ANNUAL REPORT

OF THE

DIRECTOR

OF THE

BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1922

(Miscellaneous Publications—No. 50)

WASHINGTON
GOVERNMENT PRINTING OFFICE
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BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE

Washington, D. C.

1922

FUNCTIONS

Development, construction, custody, and maintenance of reference and working

STANDARDS - - - - - - - - - - - - -

and their intercomparison, improvement, and application in science, engineering, industry, and commerce.

9644—22. (Face p. 1.)

REPORT

OF THE

DIRECTOR, BUREAU OF STANDARDS.

Department of Commerce,
Bureau of Standards,
Washington, July 1, 1922.

Sir: There is submitted herewith a report of the work of the Bureau of Standards for the fiscal year ended June 30, 1922.

I. FUNCTIONS, ORGANIZATION, AND LOCATION.

Before describing in detail the various scientific and technical problems in which the Bureau of Standards is engaged the following brief statement as to its functions and organization may be helpful to those unfamiliar with the subject of standardization in its broad and modern sense.

The standards with which the bureau is authorized to deal may be conveniently classed as follows: Standards of measurement, standard values of constants, standards of quality, standards of mechanical performance, and standards of practice.

DEFINITION OF STANDARDS.

Standards of Measurement.

A standard of length may be taken as an example of a standard of measurement. It must be a length which is unchanging, reproducible, and capable of being compared with the working standards used in the most precise scientific work or with those used in commerce and industry. In order to carry out such comparisons, working standards must be prepared which are subdivisions and multiples of the fundamental standard, and this process of subdividing and multiplying the standard involves difficulties as great as those met with in the preparation of the fundamental standard itself.

The construction of a set of standard weights from a single unit is also an illustration; a whole set of standard weights must be prepared before the standard weight of the Government can become available to the public. Before these working standards, made up of subdivisions and multiples of the fundamental standard, can be prepared questions as to the methods of comparison arise, which again involve the solution of difficult scientific problems in connection with the balance or the methods used. These balances range from that capable of measuring the thousandth part of a milligram to the large testing machine with a capacity of thousands of tons. The

