metals to certain specific problems such as corrosion. Fig. 1 shows a general view of the laboratory devoted to the microscopy of metals.

2. THERMAL ANALYSIS AND HEAT TREATMENT

The determination of the thermal characteristics of metals and alloys by means of the method of thermal analysis, "heating and cooling curves," by which critical transformations are located on the temperature scale, is of vital importance in the development of the best properties of metals, particularly steels. Upon such data are based the processes, often rather complex, familiarly known as "heat treatment," which term includes annealing, normalizing, hardening, tempering, and similar operations. Other lines of investigation include the study of cementation and similar processes, furnace control for heat treatment, determination of the efficiency of various quenching media, as well as the practical heat treatment of given materials to produce certain specified

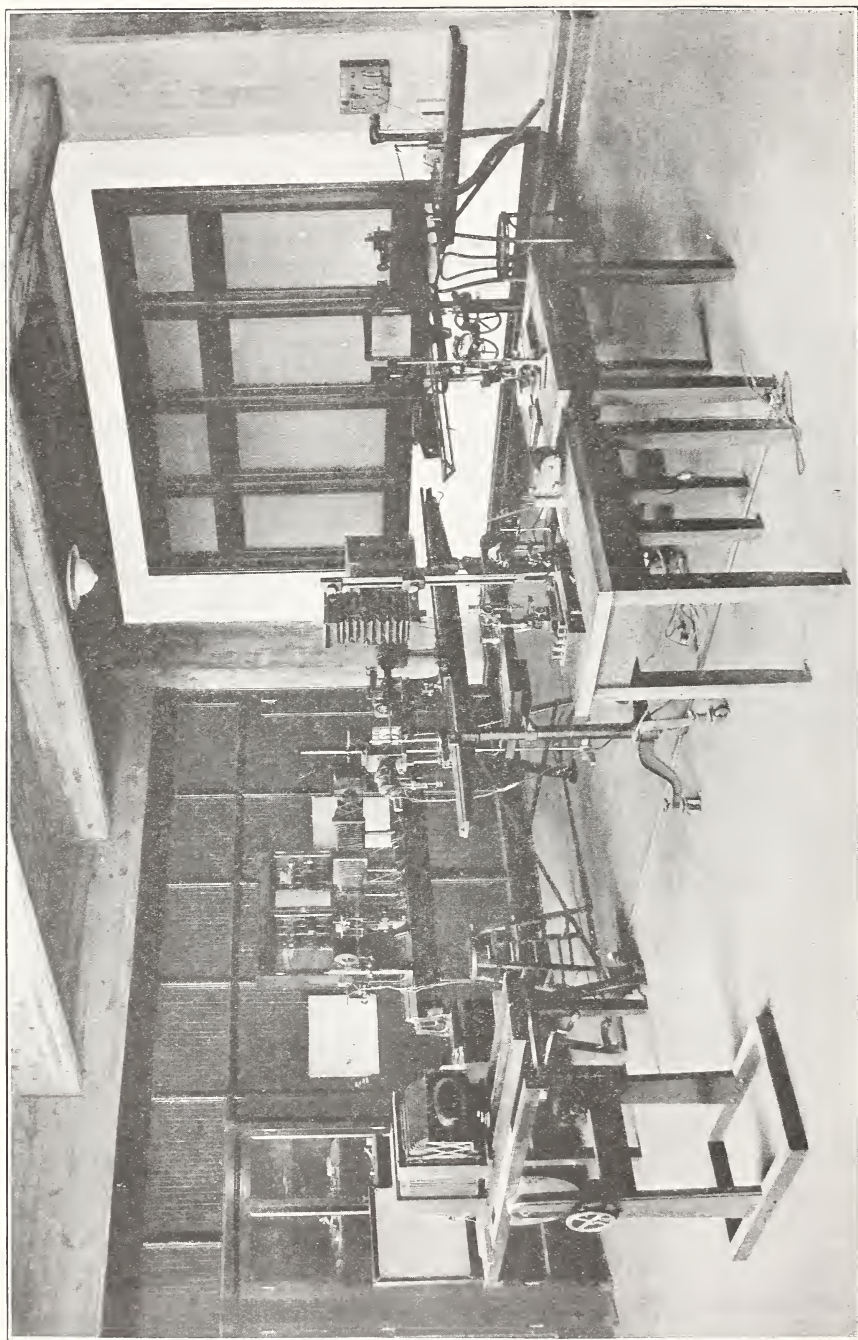


FIG. 1.—General view of Bureau of Standards laboratory devoted to the microscopy of metals

