DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 45

THE TESTING OF MATERIALS

[1st Edition]
Issued November 1, 1913

WASHINGTON
GOVERNMENT PRINTING OFFICE
1913

DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 45

THE TESTING OF MATERIALS

[1st Edition]
Issued November 1, 1913

WASHINGTON
GOVERNMENT PRINTING OFFICE
1913

CONTENTS

I. Introduction. Page

1. Purpose ... 9
2. Testing of materials ... 9
3. Classes of materials ... 10
4. Properties of materials ... 11
5. Determination of properties of materials ... 12
6. The measure of quality ... 12
7. Specifications or standards of quality ... 15
8. Improvement of specifications ... 16

II. General Information Concerning the Testing of Materials.

1. Choice of tests ... 17
2. Sampling and selection of test pieces ... 17
3. Application for testing ... 19
4. Shipping directions ... 19
5. Identification marks ... 20
6. Time required for testing ... 20
7. Results of tests and their interpretation ... 20
8. Fees for testing ... 21
9. For whom tests are made ... 21

III. Special Information Concerning the Classes of Materials Tested.

1. Metals ... 23
   - A. Metals and metal products ... 23
     - (1) Definition ... 23
     - (2) Sources and uses ... 23
     - (3) Purpose of tests ... 23
     - (4) Nature of tests ... 23
       - (*a*) Chemical analysis ... 24
       - (*b*) Metallographic examination and heat treatment ... 24
       - (*c*) Mechanical tests ... 24
         - (1) Tension tests ... 25
         - (2) Compression tests ... 26
         - (3) Flexure tests ... 27
         - (4) Torsion tests ... 27
         - (5) Hardness tests ... 27
         - (6) Strain measurements ... 27
       - (*d*) Miscellaneous physical tests ... 27
     - (5) Sampling and testing under specifications ... 28
   - B. Composite metal products ... 28
     - (1) Plated and coated metals ... 29
     - (2) Enamels for cast iron and steel ... 30

III. Special Information Concerning the Classes of Materials Tested—Con. Page

2. Cements (hydraulic) and concrete 30
A. Portland cement 30
(1) Definition 30
(2) Sources 31
(3) Uses 31
(4) Properties of cement 31
(*a*) Chemical tests 31
(*b*) Physical tests 32
(1) Soundness 32
(2) Time of setting 32
(3) Tensile strength 33
(4) Fineness 33
(5) Specific gravity 33
(6) Sampling 33
B. White cement 34
C. Natural cement 34
D. Raw cement materials 35
E. Sand and stone screenings 35
(1) Source 35
(2) Uses 35
(3) Properties 36
(4) Tests 36
(5) Sampling 36
3. Ceramics 37
A. Clays and shales 37
(1) Sources 37
(2) Properties 37
(3) Tests 37
(4) Sampling 37
B. Clay products 38
(1) Clay building brick 38
(2) Architectural terra cotta 38
(3) Roofing tiles 39
(4) Floor tiles 39
(5) Glazed wall tiles 39
(6) Paving blocks and bricks 40
(7) Sewer pipe 40
(8) Drain tiles 40
(9) Porcelain and white ware 40
(10) Fire clays 41
(11) Fire proofing for steel protection 41
(12) Refractories 41
(*a*) Sources 41
(*b*) Uses 41
(*c*) Properties 42
(*d*) Tests 42

III. Special Information Concerning the Classes of Materials Tested—Con. Page
4. Lime ... 42
A. Burnt lime ... 42
(1) Definition ... 42
(2) Sources ... 42
(3) Uses ... 42
(4) Properties and tests ... 43
(5) Sampling ... 43
(6) Other conditions of test ... 43
B. Hydrated lime ... 44
(1) Definition ... 44
(2) Properties or quality ... 44
(3) Tests ... 44
(4) Sampling ... 44
(5) Other conditions of test ... 44
C. Raw materials for lime ... 44
(1) Definition ... 44
(2) Properties ... 44
(3) Tests ... 45
(4) Sampling ... 45
(5) Other conditions of test ... 45
D. Sand lime brick ... 45
(1) Definition ... 45
(2) Sources ... 45
(3) Uses ... 45
(4) Properties or quality ... 45
(5) Tests ... 45
(6) Sampling ... 45
(7) Other conditions of test ... 46
5. Stone ... 46
(1) Description ... 46
(2) Properties ... 46
(3) Tests ... 46
(*a*) Compression tests ... 46
(*b*) Freezing tests ... 46
(*c*) Absorption tests ... 47
(*d*) Transverse tests ... 47
(4) Sampling ... 47
6. Paint materials ... 47
A. Colorants ... 47
(1) Oil colors ... 47
(2) Water colors ... 47
(3) Tinting colors ... 47
(4) Enamel paints ... 47
(5) Stains ... 47
B. Oils ... 48
(1) Linseed oil ... 48
(2) Driers ... 48
(3) Volatile thinners ... 48

III. Special Information Concerning the Classes of Materials Tested—Con.

Page

6. Paint materials—Continued.
C. Varnishes 49
(1) Spirit varnishes 49
(2) Oil varnishes 49
D. Tests 50
(1) Paints 50
(2) Varnishes 51
E. Sampling 52
7. Bituminous materials 52
(1) Definition and classification 52
(2) Use and general requirements 53
(3) Tests and interpretation of results 53
(4) General statement 55
(5) Sampling 56
8. Inks 56
A. Writing inks 56
(1) Description 56
(2) Tests 57
(3) Sampling 57
B. Printing inks 57
C. Stamp pad inks 58
(1) Drying power 58
(2) Fastness of color 58
(3) Sampling 59
9. Paper 59
(1) Definition and sources 59
(2) Uses 59
(3) Quality 59
(4) Sampling 61
10. Textiles 62
A. Fibers, yarns, and fabrics 62
(1) Definition and sources 62
(2) Uses 62
(3) Properties 62
(4) Tests 63
(5) Sampling 63
B. Manila rope 64
(1) Quality 64
(2) Tests 64
(3) Sampling 64
11. Rubber 64
(1) Definition 64
(2) Sources 64
(3) Uses 65
(4) Properties 65
(5) Tests 65
(*a*) Physical tests 65
(*b*) Chemical tests 67
(6) Sampling 67
(*a*) Other conditions governing tests 68
12. Leather 68

III. Special Information Concerning the Classes of Materials Tested—Con. Page
13. Lubricating oils and greases ... 68
A. Oils ... 68
(1) Mechanical testing ... 69
(a) Viscosity ... 69
(b) Cold test ... 69
(c) Flash and fire points ... 69
(2) Chemical testing ... 70
(a) Mineral acid ... 70
(b) Soap ... 70
(c) Ash ... 70
(d) Asphalt test ... 70
(e) Organic acid ... 70
(f) Fat ... 71
(g) Carbonization ... 71
(h) Evaporation and gumming ... 71
(i) Specific gravity ... 71
B. Greases ... 71
14. Chemicals ... 72
15. Miscellaneous technical materials ... 72
A. Electrical and magnetic materials ... 72
B. Optical materials ... 73
C. Thermal materials ... 73
D. Water for boiler and technical use ... 74
E. Miscellaneous materials ... 74
F. Standard analyzed samples ... 74
16. Testing of instruments used for testing materials ... 76
IV. Schedules of Fees ... 77
222. Metals and metal products ... 77
223. Metallography ... 77
224. Composite metal products ... 78
242. Cement ... 78
243. Cement materials ... 78
232. Clay and clay products ... 79
251. Lime ... 79
252. Raw materials for lime and sand lime brick ... 79
262. Stone ... 80
292. Paint materials ... 80
312. Bituminous materials ... 80
282. Inks ... 80
212. Paper ... 80
200. Raw and unspun textile fibres ... 81
201. Yarn, thread, and twine ... 81
202. Fabric ... 81
209. Rope ... 82
115. Rubber—physical tests of ... 82
116. Rubber—chemical tests of ... 82
V. Publications ... 83
Index ... 87

THE TESTING OF MATERIALS

I. INTRODUCTION

1. PURPOSE

Many inquiries are received by the Bureau of Standards regarding the testing of materials. This circular is designed to furnish information upon some of the more general aspects of this branch of the Bureau's work. The several groups of materials are not treated with equal fullness and the treatment is not intended in any case to be complete. The circular is intended mainly for the user or buyer of materials rather than the industrial expert. The aim is to outline briefly with respect to each class of material the tests usually made, the conditions under which such work is undertaken, and some of the limitations due to the status of technical knowledge.

The subject of testing materials is of such fundamental importance as to justify a brief discussion of the theory upon which it is based and to outline its purpose and ultimate aim.

2. TESTING OF MATERIALS

To determine the value of any material for a given purpose, its properties must be measured, assuming of course that the properties upon which its use depends are known and are measurable. Again, these properties may have limiting values which must be regarded or the material may prove worthless, costly, or even harmful for the purpose intended. The testing of materials may prove a needless waste of time and money unless due consideration has been given to the nature of the tests to be applied, the conditions under which they are to be made, and the interpretation of results. It includes measurements of both quantity and quality. These may vary from a simple visual inspection to an investigation involving laboratory and technical work of the most difficult and precise nature.

The growing appreciation of the vast waste due to the use of defective materials and the misuse of good materials has raised the question of efficiency and made it the object of a searching inquiry in many different fields. In the industries, the solution of the problem has for its key the scientific testing of materials.

The testing of materials serves two important and distinct purposes; first, to ascertain whether or not they comply with specifications, and second, to add to the general fund of knowledge regarding them. When done with both objects in view it ceases to be of merely transient value for the immediate case in hand, important as this may be, but adds to the world's useful knowledge of the materials. Data accumulate rapidly in the regular work of the testing laboratory and when properly correlated will yield information of permanent value in the industries.

3. CLASSES OF MATERIALS

Materials may be classified in many different ways, for example: Chemically, physically, according to their technical applications, and likewise by any other aspect selected as a criterion. The fundamental classes of material, viewed chemically, are: (1) Elements which contain only similar atoms; for example, iron, mercury, hydrogen; (2) compounds, of which the molecule contains unlike atoms or groups of atoms, such as salts, water, or carbon dioxide; and (3) mixtures, such as coal, petroleum, or the atmosphere which contain unlike molecules. The physical classification into solids, liquids, and gases is technically important, since the methods of handling, measuring, weighing, and testing demanded by each are quite different.

Classification according to the use of the material is especially significant, since the testing of materials is primarily with a view to their efficient use. Special classes of materials grouped according to their use are, for example, electrical materials, refractories, lubricants, illuminants, colorants, abrasives, optical materials, and many others. There the materials within each group possess related properties useful for a specialized purpose. An important group, based upon use, is "structural materials," such as metals, stone, cement, brick, wood, protective coatings, paints, etc. Structural materials have for their practical function to maintain predetermined space relations of the parts of a structure under service conditions, or to protect a structure from the action of unfavorable agencies. Strength and rigidity usually characterize structural materials, since these qualities enable structures to resist deformation. In many cases rigidity alone would be detrimental, and here the material must be yielding under the combined stresses of high pressure and temperature.

Another group includes materials in which pliability or flexibility is a desirable quality. This class includes textiles, paper, rubber, leather, and similar materials. Here the practical function is to permit change

of space relations of the parts of an article within desired ranges without rupture. For example, a leather shoe or a cloth garment should yield with bodily motion, a rubber tire should be resilient under shock, and paper flexible enough to be folded. Such materials, however, may be hardened or stiffened by various means, until this class merges into other groups where rigidity as well as elasticity is important. Thus paper may be made into car wheels, cloth into stiff collars, and hardened rubber into many articles in daily use.

Another group consists of materials which form the surface upon other materials by adhesion or absorption. These include, for example, protective coatings, such as metallic coatings and paints, of which ornament—usually incidental—is often the main purpose; inks, used to impress design or print upon paper and other materials; stains and dyes, which may incidentally penetrate the materials; oils and varnishes, which may serve to protect as well as beautify.

Many other groupings might be mentioned as examples, since the modes of classifying materials found in nature or in the industries are practically numberless. The varieties of their uses are equally limitless. The utility of materials depends upon the nature, magnitude, and stability of their properties. To determine these is the object of the testing of materials.

4. PROPERTIES OF MATERIALS

The properties of materials are displayed in their behavior under varied conditions and relations. Among primary properties may be cited extension, impenetrability, porosity, divisibility, cohesion, expansion, and adhesion. The properties of matter are, however, as numerous and varied as the relations or aspects of matter and energy. The modes of classifying these properties are again very numerous. Geometrical properties relate to form, size, and spatial relations; physical properties may involve also mass, time, and energy; chemical properties, molecular structure and reactions, and so on. The groups of properties usually considered for any one application are, however, not numerous.

For a complete study of the properties of a material all of its properties would have to be studied through all ranges of conditions. Considerations of economy generally make such full tests impracticable, although the conviction is growing that the systematic study of the properties of materials would be a most effective means of technical progress.

The economic value of any given property depends upon its relative effect upon the net efficiency of the material for a given purpose. For some

uses a property may be of great value, while for others the same property may make the material useless or even dangerous. The close correlation of property with use is, then, the main problem in the modern testing of materials.

5. DETERMINATION OF THE PROPERTIES OF MATERIALS

An adequate measure of a given property is possible when (1) the property can be defined with sufficient exactness, (2) the material is of known composition or purity, (3) the attending conditions are standard or are known, (4) the experimental methods are theoretically correct, (5) the observations and their reductions are made with due care, and (6) the order of accuracy of the result is known.

This ideal is rarely if ever reached, but as it is striven for the results pass from the qualitative to the quantitative stage and are called "constants" because redeterminations will not yield sensibly different results. Approximate results are improved upon steadily as more precise instruments and methods are devised.

The degree of accuracy to be sought becomes a very practical matter in a testing laboratory. The time and labor involved in such tests increase out of proportion as the limits of attainable accuracy are approached. For the determination of physical constants or fundamental properties of materials the degree of accuracy sought may be the maximum possible. For example, a minute may suffice to determine the density of alcohol for commercial purposes by means of a hydrometer. Months, however, may be well spent in a precise determination of its density as a physical constant of great technical importance. In general the degree of accuracy striven for should be that which is strictly good enough for the purpose in hand—whether the work be routine testing or scientific research. The selection of the degree of accuracy to be sought for in each case requires the experience and judgment of the specialist.

6. THE MEASURE OF QUALITY

Quality in the sense here used is that which fits a material for a given use. A material is not simply good—it is good for a certain purpose, and the word quality is meaningless apart from the use in view. Good quality means good for a definite use. The test of the material is to determine *how* good for that use. This measure may be made directly by a service test, indirectly by a test under simulated service conditions, or still less directly by a laboratory test of separate properties upon which the quality is known or assumed to depend.

As the scientific method is applied to the study of materials, the quality is found to be not a vague characteristic which could only be judged by experienced users, but rather as the utility aspect of a material in terms of a property or group of properties, each of which is measurable. The variation in these constituent properties causes differences in quality. Personal opinion as to a quality may differ widely. Intelligent judgment, even, has no sure foundation until measured data are available with sufficient fullness to practically determine the conclusion. The personal factor is eliminated in direct ratio as a true measure of quality is developed. When this is complete, quality may be graded numerically as utility efficiency in terms of some ideal standard selected. The quality of coal may be specified and measured for a given use whether for direct combustion or gas production by finding the net utility per pound for the purpose in view. The heat efficiency depends directly upon the combustible matter and is expressed in heat units per pound of fuel. Many qualities of materials are already placed more or less definitely upon such a measurable basis. The ultimate aim is to define all qualities in terms of units of measure.

It is also known that there is usually a certain magnitude for each property which is best for a given use and which may be ascertained by investigation or service experience. To obtain in practice this best magnitude of each pertinent property is the object of technical specifications. Such specifications usually fall short of the ideal owing to obvious limitations—economy of production, sources of materials, and other conditions which can not be ignored. These considerations necessitate the fixing of suitable limits for each property within which it may vary. The maximum and minimum to be set become the subject of experiment in order to assign limits of tolerance to restrict the properties within acceptable ranges. These correspond to the size limits allowed in making machine parts where such variation in size of each part as conduces to economy in manufacturing the machine without unduly impairing the efficiency of the assembled machine. In fixing these limits of tolerance for material care must be exercised to avoid too narrow ranges on the one hand and too wide variations or poor quality on the other. These limits often involve safety and generally involve durability and efficiency.

Too much stress can not be laid upon the economic value of testing the quality of materials before their use. The integrity of steel used for rails is of great importance in the railroad and steel industries, and a study of the effects of slight additions of other metals or change in heat treatment or mode of making may be of great economic advantage to the railroads.

On the other hand, the failure of a rail due to brittleness may involve more than merely the cost of a new rail. Serious accidents with great loss of life may be avoided if the properties which determine the reliability of the rail are known and if the rails are tested for such properties. The length of service of the rail could then be restricted by the limits of safety exactly as it is now restricted of necessity by the wearing down of the rail in service. In other words, a failure of material may in some cases merely require replacement and the expense for the new material—a loss which must not be ignored—but far more serious are those cases which involve human life or where the replacement is only a small part of the damage caused. Needless risk of life should not be incurred by the waiving of any essential requirement.

The time has passed when the strength of materials can be left to guesswork or even to intelligent opinion alone. With the rapid increase in the height of buildings, length of span for bridges, and speed of transportation, new problems in safety and efficiency arise. The measure of the quality of structural materials in advance of their use thus becomes a matter of supreme importance, for the safety of buildings, bridges, railroads, dams, car wheels, and similar constructions, must not depend upon merely estimated strength and durability. They must be guaranteed by specification and test. For example, an engineer assumes a stated strength of the structural materials called for in his design. The testing laboratory, however, can test these materials by sample in advance of their use, and by means of the strain gage can determine the net strain of the structure during its construction and after erection or assembling. The strength of the material may be ample in certain cases, but through fault of construction or design undue strain may be introduced which leaves but slight margin for the working load. The steel in a locomotive driving tire may be amply strong, but if the fit on the wheel center is so snug as to require excessive heating to expand it sufficiently to go in place internal strains may be developed which may cause failure in service. Suitable tests during and after construction might be prescribed in building or inspection regulations and made part of the original specification in all cases. Under these circumstances the responsibility for failure of structures must rest with those who knowingly omit adequate tests where such are available.

This circular treats of the more usual tests applied to the various materials. In many cases the best methods for testing quality have yet to be devised. As rapidly as practicable, the Bureau is selecting or developing standard methods of testing each useful quality of materials. This leads directly to the establishment of specifications or standards of quality.

7. SPECIFICATIONS OR STANDARDS OF QUALITY

While the testing of materials in the modern sense is now a most important factor in the industries, such testing is still in its initial stage with respect to the establishment of rigorous standards of quality. Standards of quality can be developed only by research with the aim of correlating the properties of the material with specific qualities or utilities which they determine. The relation of the properties of a material to its use, which is so apparent in the simpler cases, must be ascertained for the more complex cases if quality is to be measured or determined. The measure of quality has not yet attained the higher position of simpler kinds of measure, because material testing has been so largely limited to separate properties or to experimental trial under simulated service conditions.

A specification is in a sense a working standard of quality—at least for purchase and sale—and indicates the quality desired and the conditions needed to insure it. A specification is too often not a real standard of quality at all. It may be narrow and exclude efficient material or so loose as to admit material of poor quality. To specify a particular composition for a bearing metal might exclude even the best on the market, and to simply specify "babbitt metal" may admit the poorest. A specification, too, may require tests which do not gage any desirable property and yet omit tests of vital importance. For example, a paint specification may limit the ratio of hydrate of lead to carbonate of lead and yet omit any test of optical covering power—a property of utmost importance. Defect may be due to lack of knowledge or, too often, to an effort merely to duplicate material once found satisfactory. This is done by prescribing a special brand and adding the words "or equal," or by minutely describing the properties of the acceptable brand. Both methods are used in place of specifying the use required of the material—a practical recourse where a definite standard is still impracticable.