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STANDARDS	PURPOSE
1. STANDARDS OF MEASUREMENT — Reference and working standards for measurements of all kinds, including fundamental and derived STANDARDS OF MEASUREMENT for expressing the quantitative aspects of space, time, matter, energy, motion and of their interrelations. By definition, specification, or material standard, covering, for example, length, area, and volume; mass, weight, density, and pressure; heat, light, electricity, and radioactivity, including quantity, flux, intensity, density, etc.	To aid ACCURACY IN INDUSTRY through uniform and correct measures; To ASSIST COMMERCE IN SIZE STANDARDIZATION of containers and products; To PROMOTE JUSTICE IN DAILY TRADE through systematic inspection and regulation; To facilitate PRECISION IN SCIENCE and TECHNOLOGIC RESEARCH through calibration of units, measures, and instruments involved.
2. STANDARD CONSTANTS — Natural standards or the measured numerical data as to materials and energy, known as physical or STANDARD CONSTANTS, i. e., the fixed points of quantities which underlie scientific research and industrial processes when scientifically organized. Mechanical equivalent of heat, light, and electricity and of gravitation; specific densities; viscosities; melting and boiling points; heat capacity; heats of combustion; velocity of propagation of light; conductivities of materials to heat and light; electrochemical and atomic weights and many similar magnitudes determined experimentally with maximum precision and referred to fundamental standards of measure.	To SERVE as an EXACT BASIS for scientific study, experiment, computation, and design; To FURNISH an EFFICIENT CONTROL for industrial processes in securing reproducible and uniformly high quality in output; To SECURE UNIFORMITY OF PRACTICE in graduating measuring instruments, compiling tables, in standards of quality and performance, and wherever uniformity is desirable; To AID LABORATORY RESEARCH BY REDUCING ERRORS and uncertainty caused by use of data of doubtful accuracy.
3. STANDARDS OF QUALITY — Specifications for material (by description, sample, or both), known as STANDARDS OF QUALITY, fixing in measurable terms a property or group of properties which determine the quality. The numerical magnitude of each constituent property pertinent to the quality involved, and specific magnitude in units of measure of such significant factors as uniformity, composition, form, structure, and others.	To secure HIGH UTILITY in the PRODUCTS of industry by setting an attainable standard of quality; To furnish a SCIENTIFIC BASIS for FAIR DEALING to avoid disputes or settle differences; To PROMOTE TRUTHFUL BRANDING and ADVERTISING by suitable standards and methods of test; To PROMOTE PRECISION and AVOID WASTE in science and industry by affording quality standards by which materials may be made, sold, and tested.
4. STANDARDS OF PERFORMANCE — Specification of operative efficiency or action for machines and devices, STANDARDS OF PERFORMANCE specifying the factors involved in terms susceptible of measurement. Numerical statement of speed, uniformity, output, economy, durability, and other factors which together define the net efficiency of an appliance or machine.	To CLARIFY THE UNDERSTANDING between maker, seller, buyer, and user as to operative efficiency of appliances and machines; To make EXACT KNOWLEDGE THE BASIS OF the buyer's choice; To STIMULATE AND MEASURE MECHANICAL PROGRESS.
5. STANDARDS OF PRACTICE — Codes and regulations impartially analyzed and formulated after study and experiment into STANDARDS OF PRACTICE for technical regulation of construction, installation, operation, and based upon standards of measurement, quality, and performance. Collation of standard data, numerical magnitudes, and ranges of the pertinent factors defining quality, safety, economy, convenience, and efficiency.	To FURNISH for each utility a single IMPERSONAL STANDARD of practice as a BASIS FOR AGREEMENT of all interests clearly defined in measurable terms; To INSURE EFFECTIVE DESIGN and INSTALLATION of utilities of all kinds; To PROMOTE SAFETY, EFFICIENCY, and CONVENIENCE in the maintenance and OPERATION of such utilities; To SECURE UNIFORMITY OF PRACTICE where such is practicable, and EFFECTIVE ALTERNATES in other cases.

complete range must be covered, which involves not only a large number of working standards, all of which must agree with the fundamental standard, but apparatus suitable for the comparison of these standards with all of the lengths or weights found in practice. These steps and equipment are absolutely essential in order to secure uniform measurements of length or weight throughout the country, and they have their counterpart in every quantity that has to be measured, whether it be length, weight, temperature, heat, light, or the various electrical measurements or other standards of measurement. These standards in one form or another are involved in practically every scientific investigation, industrial process, engineering structure, or commercial transaction.

Physical Constants (Standard Values).

There are many fixed relations between physical quantities, the values of which it is extremely important to know. These values are usually termed "physical constants" and are used in every branch of scientific work or industry. The amount of heat required to change a pound of water into steam under normal conditions and the relation between heat and mechanical energy are two important physical constants. Their values are used in practically every computation in connection with the designing of steam engines and boilers, the tests of their efficiencies, or the measurement of their output. The amount of heat required to turn liquid ammonia into vapor or the amount of heat required to melt a pound of ice are constants equally important in the refrigerating industries. The value of the relation between electrical and mechanical energy is involved in many commercial transactions concerned in electricity.

Accurate and authoritative values of these constants are just as essential as in the case of standards of measurement. Many of those now in use are old and obsolete and need redetermination by means of the best modern facilities for physical measurement. Their determination involves the most difficult and precise work in all branches of physics and chemistry—a fact not generally known by those not engaged in the scientific or technical work where these constants are used.

Standards of Quality.