properties. In Fig. 2 the apparatus used in the thermal analysis of metals and alloys is shown.

3. MECHANICAL WORKING OF METALS AND RELATED PROPERTIES

The determination of certain mechanical properties is usually required as a preliminary to the study of the "working properties" of metals. The processes of rolling, pressing, forging, drawing, and extruding as well as methods of joining metals, welding, soldering, and the like are investigated and applied practically to

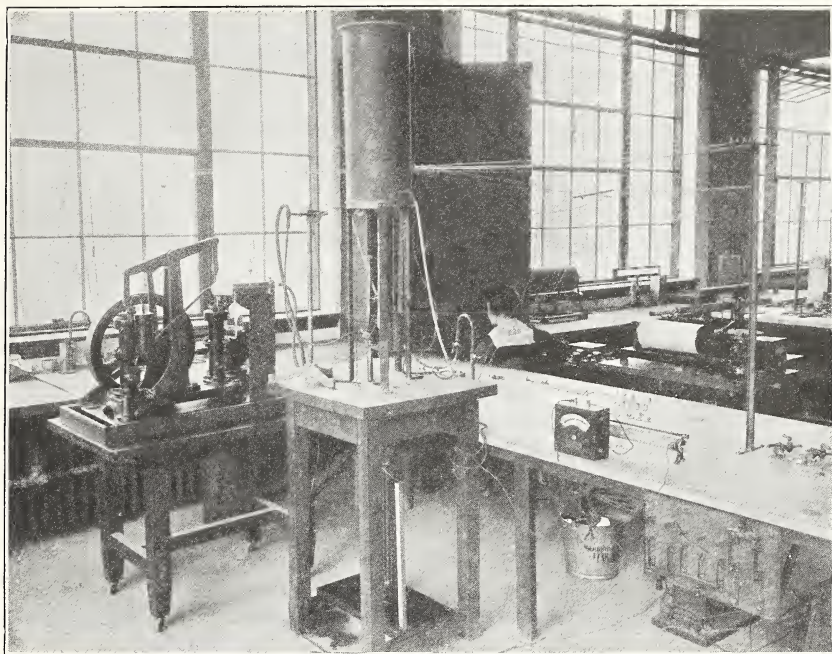


FIG. 2.—Equipment for the thermal analysis of metals

materials submitted. Advice concerning the efficiency of manufacturing appliances and processes for working metals is also given. The properties of the material after fabrication, particularly its mechanical uniformity, that is the condition with respect to initial internal stresses, are of importance. The characteristics and behavior of metals used under special and peculiar conditions such as bearing metals, safety boiler plugs, etc., are determined. The drawing up of specifications of metals to meet special needs also receives considerable attention. Fig. 3 shows the experimental 16-inch rolling mill installed for the study of the "working" properties of metals.

4. CHEMICAL METALLURGY

The investigations of this nature include the small-scale preparation of very pure metals and alloys, the determination of the effect of metallurgical auxiliary materials such as slags, deoxidizers, and refractories upon the properties of metals prepared in contact with such substances. Considerable stress has been laid on the subject of the determination of gases in metals, together with the origin of such gases and their effect upon the properties of the material. In general, the aim in the study of the chemical