Defective specifications, whether due to compromise of quality for economy or through lack of data, should be replaced by those in which the best magnitude of each property involved is so specified as to predetermine the definite quality best meeting the need. This is strictly analogous to specifying the dimensions of a bridge member. Each dimension called for in the design must be met by the part submitted. The quality specification should be just as definite to suit the conditions of use which it must meet. Each essential dimension, whether of size or quality, must be correct within certain limits or the article is unsatisfactory or useless for the purpose.

An ideal specification for material regards both economy and efficiency and does not ignore depreciation, replacement, repair, and service, which equally with the first cost enter into the net cost per unit of utility. For example, in judging rubber tires for automobiles a "tire mile" might be viewed as a unit of utility. If the cost of the tires is reduced to the cost per "tire mile," a comparison is then possible. If first cost alone governs, inefficiency is almost certain, whereas if economic quality is the criterion the ideal specification and the true standard of quality coincide. High cost may make the best material for a given purpose impracticable, but as the lowest price is often associated with the poorest quality a compromise may be necessary for economic reasons. It is as false economy, however, to require too good as too poor a quality; that is, the materials which are strictly "good enough" should compete for selection on the basis of net cost per unit of utility. Mature judgment is needed to decide the relative stress to be placed upon economy and upon efficiency, since one may be lost by undue emphasis upon the other.

8. IMPROVEMENT OF SPECIFICATIONS

The basis of specifications should be made the subject of constant study, and changes should be made as soon as new technical knowledge necessitates. In such work standardizing institutions, technical societies, individual investigators, and industrial laboratories cooperate, with the result that the ideal specification is becoming a truer standard of quality. As this result is gained and methods of test are perfected, the testing of materials becomes a real test of fitness. With the active cooperation of manufacturer, seller, user, and technical testing laboratory, the specification becomes a means of steady progress in the industry concerned, and combined with service experience facilitates the more efficient adaptation of materials to their uses. Service experience, viewed in the light of the laboratory tests, must, however, be the criterion for judging the adequacy of the specifications themselves.

Ideal standards of quality in most cases are still impracticable through lack of data, and the practical step has been the tentative specification. The specification is designed to obtain the quality best suited to the case in hand, and usually reflects the status of knowledge upon the subject. To the extent that it embodies the results of experience, it is the best that can be done until rigorous standards of quality are developed. Inflexible specifications retard technical progress; but if allowed to advance apace with new technical knowledge, the specification becomes a distinct aid to such progress.

II. GENERAL INFORMATION CONCERNING THE TESTING OF MATERIALS

1. CHOICE OF TESTS

With the large variety of tests which may be made of a given material those should be selected which suffice to show with commercial accuracy its fitness for the purpose in view. Economy dictates this limitation since in many cases the time and labor needed for more elaborate tests wolud make them prohibitive, and nullify the economic value of such testing. Tests of quality may be made with varying degrees of completeness except where existing specifications define the tests to be applied. Even such tests may be modified in emergencies and made less or more exacting.

A brief outline of tests applicable to the several classes of material will be found in later sections of this circular. The treatment, in the nature of the case, is usually incomplete. Where more definite tests can not yet be announced, the Bureau will endeavor to furnish information and possibly arrange special tests.

As far as practicable the Bureau should be given all the facts with respect to the material sent for test and the use for which it is intended. Otherwise a test can not be as well planned and the user may be unable to correctly interpret the report of the test. With a full knowledge of the material, however, and the use intended, the Bureau will be able to avoid needless work and may be of greater service by selecting the most effective tests for the purpose. With such knowledge the results will also be of value to other branches of the service and eventually to the public and the industry concerned.

The selection of the accuracy to be sought in a given case should usually be left to the testing laboratory to be chosen in accordance with the use for which the material is intended. Here, as elsewhere, the Bureau aims to make only the tests needed in each case and with an accuracy which meets the purpose in view.

2. SAMPLING AND SELECTION OF TEST PIECES

An incorrect method of selecting test samples and protecting them before test may, and frequently does, entirely vitiate a test as a measure of the quality of a given material. The form and quality may vary even in one delivery of a single brand of material. The extent of this variation

is usually not known by the user, who is aware merely that at times his material fails. The best manufacturers aim to keep their product within an acceptable range of quality. The obvious effect of variations in quality upon the utility of a material makes it important to know the nature and extent of such variation as well as the average quality. This is ascertained by comparative tests upon various samples of the material, and the test then becomes incidentally a determination of the degree of uniformity—an important characteristic for many technical purposes.

A single test piece, then, seldom shows the average quality of the material as a whole. If the test is designed to determine the average quality, sample test pieces should be taken from the various parts of the product. Within the same ingot a steel may differ in structure and resulting strength, and in composition as well. So, too, the length and fineness of wool fiber may vary according to the part of the sheep from which it is clipped.

Not merely is it true that the same delivery varies, but a single test piece may vary in different parts or in different directions, e. g., the magnetic properties of sheet steel not only vary in different parts of a sheet, but the properties differ in value along the direction of rolling and at right angles to this direction. In requesting a test upon any material, therefore, several samples should be sent, so that the nature and extent of the variation in quality may be ascertained. This is better practice than attempting to secure an average or composite sample. If the property to be ascertained varies, the test direction should be indicated when necessary upon the sample.

Again, the properties of a material sometimes change on exposure to light, air, moisture, or other agencies, e. g., light alters certain colorants, air and moisture rust steel, moisture weakens artificial silk, air hardens varnish, so that unless properly protected a sample may cease to be typical. Samples which are liable to change upon exposure should be protected in such a manner as to insure constancy until the test is made. All samples should, of course, be protected from all sources of contamination.

Only where samples are so submitted and the special requisites of the test are clearly known can the test be a true index of quality. Suggestions for sampling are given for the several classes of materials under the respective sections of this circular.

3. APPLICATION FOR TESTING

Communications should be addressed "Bureau of Standards, Washington, D. C." (or if for Pittsburgh branch, "Bureau of Standards, Fortieth and Butler Streets, Pittsburgh, Pa."). The written request for a test should give a list of the materials, with identification marks of each, and should state explicitly the nature of the test desired and any unusual conditions. If the test is to check compliance with specifications, a copy of the specifications should accompany the request. Under the separate sections of this circular are mentioned the specific data desired for the several classes of material. It is particularly important that details be given as to the source, brand, and use of the material—data which may modify the test selected to ascertain the fitness of the material for a specified use. The records of these tests then become valuable as an indication of the uniformity of a given manufacturer's product, and are also available for use in making suggestions as to specified materials.

When communications are made by telephone, they should be confirmed in writing, as the danger of error prevents the Bureau assuming official responsibility for informal and unofficial arrangements or information so given.

4. SHIPPING DIRECTIONS

Materials to be tested in Washington should be addressed in the manner indicated above. Materials sent by wagon from other branches of the Government in Washington may be forwarded direct to the Bureau (Pierce Mill Road, near Connecticut Avenue) or delivered properly marked at the Department of Commerce (platform in the rear of Nineteenth Street and Pennsylvania Avenue). Articles delivered in person or by express to the Bureau should be accompanied by the written request for the test.

Materials should be carefully and securely packed to avoid damage or loss in transit. Material liable to change upon exposure to the air should be packed with special care. The section upon the subject of sampling should be noted in this connection. Packing in fragile containers should be avoided.

Transportation is at owner's risk and should be prepaid. Samples tested will not be returned except upon request.

5. IDENTIFICATION MARKS

Samples of materials and the containing packages should be plainly marked to facilitate identification, preferably with the manufacturer's name, brand, and special identification numbers for each sample, which should be referred to in the application for the test. These numbers may then be used in the report of test, thus connecting the requests with the particular samples. Proper marking avoids difficulty in identification and consequent delays. The B. S. test number will be given in the acknowledgment of the receipt of the application for the test, and this test number should be used in all further reference to the test.

6. TIME REQUIRED FOR TESTING

Tests are usually made in the order in which applications and materials arrive, except as this practice may be varied by grouping similar tests together. If results are urgently needed by a specific date, the application and materials should be at the Bureau in time to allow the test to be made without prejudice to others already in hand. Exceptions are allowed where routine tests are regularly made of deliveries on contracts to determine compliance with specifications when special arrangements are made. Such tests are sometimes completed and reported upon the same day that the samples are received. Unusual tests require time to prepare the needed apparatus or devise proper methods of testing.

7. RESULTS OF TESTS AND THEIR INTERPRETATION.

Reports covering the results of tests are issued for general materials except in the case of standard analyzed materials where certificates are furnished.

In all cases where materials are submitted to determine compliance with specifications, a copy should accompany the request. While the acceptance or rejection of material does not rest with the Bureau unless requested, the interpretation of the results of the tests should invariably be made by the Bureau as it can best appreciate the limits of accuracy of the tests and of the tolerances which may be allowed.

8. FEES FOR TESTING

The Bureau performs tests for the National and State governments without charge. The fees for others are listed in the schedules appended. However, the Bureau will determine what tests will be undertaken and what fees will be charged in special cases. As fees must be paid in advance, they should be sent with the request for test if possible. Otherwise results of tests are not sent until all fees are paid. Payments should be made by money order or check drawn to the order of the Bureau of Standards. For schedules of fees see pp. 77 to 82. Where fees are not given, they will be specially fixed for each case.

9. FOR WHOM TESTS ARE MADE

Tests of materials are made for the public where the Bureau is asked to act as referee or where an authoritative test is demanded by the nature of the case, or in other cases where the Bureau is primarily interested in the test in connection with investigation. The right is reserved to make such use of the results of these tests as is deemed desirable. The Bureau will cooperate with investigators, manufacturers, testing laboratories, and others, not only in executing tests, but also on request, in furnishing any information at its disposal concerning materials or methods of testing.

III. SPECIAL INFORMATION CONCERNING THE CLASSES OF MATERIALS TESTED

1. METALS

A. METALS AND METAL PRODUCTS

(1) **Definition.**—Under this heading are included the elementary metals, both of high and commercial purities; ferrous alloys, including all kinds of steel; nonferrous alloys, including bronzes, brasses, compositions, special alloys, etc.; together with manufactured material or devices made from these as may properly be subject for laboratory examination, such as plated metals, enameled ware, columns, girders, beams, trusses, and other structural or mechanical fabrications, including tie-rods, chains, cables, car couplers, turnbuckles, springs, steel rails, etc.

(2) **Sources and uses.**—These are so varied and extensive that a discussion of these matters for metals and metal products would be beyond the scope of this circular, but will be treated of from time to time in special circulars.

(3) **Purpose of tests.**—Metals and metal products may be submitted to the Bureau of Standards for test:

(*a*) For the determinations of the quality or properties of a given material.

(*b*) For acceptance or rejection of materials bought under contract, which are to fulfill certain specifications.

(*c*) For ascertaining the causes of failure in metal products or structures.

(*d*) For decision by the Bureau in cases of dispute or litigation as to the properties of metals, metal products, and manufactures.

(4) **Nature of tests.**—The tests on metals and metal products may be grouped into four classes, (1) chemical analysis, (2) metallographic examination and heat treatment, (3) mechanical tests, and (4) miscellaneous tests of physical properties.

It is extremely rare that a complete determination of all physical and mechanical properties as well as chemical analysis and metallographical examinations are required. It is advisable when submitting any metallic material to the Bureau for test, to state fully the requirements of the case and then the most advantageous tests to be made can be decided upon.

(*a*) CHEMICAL ANALYSIS.—Chemical analysis will not in general be made of metals and metal products by the Bureau for individuals or corporations except when necessary to supplement other tests, or when in the opinion of the Bureau such analysis is of sufficient importance, as in cases of dispute.

In the case of iron and steel products the material will in general be analyzed with the usual degree of accuracy (being reliable within 0.01 per cent, except for sulphur and phosphorus, which are taken to 0.001 per cent) and for the elements usually present; carbon, silicon, manganese, sulphur, phosphorus, and other alloying elements which may be asked for or known to be present.

In the case of other metals and alloys the analysis will be made only after correspondence concerning the accuracy and completeness desired.

(*b*) METALLOGRAPHIC EXAMINATION AND HEAT TREATMENT.[1]—The Bureau is equipped for the microscopic examination of the internal structures of metals up to 1000 diameters. Such examination may be useful, for example, in determining the homogeneity of a material, purity, and slag inclosures; for the correlation of the structural, mechanical properties, and thermal treatment, either to decide what heat treatment the material has undergone or what treatment is best suited to it for a given purpose; and for the determination of the causes of failure.

Samples may also be submitted to the Bureau for thermal analysis, i. e., the location, by means of heating and cooling curves, of critical temperatures or regions, a knowledge of which serves as a basis for determining what heat treatment should be given to the material in order to realize the desired mechanical or physical properties. The heating and cooling curves will be furnished when desired. In general, the thermal and microscopic analyses together with the determination of the mechanical properties are sufficient to define the qualities of an alloy (including steels of various kinds) for ordinary uses.

The Bureau will also receive samples to which it is desired to give a definite heat treatment, as hardening, annealing, tempering, etc.; and also samples which are to fulfill specifications such as withstanding a definite heat treatment in fulfillment of specifications.

(*c*) MECHANICAL TESTS.—The mechanical tests of materials are dependent upon the property possessed by solid bodies of resisting change in shape. The different kinds of stress that can be applied to cause change of shape form the material basis of division of mechanical tests. In requesting tests it is well to keep the above facts in mind and to request those

[1] See also Bureau Circular No. 42.

mechanical tests which most nearly simulate the conditions to which the material is subjected in service.

When submitting materials for test in specimen form a brief outline of the history of the material and the conditions to which it is subjected in service is desirable, especially if the possibility of better selection of material for a given purpose is under advisement.

The Bureau is prepared to test metals and metal products in specimen form and members for tension and compression up to lengths of 25 to 30 feet, and for loads of compression up to 2 400 000 pounds and for tension 1 200 000 pounds. These loads apply to the test of full-sized structural members, and represent work which can be done at the Washington laboratory. In the Pittsburgh laboratory the test of compression members up to 25 feet in length can be carried on to a maximum load of 10 000 000 pounds. In regard to the form of specimens, the Bureau should be communicated with when special tests are desired. In the case of flats and rounds of iron and steel, the specimens should not be over 3 inches in width for ordinary specimens for test and have a length from 15 to 18 inches. Specimens with threaded ends may be tested; the form of thread and length of specimen will be furnished by the Bureau upon application. Tests can be made on all kinds of structural materials; iron, steel, wire rope, and timber.

(1) *Tension tests.*—Complete tension tests may be made on specimens requiring a load of not over 1 200 000 pounds and up to 30-feet gaged lengths. This test includes the following determinations: Modulus of elasticity, elastic limit, tensile strength, elongation, reduction of area, appearance of fracture.

Rectangular specimens: Flat specimens up to and not exceeding 3 inches in width and 200 000 pounds maximum load should be at least 18 inches in length. Flat specimens over 200 000 pounds and not exceeding 600 000 pounds should be at least 30 inches long, and the width should not exceed 4¾ inches.

Specimens which are sheared out of larger plates or structural shapes or which have scored or rough edges should be preferably machined upon such edges to avoid incipient cracks or premature failures. The faces should be parallel the entire length. With a milling machine the specimen is often shaped as shown in the following sketch:

When this is done the parallel faces of reduced section made by milling should be at least 9 inches long and the reentrant angles at shoulders should have fillet curves of radius not less than one-half inch to avoid incipient

failure.[2] For any increase over this 9 inches there should be a proportionate increase in the total length given above.

Cylindrical specimens: Cylindrical specimens up to 200 000-pounds capacity and not exceeding 1¾ inches diameter should be at least 18 inches in length. Specimens over 200 000 pounds up to 600 000 pounds, inclusive, should be at least 30 inches in length and in diameter may extend from 1¾ inches to 4 inches, inclusive. To avoid slipping in grips, however, the diameter should preferably not exceed 3 inches or 3½ inches.

Specimens which are liable to deform in grips will require connections and must be arranged for by correspondence.

For turned down and shouldered specimens the turned portion should be at least 9 inches in length in the clear and the end shanks preferably should be at least one-fourth inch greater than the turned diameter. The shoulders should be properly filleted. If turned length is over 9 inches then the above total lengths are to be increased a like amount.

Irregular cross sections: Many shapes, such as some types of concrete reenforcing rods, may be tested in a similar manner as the rectangular specimens. Otherwise, special connections must be arranged.

Wire rope is tested for tensile strength, to destruction. Samples should be of 6 feet 6 inches length. The ends to be tightly wound for distance of 2 inches with No. 20 wire. (Cables should be attached to a board to prevent bending, and otherwise protected by burlap covering.) Samples should be tagged with name of maker, diameter, number and diameter of strands, core, and separate wires.

(2) *Compression Tests.*—Complete compression test on cylinder, cube, or column. The following properties are determined: Modulus of elasticity, elastic limit, compressive strength.

When the nature of the material does not permit of the determination of above properties the compressions for definite increments of load can be determined.

Medium size columns can be tested up to 600 000-pounds maximum load in lengths not exceeding 30 feet over all between platens of machines. Suitable planed plates must be provided for protection of top and bottom machine platens against indentation from column. These platens measure 30 inches by 30 inches in the clear.

Large size columns can be tested up to 10 000 000-pounds maximum load in lengths not exceeding 25 feet between machine platens. Planed plates must be provided as before.

---

[2] See also American Society for Testing Materials Year Book for 1912.

In both cases the thickness of the plates should not be less than one-half inch for the smaller columns and three-fourths inch for the larger ones, and these thicknesses are to be deducted from the lengths given above in computing finished lengths of column specimens.

The necessary accessories for pin, ball and socket, or other end connections must be provided for.

(3) *Flexure Tests.*—Static Transverse Test: The test includes the approximate determination of modulus of elasticity, limit of proportionality, modulus of rupture.

Transverse tests can be made upon beams, girders or trusses in spans up to 25 feet center to center of bearing plates. Such tests are to be arranged through correspondence.

Alternating-Stress Test: The test includes the determination of the number of alternations required to rupture, and the elastic deflections during the different stages of the test.

Cold-Bending Test: The test includes the determination of angle of bend at rupture or if specimen does not rupture it can be bent through 180°.

Alternating Impact Test: The test includes the determination of the number of alternations required to rupture the specimen.

(4) *Torsion Tests.*—The complete torsion test determines the modulus of shearing elasticity, elastic limit, and torsional strength.

(5) *Hardness Tests.*—The hardness can be determined by Brinnel sphere and cone indentation tests. Other hardness tests are the Shore scleroscope, ball impact, and Keeps drill test.

(6) *Strain Measurements.*—The laboratory is prepared to make measurements of strains in materials, deflections, and other displacement measurements as may be practicable and arranged through correspondence.

The above-described tests can be made upon the sizes and shapes of specimens which are standard in this country. Blue prints will be furnished upon application showing the exact form and size of specimens for each test. Statement of fee will be transmitted at the same time if so desired.

(*d*) Miscellaneous Physical Tests.—In addition to the above described mechanical, thermal, and metallographic tests, the Bureau is prepared to make tests on practically any of the physical properties of metals, including densities or specific gravities; specific and latent heats, melting points, expansion coefficients; optical constants; electrical properties, such as temperature coefficient and specific resistance; and magnetic properties, particularly of ferrous materials. Such tests will be arranged for by correspondence.

For fees, see Schedule 222, p. 77.

(5) **Sampling and Testing Under Specifications.**—When material is submitted for test for acceptance or rejection under specifications, that fact should be stated, and a copy of the specifications inclosed with application for test. Information should also be given of the service required, the form, nature (for example, whether cast iron, wrought iron, or steel, finished or crude), and quantity (in tons, pounds, number of pieces, etc.) of the shipment or consignment of material.