A standard of quality for a given material may sometimes take the form of a sample of that material with which other materials of the same kind can be compared, but this is generally a makeshift of the poorest sort. It is only resorted to in the absence of definite and reliable specifications in terms of measurable properties; that is to say, a standard of quality of a material usually takes the form of a specification or definition of its properties, involving, of course, the measurement of those properties by means of the usual standards of measurement. A certain kind of steel, a cement, a paint, an oil, a paper, or a cloth is found by use to be good or poor for a definite purpose. The questions then arise: Why is it good or poor? What are the physical or chemical properties or the particular combination of elements which make it of good or poor quality? How are its properties to be measured or its constituents determined? These are questions for the laboratory to answer and involve physical and chemical investigations of the most difficult sort.

A standard of quality for a given material necessarily takes into account the purpose for which the material is to be used. To set the standard too low results in losses, poor efficiency, and even loss of life; to make it too high may result precisely in the same thing; that is to say, the material must be suitable for the purpose intended, and the bureau's investigations in connection with the properties of materials are to enable the user of these materials, first, to select intelligently the material best suited for the purpose; second, to specify it in terms which the producer can not mistake; and, third, to make the necessary tests to ascertain whether or not the material supplied is in accordance with the specifications.

Standards of Performance.

The value of an instrument, device, or machine almost always depends upon the efficiency of its performance. In such cases it is necessary to state the performance desired or guaranteed in terms which are correct and susceptible of measurement. As in the case of standards of quality, the standard involved is more often in the form of a specification, but specifications are useless unless based upon correct scientific and mechanical principles and supplemented with a statement of the method to be used in ascertaining whether or not the specification or guaranties have been complied with.

The performance of an engine or boiler, a pump, an electrical generator or motor, a weighing device, or a telescope can usually be measured, but the quantities to be measured and the methods used must be specified correctly and understood by all the parties concerned in the construction, purchase, or use of such apparatus. To secure information upon which to base proper standards of performance involves investigations quite as scientific in character and as difficult as in the case of other standards, as well as a knowledge of technical and manufacturing processes. In this field, as well as in the field dealing with the properties of materials, the bureau has had the hearty cooperation of the various Government experts, manufacturers, engineers, and technical societies. It has conducted many investigations which have led to improvements in machinery, appliances, and manufacturing processes.

Standards of Practice.

Standards of practice are generally involved in the enactment of laws when technical and scientific matters are concerned, in the ordinances relating to the regulation of public utilities, and in the establishment of building and safety codes. Like standards of performance, they are dependent upon standards of measurement and standards of quality and are of the most vital importance in questions pertaining to the welfare and safety of the public. In a field so broad the bureau can only touch upon the more important aspects of the work, where national uniformity is desired—fields which are not covered in private laboratories.

RELATION OF THE BUREAU'S WORK TO THE PUBLIC.

Comparison of Standards of Scientific and Educational Institutions or of the Public with Those of the Bureau.

It is perfectly obvious, even to one unfamiliar with the subject, that the maintenance on the part of the Government of correct standards of measurement or quality or performance calls for continuous scientific and technical investigations of the highest grade, involving the most competent expert services and the best scientific equipment. When this is accomplished, there still remains the serious problem of making the results available and useful to the public.

The bureau compares with its own standards of measurement the standards and measuring instruments of States, cities, scientific laboratories, educational institutions, and the public. In this way the standards of the National Government are made available to everyone in the country. For these comparisons a nominal fee is charged, except in the case of National and State Government institutions. The bureau is at all times glad to assist these institutions in matters concerning these standards or their use, whether it be in connection with the enactment of laws, regulations, or ordinances concerning the weights and measures of everyday trade or in connection with precision standards used in scientific work.

Work of the Bureau in an Advisory Capacity.

The bureau serves in an advisory capacity for those officials of the States and municipalities charged with the administration of the laws governing weights and measures. Likewise its advice is gladly given concerning the use of exact standards in all lines of work. This information is of the first importance to many individuals and industries. As an example it may be stated that the success or failure of an industrial enterprise may depend upon the securing of correct information concerning the control of temperature, advice which can be secured only from such an institution as the bureau.