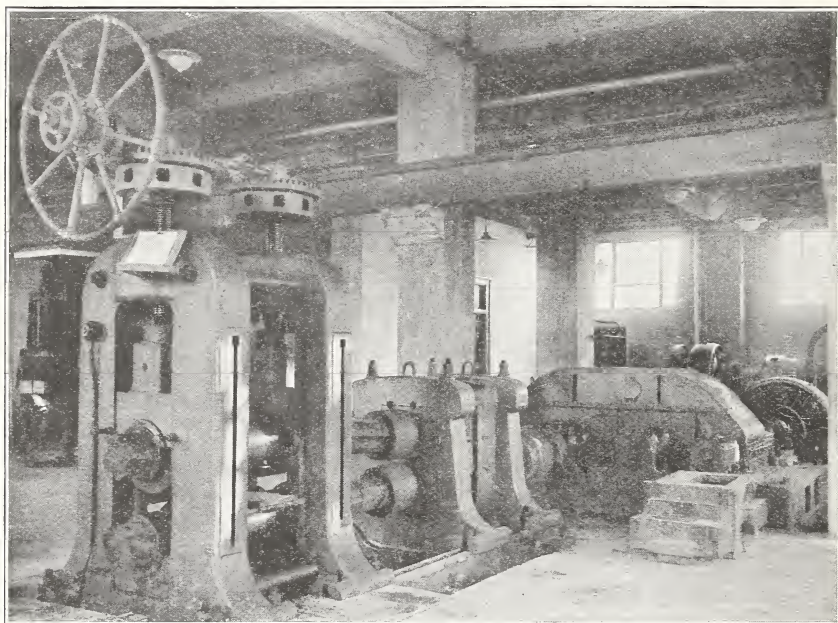


FIG. 3.—Sixteen-inch experimental rolling mill installed for the study of the "working" properties of metals

factors is to show the effect in any particular case, of chemical treatment on the properties of the resulting material.

5. MELTING OF METALS

Investigations connected with the melting of metals include such problems as the determination of the melting temperature, or temperature range, for any alloy or metal, methods for casting ferrous and nonferrous alloys, methods of molding, properties of foundry sands, preparation of alloys to order, furnace operation as applied to the melting of metals, and similar related subjects. In Fig. 4 is shown one of the electric furnaces used in the melting of metals.

In some cases properties not included in the above list may be necessary, such as temperature coefficient of electrical resistance or of thermal expansion, specific heat, etc. Such must be arranged for in advance by correspondence; likewise examinations of a very special character, such as the radiography of metals and

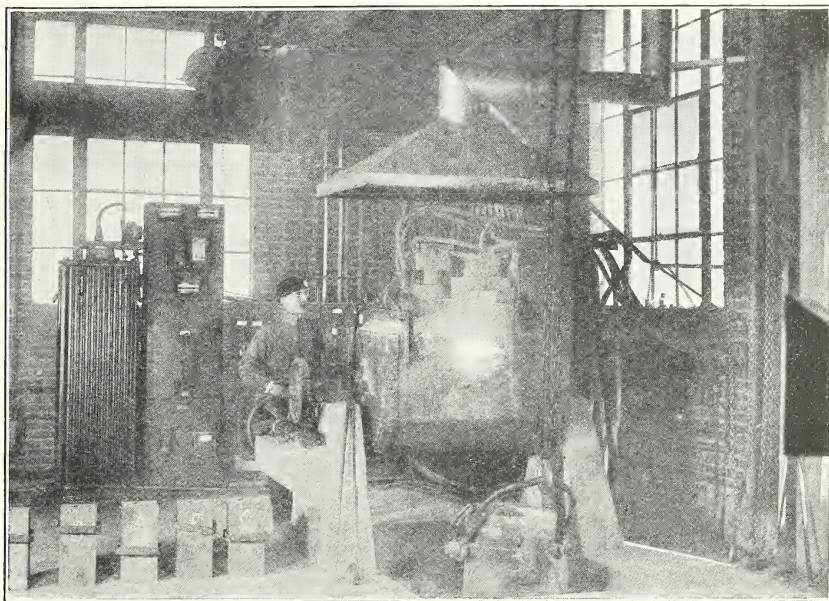


FIG. 4.—*Electric arc furnace used in the melting of metals; capacity, 500 pounds*

the determination of the magnetic characteristics of iron and steel.