Instructions will then be furnished by the Bureau concerning the method of selecting and preparing the test pieces for mechanical, physical, and metallographic tests, and drilling on other samples for chemical analysis. The methods of sampling are in many cases of such importance that the right is reserved to reject all test bars, test specimens, or drillings not selected in accordance with the Bureau's directions.

Drillings sent for chemical analysis should be free from oil, slag, moisture, dirt, or other contaminations, and should preferably be in glass containers, although other clean containers may be used. Very large particles in the sample are to be avoided; the Bureau prefers samples for chemical analysis all particles of which will pass a 10-mesh sieve. The numbers of the heats or castings, and name of company or person supplying the material and of party for whom test is made should appear in the container; also the nature of the material. Containers of samples should be carefully packed to avoid destruction of package in transportation, contamination of sample by packing material, access of moisture, and the like.

Test bars for mechanical tests and samples furnished for metallographic or physical tests should when practicable be stamped with an identification number or else be packed in separate, properly labeled containers. Before taking samples for metallographic examination for causes of failures the Bureau should be communicated with.

Samples for thermal analysis should be fairly representative of the whole and preferably in the form of cylinders 25 mm (1 inch) long and 15 mm (5/8 inch) diameter bored to center with a 3-mm (1/8 inch) hole along the axis.

(For fees, see Schedule 222, p. 77.)

B. COMPOSITE METAL PRODUCTS

In addition to the metal products above enumerated composed of a single material, there is a class of metal products which may be tested and which is composed of two or more materials, for example, plated, enameled, and case-hardened metals.

(1) **Plated or Coated Metals.**—This material includes roofing terneplate, "bright tin," galvanized iron, etc. Those specified are of especial importance. They all consist of an alloy or a single metal applied to a steel or iron base called black plate. The coating on terneplate consists of an alloy of lead and tin; that on "bright tin" plate is pure tin and that on galvanized metal is zinc applied to the black plate.

Terneplate and galvanized iron are used in general building construction while "bright tin" is used in the canning industry and for cooking and domestic utensils.

The coating should be adherent and continuous, free from pin holes and imperfections and the base and coating should stand the required bending and distortion necessary to make proper joints and seams without fracture, or separation of coating from base.

The tests consist of determining the weight of the sheet per unit area, the quantity and composition of the coating and the composition of the base. Physical tests are also made to determine if it will meet the bending requirements. The determination of weight per unit area should be made if possible on a full-sized sheet, as the quantity of coating is not uniform, due to the method of manufacture. For this reason, the sample used for the determination of quantity of coating is taken from the center of the sheet and so prepared that a truly average sample is obtained.

Owing to the advance in the metallurgy of iron and steel, the composition of the black plate is no longer a means of positively distinguishing between these two products. The determination of carbon, manganese, phosphorus, sulphur, and silicon will give, however, a strong indication of the process used in making the black plate, and a further microscopic examination together with an etching test will furnish additional information.

In general the Bessemer and open-hearth steel have an appreciable manganese content and the Bessemer metal is further characterized by a higher phosphorus and sulphur content than the open-hearth product.

The wrought iron used in the black plate is usually lower in manganese and sulphur than normal steels, but higher in phosphorus than the open-hearth product. It is further characterized by a "ferrite" structure when examined under the microscope, and laminations are developed by the etching test.

A very pure metal is now made in the open-hearth furnace which usually contains less carbon, manganese, phosphorus, and silicon than either steel or wrought iron. It has the characteristic "ferrite" structure of iron but lacks the laminations of wrought iron. Much of this material

has had a high copper content, but this is not a necessary characteristic of this product. Recent investigations have shown that a relatively small copper content retards solution of the metal in sulphuric acid to a marked degree and there are indications that its resistance to normal agencies of corrosion are also increased, but this latter fact has not been fully established.

The relative value of these materials as a base for coated metals is still an open question, but there is abundant evidence to support the claim that both steel and iron have been satisfactorily employed. Much of the coated metal which has failed in recent years has been made on a Bessemer steel base and has been deficient in quantity of coating. It can be stated, however, from extended experience that roofing terneplate made on a wrought-iron base coated with approximately 40 pounds of coating containing about 75 per cent of lead and 25 per cent tin to the box of 112 sheets 20 by 28 inches, has given satisfactory service. This, however, does not mean that black plate of different origin, when used as the base would not give equally satisfactory service.

Samples should be full-sized sheets selected at random; two sheets to represent a box will usually be sufficient on small orders. On larger orders the number of sheets may be less.

(2) **Enamels for cast iron and steel.**—Enameled iron or steel is produced by thoroughly cleaning the surface and applying a coating of thin paste (slush or ground coat), which consists of a fairly basic mixture of boro-silicates. After heating and fusion of this layer a second, more glassy coating is dusted on, which, after a second heating, forms the enamel proper.

The principal properties to be desired in connection with iron enamels are resistance to the action of dilute acids, resistance to sudden heating and cooling, and good adhesion to the metal under conditions of impact.

These qualities are determined by treatment with diluted acetic acid under prescribed conditions, by heating and quenching tests and the application of a standardized impact test.

(For fees, see Schedule 223, p. 77.)

2. CEMENTS (HYDRAULIC) AND CONCRETE

A. PORTLAND CEMENT

(1) **Definition.**—The most common type of hydraulic cement is known as Portland cement. Portland cement may be defined as the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate mixture of properly proportioned argillaceous and calcareous substances, with only such additions subsequent to calcining as

may be necessary to control setting properties. Such addition should not exceed 3 per cent of the calcined product.

(2) **Sources.**—Portland cement is essentially a mixture of lime, silica, alumina, and iron oxide, obtained by combining a limestone or marl with clay or shale. Low magnesia blast furnace slag may be substituted for the clay or shale. An impure limestone commonly called "cement rock" which contains all of the necessary constituents in approximately the correct proportions is much used.

(3) **Uses.**—There is perhaps no structural material susceptible of a greater variety of uses than cement. This is due to the fact that it is handled and placed as a plastic material, it obtains great strength in a comparatively short period of time, it is of constant volume and relatively permanent, and is almost universally available.

(4) **Properties.**—The more important properties of cement are its strength as a binding medium and its durability. But since we have no means of directly measuring these properties, it is necessary to set certain limits upon the composition and physical properties which have been found by experience to furnish a cement of good quality.

A normal American Portland cement which meets the standard specifications for soundness, setting time, and tensile strength, has an approximate composition within the following limits:

	Per cent
Silica	19–25
Alumina	5–9
Iron oxide	2–4
Lime	60–64
Magnesia	1–4
Sulphur trioxide	1–1.75
Loss on ignition	0.5–3.00
Insoluble residue	0.1–1.00

The composition of normal Portland cement has been the subject of a great deal of investigation, and it can be said that the quantities of silica, alumina, oxide of iron, lime, magnesia, and sulphur anhydride can vary within fairly wide limits without materially affecting the quality of the material.

It is also true that a number of cements have been made both here and abroad which have passed all standard physical tests in which these limits have been exceeded in one or more particulars, and it is equally true that a sound and satisfactory cement does not necessarily result from the above composition.

(*a*) Chemical Tests.—It is probable that further investigation will give a clearer understanding of the constitution of Portland cement, but

at present chemical analysis furnishes but little indication of the quality of the material.

The analysis of a cement will show the uniformity in composition of the product from individual mills, but will furnish little or no indication of the quality of the material. Occasional analysis should, however, be made for record and to determine the quantity of sulphuric anhydride and magnesia present.

The effect of relatively small quantities of magnesia (MgO) in normal Portland cement is still under investigation, but it can be considered harmless. Earlier investigators believed that as magnesia had a slower rate of hydration than lime, the hydration of any free magnesia (MgO) present would occur after the cement had set and cause disintegration.

The effect of magnesia was considered especially injurious when the cement was exposed to the action of sea water. More recent investigation has shown that cement can be made which is perfectly sound under all conditions when containing 5 per cent of magnesia, and it has also been found that the lime in Portland cement exposed to sea water is replaced by magnesia.

The maximum limit for magnesia has been set at 4 per cent, as it has been established that this quantity is not injurious and it is high enough to permit the use of the large quantities of raw material available in most sections of the country.

The most common adulterant for cement is ground unburned (cement) material; an excess of "insoluble residue" would reveal the addition of silicious material, and an excess in "loss on ignition" would point to the addition of calcareous material when either is added in sufficient quantity to make the adulteration profitable.

(*b*) Physical Tests.—The physical tests most frequently made to determine the quality, in the order of their importance are: Soundness, time of setting, tensile strength, fineness, and specific gravity.

(1) *Soundness.*—The purpose of this test is to detect those qualities in a cement which tend to destroy the strength and durability.

(2) *Time of Setting.*—The determination of the time when the plasticity of the mixture ceases or the "initial set" is obtained is very important, for the subsequent disturbance of the material may cause a loss of strength; thus it is important that the mixing and molding or the incorporation of the material into the work be accomplished within this time. A knowledge of the time required for final or hard set is also of importance, especially if the cement is to be used in cold weather or in marine construction.

(3) *Tensile Strength.*—This test is a direct measurement of the cohesive strength of the material and is important in view of the fact that a cement may meet the requirements of all the other tests and yet have very little cementing value. This test is made because it is believed that slight variations in the cementing value are more quickly shown by the tensile test than would be the case by a compression test.

(4) *Fineness.*—Only the extremely fine powder of cement called flour possesses appreciable cementing qualities and the coarser particles are practically inert, adding little to the cementing value for several weeks or months after mixing with water. No sieve is fine enough to determine the flour in a cement, nor is there any other means of accurately and practically measuring the flour. Some cements grind easier than others; thus, although a larger percentage of one cement may pass the 200-mesh sieve than another, the former may have a smaller percentage of actual flour due to the difference in the hardness and the character of the clinker and the method used in grinding. Therefore the cementing value of different cements can not be compared directly upon their apparent fineness through a 200-mesh sieve. With cement from the same mill, with similar clinker and grinding machinery, however, it is probable that the greater the percentage which passes the 200-mesh sieve the greater the percentage of flour in that particular cement.

(5) *Specific Gravity.*—The specific gravity of a Portland cement is not an indication of its cementing value. It will vary with the constituents of the cement, especially with the content of iron oxide.

It is materially affected by the temperature and duration of burning the cement, the hard-burned cement having the higher specific gravity. A comparatively low specific gravity does not necessarily indicate that a cement is underburned or adulterated. Large percentages of raw materials could be added to a cement with a normally high specific gravity before the gravity would be reduced below 3.10.

The value of the specific gravity determination lies in the fact that it is easily made in the field or laboratory, and when the normal specific gravity of the cement is known, any considerable variation in quality due to underburning or the addition of foreign materials may be deducted.

(6) *Sampling.*—The samples of cement should be so taken as to fairly represent the material. If complete physical tests are desired, an 8-pound sample should be taken. If tensile tests are not desired, 4 pounds will be needed. The entire sample should be taken from one package, or if taken from a conveyor belt at the mill the entire sample should be taken from the

belt at one time. Automatic belt samplers should not be used. When samples are taken from a bin after it is filled, a sampling iron should be used and the sample taken so as to represent various layers in the bin. If samples are taken at the bin each sample should represent about 100 barrels. If samples are taken from sacked material on the cars or after delivery, each sample should represent not over 50 barrels.

When samples are taken at the mill it may not be necessary to make complete tests for each, but every sample should be tested for soundness. Samples should be carefully packed in air-tight cans or tight woven cloth bags and clearly marked.

B. WHITE CEMENT

Most of the white cements now manufactured are white Portland cements, as they are manufactured in the same manner and possess practically all of the properties of a Portland cement. Their light color is due to the absence of iron in the composition, which is controlled by using raw materials free from iron in its manufacture.

It is used largely in the manufacture of art stone for stuccos, and most work where colored or tinted surfaces are desired; also in mortar for laying limestone and marble, which it is claimed may be discolored or stained by the iron of a normal Portland cement. It is necessary in most cases to use white cement if pigments are to be added for tinting, as the normal Portland cement is gray and clear colors can not be obtained with it. The same tests are applied to white cement as are applied to Portland cement.

C. NATURAL CEMENT

Natural cements are little used at the present time, owing to the superiority, cheapness, and availability of Portland cement. There are several natural cements being used primarily because of their so-called "nonstaining" qualities. They are used in mortars for laying limestone or marble, which it is claimed may become stained near the joints if ordinary Portland cement were used. It is claimed that the staining or discoloration is due to the iron salts of the cement being carried by capillarity or absorption and deposited in the pores of the stone.

The same tests may be made upon natural cement as are specified for Portland, although since great strength is not usually required tests for soundness, time of setting, fineness, and specific gravity are usually found sufficient. It has not been established that the staining of stone laid in cement mortar is due to the iron salts from the cement, but it may be desirable to make a determination of iron content.

General Inspection.—The Bureau is now prepared to supervise the inspection, testing, and shipment of cement purchased on contract by any Government office, if the purchase is made from a mill within 100 miles of any of its three laboratories: At Washington, D. C., Pittsburgh, Pa., or Northampton, Pa., without expense to the purchasing office.

Inspections will be made at a greater distance from the laboratories, provided the traveling expenses of the inspector are paid by the purchasing office. The Bureau has inspected and tested cement under seal ready for shipment at many of the eastern mills which is available for immediate shipment on any Government orders, request being made to the Bureau.

Cement is not tested for the public excepting under unusual conditions or in connection with investigation work.

(For fees, see Schedule 242, p. 78.)

D. RAW CEMENT MATERIALS

Raw cement materials such as limestone, clay, cement rock, marl, slag, etc., are tested to determine their suitability for the manufacture of cement.

The tests made consist in grinding and burning the materials in a rotary kiln at the proper temperature, grinding the clinker, and testing the resulting cements to determine their physical properties or quality.

E. SAND AND STONE SCREENINGS

Natural sand may be defined as the fine particles of natural water-worn stone or other mineral material. Stone screenings is essentially an artificial sand.

(1) **Source.**—Sand may be formed from various types of stones, but the better grade is composed chiefly of inert siliceous material. Since sand is formed by the breaking up of stones in river beds, it is available in many localities. The finer grades of plastering and building sand are usually beach or pit sand, and while the coarser so-called concrete or torpedo sand is usually a river or bank sand, some excellent torpedo sand is found as beach sand.

Stone screenings may be obtained from any kind of stone and is the product received from the stone crusher which passes the ¼-inch mesh sieve.

(2) **Uses.**—Sand is graded according to the uses for which it is intended. For fine plaster work the sand practically all passes a 20 or 30 mesh sieve, for mortar it all passes a 10-mesh sieve, and for use as fine con-

crete aggregate it all passes a ¼-inch mesh sieve. Sand is also largely used in the industries, as in the manufacture of glass, etc.

Stone screenings are used primarily in the construction of roads and as fine concrete aggregate.

(3) **Properties.**—Sand varies in chemical composition, size of grain, sharpness, porosity, hardness, and cleanliness.

Stone screenings will vary in chemical composition, shape of particle, porosity, hardness, strength, and cleanliness or freedom from dust.

A knowledge of the chemical composition of sand or stone screenings to be used for building purposes is of little or no value. Round sand is as good as sharp sand. The shape of stone screenings will depend upon the type of crusher used and character of stone crushed. A stone crushing into flake particles is not considered the best for a concrete aggregate. The particles of sand or stone should be graded so as not to be of uniform size to give maximum density in mortar or concrete. The hardness of sand and stone screenings is of importance if the material is to be exposed to abrasion, as in roads, concrete floors, walks, etc. An apparently good sand is at times found to give very poor results in a mortar or concrete. This is found to be due in many cases to the presence of loamy clay, organic, or mineral matter which coats the particles and prevents adhesion of the binding medium. If there is a large quantity of dust in stone screenings it has a similar effect upon the value of the screenings as a concrete aggregate.

(4) **Tests.**—The following tests may be made: The weight per cubic foot and percentage of voids, which may be of value in proportioning the mortar or concrete. Granulometric analysis, which is of value in properly grading the aggregate or in combining with other aggregates. The percentage of silt, which is usually the deleterious material. The tensile and compressive strength as compared with a standard sand. Chemical determination of the presence of organic matter, sulfides, soluble alkalies, etc. The chemical tests need not be made unless the material is found to be inferior in quality and the cause can not be determined by physical tests.

(5) **Sampling.**—For complete tests, at least a 100-pound sample should be submitted. The sample should be carefully selected, so as to fairly represent the material, and should be packed in double duck or other tight container, so that the dust and fine material will not be lost.

(For fees, see Schedule 243, p. 78.)

3. CERAMICS

A. CLAYS AND SHALES

Clays are mixtures of minerals or rocks in which hydrous silicate of alumina is present in sufficient amount to impart its characteristics to the mass to a sensible degree. Shales are hardened clays possessing a more or less well-defined cleavage. The chief characteristic of clays is that by virtue of their plasticity they may be shaped and molded. Upon drying and burning they form a hard mass, showing a structure which varies for different clays, from a stonelike to a vitrified, more or less glassy, character. Due to the manifold conditions of their geological formation, clays vary widely in their properties.

(1) **Sources.**—Clays and shales are found in practically every State in the Union. The white clays, usually of primary origin, are obtained as the decomposition products of igneous rocks, while the buff and red-burning materials are associated with various sedimentary beds, sandstones, limestones, and coal. Many surface deposits are recent in origin and are alluvial or glacial in character.

(2) **Properties.**—The main properties with which the user of clays is concerned are: Plasticity and working quality, bonding power, drying shrinkage and behavior, burning shrinkage, vitrification range, color, and fusibility. Note must also be taken of the presence of impurities, like carbon, gypsum, pyrites, etc.

(3) **Tests.**—The properties made mention of above are determined by means of various tests, consisting principally of physical examination. Thus the plasticity is estimated by forcing the clay through dies, by determining the amount of water required to produce the plastic state, the tensile strength of the dried clay, and the drying shrinkage, measured by means of the voluminometer. The rate of vitrification at different temperatures of firing is measured by means of absorption and specific-gravity determinations. In the case of fire clays the refractoriness is estimated by means of softening-point determinations. In certain other cases special tests may be required to bring out all of the facts in the case. Chemical analysis is not necessary in the testing of clays excepting in the case of high-grade materials, such as kaolins, flint clays, and refractory clays. Occasionally a partial analysis may be needed to throw light upon some peculiar phenomenon.

(4) **Sampling.**—It is of the utmost importance that a clay deposit be sampled thoroughly in order that any tests made may be reliable. Unfortunately,

this is not the general practice, and many so-called samples are practically worthless. The best practice is to remove the surface of the outcrop or exposure so as to eliminate the weathered portion. A straight and uniform channel is then cut into the fresh face from the top to bottom and, according to the height, from 400 to 1000 pounds or more of the material is thrown into a heap. This is thoroughly mixed by shoveling, and not less than 150 pounds collected for the test. In case the deposit consists of two or more distinctly different materials, as indicated by their appearance, these are sampled separately by not cutting the channel beyond each layer until the clay which has been removed is sampled and the face cleaned up for the next cut. It is necessary that a legible identification tag be placed inside of each sack or barrel of clay in addition to the one on the outside of the container. The most practical tag is one consisting of a smooth piece of wood into which the sample number is cut.

Two kinds of tests are made—preliminary tests, requiring a well-selected sample of not less than 2 pounds, and complete tests, for which not less than 150 pounds of material should be sent. The preliminary test is intended to eliminate clays having no value, thus saving the trouble and cost of complete tests. No fee is required for the preliminary test.

(For fees, see Schedule 232, p. 79.)