A great many inquiries are also received concerning the use of the various materials of construction. The bureau has frequently been able to assist in the intelligent selection of materials for given purposes and in advising concerning the best forms of construction to use under difficult or peculiar conditions.

Many questions of disagreement between the public and utility companies as to matters involving the use of standards are referred to the bureau for advice or adjustment, often avoiding unfair and inconsistent regulations, as well as long-drawn-out and expensive litigation. There is a great need on the part of the public for unbiased and reliable information pertaining to the standards entering into the regulation and sale of the services of public utilities. As far as possible such information is given in the form of publications upon definite subjects.

In the formulation of safety codes, designed to govern electrical and other construction, the bureau has taken an active part, particularly in the collecting and study of data, upon the correct interpretation of which the success of such regulations must always depend.

RELATION OF THE BUREAU'S WORK TO THE INDUSTRIES.

Assistance in Establishing Exact Standards of Measurement Needed in Industries.

As before mentioned, it must not be inferred from the above that the bureau's activities are devoted principally to the interests of the user or consumer. The fundamental facts regarding standards of measurement, quality, or performance are the very things which most deeply concern manufacturers; they are fundamentally concerned, either directly or indirectly, with the improvement of methods of production or the quality of the output. It may be said that the bureau occupies somewhat the same position with respect to the manufacturing interests of this country that the bureaus of the Department of Agriculture do to the agricultural interests. Many industries realize the importance of scientific investigation which, in practically every case, involve some kind of precision measurement.

It is upon quality as well as upon price that competition must finally depend, whether in domestic or foreign commerce. The use of exact methods and scientific results is the greatest factor in the improvement of quality, efficiency, or the development of new industries. The educational value of the bureau's work in this respect is almost entirely unknown to the general public, and yet the bureau receives hundreds of letters, as well as many personal visits, from manufacturers seeking information as to standards of measurement, how to use them, how to measure the properties of materials, or as to the fundamental, physical, and chemical principles involved; also, what is of even greater importance, how to initiate and carry out scientific investigations and tests on their own account in their particular fields of work.

The importance of maintaining scientific institutions having to do with standardization and the application of precise measurements to the industries has been recognized by all the leading countries of the world. Great Britain maintains the Standards Department of the Board of Trade, which is in charge of the standards and inspection service of the trade weights and measures; also the National Physical Laboratory, whose functions include matters pertaining to scientific and technical standards, physical constants, and to some extent the properties of materials. The Laboratoire d'Essais of France, while not as extensive as the English institution, is charged with similar duties. Germany maintains three such institutions—the Normal-Eichungs Kommission, equipped with the buildings, personnel, and apparatus necessary in standardizing and controlling the weights and measures of trade; the Physikalisch-Technische Reichsanstalt, covering testing and investigations in connection with scientific and technical standards other than weights and measures; and the Materialprüfungsamt of the Prussian Government, a large institution devoted to the investigating and testing of structural, engineering, and other materials. It is generally recognized that these institutions have been exceedingly important factors in the industrial progress of these countries.

The Collection of Fundamental Data for the Industries.

During the past year the bureau has continued its close cooperation with American industries. It has continued to act as a clearing house for fundamental, scientific, and technical information, and manufacturers are coming to realize more and more that they can often secure from the bureau general and sometimes even specific advice concerning improvements in their particular industrial processes. The solution of many difficult problems in the industries can not be reached in commercial plants, but requires the work of a specially equipped research laboratory, working always in close cooperation with manufacturers who are the best judges of the practical aspects of the problem.

Standardization.

Definition.—Standardization is the unification of methods and practices involved in manufacturing and construction and all lines of endeavor which present the necessity of performing repetition work.