6. INFORMATION REGARDING METALS

Considerable attention is given to the dissemination of information relating to the general subject of physical metallurgy. The Bureau is constantly receiving requests for information concerning the properties, statistics, etc., of metals and alloys. Such information is rarely to be found in systematic form; generally the different sources of this information are difficult of access and their accuracy is not always certain. The Bureau plans to issue from time to time circulars on individual metals and alloys, dealing primarily with the physical properties, with the idea of summarizing and grouping in these circulars all of the best information which the Bureau has acquired as a result of its tests and investigations of such materials.

The following circulars of this kind are now available: Circular 73, Copper; Circular 76, Aluminum and Its Light Alloys; Circular 100, Nickel.

Other circulars discussing the general lines of investigation indicated above, which constitute the subject of physical metallurgy, are also planned. Of these, Circular 113, The Structure and Related Properties of Metals, is now available.

III. REPORTS

In general the Bureau will not in a formal report express an opinion as to the suitability of a metal or alloy for any specific purpose, this restriction to apply in particular to proprietary alloys for advertising purposes. The results of the examination by which the properties and the structure of the material are determined will be given. Photomicrographs will be accompanied by statements as to the various constituents which are shown and the conditions under which the examination was made. In describing the microstructure of iron and steel the Bureau will conform, in general, to the "Nomenclature of the microscopic substances and structures of iron and steel," recommended by the Sixth Congress of the International Society for Testing Materials.

IV. DIRECTIONS CONCERNING TESTS

The request for examination of any material should state explicitly the purpose for which the examination is to be made.

1. IDENTIFICATION

Both the specimens and the packages in which they are shipped should be plainly marked to facilitate identification. Preferably the name of the shipper should be on the outside of each package and a list of the contents should be inclosed within, each sample being given a special identification mark or number.

2. SIZE OF SPECIMEN

Whenever possible the Bureau should be consulted in advance as to the size and number of samples which should be submitted for any particular examination. It is usually simpler to send the original piece so that the sampling can be done at the Bureau. For some of the simpler tests, however, small specimens may be submitted directly. Thus for microscopic examination a piece which will present a polishing face of 1 by 1 cm, or larger, may be submitted; for thermal analysis a cube approximately 1 cm on an edge will furnish sufficient material.

3. SHIPPING DIRECTIONS

Material should be securely packed in cases which may be used for returning the same in case this is necessary. In general, materials will not be returned except in case of materials submitted for a special treatment; in case of microscopic examination part of the sample, polished ready for examination, will be sent with the results of the examination when requested at the time the material is submitted.

4. ADDRESS

Packages should be addressed "Bureau of Standards, VIII, Washington, D. C."

5. FEES

Fees may be remitted by money order or check drawn to the order of "Bureau of Standards." No articles are returned or results of tests given out until all fees due thereon are received.

Inasmuch as most of the metallurgical examinations are of a very special nature, the fee can not be stated in advance as a general rule, but must be arranged for by correspondence. The examinations for which regular fees have been established are given below.

Fee Schedule 223.—METALLOGRAPHY

(a) Determination of the fusion point of metal or alloy.....	\$10. 00
(b) Cooling curve of a steel or other alloy for critical points.....	25. 00
(c) Annealing, normalizing, hardening, or tempering of small specimens, each operation.....	2. 50
(d) Microscopic examination (preparation of specimens with photomicrograph of same):	
(1) Magnification up to 500 diameters, for first print.....	10. 00
(2) Magnification 500 to 1000 diameters, for first print.....	12. 50
(3) Magnification above 1000 diameters, fee depends upon magnification, but minimum charge for first print.....	15. 00
(4) For each succeeding print in every case.....	.75

6. DISCOUNTS

When three or more test specimens of the same kind or class requiring the same test on each are submitted together, a discount of 25 per cent from the fees in this schedule will be allowed.

For educational and scientific institutions and societies a discount of 50 per cent will be allowed on all tests.

S. W. STRATTON,
Director.

Approved:

HERBERT HOOVER,
Secretary of Commerce.