B. CLAY PRODUCTS

(1) **Clay Building Brick.**—This heading includes both common and face brick, as well as blocks and various shapes employed in brickwork.

The complete tests of bricks comprise the compression, transverse, absorption, and freezing test. The latter test need not be made unless the durability of the material is in doubt.

The transverse test is to be carried out first and the compressive-strength determination is made upon the half bricks resulting from the former placed flatwise in the machine. The top and bottom surfaces of the specimens are ground parallel on a grinding machine.

Five bricks or blocks should be submitted representing the ordinary commercial product.

(2) **Architectural Terra Cotta.**—The term "architectural terra cotta" covers decorative hollow blocks, consisting of a No. 2 or No. 3 fire-clay body and pressed in plaster molds. These may be used with a glazed or unglazed surface. When unglazed the exposed surface is usually covered by a so-called "slip," a more or less vitrified coating of clayey material colored as desired.

Tests of terra cotta exposed to atmospheric conditions consist of visual inspection for cracks due to crazing or shivering, determination of the absorption, determination of the resistance to freezing and thawing, and of the resistance of the glazed surface to the action of diluted hydrochloric acid and its fumes. In doubtful cases compression tests may be desirable.

The number of samples necessary depends upon the number of the principal colors used in the structure.

The cost of such tests varies according to the nature of the tests required.

(3) **Roofing Tiles.**—Clay roofing tiles are usually manufactured without a glazed surface, though increasing use is now being made of glazed products. The unglazed tile are tested for absorption, permeability, and resistance to repeated freezing and thawing.

The glazed products are subjected to the same tests, and in addition the glazed surface is exposed to the action of dilute hydrochloric acid and fumes of this acid in order to estimate the resistance of the glaze to decomposing influences.

Six samples are required for each set of tests.

(4) **Floor Tiles.**—Ceramic floor tiles are produced from mixed or natural bodies burned to vitrification. The main consideration in products of this kind is hardness coupled with imperviousness to liquids. The tests applied are the standardized sand-blast test, the determination of the water absorption, and examination of structure. In some cases the loss in weight upon abrasion in a standardized rattler is desirable as a measure of toughness. Six tiles of the proper size are required for the ordinary tests, 18 for the tests including the loss upon abrasion.

(5) **Glazed Wall Tiles.**—Ceramic tiles covered with a bright glaze and used for the facing of walls.

The tests required are visual inspection, the determination of the water absorption, and the crazing test.

In the examination of the tiles the evidence of hair cracking due to crazing or the splintering due to shivering are noted as well as dullness of the glaze, discoloration, or bubbling.

In the crazing test three tiles are immersed in a concentrated solution of common salt and boiled for five hours. After removing and drying, the glazed surface is examined and the number of meshes of hair cracks determined per square inch.

Six samples are required for these tests.

(6) **Paving Blocks and Bricks.**—These consist of vitrified shale or No. 2 fire clay and are used for the surfacing of streets. The proper construction of such streets is of as great if not greater importance than the quality of the blocks. Specifications like those offered by the National Paving Brick Manufacturers' Association should be followed in every detail.

Paving blocks are tested for loss by abrasion in the new standard rattler adopted by the association made mention of above. Eleven paving blocks or 15 bricks should be sent for each test. Samples should be selected from different parts of the car, or in the case of large shipments, the sampling should be done at the plant furnishing the material.

(7) **Sewer Pipe.**—Pipes up to 36 inches or more in diameter made of hard burnt clay and provided with a salt glaze.

Sewer pipe is usually made from shale or No. 2 fire clay, rarely from surface clays. In products of this kind no evidence of excessive lamination or of an overburned, vesicular structure must be present. Any pipe showing black coring should be rejected. The walls of the pipes should be straight and uniformly glazed. No bare, unglazed surface, cracks, blisters or other defects must be observed. When struck with a hammer the pipe must give a clear ring.

The tests commonly made consist in the examination of the surface and the internal structure, and of the absorption determination. Compression and hydraulic tests may be necessary in some cases.

(8) **Drain Tiles.**—Pipes consisting of burned clay, usually unglazed, up to 24 or more inches in diameter and used for the carrying away of drainage water. They are usually made of red burning clay or shale and are rarely vitrified. The tiles should be well burnt, straight, without cracks, and should be cut off square at the ends. The clay body should show no evidence of lime pebbles larger than 0.5-mm diameter. The tests to be made of drain tile are the determination of the water absorption and the determination of the transverse strength. At least three samples should be submitted. The tiles should not absorb more than 10 per cent of water in terms of the dry weight. The procedure of the transverse test is that based upon recent reports before the American Society of Testing Materials.

(9) **Porcelain and White Ware.**—Ceramic products manufactured from white burning mixtures of kaolin, ball clay, feldspar and flint, when burned to the stage of translucent vitrification may be called porcelain. Similar mixtures not carried to complete vitrification are known as white ware or earthenware bodies. A great variety of products may be included under

this heading, of which three groups are especially prominent, white pottery, known as porcelain, china, semiporcelain, white ware, etc., white sanitary ware, and electrical porcelain.

The qualities important for most of these products are freedom from flaws, such as crazing or shivering of glaze or dunting of the body, hardness of the glaze, degree of vitrification of the body, toughness of the latter, permanency of overglaze colors, dielectric strength, etc.

Owing to the variety of products a fee schedule can not be given, but each case must be arranged for.

(10) **Fire Clays.**—In testing fire clays to be used for mortar in laying up fire-brick work, determination of the softening temperature is most important. No. 1 fire clays should possess a softening point not below cone No. 31.

No. 2 fire clays should not soften below cone No. 28.

About 1 pound of the ground clay should be submitted, contained in a tight receptacle to prevent loss.

(11) **Fire Proofing for Steel Protection.**—Clay fireproofing consists of porous tiles shaped to adapt themselves to steel girders, beams, and columns which are to be protected from the high temperatures produced in conflagrations. This material is made from fire clay of the No. 2 and No. 3 type and should have sufficient mechanical strength to carry the loads imposed upon it, should be refractory enough to withstand average furnace temperatures and should be able to withstand sudden temperature changes.

The tests applied consist of the determination of the compressive strength of a short section, of the refractoriness as estimated by the softening temperature, of the absorption, and the resistance to sudden heating and cooling.

Sampling and the testing of fireproofing, as well as the fees required for the work, are to be arranged for in each particular case.

(12) **Refractories.**—The term "refractories" covers all the materials used to resist high temperatures.

(*a*) SOURCES.—They may be produced from various raw materials of which the most common ones are: Fire clays, silica as quartz or quartzite, magnesia, and alumina. Special refractories may consist of carbon, zirconium oxide, boron nitride, carborundum, etc.

(*b*) USES.—Refractory materials are used for lining the walls of furnaces, ovens, and kilns, for making crucibles, retorts, glass pots, and for many other purposes.

(*c*) PROPERTIES.—The conditions to which refractories are subjected vary widely. The action of high temperatures, load and strain conditions, the effect of slags, clinker, glass, reducing gases, vapors, sudden temperature changes, all contribute toward the destruction of these materials. Hence the properties to be taken into consideration depend primarily upon each special case. However, certain qualities apply preeminently to the great majority of refractories. These are: Refractoriness as estimated by the softening temperature, softening at furnace temperatures under the influence of small loads, freedom from objectionable impurities, which are basic fluxes in the case of clay and silica refractories, and acid constituents in basic products.

(*d*) TESTS.—The tests commonly made on clay refractories are the determination of the softening temperature, the load test, made by subjecting the brick or block placed on end, to a compression of 50 pounds per square inch at 1350° C, and the chemical analysis.

These conditions are varied for other refractories. Likewise supplementary tests are employed for clay and other refractories to determine such qualities as the volume changes upon refiring once or repeatedly, resistance to sudden heating and cooling, permeability to fluid slags, lime or glass, and heat conductivity. At least three bricks or their equivalent are required for the determination of the softening temperature, the load test, and chemical analysis. For additional tests more bricks are to be supplied.

For refractories other than clay, fire brick, etc., the testing conditions are varied to correspond to the nature of the materials and the purpose for which they are intended.

4. LIME

A. BURNT LIME

(1) **Definition.**—Lime consists essentially of calcium oxide or of calcium and magnesium oxides. It may be defined as the product obtained when limestone, marble, dolomite, or similar calcareous material is calcined at a temperature below the sintering point, provided that such product will slake when treated with water.

(2) **Sources.**—Lime is generally obtained from limestone, marble, or dolomite, which are very widely distributed throughout the United States. In rare cases it has been found economical to make it from marl, or from oyster shells.

(3) **Uses.**—The uses of lime may be divided into four general classes, each of which requires certain properties in the material: (1) Building lime

is used for mortar in laying brick or masonry. It may also be used for the first coat of plaster on a wall. (2) Finishing lime is used for the last or exposed coat in plastering. (3) Chemical lime has a great many uses in different kinds of manufacture, e. g., bleaching powder, paper, calcium carbide, glycerine, sand-lime brick, etc. (4) Agricultural lime is used as a fertilizer.

(4) **Properties and tests.**—(1) The important properties of a building lime are: Sand-carrying capacity, which may be defined as the amount of sand which must be added to a standard putty in order to produce a mortar of standard consistency; yield, or the number of cubic feet of standard putty produced by slaking 1 pound of lime; and crushing and tensile strength of 1:3 mortar when 90 days old. (2) Finishing lime should be well-burned, of good color, plastic, and free from material which will not slake. The tests devised for this class of lime are: Rate of hydration, or the time required to reach a maximum temperature when slaked; plasticity, which is the per cent of lime in a paste of standard consistency; sand-carrying capacity; color, which is determined by comparison with standards; waste, or the amount of residue left on passing a standard paste through a 40-mesh screen; yield; hardness, which is the per cent loss of weight of a mortar under standard conditions of abrasion; time of set; and volume shrinkage of a 1:3 mortar when 90 days old. (3) Chemical lime should be well burned, and should have the chemical composition required by the purpose for which it is to be used. The tests for this class consist of the rate of hydration and chemical analysis. (4) Chemical analysis only is of importance for agricultural lime.

(5) **Sampling.**—If the lime is in bulk, at least 10 shovelfuls should be selected from different parts of the lot, with care not to take a disproportionate amount from any exposed surface of the pile. The sample, which should weigh at least 100 pounds, should be broken to about 1 inch or smaller, mixed and quartered. The 25 pounds thus obtained should be sealed air-tight and shipped to the laboratory for testing. If the lime is in barrels or bags, empty at least 3 per cent of the packages in a pile and sample as for bulk lime.

(6) **Other Conditions of Test.**—The sample is to be shipped by express prepaid to the Bureau of Standards (branch laboratory), Fortieth and Butler Streets, Pittsburgh, Pa. Each sample must be plainly marked by a tag inside of the package so that it can be identified. Under separate cover state specifically what tests are desired, and inclose a check to cover the fee. The tests for hardness, crushing strength, tensile strength, and shrinkage require

90 days for their completion; all other tests will be reported one week after receipt of sample. No tests will be made on lime which does not reach this laboratory in an air-tight package.

B. HYDRATED LIME

(1) **Definition.**—Hydrated lime is a dry, flocculent powder which is prepared by slaking lime with an amount of water insufficient to form a paste, but enough to combine with the calcium oxide present. It consists essentially of calcium hydroxide, with or without magnesium oxide or hydroxide.

Hydrated lime may be prepared from any kind of lime. Except in certain chemical industries, hydrated lime may be used for any purpose instead of lump lime. It is also used as an addition to cement mortars to improve their working qualities.

(2) **Properties or Quality.**—Hydrated lime should have the same properties as the lump lime in place of which it is to be used. In addition it should contain no free calcium oxide, and, when used for certain purposes, the fineness of the material is important.

(3) **Tests.**—Hydrated lime is tested for free calcium oxide by means of the microscope. Its fineness is determined by passing it through a 100-mesh screen. For all other tests see under "Lime."

(4) **Sampling.**—At least 3 per cent of the bags composing the shipment should be sampled from the outside to the center of each bag. The material collected should be mixed and quartered until a sample of about 25 pounds is obtained, which should be sealed air-tight and shipped to the laboratory.

(5) **Other Conditions of Test.**—For shipping directions, etc., see under "Lime." No tests will be made on hydrated lime which does not reach this laboratory in an air-tight package.

The schedule of charges for tests is the same as that given under "Lime."

C. RAW MATERIALS FOR LIME

(1) **Definition.**—Almost any highly calcareous material is available for making lime. The substances generally used are limestone, marble, dolomite, marl, and oyster shells.

(2) **Properties or Quality.**—The material should consist essentially of calcium carbonate or of calcium and magnesium carbonates. It should be capable of being calcined through a rather wide range of temperature without materially affecting the product.

(3) **Tests.**—The test of most importance is the chemical analysis. In addition, samples of the material may be burned at different temperatures and the rate of hydration of the product noted.

(4) **Sampling.**—The manner of sampling will depend upon the kind of material and many other factors, so that no specific directions can be given. The sample should represent the average character of the deposit as fairly as possible.

(5) **Other Conditions of Test.**—For the two tests noted above send about 1 pound of the material to the Bureau of Standards, Fortieth and Butler Streets, Pittsburgh, Pa. The sample should be marked by a tag inside the package. Under separate cover state specifically the information required, and inclose check to cover the fees.

The selection of a test for raw material depends on the kind of material and the purpose for which it is to be used. The Bureau is prepared to make a number of different tests which may be of value when examining different materials, and will furnish further information upon request.

D. SAND-LIME BRICK

(1) **Definition.**—Sand-lime brick consists essentially of sand which is bound together by a hydrated calcium silicate formed by the action of lime on sand under the influence of steam.

(2) **Sources.**—Such a brick can be made from almost any highly siliceous material and any lime which does not contain too much magnesia.

(3) **Uses.**—Sand-lime brick is used for ordinary building purposes, instead of common or face brick.

(4) **Properties or Quality.**—The distinguishing property of sand-lime brick is its color, which should normally be nearly white, and should be readily susceptible of change by the addition of various pigments. It should be comparable with common clay brick in regard to crushing and transverse strengths. The quantity of water it can absorb is important, and also the crushing strength when it is wet.

(5) **Tests.**—The whole brick is first broken under transverse strain. One-half is then crushed. The other half is soaked in water for 48 hours and the amount of water absorbed is weighed. This half is crushed while still wet. A microscopic examination will show the presence of any calcium hydroxide which has not combined with the silica. The determination of the amount of carbon dioxide in the brick will indicate the proportion of calcium carbonate present.

(6) **Sampling.**—At least 10 whole bricks should be selected from different parts of the pile.

(7) **Other Conditions of Test.**—The bricks are to be shipped by express, prepaid, to the Bureau of Standards, Fortieth and Butler Streets, Pittsburgh, Pa. Each sample should be plainly marked by a tag inside of the package. Under separate cover state specifically the information required, and inclose check to cover the fee.

5. STONE

(1) **Description.**—Structural or building stones are of several types and of considerable variety. The sedimentary class includes sandstones, limestones, slates, etc. The metamorphic class includes marbles, and the igneous rocks include traps and granite. In many localities throughout the United States all types of stones are found, although any locality may have its peculiar variety. Building stones are used mainly in structures where they are exposed to the elements and required to withstand great pressures or abrasive forces, as in masonry arches, dams, retaining walls, buildings, roadways, etc.

(2) **Properties.**—Since stones are usually called upon to withstand great pressures and are exposed to the elements, the important physical qualities are strength and resistance to "weathering."

Stones of the same class vary greatly in texture and color, so that the selection of the stones should depend upon the service exacted.

(3) **Tests.**—The compressive or transverse strength and the abrasive quality of stone may be directly determined in the laboratory, but its weathering qualities can only be definitely determined by experience or by an inspection of outcroppings at the quarry. As it is often not possible to find outcroppings of the stone as quarried, laboratory tests are made, such as the determination of injurious or soluble elements, as the alkalies or pyrites, and the determination of the water absorptive qualities and the effect of alternate freezing and thawing.

(*a*) Compression Tests.—If the stone is of fairly uniform texture, three cubes should be submitted. If the stone shows marked stratification, six cubes should be submitted, three to be tested on "bed" and three to be tested on "edge" (parallel with the strata). If the stone is to be used where exposed to constant water immersion, tests should also be made of water-saturated stone, since the moisture condition may impair the strength.

(*b*) Freezing Tests.—Three additional cubes should be submitted if freezing tests are desired, as they are tested for compressive strength after freezing, and the results compared with those normally obtained.

(*c*) ABSORPTION TESTS.—The absorption can be obtained on the same samples submitted for compressive or freezing tests, or if other tests are not required three samples should be submitted, and they need not be in the form of cubes.

(*d*) TRANSVERSE TESTS.—If transverse tests are desired, three rectangular test pieces at least 2 inches square in section and 12 inches in length should be submitted.

(4) **Samples.**—The Bureau is not at present equipped for dressing stone, therefore all specimens should be submitted approximately to size. Preferably the stone should be dressed by sawing and grinding. The cubes for compressive tests may be any size from 2 to 20 inches edge. Each specimen should be roughly dressed on all surfaces, and two opposite surfaces should be made smooth and closely parallel. For freezing tests the cubes should not be more than 4 inches edge.

6. PAINT MATERIALS

This class includes dry pigments, pigments ground in oil and in japan, ready-mixed paints, water colors, tinting colors, enamels, stains, paint oils, volatile thinners, driers, oil and spirit varnishes, etc.

Paints and varnishes are the finished products and are generally used to protect and decorate the surface to which they are applied; the others are paint materials used to produce the finished product.

A. COLORANTS

(1) **Pigments** are ground in oil and in japan to facilitate further thinning to the consistency desired.

(2) **In Water-Color** paints the pigment is mixed with water containing a soluble glue or gum.

(3) **Tinting Colors,** as the name indicates, are used to furnish the desired colors or tints. They should have maximum color strengths.

(4) **Enamel Paints** are pigments ground in varnish, and are characterized by a hard lustrous surface.

(5) **Stains** are prepared from tansparent pigments or dyes which color without hiding the grain of the surface to which they are applied; they are often used with a finishing varnish coat.

The pigments are usually finely divided solid substances insoluble in the vehicle; they furnish the color desired and aid in affording protection.

Pigments should be finely ground; they should furnish a permanent, opaque surface of the shade or hue desired; they should not chalk, check,

or crack, nor discolor when exposed to normal conditions of exposure, and should have no corroding action on the surfaces protected, and the dried paint film should be as impervious as possible to moisture, air, and gases.

Many single pigments do not have all these requisite characteristics; some have high tinting power but lack in opacity or optical covering power; others have a tendency to chalk or peel when used alone; others have such strong coloring strength that they can be diluted with cheaper pigments without any sacrifice of quality. In other words, purity is not necessarily synonymous with quality. On these accounts the best results are frequently obtained by proper blending of pigments.

B. OILS

(1) **Linseed Oil,** obtained from the seed of the flax plant (*Linum usitatissimum*) is the chief drying oil. It absorbs oxygen from the air and changes from a liquid to a solid leatherlike substance which holds the pigments to the surface. Raw linseed oil has been the subject of extended investigation. Samples have been examined from the chief centers of production during the past few years, so that definite specifications can be drawn, at least for American-grown seed.

Other oils, such as tung oil (Chinese wood oil), soya-bean oil, fish oil, etc., have this property of absorbing oxygen to a greater or lesser degree and may furnish a satisfactory substitute for linseed oil.

The drying action of these oils may be increased by heating them with metallic salts, especially compounds of lead and manganese. Such treatment produces boiled oils, though the same result may be obtained by adding a liquid or solid drier to the raw oil with sufficient heating to insure thorough incorporation of the drier.