Phases of standardization.—Standardization of nomenclature enables buyer and seller to use the same language and makes it possible to compel competitive sellers to do likewise. Standardization of variety, or simplification, involves the elimination of unnecessary types, shapes, sizes, and grades of manufactured articles. Dimensional standardization insures ready interchangeability of supplies and the proper interworking of parts which may be manufactured or assembled by different manufacturers. Standard specifications and tests put tenders on an easily comparable basis and promote fairness in trade competition.

Benefits.—In industrial standardization it is the buyer in the first instance to whom standardization is of the greatest importance and value, for it enables him to know exactly what he can purchase and to be sure that he gets what he asks for in return for his money. But it is also of great value to the manufacturer, for it simplifies his work and enables him to produce what is required by the purchaser cheaply and expeditiously.

How accomplished.—For many years the Bureau of Standards has been serving in an advisory capacity and as a testing laboratory for the various branches of the Government and to industry with reference to the best methods of testing materials. It has also made tests and inspections and aided in the preparation of specifications.

This has been very useful to the bureau as well as to the Government and industry, for it has brought the bureau into direct contact with the actual user. An important function of the bureau is to build up specifications on a proper scientific basis.

In the building up of these specifications or in the investigation of materials the bureau can not proceed far nor would it be fair or proper to do so without cooperation with the manufacturer, for it is, of course, very important to know the conditions and limitations with which the manufacturer is confronted in producing the material before prescribing the conditions, requirements, and tests which his product should meet.

Bureau experts handling the particular work meet with representatives of the manufacturers and users of the materials and discuss the subject from every angle. From the combined experience of all concerned standards and specifications are developed. Subsequent meetings bring out the improvements in the art of production and conditions of use and it becomes necessary to revise the specifications and methods of testing. This requires constant contact between user and manufacturer.

Results.—During the past year the Federal Specifications Board has been organized as a part of the economy program of the Government under the Bureau of the Budget. This board is bringing about the use of standard specifications by all departments and independent establishments of the Government for use in connection with the purchase of the more important materials. This is done by the cooperation and advice of the experts in the use of a given article or material in the Government service, and especially through the research and testing bureaus of the Government.

The Bureau of Standards has taken an active part in this work, and a complete revision of the Government specifications for the more important commercial materials is well under way. Several standard specifications have been adopted and promulgated as official Government standards. Those promulgated to date are: Portland cement; petroleum products; pneumatic and solid tires and inner tubes; various paints, varnishes, and oils; incandescent electric lamps; lumber; feeds and forage; soap; leather belting; and fire extinguisher liquid. Technical committees are at work on specifications for the following groups of materials: Rubber products; refractories; electrical supplies; metals; builders' hardware; plumbing fixtures; textiles; wire rope and cables; bituminous roofing and waterproofing compounds; pipe, tubing, and valves; linoleum and mastic flooring; heat insulating material; gaskets and packing; coal; brushes and brooms; hand fire extinguishers; and miscellaneous oils.

Simplification.

Another very important class of work in which the Department of Commerce is greatly interested is the simplification of industrial products through the elimination of useless sizes, unnecessary variations in the composition of materials intended for the same purpose, and the concentration of the attention of manufacturers upon articles of the greatest interchangeability.

To illustrate the need of this work, it is only necessary to consider that in the majority of our industries many sizes and styles of products have come into use, not through any real demand for such a variety of articles but through the natural expansion of the business. The keeping of so many sizes and styles in stock is a source of unnecessary expense, and several investigations recently conducted have shown that large sums can be saved to many of our industries by simplifications of this sort.

Elimination of Industrial Wastes.

In cooperation with the industries of the country the bureau is assisting in the great problem of the elimination of industrial wastes, which, like all major problems, depends for its solution upon correct fundamental scientific and technical data. For many years the bureau has kept in touch with industrial processes and has acted as a clearing house for certain kinds of information concerning improvements in methods of production. It has assisted in the preparation of specifications, codes, and ordinances, all having for their primary object the increasing of industrial efficiency. Through its researches ways and means have been found for the better utilization of our raw materials, for cheapening and improving the quality of manufactured articles, and for turning to useful purposes the by-products of industrial plants. The following are some of the investigations directly bearing on this subject, which are now in progress in the bureau's laboratories:

A complete study of automobile engine performance, both in the laboratory and in cars on the road, is being carried out with the object of increasing the efficiency of internal-combustion engines. If the bureau, through this work, can assist in lowering the gasoline consumption of automobiles only 10 per cent for a given mileage, it will represent a saving to the country of something like $100,000,000 per year.