(2) **Driers** are usually compounds of lead or manganese and linseed oil, rosin, or other gum resins. These compounds or metallic soaps are made by heating the oxides of the metals with the oil or resin. They may be either dissolved directly in an excess of raw oil by means of heat, or they may be dissolved in turpentine or benzine and added in liquid form to the oil in the cold. They have the property of hastening the drying action of the oil.

(3) **Volatile Thinners** are usually turpentine or a volatile petroleum product. Turpentine is chiefly obtained by refining the sap of the long-leaf pine (*Pinus palustris*). It is also obtained by a steam distillation process from the wood and stumps of the same tree. When obtained from the sap it is called "gum spirits," while the turpentine obtained from the wood or

stumps, etc., is called "wood" or "stump" turpentine. Both products can be produced so as to be practically identical in all chemical and physical constants and equally satisfactory as a paint material.

The petroleum products should be completely volatile at ordinary temperatures, but they should not volatilize so rapidly as to prevent a proper flowing out of the brush marks. As the volatile thinners are lost by evaporation, turpentine may be replaced, under certain conditions, by the cheaper volatile petroleum product to economical advantage.

Volatile thinners are frequently added with the drier in ready-mixed paints to aid in the ease of spreading, to produce a flat surface, or to obtain better penetration. In final coats for outside painting an amount in excess of 8 to 10 per cent is probably objectionable. In varnishes they have a distinct function to perform, as the combination of oil and gum is too thick and heavy to be applied without thinning.

C. VARNISHES

Varnishes are divided into two classes, "spirit" and "oil."

(1) **Spirit Varnishes** consist of a partial solution of the gum resins usually in alcohol, though turpentine is used with certain resins such as damar. The vehicle evaporates, leaving the gum unchanged on the surface to which it is applied. Spirit varnishes usually have a high gloss but lack of durability.

(2) **Oil Varnishes** are made by prolonged heating of the harder gum resins, such as copal, kauri, manila, etc., with linseed oil, Tung oil, etc., and metallic driers at a high temperature, usually above 300° C, till the resins and oil amalgamate to a homogeneous mass, which is subsequently thinned down with a volatile thinner such as turpentine or benzine.

When used the volatile thinner evaporates, the oil dries by oxidation, and the film is hardened by the gum resins it contains.

The manufacture of varnish is a delicate operation, requiring much skill and experience to produce a satisfactory product. With proper methods of manufacture a durable varnish can be made from what are usually considered inferior materials, while high-grade stock does not necessarily insure a superior product. Varnishes are sold under a great variety of names offered for a variety of uses. These differ in many cases only in name. For general use, interior, exterior, rubbing, and floor varnishes will meet the usual demands of service. Interior and rubbing varnishes are classed as "short-oil" varnishes containing a larger amount of resin than exterior or spar varnishes, classed as "long-oil" varnishes. Floor varnishes should be hard and very tough and elastic, so as not to be marred by footmarks.

D. TESTS

The tests are so varied and cover such a variety of materials that it is impossible to describe them in detail.

In general they may be outlined as follows:

(1) **Paints.**—Determinations of quantity and character of pigment, oil, and volatile are made.

Tests to determine fineness of grinding pigment, time of drying, and general character of film, together with exposure tests where time admits.

Such pigments as red lead, white lead, zinc white, chromate of lead, etc., of definite chemical composition can generally be judged by composition, but physical tests should also be made to determine covering power, color strength, fineness, etc.

Pigments of the earth type are chiefly valued on physical tests, as chemical composition gives little or no indication of pigment value. Chemical analysis will be of value, however, as a matter of record or for comparison to identify sources, etc.

The identification and determination of oils in mixtures, especially after they are combined with the pigment and driers, is always a difficult problem, and in many cases they can not be determined; but tests to determine time of drying and character of film will usually give some indication of the quality of the paint.

Tests to determine quantity and character of the volatile can usually be made with reasonable accuracy.

Tests of driers consist in determining specific gravity, amount, and composition of the metallic oxides present, amount and character of the volatile, and the presence of resin, etc.

Tests are also made to determine time of drying when a fixed quantity is added to a standard linseed oil.

With the wide range of paint materials and varied uses and conditions under which they are applied, it is impossible to make any specific recommendations regarding these materials. There can be no question that a large number of ready-mixed paints and paint materials on the market are inferior, due to adulteration, but it is not true that blended pigments are necessarily inferior on that account.

The white-lead pigments have an almost universal application as the basis of white and light-colored paints, but they may be combined with other pigments to advantage. For instance, basic carbonate white lead mixed with linseed oil has a tendency to turn yellow when used for interior painting, while zinc oxide remains white. The addition of zinc oxide to

white lead tends to lessen this action, so such a combination may frequently be used to advantage.

It has also been found that the tinted white pigments are usually more durable than the same white pigment to which the tinting color has not been added.

There is much difference of opinion regarding the relative value of white lead and composite paints for outside exposure, but it is probably true that certain combinations of white lead and white zinc are superior to the single pigment for certain purposes, and it is also possible that the addition of small quantities of the so-called extending or inert pigments, as silica, asbestine, barytes, china clay, etc., may be a further advantage, but such additions should not be in such quantities as to make the paint deficient in covering power.

The natural-earth pigments, such as ochres, umber, sienna, red oxide of iron, etc., are usually very durable and permanent; and also such strong colors as the red oxides of iron can, for most purposes, be diluted with some of the white extending pigments with no sacrifice of quality.

Very extended investigations have been conducted on protective paints for ferric structures and especially to determine the cause of corrosion. It has been suggested that differences in electrical potential between the pigment and the surface to which it is applied may be a factor; and while laboratory experiments show that such action does exist, no positive relation has been established between such tests and actual service.

It has been found from both laboratory and service tests, as well as actual service, that both red lead and the chromate pigments do furnish excellent protection for iron and steel structures, and it is believed that such pigments can generally be used to advantage.

Beyond these general statements no specific recommendations are warranted without detailed information regarding conditions and requirements.

(2) **Varnishes.**—Spirit varnishes are tested to determine the quantity and character of the gum resin and volatile.

Oil varnishes can only be tested in a general manner, as no satisfactory method has been developed to determine the quantity of resins present. Certain resins can be detected when present, but there is no means of distinguishing between the various fossil and hard resins.

The quantity of volatile matter can be determined and identified and the metallic oxides present can be determined.

An excessive quantity of lime usually indicates rosin, which can be confirmed by a direct test to detect the presence of that resin.

In general, the presence of lime, rosin, and benzine indicates a cheap grade of varnish, but it is not necessarily inferior on that account.

Exposure tests are made, when time admits, to furnish a more positive indication of the quality of the material.

E. SAMPLING

The amount required for a ready-mixed paint, oil, drier, varnish, or other liquid product should be at least 1 quart.

When the sample is taken from a larger quantity the entire contents of the container should be thoroughly stirred so as to insure a uniform average sample.

One pound of dry pigment or paste will be required. All samples should be shipped in sealed containers to prevent loss by evaporation or leakage or change by oxidation.

7. BITUMINOUS MATERIALS

(1) **Definition and Classification.**—In the broad sense the term "bituminous materials" applies to materials containing mixtures of native or pyrogenous hydrocarbons and their nonmetallic derivative, which may be gases, liquids, viscous liquids, or solids, and which are soluble in carbon disulphide. This definition is still a matter of controversy, but has the sanction of technical use. As used here it is limited to the plastic materials derived from natural asphalts, from oxidized petroleums, and from the tars and pitches obtained from the destructive distillation of coal, mineral oil, etc. These materials may be broadly classified as natural asphalts, products of destructive distillation, and oxidized petroleum products. The natural asphalts range from the light fluid malthas consisting of an asphaltic base and a light volatile hydrocarbon to the hard solid asphalts of the Gilsonite type.

The tars and pitches may be obtained as the by-products in the manufacture of coal gas, water gas, oil gas, coke, or in any process where carbonaceous matter is burned with a limited supply of air.

The oxidized petroleums are obtained by blowing air through usually heavy petroleum residues at elevated temperatures. The changes produced are complex, but in brief, part of the hydrogen present in the oil combines with the oxygen contained in the air and passes off as water vapor or steam, so that the per cent of carbon is increased. The physical character of the oil is changed from a viscous liquid to a more or less rubber-like solid.

All of these materials vary to such an extent with their origin, treatment, method of refining, and final blending that a classification based either on origin, method of production, or subsequent treatment is impracticable. This is due in part to the fact that very few asphalts are used in their natural condition; they are treated in a variety of ways and blended with other materials to modify their original character. The harder asphalts are fluxed with petroleum oils so as to make them more plastic, while the more fluid are frequently heated so as to drive off the more volatile products. The artificial asphalts, obtained by oxidation of petroleum residues, may be modified in the same manner, while the tars and pitches vary with their source, method of production, and subsequent treatment.

(2) **Use and General Requirements.**—All of these materials are used as waterproofing and damp-proofing mediums in general building construction. They are usually applied hot either alone or in combination with a felt, paper, or cloth fabric. The materials should bond strongly to the surface to which they are applied; they should be sufficiently plastic to expand and contract with normal change in temperature without cracking, and should not be materially affected by exposure to water, air, and normal conditions of service.

(3) **Tests and Interpretation of Results.**—Bituminous materials are examined to ascertain, if possible, their origin, though in blended materials of similar character this is frequently impossible. The melting point, specific gravity, quantity of fixed carbon, free carbon, and ash are also determined. The plasticity is measured by the penetration of a standard needle with fixed weight at varying temperatures, the character and quantities of the volatile matter yielded by distillation is determined, as well as the effect of exposure to air and water.

The specific gravity gives an indication of the origin and treatment; most of the asphalts and tars are heavier while the oxidized petroleums are usually lighter than water, though this may be materially modified by the flux used and method employed in refining and production.

The ash is extremely low. The material is further characterized by being less affected by changes in temperature than the other products. In general, the oxidized petroleums do not have the property of penetrating and bonding well to the surface to which it is applied.

As these materials are mixtures, not true chemical compounds, the melting points are not definite, but must be determined in an arbitrary specified manner. This point is necessary in determining the value of the material for the use specified; bitumens for underground foundations,

where the temperature is fairly low and uniform, should be softer than when used on roof construction subject to the direct heat of the sun. As these materials are plastic below their melting point, they can not be used satisfactorily on steep roofs.

Hardness is more directly measured by penetration which is determined by measuring the depth of penetration of a standard needle loaded with a fixed weight. This determination may be made at two or more temperatures to show the changes in hardness so produced.

The quantity and composition of ash is an indication of origin. The tars, oxidized petroleum, and some of the refined natural asphalts normally contain only a very small quantity, while Trinidad asphalt, even after refining, contains 30 to 40 per cent of ash of fairly definite composition.

The fixed carbon is an arbitrary determination, measuring the quantity of coke remaining when a fixed weight of the material is heated in a specified manner. It is used to measure uniformity.

The free carbon is a normal characteristic of the tars and measures the quantity of carbon set free in the process of destructive distillation. Water gas tars usually contain a smaller quantity than coal tars.

Fractional distillation is an aid in determining the fluxing material used with the asphalts and indicates if the tars are a "straight run" or "cut back" product. The "straight run" is the material as it comes from the still, while the "cut back" is the harder pitch which has been softened by an addition of some of the lower distillates. The straight run products are usually specified.

To determine the effect of normal water and air exposures, rather thin layers of these materials are exposed to the action of these agencies and the effect noted. Some of the asphalts seem to lose their life when exposed to water, ultimately becoming friable. Tars are usually unaffected by this treatment, but may dry out when exposed to dry, warm air and become brittle. The thickness of the coating is a factor, however, as the dried surface skin seems to protect the under layer from further action.

All are materially soluble in water containing "gas drip," leakage from gas mains, and this frequently causes failure in city constructions. Accelerated tests under abnormal conditions have been suggested to determine these points while the more definite tests are in progress, but as yet no such tests have been developed which invariably give the same results as prolonged normal exposure.

The **saturated felts, papers,** etc., are examined to determine number of ply, weight per unit area, the water absorption, the tensile strength, the

quantity and character of the saturating material, and the composition of the fiber. The number of ply is usually specified. It is determined on the sample from which the bituminous material has been extracted.

The weight per square foot is also usually specified and the determination requires no explanation.

The water absorption is determined by immersion of a sample in water at a definite temperature for a specified time and the gain in weight as well as the effect is noted. A similar test is made by folding the paper so as to form an open box and filling it with water. Such tests apply more logically to such prepared roofing papers as are laid with lap seams without binder than to other types which are used in conjunction with a bituminous binder.

The tensile strength may be determined on the original material; on the material after the bitumen has been extracted, and on the material after exposure to action of water, air, etc.

The determination of the quantity and character of the saturating material is subject to certain limitations. The asphalts can be completely extracted by the use of a suitable solvent and further examined, but the quantity and constitution of the ash may be modified by the ash of the paper so as to prevent identification. The composition of the tars may also be modified by the retention of part or all of the free carbon in the fiber of the paper, which complicates further interpretation of the results.

The composition of the felt or paper, etc., is determined on the material after the bitumen has been removed. None of the so-called "wool felts" are composed entirely of wool; they usually contain from 60 to 90 per cent cellulose, the balance is wool with a certain quantity of ash. This quantity of wool is desirable in giving additional strength and increasing the absorption of the bitumen by the felt.

In the light of the previous discussion under "Bituminous material," further statement regarding the purpose of these tests does not seem necessary.

(4) **General Statement.**—It can be stated that all of these products can be so prepared as to produce satisfactory waterproofing and roofing materials. In general, the tars seem to stand water action on below-grade construction fairly well, while asphalts retain their life when exposed to the drying action of free air circulation and high temperatures on roofs. The oxidized petroleums promised well, on account of their stability under both conditions and resistance to change due to temperature, but their lack of penetration and deficiency in bonding are serious objections.

This description of the character and uses of these materials can only be considered to have general application. More specific recommendations may only be furnished when detailed information regarding use and conditions are supplied.

(5) **Sampling.**—One kilo (2-pound) samples of the bitumen should be furnished in tight tin cans and at least 3 square feet of the felt or paper.

(For fees, see Schedule No. 312, p. 80.)

8. INKS

A. WRITING INKS

(1) **Description.**—The only inks which can be relied upon as sufficiently permanent for records are those containing finely divided carbon (india ink, etc.), those in which iron gallotannate is the chief coloring matter, and only occasionally other metallic compounds.

The great majority of writing inks are iron gallotannate inks, made by mixing together various tanning extracts with solutions of iron salts. A mineral acid is added to keep the iron compounds in solution. Gum is added to prevent excessive fluidity, and an antiseptic to preserve the ink from mold. An organic dye is added because the fresh writing would otherwise be too pale. It requires some hours or even days for writing with iron gallotannate to reach its maximum intensity. Some writing inks, and most of the ink powders intended for making writing fluid by dissolving in water, are made solely of dyes. The nigrosine dyes make ink of quite satisfactory intensity of color, and they are fairly resistant to the action of sunlight and many reagents, but should never be relied upon for permanent records.

Copying inks, for obtaining copies of documents in the letterpress, are of heavier body than ordinary record inks. If they contain only dyes, or if the dye alone is transferred to the second sheet of paper, the copies can not be regarded as permanent records. In order that some of the necessary iron salts be transferred, these are increased in amount, and at the same time sugar, glucose, dextrin, or some similar substance is added to prevent a too rapid drying out of the writing.

A widely adopted formula for a standard record ink is the following, first published in 1890 by Schluttig and Neumann in their book Die Eisengallustinten:

Tannic acid, 23.4 parts by weight; gallic acid crystals, 7.7 parts; ferrous sulphate crystals, 30 parts; gum arabic, 10 parts; diluted hydrochloric acid (containing 10 per cent of the gas), 25 parts; phenol (carbolic acid), 1 part; water to make up to 1,000 parts. To this is added just sufficient of a soluble blue dye to give an immediate blue-black color.

It is not to be expected that manufacturers will actually make ink according to this formula, on account of the high cost of the tannic and gallic acids. Extracts of various tanning materials which contain these acids in proper amount are used, but writing made with inks so prepared must be of as intense a black and fully as permanent as that made with the standard ink. Colored inks are generally made by dissolving the so-called aniline dyes, either in pure water or with various additions. Most of these are readily destroyed by sunlight, water, and various chemical reagents, and they should not be used for permanent records.

(2) **Tests.**—The most important determination is the amount of iron in a given volume of ink. The formation of a sediment or the growth of mold when the ink is kept in an open vessel for a week, in a place free from dust, indicates a poor quality of ink. The amount of acidity is indicated by the loss in weight of carefully cleaned steel pens immersed in a measured volume of the ink for a definite time.

For most of the other tests "streaks" are prepared by allowing small amounts of the ink to flow across a sheet of paper held in an inclined position. Some of these streaks are placed in direct sunlight, preferably without covering with glass; others are immersed in water and dilute alcohol; still others are treated with acids, alkalies and bleaching agents; and still others are used for testing the copying power, and these copies are subjected to the same tests as the original streaks.

From all of these tests it is usually easy to say which of a series of inks is the best. Red and other colored inks are subjected to the same tests as black inks, except that the determination of iron is omitted.

The determination of specific gravity and of total solids in a given volume of ink is of little practical value.

(3) **Sampling.**—At least 1 pint of ink, preferably in the original bottle, should be sent.

(For fees, see Schedule No. 282, p. 80.)

B. PRINTING INKS

These are generally classified as web-press, flat-bed, job, halftone, and colored inks. In addition to these there are inks made for particular purposes, such as money orders, postal cards, etc.

The analysis in general should give approximately the composition of ink, and at the same time reveal the presence of materials which would be objectionable for the class of work for which the ink is intended. This analysis would consist of a separation of the ink into oil and pigment by means of suitable solvents and a determination of their composition.

The oil is first saponified with alcoholic potash, and unsaponifiable matter extracted. More than 1 or 2 per cent extract would indicate the presence of mineral oils or rosin oil. The presence or absence of the latter is shown by means of the Liebermann-Storch reaction.

The saponified solution is made acid, and the fatty acids are extracted with ether. These acids are examined for colophony (common rosin), and if the latter is present it may be determined quantitatively. Tests for other than mineral oils, rosin, or linseed oil may be made.

The pigment of the black inks is tested for the presence of lampblack, boneblack, aniline dyes or lakes, prussian blue, mineral fillers, and oil driers.

The colored inks are examined qualitatively for their coloring material, and wherever possible the amount of such material is determined.

In all kinds of inks the fastness of the dyes present toward cellulose and their solubility in the oil employed are determined.

Samples for analysis should consist of at least half a pound of ink, packed in clean, dry tin cans, with tight-fitting covers, and marked with the brand, name of maker, and purpose for which the ink is intended. If more than one sample is sent at a time they should be so marked as to permit of easy and complete identification.

(For fees, see Schedule No. 282, p. 80.)

C. STAMP-PAD INKS

These consist in general of pigments and dyes in a suitable vehicle. The latter is usually glycerol, but may be of an oily nature, as in the case of the immediate drying inks.

(1) **Drying power.**—This is determined by the rate of the evaporation of the ink when exposed in a thin layer in a shallow dish of specified size. The determination is not of much value, because the rate of drying depends on the temperature and, in the case of inks with a glycerol base, on the humidity also. These can be controlled in the laboratory but not in practical use.

Absorption by strips of blotting paper gives an indication of the value of the ink, by showing how rapidly it enters the pores of the paper and whether or not the coloring matter is carried along with the base.

(2) **Fastness of color.**—This depends chiefly on the nature of the ink, but the permanence of impressions made with the ink is influenced considerably by the extent to which the coloring matter is carried into the paper. Impressions made with a rubber stamp are too intense to afford satisfactory

indications of fading in a short time, so that in this Bureau impressions are made with the end of a rubber stopper about 1 inch across. These are much paler than if made with a stamp, and the slightest fading can be detected when one-half is cut off and preserved in the dark, while the other half is exposed to the action of sunlight or reagents.

(3) **Samples.**—At least 4 ounces should be sent, preferably in an original package.

(For fees, see Schedule No. 282, p. 80.)

9. PAPER

(1) **Definition and Sources.**—Paper is a matted felting of fibers, usually of vegetable origin, made into flat sheets for printing, wrapping, writing, and other purposes. Paper is produced from a very wide range of sources, since it is possible to produce a sheet of paper from almost any fibrous vegetable material. The most important sources are:

1. Seed hair fiber, such as cotton.
2. Bast or stem fibers, such as flax or linen, hemp, jute, straw.
3. Leaf fibers, such as manilla hemp.
4. Wood fibers: (*a*) Resinous woods—spruce, pine, hemlock; (*b*) nonresinous woods—beech, gum, poplar.

Of these various sources, the most important are rag (cotton and linen), woods of pine family, and woods of the poplar family.

(2) **Uses.**—The uses to which paper may be put are even more varied than the sources. As usually known, in the form of thin sheets it is principally used for writing, printing, or wrapping, and a great variety of special uses. In other manufactured forms its uses are almost numberless for making substitutes for metal, wood, rubber, horn, and ivory, and as material for making the stiff backs of books, for making yarn to be spun into cloth, for making artificial silk, coverings for walls, boxes, books, etc., and recently for towels, table coverings, dishes, etc.

(3) **Quality.**—The suitability of a paper for a definite purpose depends upon, first, the kind and quality of the raw material entering into its composition; second, the degree of care with which a paper is made; and, third, the absence in the finished product of any material or materials detrimental to its life or usefulness. In order that the user may more correctly judge a paper, and determine its usefulness for the purpose intended, he should be informed upon the following points:

1. The fiber composition (with per cent of various kinds contained therein).

2. The bursting strength.
3. Tensile strength.
4. Folding endurance.
5. Thickness.
6. Weight per standard ream.
7. Ratio of strength to weight.
8. Per cent of filler retained in the paper, kind and per cent of sizing material used.
9. Presence of any material detrimental to the life of a paper.

The above influencing factors alone do not in every case control the quality of a paper, since even with the best of raw materials the paper may be of very low quality, due to careless handling during the process of manufacture. There are still other important properties that affect the quality of a paper, such as "opacity," "color," "finish," "formation," "dirt," "rattle," and the "feel" of a paper.

It should be understood that every paper does not require a full test to enable one to judge quality. For example, a wrapping paper for best quality should have a high bursting and a high folding strength, and a resistance to water or dampness. These are the controlling factors, while for a high-grade chart paper every test that may be applied is of importance, for such a paper must stand much handling, a wide range of atmospheric conditions, and the most severe printing requirements.

The following is a list of tests and determinations to be made with corresponding characteristics which each test helps to determine:

1. Microscopical examination, to determine fiber composition and show the presence of injurious fibers.
2. Bursting strength, tensile strength, and folding endurance, to determine quality of material used and care in handling during process of manufacture.
3. Weight per ream, to determine compliance with contract specification.
4. Thickness, to determine bulk.
5. Expansion and absorption, to determine resistance to changes due to moisture.
6. Per cent of ash, to determine kind and amount of loading material.
7. Per cent of sizing, to determine kind and amount of sizing materials used.

(4) **Sampling.**—The following should be noted in regard to submitting samples for test:

Whenever possible nine sheets each, accurately cut, 10 by 12½ inches should be submitted. These sheets should be picked out in such a manner as will most nearly represent an average of the total amount delivered. The nine sheets of each lot should be carefully fastened together, and one outside sheet should be marked according to one of the following forms:

Samples submitted by Government departments should be marked in upper left-hand corner of sheet as follows:

Date ..... Identification marks .....
Submitted by
Kind of paper
Item number
Name of manufacturer
Tests for compliance with schedule
Remarks: (Any other information concerning the paper.)

Samples submitted by private parties, mark in upper left-hand corner of sheet as follows:

Date ..... Identification marks .....
Submitted by
Kind of paper
Use of paper
Ream size and weight
Tests required
Remarks: (Any other information concerning the paper.)
Paper made by .....

NOTE 1.—In order to secure representative samples for test, it is advisable to proceed as follows:

Case Lots.—Select one case from each one-third of the total delivery, and then select one sheet from each one-third of the case. Mark large sheets Nos. 1 to 9, inclusive, and from the large sheets cut 10 by 12½ inch sheets for test, also save remaining portion of large sheet for record purpose. Deliveries in "frames" and bundles are to be sampled in the same way. Deliveries in small boxes or small packages, when possible, should be sampled by selecting one sheet from each of nine boxes.

Rolls.—Sample by taking one sample each from nine rolls not less than four sheets in from outside of roll. If not practical to do this, then select three sheets from each of the rolls.

A careful record should be kept by the sender so that the identification marks may be used in the certificate to avoid repeating the detailed description of the paper.

All samples of paper should be put up for shipment carefully protected by cardboard or other material to insure arrival in good condition. All paper samples themselves should be plainly marked "For Paper Testing Laboratory, Bureau of Standards, Washington, D. C."

The Bureau is equipped to make complete examination of papers for Government offices or bureaus, and will, in its discretion, perform similar service for the general public when asked to act as referee or where the nature of the case calls for an authoritative test. The Bureau thus reserves the right to accept or decline requests for tests, depending upon the conditions in each instance.

All tests for the National and State Governments are made free of charge. For municipal governments or private parties charges are made according to the nature and extent of the work required. Where such tests

are accepted the fees will, in general, be based upon the following schedule, which states the fee for each test on a single sample, and the charge for the same test on each additional sample where several are submitted at the same time.

Details of the methods of testing and the significance of the results will be given in a special circular, to be issued in the near future, upon the testing of paper.

10. TEXTILES

A. FIBERS, YARNS, AND FABRICS

(1) **Definition.**—Broadly speaking, textile material includes all spun or woven fabrics or fibers suitable for spinning or weaving. The fibers employed for such purposes may be animal, vegetable, artificial, or mineral. Animal fibers include the wool clipped from sheep, silk from the silkworm, and animal hair from goats, camels, and other animals. Cotton ranks first among the vegetable fibers, is grown largely in warm latitudes, flax and hemp being cultivated for fiber production in more temperate climates. Jute, ramie, and abaca or manila hemp come chiefly from the Orient. Palm and straw fibers are also extensively used. The artificial fibers are mainly artificial silk and artificial horsehair, produced by numerous processes, chiefly in Germany, France, Belgium, and the United States. Asbestos, the fibrous form of certain incombustible minerals, is the principal mineral fiber in use.

(2) **Uses.**—Textile fibers have a wide range of uses, e. g., unspun or raw textile materials are used as packing in many industries, as insulating material, as felting for hats and other articles, for paper making, spinning into yarn, and so on. Yarns are used primarily for weaving fabrics and are twisted into threads, twines, cords, and ropes. Knit and woven goods include by far the most important group of textile uses, e. g., clothing, household furnishings, bookbinding, bagging, sail cloth, and a great variety of uses involving utility, comfort, convenience, and decoration.

(3) **Properties.**—Among the properties which the ultimate fibers should possess are fineness, length, strength, and flexibility. Yarns should have good weaving and dyeing qualities; minimum slipping in the fabric and a high luster are often desirable. Fabrics should be well woven and finished, with even and straight selveges, a minimum of spots and blemishes, and uniformity as to color and strength. Twines and cordage should be evenly spun, uniform in strength, of good color, and contain the normal amount of moisture.

(4) **Tests.**—The scope of testing which this Bureau is prepared to undertake is as follows:

1. Determination upon raw and unspun fibers:
   - (*a*) Identity of fiber.
   - (*b*) Approximate length.
   - (*c*) Moisture content and "regain."
   - (*d*) Quantity of oil, grease, and foreign substances contained.
   - (*e*) Percentage loss in scouring wool.
2. Determinations upon yarns, thread, and twine:
   - (*a*) Length.
   - (*b*) Tensile strength and elasticity.
   - (*c*) Count or number.
   - (*d*) Twist.
   - (*e*) Percentage of loading, sizing, and coloring material.
   - (*f*) Percentage fiber composition.
3. Determinations upon fabric:
   - (*a*) Weight.
   - (*b*) Tensile strength and elongation.
   - (*c*) Percentage fiber composition.
   - (*d*) Thread count.
   - (*e*) Yarn number or size.
   - (*f*) Folding endurance.
   - (*g*) Action of light on colors.

In recent years the laboratory testing of textiles has become of primary importance in the advance of the industry. Selection of textiles for specific uses can be placed upon a scientific basis only by the direct measurement of the properties involved in the special quality required. The selection of the properties to be tested depends in each case upon the use involved. For example, weight may be important in draperies, folding endurance in binding cloths, tensile strength in bandage tapes, fineness in dress goods, closeness of weave in sacking for powdered material. Fiber composition also may be vital in securing appearance, endurance, and such other qualities as may be required in each particular case, with due consideration of economy.

(5) **Sampling.**—For identification of raw and unspun fibers, a 1-pound sample is required; for other tests desired under heading No. 1, 5 to 10 pound samples must be furnished.

For yarns wound upon cops, bobbins, spools, or in the form of skeins, 10 samples are necessary for testing.

For the testing of thread and twine, 5 spools or 5 balls are required.

For the analysis of a fabric there must be furnished 36 inches in length, including both selveges.

Samples intended for the determination of moisture must be inclosed in air-tight containers.

B. MANILA ROPE

(1) **Quality.**—The quality of manila rope depends upon the length and strength of the constituent fibers, the lay of the strands, and the tensile strength of the rope.

(2) **Tests.**—The tensile strength is determined at the breaking point applied to destruction. The fibers are also examined.

(3) **Sampling.**—Specimens to have eye splice in each end, inside diameter of eye not less than 7 inches, each splice to have at least three tucks, using full strands, after which strands are to be divided to about half the former size, and two or more tucks taken. Length between splices should be about 5 feet for all samples. Splices should be carefully made to insure specimen breaking in body of rope. Samples may be rolled for shipment, but should be carefully burlapped to insure protection agains dirt or moisture. Samples should be tagged, giving name and location of maker, kind and diameter of rope, and preferably use to which it is to be put.

(For fees, see Schedule 209, p. 82.)

11. RUBBER

(1) **Definition.**—Crude rubber is obtained by coagulating and drying the milky latex derived from certain trees and plants. The quality of the crude rubber which determines its market value depends not merely upon the species of plant from which the latex has been secured, but also upon the locality in which it is grown, and in a great measure upon the methods followed in its collection, coagulation, and drying.

The term "rubber," as commonly employed, does not refer to the commercially pure gum, but to a vulcanized compound which consists of gum, mineral matter or pigments, and sulphur, mixed in various proportions, according to the purpose for which it is intended. Mineral matter, or the so-called fillers, serve a very useful purpose, both in cheapening the product and in adding certain desirable properties which could not otherwise be obtained. Their presence, therefore, should not be looked upon as adulteration.

(2) **Sources.**—The principal sources of crude rubber are South America, Central America, Africa, and Asia. The Amazon district of South America is noted for the excellent quality of its rubber. In addition to the large quantity which is collected by natives from trees in the wild state, much rubber is secured from plantations where rubber-bearing trees are cultivated according to scientific principles. This is generally known as plantation rubber.

(3) **Uses.**—There is a limited demand for pure gum by the medical profession and a very considerable amount is used in the manufacture of stationery bands, elastic thread, etc., but the amount of rubber thus consumed is insignificant as compared with the enormous quantity used in the manufacture of mechanical rubber goods, such as automobile tires, hose, packing, and footwear. There is an enormous demand for inexpensive mixtures such as are used for garden hose and the lower grades of packing.

(4) **Properties.**—The properties that are desirable in rubber depend in a great measure upon the use for which it is intended. For example, rubber intended for steam hose or steam packing should be of a composition to withstand high temperatures, while rubber for the tread of an automobile tire should offer great resistance to abrasion.

The real value of rubber in any case depends upon the length of time that it will retain those properties which are desirable, and it is a matter of common observation that rubber often deteriorates less rapidly when in use than when lying idle. Deterioration as indicated by loss of strength and elasticity is considered to be the result of oxidation, which action is accelerated by heat and very greatly by sunlight. Other things being equal, the better grades of rubber possess greater strength and elasticity, and may be stretched to a greater extent than the poorer grades, and they also deteriorate less rapidly. The physical properties of rubber, however, are subject to variation within wide limits, depending upon the proportion of gum present, the materials used as fillers, and the extent of vulcanization.

(5) **Tests.**—(*a*) Physical Tests.—Rubber testing in the present stage of its development is not susceptible of very great refinement as regards measurement. The nature of the material is such that refinement seems of less importance than uniformity of methods, which is absolutely essential where the work of different laboratories is to be compared. A more general interest in this matter would result in a substantial benefit not only to reputable manufacturers and large consumers, but also to the general public.

The different properties that have been found desirable in rubber intended for various purposes have naturally given rise to numerous tests, of which the most widely applicable are the various tension tests. These tests in various forms are used to determine the more important physical properties, such as tensile strength, ultimate elongation, elasticity, and reduction in tension under prolonged stretching to a definite elongation.

Elasticity or "recovery" is measured by the extent to which the material returns to its original length after having been stretched.

The term "set," as commonly employed, refers to the extension remaining after a specified interval of rest following a specified elongation for a given period of time.

In the case of such materials as rubber hose and rubber belting, which are built up with layers of duck cemented or frictioned together with rubber, it is customary to determine the "friction" or adhesion between the plies of duck as well as the quality of rubber. It is also usual to subject hose (particularly fire hose and air hose) to a hydraulic pressure test, in order to detect any imperfections in materials or workmanship.

An important test in the case of steam hose consists in passing steam at about 50-pound pressure through a short length of the hose in order to determine if the rubber is of suitable composition to withstand the effects of service conditions. This test usually lasts for about six days, the steam being turned off at night to allow the rubber to cool. A decided hardening or softening of the rubber, or a large decrease in the value of friction, as a result of steaming, is an indication of inferior quality.

No absolutely reliable test (other than an actual service test) has been devised for rubber steam packing, but in many cases valuable information may be obtained by clamping a piece of the packing between metal plates and subjecting it to the action of steam at a pressure equal to or slightly above that under which it is to be used.

For tension tests the test pieces are cut with a metal die, which not only saves much time but also insures uniform width which it is impossible to obtain if the specimens are cut by hand. An arbor press is used to force the die through the rubber, although many prefer to make test pieces by striking the die with a mallet. The central portion of the test piece is straight for a distance of 2 inches, and the ends are enlarged to prevent tearing in the grips of the testing machine. The width of the contracted section is usually made either one-fourth or one-half inch.

Parallel lines 2 inches apart are placed on the specimens, and by means of these gauge marks, elongation and permanent extension are measured. Test pieces in the form of a ring may be used, but in this case the test requires sheet rubber of uniform thickness.

The friction of "plied" hose is determined in the following manner: In preparing test pieces, a short length of hose is pressed tightly over a slightly tapered mandrel. The mandrel is put in a lathe, and 1-inch rings are cut with a pointed knife. Beginning at the lap a short length of canvas is separated and the ring is pressed snugly over a mandrel which is free to

revolve in roller bearings. The rate at which the canvas strips under the action of a specified weight suspended from its detached end is taken as a measure of the friction..

The friction of rubber-lined fire hose is usually determined as follows: A 1-inch strip is cut and a portion of the tube separated from the jacket. The detached end of the jacket is clamped in a stationary grip and the weight is suspended from the rubber tube.

The friction between the plies of duck in rubber belting is sometimes measured in the same way, but some prefer to apply the load in a direction at right angles to the plane of separation, as in the case of "plied" hose. This is done by cutting the belt about halfway through along parallel lines 1 inch apart. The belt rests on horizontal supports just outside of the strip which has been cut, and the weight is suspended from the detached end of the duck. It is found that for a given weight the rate of stripping is decidedly greater by the former method than by the latter.

The hydraulic-pressure test as usually made consists simply in subjecting a short length of the hose to water pressure created by a force pump of any convenient type. The coupling at the free end is closed with a plug and the pump connection is made with a reducing coupling.

(*b*) CHEMICAL TESTS.—The chemical determinations include acetone extraction, chloroform extraction, alcoholic potash extraction, total sulphur, barytes and other mineral fillers, free sulphur, waxy hydrocarbons.

(6) **Sampling.**—Samples shall be taken directly from finished material. These samples should be sealed and marked with the maker's name, date of sampling, and kind of material. If more than one sample of the same material is taken at one time, the individual samples shall be marked so as to permit of easy and complete identification.

The following table shows the amount of material necessary for tests:

Physical Tests

Hose of all kinds, up to 2 inches diameter	feet..	2
Hose over 2 inches diameter	do....	1
Hose for pressure test	do....	5
Packing	square foot..	1
Insulated wire	feet..	3–6
Mechanical goods (sufficient material to give at least 6 pieces)	inches..	1 by 6

Chemical Tests

Hose up to 2 inches diameter	foot..	1
Hose over 2 inches diameter	inches..	6
Packing	square inches..	36
Insulated wire	feet..	2–3
Mechanical goods (sufficient to give at least 4 ounces of rubber).		

(*a*) Other Conditions Governing Tests.—Every precaution must be taken to prevent samples being contaminated with any foreign matter. Samples must be kept in a cool place. The object of these precautions is to insure that the sample is received in exactly the same condition as it is offered by the contractor.

Samples should be forwarded by mail or express, addressed to "The Director, Bureau of Standards, Washington, D. C." All charges must be prepaid.

Under separate cover, notice of the sending of samples should be given, stating what information is desired, and inclosing copy of specifications.

(For fees, see Schedules Nos. 115, 116, p. 82.)

12. LEATHER

The Bureau is equipped for making physical tests of leather. The usual tests for leather belting consist of determinations of tensile strength, elongation under a specified load, the absorption of water, and weight per square foot. For such tests a sample of 1 square foot should be provided.

The fees for the testing of leather will depend upon the requirements of each case.

13. LUBRICATING OILS AND GREASES

These are used for so many different purposes, for so many kinds of machinery, and under such widely differing conditions of speed, load, etc., that it might almost be said that each combination of the above variables forms a class by itself. As an extreme instance may be mentioned clock oils, which are extremely fluid and are used for delicate mechanisms where there would be little friction, even without lubrication, and the heavy, viscous cylinder oils intended for low-speed, high-pressure engines. In separate categories may be placed grease and the lubricants for the cylinders of internal-combustion engines. Laboratory methods of testing have not yet been devised which will determine satisfactorily in advance whether or not a given lubricating oil is suitable in any specific case. At present the chief value of these tests is to learn whether or not an oil meets the requirements of the specifications, which are not based on exact knowledge, and to accumulate data from which valuable inferences may at sometime in the future be drawn. The more usual tests are discussed briefly below.

A. OILS

At the present time most lubricating oils are straight mineral oils, made from the different distillates of petroleum. Many, however, are "compounded" oils, made by mixing animal or vegetable fats and oils, soaps, etc., with the petroleum distillates. Opinions differ as to whether

or not oils should be compounded and if so, what fats should be added. Without attempting to decide, it seems from the chemical point of view that of two oils, one a straight mineral oil and the other compounded, which have the same lubricating value, the former should be selected in preference to the latter. The reason for this is that the fatty oils are liable to be decomposed into glycerol and fatty acids. Not only is the lubricating power thereby lowered, but fatty acids are set free which may cause corrosion of the metal.