Large sums are lost each year through the corrosion of underground pipes, conduits, and metal structures. Part of this is the result of electrolytic action, while part is caused by conditions of the soil. The bureau has mapped out an extensive program to study this subject, and, if possible, to suggest means for preventing this waste. Pieces of pipe have been buried in different sections of the country, and the effect of the soil in these localities on the metal will be studied.

Most appliances used for heating by gas are operated at very low efficiency, with a consequent waste of gas and also with a very bad effect on persons working in the same room, because imperfect combustion means generation of carbon monoxide, which is extremely poisonous. The bureau has studied very thoroughly the subject of improving both natural and artificial gas burners and has already issued recommendations which will greatly reduce gas consumption and improve the health of the users.

In the field of building construction more material than is necessary is often used for a wall, column, or floor slab, because information concerning the stresses which such structures or members can safely bear, their ability to resist fire, etc., is inaccurate or incomplete. In order to more definitely formulate safe and economical standards in this field the bureau is investigating the suitability of rerolled steel as a reinforcement for concrete, the strength of walls and floors, the resistance of buildings to fire, and the constitution of cement and concrete.

Electroplating plays an important part in many industries, but until recently very little attention has been paid to the scientific side of the problem. The bureau has found that by properly controlling the baths, regulating the current, etc., great economies can be effected and a more satisfactory product turned out. For this reason a great deal of work is being done in this field with the hearty cooperation of the electroplating industries.

Work of equal importance in connection with the elimination of waste now in progress in the laboratories includes: Research on electric batteries; determination of dielectric losses; study of heat flow in structures and materials; thermal conductivity of materials at high temperatures; study of sound transmission of structural materials; spectroscopic analysis of metals; elimination of gases in metals; power losses in automobile tires; reclamation of used lubricating oil; use of low-grade cotton for bagging, etc.; study of the heat-retaining properties of blankets and clothing; utilization of American clays in the paper industry; utilization of flax straw and tow for making paper; utilization of refuse molasses; recovery of waste sugar, as well as many other investigations.

Training of Experts in Various Industrial Fields.

One of the greatest services which the bureau performs for the industries is the training of men for scientific and technical research work. Many young men receive what is, in some respects, better than a postgraduate course by working in some of the minor scientific positions at the bureau during the years immediately following the completion of their college course. These men then go into the industries with a better conception of the problems of research work.

In this connection it should be mentioned that, while the entrance salaries in these lower-grade positions are perhaps sufficient, those paid the more experienced members of the scientific staff are wholly inadequate. This has resulted in the present difficulty of retaining the most valuable men in the Government service. It is assumed that as soon as possible this unsatisfactory condition will be remedied and the salaries of these experts placed more on a plane with the compensation for similar work in industrial and even educational institutions. Unless steps are taken to meet this situation it will be impossible to maintain the bureau's staff on the high plane of efficiency which it has always occupied.

RELATION OF THE BUREAU'S WORK TO THE GOVERNMENT.

Comparison of Standards of Other Government Departments with Those of the Bureau.

The use of standards enters into almost every activity of the Government, as it does into every industry and into the everyday life of all persons. The work done for the Government is in no wise different from that carried on for individuals and involves the same problems.