(1) **Mechanical Testing.**—Various forms of apparatus have been devised for purpose of subjecting oils to a "practical" test by using them on specially prepared bearings under varying conditions of load and speed. The loads at which an oil fails to lubricate at different speeds and the rise in temperature of the bearings are supposed to give an indication of the value of the oil. Unfortunately it has been found that results so obtained do not parallel those in practice, and besides when changing to a new oil the effect of the one that preceded can be noticed for a long period, which may lead to erroneous conclusions.

(*a*) VISCOSITY.—The viscosity of an oil, which may be measured by its rate of flow through a small aperture or by the rotation of vanes immersed in it, gives a rough idea of the lubricating value of an oil. It is commonly determined at two different temperatures, selected with reference to the class of oil which is under test. At this Bureau viscosity is expressed in Engler degrees, found by determining the time in seconds taken by 200 cc of the oil to flow out of the apparatus at the given temperature and dividing this by the time of outflow, in seconds, of 200 cc of water at 20° C.

(*b*) COLD TEST.—An oil intended for use on machinery subjected to low temperatures should remain liquid at all times. It is ordinarily tested by cooling to a given temperature, as −15° C. If it solidifies it is allowed to warm up gradually, stirring constantly, with a thermometer, and noting the temperature at which it will flow from one end of the bottle to the other.

(*c*) FLASH AND FIRE POINTS.—For ordinary lubricants the determination of these values is chiefly to ascertain the fire risk. In the case of oils for the cylinders of internal-combustion engines these points are of some slight assistance in determining their value, for such oils should to a great extent burn out of the cylinders and not accumulate and form a coating of so-called "carbon."

At this Bureau the Pensky-Martens closed-cup apparatus is used. In it the oil is heated at a definite rate and a test flame is applied to the opening at every degree of rise in temperature. The temperature at which the

vapors arising from the oil ignite for an instant is called the "flash point." The closed-cup apparatus gives somewhat lower values than the open-cup form, which is frequently employed, because the vapors do not diffuse out of the closed cup so readily. After the flash point has been found, the cover is removed and the heating continued until the oil itself catches fire, thus giving the fire point. The temperature at which the oil ignites depends not only on the oil, but on the rate of heating, the dimensions of the cup, etc.

(2) **Chemical Testing.**—(*a*) MINERAL ACID.—This may be detected by shaking the oil with hot water colored slightly with methyl orange, which will turn red if a mineral acid be present. It is very seldom found in lubricating oils, and if present would cause corrosion. It may be determined quantitatively by titrating a weighed amount of oil with standard alkali, using methyl orange as indicator. Mineral acid may also be detected by the production of a green color when one or two drops of the oil are placed on a piece of polished copper and left for 24 hours or longer.

(*b*) SOAP.—Soaps are added to oils to give them increased body, but the lubricating value is not greatly increased. The qualitative test for mineral acid gives at the same time an indication of the presence of soap, for if this is present the oil and water will emulsify.

(*c*) ASH.—This is determined by burning off a definite amount of the oil and weighing the residue. In a properly refined straight mineral oil not more than one or two one-hundredths of 1 per cent should be present, and this is mainly iron oxide. A considerable amount indicates improper refining or the addition of soap.

(*d*) ASPHALT TEST.—Improper refining is indicated by the precipitation of a dark-brown or black deposit of asphaltic substances when 5 cc of the oil is diluted with 95 cc of petroleum ether and the mixture allowed to stand for some hours. Most cylinder oils give at least a slight deposit. There should be none at all in the case of the lighter engine and dynamo oils, and its presence is particularly objectionable in oils for internal-combustion engines, as it tends to greatly increase the amount of "carbonization."

A mixture of alcohol and ether in definite proportions is sometimes used to throw down tarry and asphaltic substances, which are then filtered off and weighed.

(*e*) ORGANIC ACID.—All oils, especially after they have been stored for some time, contain organic acids. The acidity is greater when they have been improperly refined or when they have been exposed to the combined action of sunlight and air. The acidity is determined by heating a weighed

amount of the oil with strong alcohol and then titrating with standard alkali, using phenolphthalein as indicator. It is usually calculated as oleic acid, but the practice of this Bureau is to report organic acidity in terms of the amount of potassium hydroxide required to neutralize 1 gram of oil.

(*f*) FAT.—This includes all fatty oils and solids of animal or vegetable origin. The simplest qualitative test is to heat a sample with a piece of sodium hydroxide in a small test tube from 230° to 250°. The presence of any considerable amount of fat is indicated by foaming or even by the formation of a solid plug of soap which may be forced up to the mouth of the tube. When only a little fat is present there is not much foaming, but on allowing the oil to cool and stand for about an hour it will usually set to a jelly.

The amount of fat added is found by determining the saponification number of the compounded oil and calculating the percentage of fat from this. Most of the ordinary fats and oils have a saponification number of about 195, and it is the common practice to assume this number in calculating the percentage.

(*g*) CARBONIZATION.—This depends not only on the oil but on the conditions under which it is used. A method of testing has been adopted in this Bureau which gives the relative amount of carbonization to be expected from a series of oils. This test is employed only in the case of oils for internal-combustion engines.

(*h*) EVAPORATION AND GUMMING.—The amount of evaporation and the extent to which an oil becomes gummy thereby are sometimes determined. Not only the temperature and time of heating should be specified, but also the amount of oil taken and the size of the vessel. In this Bureau brass vessels 5 cm in diameter with straight sides 3 cm high are used. Five grams of oil is a convenient amount to use. The temperature at which the oil is heated depends on the purpose for which it is intended.

(*i*) SPECIFIC GRAVITY.—Nearly all specifications give the limits between which the specific gravity of the oil must lie, but this, taken in conjunction with the other constants, usually results in limiting the source of the oil to one or two kinds of crude petroleum. In other words, it excludes from competition many oils that might otherwise be satisfactory. Under present conditions the only value this determination has is as an aid in identifying a given brand.

B. GREASES

These are mixtures, in widely varying proportions, of the greatest variety of fats, oils, soaps, and mineral matter. The chemical tests employed depend on the nature of each particular grease. The melting

point, and whether or not there is a separation into liquid and solid portions on melting, give some indication of the value. The acidity and percentages of soap, mineral matter (graphite, etc.), and water are among the more usual determinations.

Samples.—At least 1 quart of a lubricating oil is necessary if physical and chemical tests are to be made. The containers should be perfectly clean and dry, and no sealing wax or similar material should be used on the stoppers. Whenever possible, the maker's name, the brand of oil and the purpose for which it is intended should be indicated.

14. CHEMICALS

The testing of chemical materials includes in the broader sense the tests of chemicals needed to insure their reliability for technical purposes. In the Bureau this is limited to the necessary work involved in special researches and investigations and in the preparation of standard samples—in particular in developing chemicals of the highest purity to be used as standards. The analysis of reagents is of particular urgency since the presence of unsuspected impurities, even in so-called C. P. materials, may vitiate the results of important researches. For this reason, the standardization of chemical reagents is a subject of much importance, and the Bureau will cooperate, so far as other work permits, with technical committees working upon this subject. Practically all tests of materials are at times supplemented with chemical tests.

15. MISCELLANEOUS TECHNICAL MATERIALS

A. ELECTRICAL AND MAGNETIC MATERIALS

Among the vitally important materials used in electrical work are conductor materials, magnetic materials, and insulating materials. Copper and aluminum are the principal conductor material. Where the desirable properties are high conductivity and high tensile strength copper-clad steel is used. Samples are submitted in the form of wires or rods and are tested for conductivity, resistance-temperature coefficient, resistance and inductance to alternating current or tensile strength.

Closely related to conductor materials are resistance materials, including such alloys as manganin, constantan, and therlo, for use chiefly in electrical instruments and meters; calorite and other alloys are especially adapted to electric heating devices. Such materials are tested for resistivity, temperature coefficient, and thermal electromotive force against copper. Melting points are also determined when desired.

Among insulating materials for the testing of which the Bureau is partially prepared may be mentioned rubber (as a covering for wires and cables), insulating cloth, paper, tape and varnish, vulcanized fiber, pressboard, and transformer oils.

Iron and steel, the only magnetic materials of commercial importance, are tested for two general magnetic properties: First, the ballistic test, which gives the permeability data of interest when the material is used for direct-current electromagnets; and, second, the loss test. This latter determines the total losses occurring in a definite amount of the material when subjected to alternating magnetization at stated frequencies and flux densities. (See Circulars Nos. 6, 17, 20, 21, 31, 36, and 37.)

B. OPTICAL MATERIALS

The following optical tests of materials will be made as desired:

1. Identification of glasses, crystals, and fluids by a determination of the refractive index to the fourth decimal place. A polished plane surface of 20 mm on a solid or a few drops of a fluid are sufficient.

2. Refractive index and dispersion of glasses, crystals, and fluids through the visible and ultraviolet spectra to the fifth decimal place. A 30° prism of the glass with two well-worked plane surfaces at least 10 mm across or 20 cc of the fluid are required.

3. Temperature coefficients of refractive index—0 to 100° for C, D, and F lines.

4. Prism angles and goniometry of crystals.

5. Curvature of lens, prism, and other surfaces.

6. Homogeneity of glass and freedom from strain.

7. Determination of direction of axis in crystalline quartz plates.

8. Absorption spectra of colored glasses and color screens.

9. Infra red and ultra violet emission, absorption, and reflection spectra of materials.

(For fees, see Bureau Circular No. 2.)

C. THERMAL MATERIALS

The thermal properties of fuels, oils, refractories, refrigerants, insulators, metals, salts, and alloys are determined by the Bureau, thus samples of metals, alloys, salts, and refractory materials, such as fire brick, may be submitted for the determination of their melting points, for test of the presence of critical points by taking their cooling curves, and for the determination of their specific heats. Samples of metal and alloy will also be

received for annealing or other heat treatment, and wire for the determination of the temperature coefficient of electrical resistance at high temperatures.

D. WATER FOR BOILER AND TECHNICAL USE

Waters for technical use are examined for color, odor, and mineral and organic matter in solution and suspension. The tests consist in determining the quantity and composition of matter in solution and suspension.

Samples of at least 2 liters (½ gallon)—in special cases more is required—should be furnished, representing an average sample, with information regarding source; if well or spring water, state depth or character and approximate flow; if river or stream water, state condition when sample is taken; flood-water, normal or low-water stage.

Ship in clean glass containers, suitably packed to avoid breakage.

E. MISCELLANEOUS SUPPLIES

Many materials of all kinds are received for test from time to time. Among these are sealing wax, glue and glue compositions, flax and asbestos packing, metal polishes, gasoline, mucilage, and many other substances. The kind and amount of samples required and the determination made are naturally different in each case. Upon request, this Bureau will send full information before samples are sent for test.

F. STANDARD ANALYZED SAMPLES

Analytical chemistry is taking each year a more prominent part in the manufacturing industries, and the chemist is required to furnish prompt and accurate information covering a widening range of materials for the guidance of the manufacturer. He is not always able to investigate the accuracy of the methods of analyses or to develop new methods to meet the special conditions of the case on account of the limited time at his command. To meet such conditions, the Bureau has prepared some standard samples covering the more important industrial materials, such as various grades of iron and steel, iron, zinc, and manganese ores, limestone, sugar, naphthalene, benzoic acid, sodium oxalate, etc. These samples have been analyzed with great care, not only in the Bureau's laboratories but also by other chemists, and the results carefully tabulated so as to indicate as nearly as possible the true composition of the material. These samples, described in detail in Circular No. 25, are furnished on application free to Government and State institutions and at a nominal charge to private parties.

From the description furnished, the desired sample may be selected and analyzed by any chemist using such methods and under such conditions

as he desires. From the results obtained the accuracy of the method used may be determined. Most of the samples are for general analytical use. The sugar sample was prepared as a polariscope standard. It can also be used in standardizing calorimeters, for which purpose naphthalene and benzoic acid were specially prepared. The sodium oxalate was prepared as a standard reducing agent in volumetric analysis.

The following steel samples are available:

Sample number	Name	Constituents determined
1	Argillaceous limestone	Complete analysis
2	Zinc Ore D	Zinc
4a	Iron B, Renewal	C, Si, Ti, P, S, Mn
5a	Iron C, Renewal	C, Si, Ti, P, S, Mn, Cu
6a	Iron D, Renewal	C, Si, Ti, P, S, Mn, Cu
8a	Steel, Bessemer, 0.1 C Renewal	C, Si, P, S, Mn
9a	Steel, Bessemer, 0.2 C Renewal	C, Si, P, S, Mn
10b	Steel, Bessemer, 0.4 C Renewal	C, Si, P, S, Mn, in preparation
11a	Steel, B. O. H., 0.2 C Renewal	C, Si, P, S, Mn
12a	Steel, B. O. H., 0.4 C Renewal	C, Si, P, S, Mn
13a	Steel, B. O. H., 0.6 C Renewal	C, Si, P, S, Mn
14a	Steel, B. O. H., 0.8 C Renewal	C, Si, P, S, Mn
15a	Steel, B. O. H., 0.1 C Renewal	C, Si, P, S, Mn
16a	Steel, B. O. H., 1.0 C	C, Si, P, S, Mn, in preparation
17	Sugar	Calorimetric and saccharimetric value
18	Steel, A. O. H., 0.1 C	C, Si, P, S, Mn
19a	Steel, A. O. H., 0.2 C Renewal	C, Si, P, S, Mn (Cu, Cr, Mo, V)
20	Steel, A. O. H., 0.4 C	C, Si, P, S, Mn
21	Steel, A. O. H., 0.6 C	C, Si, P, S, Mn
22	Steel, Bessemer, 0.6 C	C, Si, P, S, Mn
23	Steel, Bessemer, 0.8 C	C, Si, P, S, Mn
24	Steel, Vanadium, 0.15 V	C, Si, P, S, Mn, V (Ni, Cr, Cu, Mo)
25	Manganese Ore	Mn, Available O
26	Crescent Iron Ore	Al_2O_3, CaO, MgO
27	Sibley Iron Ore	SiO_2, P, Fe
28	Norrie Iron Ore	Mn (low)
29	Magnetite Iron Ore (titaniferous)	Full analysis
30	Steel, Chrome-vanadium	C, Si, P, S, Mn, Cr, V (Ni, Cu, Mo)
31	Steel, Chrome-tungsten	C, Si, P, S, Mn, Cr, W (Ni, Cu, Mo, W)
32	Steel, Chrome-nickel	C, Si, P, S, Mn, Cr, Ni (Co, Cu, Mo)
33	Steel, Nickel	C, Si, P, S, Mn, Ni (Co, Cr, Cu, W, Mo)
34	Steel, A. O. H., 0.8 C	C, Si, P, S, Mn (Cu, Cr, Mo)
35	Steel, A. O. H., 1.0 C	C, Si, P, S, Mn (Cu, Cr)
37	Brass, Rolling Mill	In preparation
38	Naphthalene	Calorimetric value
39	Benzoic acid	Calorimetric value
40	Sodium Oxalate	Oxidimetric value
41	Dextrose	Reduction value

Full information regarding these samples is obtained in Circular No. 25, which will be supplied on application.

16. TESTING OF INSTRUMENTS USED FOR TESTING MATERIALS

Among the instruments used for physical measurements, large classes of gauges and measuring appliances are devoted mainly to the testing of materials. From the large testing machines which test to destruction structural members to the delicate testing machine which measures the strength of a single cotton fiber a range of strength-measuring instruments is required. Likewise for each property of material which may be tested a range of instruments is required which must be calibrated before their indications may be accepted. In connection with such work the Bureau has announced, in a series of circulars covering practically the entire field of measuring instruments, the conditions under which such instruments are tested. For example, in Circular No. 8 the various tests are described which may be made upon thermometers for general and special purposes. Circular No. 7 describes the tests applied to high-temperature measuring instruments, and Circular No. 11 relates to the testing of calorimeters. These three circulars enable testing laboratories to standardize the measuring instruments used in determining the heat properties and constants of materials. In like manner electrical and optical instruments are tested and enable electrical and optical laboratories to insure the reliability of their apparatus before using them in the work of testing materials. The Bureau will issue in the near future a circular in which the tests of instruments will be summarized. In the meantime the list of circulars given on page 84 will indicate the range of such work and the classes of tests which the Bureau is prepared to undertake.

IV. SCHEDULES OF FEES

For tests not covered by the following schedules, fees will be fixed specially for each case. (See also sec. 7, p. 21, "Fees" for general conditions governing fees.)

METALS

FEE SCHEDULE 222.—Metals and Metal Products

CHEMICAL ANALYSES OF IRONS AND STEELS

(*a*) For determination of carbon $3.00–4.00
(*b*) For determination of manganese 3.00
(*c*) For determination of phosphorus 3.00
(*d*) For determination of sulphur 2.00–3.00
(*e*) For determination of silicon 3.00

The above covers only routine analyses in connection with other tests of metals. The charges for other determinations will be furnished on application.

MECHANICAL TESTS

(*g*) For tensile tests up to 200 000-pounds loading, obtaining yield point, reduction of area, elongation and maximum load, each $1.00– $2.00
(*h*) For tensile tests over 200 000-pounds loading with yield point, reduction of area, elongation and maximum load, each 2.00– 5.00
(*i*) For column tests, each 10.00– 50.00
(*j*) Wire rope samples up to ¾-inch diameter, inclusive, each 6.00
(*k*) Wire rope samples over ¾-inch diameter up to 1 inch, each 8.00
(*l*) Wire rope samples over 1-inch diameter up to 1½ inches, each 10.00

Other fees to be arranged by correspondence with the Bureau.

FEE SCHEDULE 223.—Metallography

3. FEES.

(*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 or other heat treatment of small specimens 2.50
(*d*) Determination of temperature coefficient of electrical resistance at high temperature .. 20.00
(*e*) Microscopic examination (preparation of specimen with photomicrograph of same):
(1) Magnification up to 500 diameters for first print 5.00
(2) Magnification 500 to 1000 diameters for first print 7.50
(3) Magnification above 1000 diameters, fee depends upon magnification, but minimum charge for first print 10.00
(4) For each succeeding print in every case ..... .50
(5) Microscopic examination without photomicrograph, half of above charges.

In the case of soft alloys or those whose sections for examination are very difficult to prepare, the above charges may be increased.

(*f*) Examination after failure (fee will depend upon the nature and amount of work required), minimum fee $25.00

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.

FEE SCHEDULE 224.—Composite Metal Products

(*a*) Analysis of terne plate	$6.00
(*b*) Analysis of galvanized iron	3.00

The charges for other determinations will be furnished on application.

The above prices are approximate and are based on data of costs of previous tests. Exact prices will be quoted upon application when data is furnished.

CEMENT

FEE SCHEDULE 242.—Cement

(*a*) Complete chemical analysis	$10.00
(*b*) SO_3 and MgO only	8.00
(*c*) SO_3	2.00
(*d*) MgO	6.00
(*e*) Specific gravity	.75
(*f*) Fineness	1.50
(*g*) Soundness	1.50
(*h*) Time of setting	.75
(*i*) Normal consistency	.50
(*j*) Tensile tests:	
Neat	1.00
Mortar	1.00

(*k*) The fee is to be doubled for check determinations.

(*l*) If less than two of the above properties are determined, the fee is to be doubled.

(*m*) Additional fee for sampling and inspecting, packing, and delivery is $3 per sample.