Many bureaus of the Government service are charged with the administration of laws and the establishment of regulations, the intelligent application of which depends very largely on the use of exact standards. This is true to a greater extent than is generally supposed. The Bureau of Standards has cooperated freely with these branches of the Government, and the service rendered has involved every department of physics and chemistry covered by the bureau's activities. The neglect of such matters in the past has been a frequent source of misunderstanding and litigation between the Government service and the public. Conspicuous examples of bureaus to which assistance has been given are the Customs and Internal Revenue Services, Steamboat Inspection and Coast Guard Services, and the Bureau of Navigation of the Department of Commerce, as well as all bureaus of the War and Navy Departments engaged in construction or development work.

Performance of Tests and Investigations and the Collection of Scientific Data of a Fundamental Nature.

The engineering and building construction in progress at all times by the Government is exceedingly great, both in variety and magnitude. In all of it a knowledge of the materials employed is of fundamental importance from the standpoints of economy, efficiency, and safety. The work of investigating the properties of structural materials was taken up and is carried on primarily for the purpose of securing the information needed by the Government service in its structural work. This information is necessary to the public in construction work, and every effort is made by the bureau to render its findings available to the public generally. The demands for information of this sort have come from practically all Government bureaus and establishments, but especially in connection with the structural work carried on by the office of the Supervising Architect, the engineering branches of the Army, the Bureau of Construction and Repair of the Navy, the Panama Canal, and the Reclamation Service.

Advisory and Consulting Capacity.

One of the most important services which the bureau has been able to render to other departments of the Government, both civil and military, has been of an advisory and consulting nature in matters pertaining to the scientific work in which these departments are interested. Too great emphasis can not be placed on the importance of this phase of the bureau's work. Its maintenance would be warranted for this reason alone, even though its usefulness in this field is but a small portion of the total service which it has rendered other branches of the Government.

The bureau's laboratories have been open and its experts available at all times to every department of the Government, and in many cases substantial help has been rendered to the military and civil departments through the familiarity of the bureau with certain kinds of work and its ability to quickly decide whether the particular methods, materials, or devices were suitable for the service in question.

The Bureau as a Testing Laboratory and Its Work in the Preparation of Specifications on Which to Base the Purchase of Materials.

The Bureau of Standards serves as a testing bureau for the various departments of the Government when called upon; and, as such, is assisting to place Government purchases upon an economical and businesslike basis. The example of the Government in such matters has a far greater influence upon the public than is generally supposed. The Government can do no greater service to the country than to place its own purchases upon a basis which may be taken as a standard by the public at large. This work involves the specification of a wide range of structural and miscellaneous materials and their testing, when delivered, to ascertain whether or not they comply with the specifications. This is especially important, since such materials are purchased by means of competitive bids, a method resulting in much fraud and injustice unless suitable standards are established and successful bidders held absolutely to this standard in making deliveries. Furthermore, most purchasing officers are realizing the great importance of having such testing done by a disinterested institution equipped with the scientific and other facilities for performing the service in a manner that is fair to both parties concerned in the purchases.

Among the Government bureaus and establishments which have utilized the Bureau of Standards as a testing institution in connection with the purchase of supplies may be mentioned the Government Printing Office, in connection with the purchase of paper, inks, and printing supplies, and the Post Office Department, in connection with the purchase of paper, twine, textiles, etc. A wide range of materials has been tested for the Quartermaster Corps of the Army, the Bureau of Supplies and Accounts of the Navy, and the Panama Canal. The General Supply Committee has called upon the bureau for assistance in the specification of all sorts of supplies and equipment, as well as the testing of samples submitted by bidders of the supplies bid upon. Practically every branch of the Government service, including the District of Columbia, utilizes the Bureau of Standards as a testing bureau. Here, again, as in other fields of the bureau's activities, it gains much useful knowledge, which is given to the public in the form of suitable publications.

ORGANIZATION.

The organization of the bureau's scientific and technical staff is based upon the nature of the expert service involved rather than upon the classes of standards. For example, the division of weights and measures has to do with all matters pertaining to standards of length, mass (weight, as it is commonly termed), time, density, and similar questions, whether they arise in connection with the precision standards used in scientific investigation, the master standards of manufacturers, or the ordinary weights and measures of trade. A standard of quality or performance where any of the above measurements form the fundamental and most important factor would be referred to this division.