FEE SCHEDULE 243.—Cement Materials

(*a*) Weight per cubic foot	$0.50
(*b*) Void	1.50
(*c*) Fineness	2.50
(*d*) Silt	.75
(*e*) Specific gravity	.75

(*f*) Tensile—	
As received	$1.00
Standard sand	1.00
(*g*) Compressive, 2-inch cubes:	
As received	1.00
Standard sand	1.00
(*h*) Chemical analysis (if required)	10.00
(*i*) Test of suitability of raw materials for the manufacture of cement, including grinding, burning, regrinding, and testing of the resulting product	75.00

CERAMICS

FEE SCHEDULE 232.—Clay and Clay Products

(*a*) Complete test of clays and shales, excepting fire clays	$25.00
(*b*) Complete test of fire clays	35.00
(*c*) Transverse and compression test of building brick and blocks, per sample	3.00
(*d*) Absorption test for five specimens	1.00
(*e*) Freezing test, special arrangement.	
(*f*) Roofing tiles, unglazed	25.00
(*g*) Roofing tiles, glazed	30.00
(*h*) Tests of floor tiles, not including abrasion test	10.00
(*i*) Tests of floor tiles, including abrasion test	15.00
(*j*) Glazed wall tiles	5.00
(*k*) Rattler test of paving blocks and bricks	5.00
(*l*) Absorption test of drain tiles, for set of three tiles	1.00
(*m*) Transverse test, per sample	1.50
(*n*) Determination of softening point of fire clays and other refractories	5.00
(*o*) Load test of refractories	10.00
(*p*) Chemical analysis	12.00

LIME

FEE SCHEDULE 251.—Lime

(*a*) Building lime	$10.00
(*b*) Finishing lime	15.00
(*c*) Chemical lime	12.50
(*d*) Agricultural lime	10.00
(*e*) Complete series, including analysis	35.00
(*f*) For the presence of calcium oxide in hydrated lime	1.00
(*g*) Fineness	.50

FEE SCHEDULE 252.—Raw Materials for Lime and Sand Lime Brick

(*a*) Chemical analysis	$10.00
(*b*) Determination of best burning temperature	10.00
(*c*) Determination of crushing strength, transverse strength, absorption, and crushing strength (wet) of sand-lime brick	20.00
(*d*) Presence of free calcium hydroxide in sand-lime brick	1.00
(*e*) Presence of calcium carbonate in sand-lime brick	1.00

STONE

FEE SCHEDULE 262.—Stone

(*a*) Compressive (per test piece)	$1.00
(*b*) Transverse test (per test piece)	1.00
(*c*) Absorption for three test pieces	3.00
(*d*) Freezing (10 times) for 3 test pieces	10.00

FEE SCHEDULE 292.—Paint Materials

The charge for special investigations of paint materials or of routine analyses of other materials than those listed will be furnished on application to the Bureau. For routine analyses as usually made by the Bureau the fees are as follows:

(*a*) Analysis of white lead	$8.00
(*b*) Analysis of graphite paint	10.00
(*c*) Analysis of red lead, dry	2.00
(*d*) Analysis of putties	8.00
(*e*) Analysis of linseed oil	5.00
(*f*) Analysis of oil driers	10.00
(*g*) Analysis of oil varnishes	10.00
(*h*) Analysis of spirit varnishes	5.00

FEE SCHEDULE 312.—Bituminous Materials

The charge for special examination of bituminous materials will be furnished on application to the Bureau.

(*a*) Routine analysis of bituminous material or bituminous felt	$10.00

INKS

FEE SCHEDULE 282.—Inks

(*a*) Test of writing ink varies according to nature of the ink and amount of work to be done	$5.00–$10.00
(*b*) Test of printing ink	25.00
(*c*) Test of stamp-pad ink	5.00

PAPER

FEE SCHEDULE 212.—Paper

	First sample.	Each additional sample.
(*a*) Microscopical examination (fiber content of stock)	$1.50	$0.75
(*b*) Bursting strength	.50	.25
(*c*) Weight per ream	.25	.25
(*d*) Thickness	.25	.25
(*e*) Tensile strength	.50	.25

	First sample.	Each additional sample.
(*f*) Folding endurance	$1. 00	$1. 00
(*g*) Percentage of ash	1. 00	. 50
(*h*) Percentage of rosin	1. 50	1. 00
(*i*) Test for presence of animal size	. 50	. 25
(*j*) Percentage of animal size	2. 50	2. 00
(*k*) Absorptive capacity papers	1. 00	. 50

TEXTILES

FEE SCHEDULE 200.—Raw and Unspun Textile Fibers

	Fee.
(*a*) Identification of fiber (if composed of one fiber only)	$1. 00
(*b*) Identification of a mixture of fibers	1. 00–2. 00
(*c*) Quantitative determination of a mixture	1. 00–3. 00
(*d*) Determination of the approximate length (if composed of one fiber only)	1. 00
(*e*) Determination of the approximate length (if composed of two or more fibers)	1. 00–3. 00
(*f*) Quantitative determination of moisture	1. 50
(*g*) Determination of the percentage of oil or grease	1. 00
(*h*) "Shrinkage" determination of raw wool (scouring and conditioning)	2. 50–5. 00

FEE SCHEDULE 201.—Yarn, Thread, and Twine

(*a*) Measuring of skeins, cops, bobbins, spools, or balls (average of 2 tests), one sample	$1. 00
(*b*) Tensile strength determination (average of 10 tests), one sample	. 50
(*c*) Elasticity determination (average of 10 tests), one sample	. 50
(*d*) Determination of the yarn count or number (average of 5 tests), one sample	1. 00
(*e*) Twist determination of single-ply yarn (average of 20 tests), one sample	. 50
(*f*) Twist determinations of two or more ply yarns (average of 20 tests), one sample	. 50–1. 50
(*g*) Percentage fiber composition (same as for raw and unspun fibers)	1. 00–3. 00
(*h*) Determination of moisture (same procedure as for raw and unspun fibers)	1. 50

FEE SCHEDULE 202.—Fabric

(*a*) Weight (calculated for any dimension), one sample	$0. 50
(*b*) Tensile strength (average of 5 tests upon warp and filling, respectively), one sample	1. 00
(*c*) Elasticity determination (average of 5 tests upon warp and filling, respectively), one sample	1. 00
(*d*) Percentage fiber composition (average of 2 complete tests, i. e., warp, filling, and whole fabric), one sample	1. 00–3. 00
(*e*) Count of threads per inch and per centimeter (average of 10 tests both in the warp and filling directions), one sample	. 50
(*f*) Determination of the yarn count or number (average of 5 tests), one sample	1. 00–2. 00
(*g*) Folding determination (average of 3 tests for warp and filling, respectively), one sample	. 50–1. 50
(*h*) Determination of the loading, sizing, and coloring materials (average of 2 tests), one sample	1. 00–2. 00
(*i*) Action of light on colors (average of 2 tests), one sample	. 50–1. 50

FEE SCHEDULE 209.—Rope

(*a*) Manila rope up to 1-inch diameter inclusive, each	$3.00
(*b*) Manila rope over 1-inch diameter up to 2 inches, inclusive, each	4.00
(*c*) Manila rope over 2 inches diameter up to 3 inches, inclusive, each	5.00
(*d*) Manila rope over 3 inches diameter up to 3½ inches, inclusive, each	6.00
(*e*) Manila rope over 3½ inches diameter up to 4 inches, inclusive, each	7.00

RUBBER

FEE SCHEDULE 115.—Physical Tests of Rubber

(*a*) Rubber water hose, suction hose, or fire hose	$3.00–$5.00
(*b*) Rubber air hose	4.00– 6.00
(*c*) Rubber air-brake hose	4.00
(*d*) Rubber steam hose	5.00–10.00
(*e*) Rubber dredging sleeves	5.00
(*f*) Rubber sheet packing	2.00– 4.00
(*g*) Rubber and asbestos sheet packing	2.00– 4.00

When a pressure test is desired, samples of hose should be about 5 feet long, otherwise a 2-foot length will be sufficient. Samples of sheet packing should be not less than 6 inches square.

FEE SCHEDULE 116.—Chemical Tests of Rubber

The Bureau will, in its discretion, make chemical analyses for the general public only when asked to serve as referee and in special cases. The fee in such cases will depend upon the nature and amount of work required. Estimates will be sent on receipt of full information.

Chemical analyses will be made for State and municipal governments. No fees are charged to State Governments. Those for municipal governments will vary from $15.00 to $30.00 per sample, according to the amount of work required.

The Bureau reserves the right in all cases to accept or decline requests for tests, depending upon the conditions in each case.

V. PUBLICATIONS OF INTEREST IN CONNECTION WITH THE TESTING AND PROPERTIES OF MATERIALS.

Since there are many Government and public testing laboratories in the various countries engaged in the study of the properties of materials, the Bureau aims only to cover the more important problems which seem most available and needed in the several divisions of its work. The publications are not designed to cover a field, but rather to give the results of work upon special problems which were pressing or for which the Bureau's facilities were specially suited. The Technologic papers relate almost entirely to investigations upon materials so that the entire list of such papers is given. The Circulars are given complete since most of them are of interest to technologic laboratories. From the Scientific papers reprinted from the Bulletin, are selected only such as involve the properties of materials or directly related subjects.

TECHNOLOGIC PAPERS

1. The Effect of Preliminary Heat Treatment upon the Drying of Clays.
2. The Strength of Reinforced Concrete Beams. Results of Tests of 333 Beams (first series).
3. Tests of Absorptive and Permeable Properties of Portland Cement Mortars and Concretes, Together with Tests of Damp Proofing and Waterproofing Compounds and Materials.
4. The Effect of Added Fatty and Other Oils upon the Carbonization of Mineral Lubricating Oils.
5. The Effect of High-Pressure Steam on the Crushing Strength of Portland Cement Mortar and Concrete.
6. The Determination of Chromium and Its Separation from Vanadium, in Steels.
7. The Testing of Clay Refractories, With Special Reference to Their Load Carrying Capacity at Furnace Temperatures.
8. A Rapid Method for the Determination of Vanadium in Steels, Ores, etc., Based on Its Quantitative Inclusion by the Phosphomolybdate Precipitate.
9. The Density and Thermal Expansion of Linseed Oil and Turpentine.
10. The Melting Points of Fire Bricks.
11. Comparison of Five Methods Used to Measure Hardness.
12. Action of the Salts in Alkali Water and Sea Water on Cements.
13. The Evaporation Test for Mineral Lubricating and Transformer Oils.
14. Legal Specifications for Illuminating Gas.
15. Surface Insulation of Pipes.

16. The Manufacture of Lime.
17. The Function of Time in the Vitrification of Clays.
18. Electrolysis in Concrete.
19. Physical Testing of Cotton Yarns.
20. Determination of Sulphur in Illuminating Gas.
21. The Dehydration of Clays.
22. The Effect of Overfiring Upon the Structure of Clays.
23. The Technical Control of the Colloidal Matter of Clays.
24. The Determination of Phosphorus in Steels Containing Vanadium.
25. Electrolytic Corrosion of Iron in Soils.
26. Earth Resistance and Its Relation to Electrolysis.
27. Electrolysis Mitigation.
28. Methods of Making Electrolysis Surveys.
29. The Variation in the Results of Sieving with Standard Cement Sieves.

CIRCULARS

2. Measurements of Length and Area, Including Thermal Expansion.
3. Verification of Standards of Mass.
4. Verification of Standards of Capacity.
5. Testing of Clinical Thermometers.
6. Fees for Electric, Magnetic, and Photometric Testing.
7. Pyrometer Testing and Heat Measurements.
8. Testing of Thermometers.
9. Testing of Glass Volumetric Apparatus.
10. Legal Weights (in pounds) per Bushel of Various Commodities.
11. The Standardization of Bomb Calorimeters.
12. Verification of Polariscopic Apparatus.
13. Standard Specifications for the Purchase of Incandescent Lamps.
14. Samples of Analyzed Irons and Steels—Methods of Analysis.
15. A Proposed International Unit of Light.
16. The Testing of Hydrometers.
17. Magnetic Testing.
18. Standard Gauge for Sheet and Plate Iron and Steel.
19. Standard Density and Volumetric Tables.
20. Testing of Electrical Measuring Instruments.
21. Precision Measurements of Resistance and Electromotive Force.
22. Standard Specifications for Transformers, Oil-immersed, Self-cooled, 60-cycle, 2200 Volts.
23. Standardization of Electrical Practice in Mines.
24. Publications of the Bureau of Standards.
25. Standard Analyzed Samples—General Information.
26. Analyzed Iron and Manganese Ores—Methods of Analysis.
27. The Testing and Properties of Optical Instruments.
28. The Determination of the Optical Properties of Materials.
29. Announcement of a Change in the Value of the International Volt.
30. Lime: Its Properties and Uses.
31. Copper Wire Tables.
32. State and Municipal Regulations for the Quality, Distribution, and Testing of Illuminating Gas.
33. United States Government Specification for Portland Cement.

34. The Relation of the Horsepower to the Kilowatt.
35. Melting Points of Chemical Elements.
36. The Testing and Properties of Electrical Condensers.
37. Electric Wire and Cable Terminology.
38. The Physical Testing of Mechanical Rubber Goods.
39. Specifications for and Measurement of Standard Sieves.
40. Sodium Oxalate as a Standard in Volumetric Analysis.
41. Testing and Properties of Textile Materials.
42. Metallographic Testing.
43. The Metric Carat.
44. Polarimetry.
45. The Testing of Materials.

SCIENTIFIC PAPERS

7. On Fibers Resembling Quartz in Their Elastic Properties.
11. Optical Pyrometry.
15. Use of Serpentine in Standards of Inductance.
38. Experiments on the Heusler Magnetic Alloys.
52. The Influence of Basic Lead Acetate on the Optical Rotation of Sucrose in Water Solution.
53. On the Colorimetric Determination of Iron, with Special Reference to Chemical Reagents.
54. On Sulphocyanic Acid.
55. Radiation from and Melting Points of Palladium and Platinum.
62. Melting Points of the Iron Group Elements by A New Radiation.
77. The Atomic Weight of Hydrogen.
78. The Best Method of Demagnetizing Iron in Magnetic Testing.
81. The Atomic Weight of Chlorine.
99. Methods of Obtaining Cooling Curves.
105. Radiation, Constants of Metals.
108. Errors in Magnetic Testing with Ring Specimens.
109. The Testing of Transformer Steel.
120. The Thermoelectric Properties of Tantalum and Tungsten.
131. Selective Radiation from Various Solids, II.
135. Specific Heat of Some Calcium Chloride Solutions between $-35°$ C and $+20°$ C.
147. The Temperature Coefficient of Resistance of Copper.
148. The Electrical Conductivity of Commercial Copper.
149. On the Constancy of the Sulphur Boiling Point.
152. The Reflecting Power of Various Metals.
153. The Action of Sunlight and Air upon Some Lubricating Oils.
160. The Behavior of High-Boiling Oils on Heating in the Air.
161. The Determination of Vanadium in Vanadium and Chrome-Vanadium Steels.
174. The Determination of Total Sulphur in India Rubber.
178. The Hydrolysis of Sodium Oxalate and Its Influence Upon the Tests for Neutrality.
182. Standardization of Potassium Permanganate Solution by Sodium Oxalate.
183. Benzoic Acid as an Acidimetric Standard.
186. Determination of Manganese as Sulphate and by the Sodium Bismuthate Method.
192. On a Modified Form of Stability Test for Smokeless Powder and Similar Materials.
193. Atomic Weight of Bromine.

196. The Diffuse Reflection Power of Various Substances.
198. A Micropyrometer.
205. Melting Points of the Refractory Elements. I.—Elements of Atomic Weight 48 to 59.

For complete list of technical papers see Circular No. 24 (a copy of which will be furnished upon request).

Any of the above papers may be obtained by those interested upon application.

S. W. STRATTON,
Director.

Approved:
EDWIN F. SWEET,
Acting Secretary.

INDEX

A

Page

Acid, mineral 70
organic 70
Application for testing 19
Architectural terra cotta 38
Ash 70

B

Bituminous material 52, 80
Blocks, paving 40
clay building 38
Bricks, paving 40
clay building 38
sand lime 45

C

Carbonization 71
Cement 78
hydraulic and concrete 30
materials 78
natural 34
Portland 30
raw materials 35
white 33
Ceramics 37
Chemical analysis 24
Chemical tests 31
Chemicals 72
Choice of tests 17
Classes of materials 10
Clay building brick and blocks 38
Clay products 38, 79
Clays and shales 37
Clays, fire 41
Colorants 47
Colors, oil 47
tinting 47
water 47
Composite metal products 28, 78
Compression tests 26

D

Page

Determination of properties of materials. 12
Driers 48
Drying power 58

E

Electrical and magnetic materials 72
Enamels for cast iron and steel 30
Evaporation and gumming 71

F

Fabric 81
Fat 71
Fees for testing 21
Fees, schedules of 77–82
Fineness 33
Fire clays 41
Fire proofing for steel protection 41
Flash and fire points 69
Flexure tests 27
For whom tests are made 21

G

General information concerning material testing 17
Gravity, specific 33, 71
Greases 71

H

Hardness tests 27
Hydraulic cement 30

I

Identification marks 20
Improvement of specifications 16
Inks 56, 80
printing 57
stamp pad 58
writing 56
Interpretation of results 20
Introduction 9

L

Page

Leather ... 68
Lime ... 42, 79
  burnt ... 42
  hydrated ... 44
  products and raw materials for lime ... 79
Lubricating oils and greases ... 68

M

Magnetic ... 72
Measure of quality ... 12
Measurements, strain ... 27
Mechanical tests ... 24
Metallographic examination and heat treatment ... 24
Metals ... 23, 77
Metals and metal products ... 23
Metals, plated or coated ... 29
Mineral acid ... 70
Miscellaneous materials ... 74
Miscellaneous technical materials ... 72
Miscellaneous tests, physical ... 27

O

Oil colors ... 47
Oil, linseed and other drying oils ... 48
  lubricating and greases ... 68
Oil varnishes ... 49
Oil, volatile thinners ... 48
Oils ... 48
Optical materials ... 73
Organic acid ... 70

P

Paints ... 50
  enamel ... 47
  materials ... 47, 80
Paper ... 59, 80
Paving blocks and bricks ... 40
Petroleum products and volatile thinners ... 48
Physical tests ... 32, 65
Pigments ... 47
Pipe, sewer ... 40
Plated and coated metals ... 29
Porcelain and white ware ... 40
Portland cement ... 30
Products, clay ... 38
  metal ... 23
Properties of materials ... 11
Publications ... 83

R

Page

Raw cement materials ... 35
Refractories ... 41
Results of tests and their interpretation ... 20
Roofing tiles ... 39
Rope ... 82
  manila ... 64
  wire ... 26
Rubber ... 64
  chemical tests ... 82
  physical tests ... 82

S

Samples, standard analyzed ... 74
Sampling and test pieces ... 17
Sampling and testing under specifications ... 28
Sand and stone screenings ... 35
Sewer pipe ... 40
Shale ... 37
Shipping instructions ... 19
Soap ... 70
Soundness ... 32
Special information concerning classes of materials tested ... 23
Specific gravity ... 33, 71
Specifications or standards of quality ... 15
Stains ... 47
Stone ... 46, 80
Stone screenings ... 35
Strain measurements ... 27

T

Tensile strength ... 33
Terra cotta, architectural ... 38
Tests ... 50
  absorption ... 47
  interpretation of results ... 53
  asphalt ... 70
  chemical ... 31
  choice of ... 17
  cold ... 69
  compression ... 26
  flexure ... 27
  freezing ... 46
  hardness ... 27
  instruments used for testing materials ... 76
  materials ... 9
  mechanical ... 25, 69

Tests—Continued. Page
physical 27, 28, 32
tension 25
time required for 20
torsion 27
transverse 47
Textile fibers, raw and unspun 81
Textiles 62, 81
Thermal materials 73
Thinners, volatile and petroleum products 48
Thread 81
Tiles 39
drain 40
floor 39
glazed wall 39
roofing 39
Tinting colors 47
Page
Torsion 27
Torsion tests 27
Twine 81

V

Varnishes, oil 49
spirit 49
Viscosity 69

W

Water for boiler and technical use 74
Water colors 47
White cement 33
White ware 40

Y

Yarn, thread, and twine 81