The division of temperature and heat has to do with heat standards, the testing of heat-measuring apparatus, the determination of heat constants, of which there are many, and all investigations pertaining to quality or performance where heat measurement is the essential and predominating factor.

Similarly, the electrical division is concerned with all the electrical problems that may be taken up at the bureau, whether in connection with the various electrical standards of measurement, electrical constants, the electrical properties of materials, or the performance of electrical equipment.

Questions in optics enter into standards of all kinds to a greater extent than has been supposed. Hence, there is an optical division provided with experts in spectroscopy, polarimetry (used in sugar analysis), color measurement, the principles of optical instruments, and the measurement of the optical properties of materials.

Practically all investigations concerning the various classes of standards involve chemistry in one form or another. There are also many chemical standards and questions which arise in connection with chemical work generally, especially in the industries. Hence, there is a chemical division cooperating with every other division of the bureau, as well as taking care of the questions of a purely chemical nature that come to the bureau and which fall within its functions.

In the case of the more important technical fields, divisions have been formed dealing more specifically with large and important classes of materials, but many of the purely scientific questions involved would be handled by one of the above-mentioned scientific divisions or jointly with it. The work of the technical divisions is just as scientific in character, but deals more specifically with manufactured products.

The work of the structural engineering and miscellaneous materials division includes the investigation, testing, and preparation of specifications for these materials, such as the metals and their alloys, stone, cement, concrete, lime, paints, oils, paper, textiles, rubber, and other miscellaneous materials.

The division of engineering physics makes investigations and tests regarding the performance and efficiency of instruments, devices, and machinery. This work includes the testing of water and other meters, aeronautic instruments, etc., as well as investigations in aerodynamic physics and the study of sound.

Questions pertaining to the manufacture, specifications, testing, and use of the metals and their alloys is so important that a separate division, known as the metallurgical division, is provided to deal with these problems.

The ceramic division is concerned with all problems in connection with the use of clays and clay products, with investigations in the field of glass manufacture, and with questions involving the use of refractory materials and enameled metals.

The division of building and housing is engaged in the problems of standardizing building materials throughout the country with the object of cheapening and improving the construction of houses.

The work of the division of simplified commercial practice includes a systematic study of the needs of standards in the industries, with special reference to the elimination of unnecessary sizes, and other means for reducing waste.

The employees engaged in clerical work, purchasing, files, records, and accounting, as well as those of the library and information section, form the office division, while those employed in the operation of the mechanical plant, the various shops, and the care of the buildings and grounds make up the engineering and construction division.

LOCATION.

The laboratories and offices of the Bureau of Standards are located on a tract of about 35 acres in the northwest section of Washington, on Pierce Mill Road, near Connecticut Avenue, and are reached by the Chevy Chase car line. They were placed outside of the business center of Washington in order to insure freedom from mechanical, electrical, and other disturbances common to the business and more thickly populated sections of a city. Furthermore, the area of ground necessary precluded a site nearer the city. It has been found by experience that the efficiency of the employees, especially those engaged in testing and scientific investigations, has been greatly increased by the location of the laboratories in a section free from the ordinary disturbances of metropolitan life.

II. SCIENTIFIC AND TECHNICAL DIVISIONS.

WEIGHTS AND MEASURES.

The division of weights and measures is concerned with measurements involving the fundamental units of length, mass, and time, and such derived or secondary units as area, volume, density, and pressure. The activities of the division also include preparation of specifications and tolerances for use in connection with standardization of weighing and measuring apparatus, gauges, and screw threads; cooperation with States in the preparation and enforcement of weights and measures legislation; the design, improvement, and inspection of weights and measures apparatus; the carrying out of researches designed to result in more accurate knowledge of physical constants; and improvements in engineering practice.

GENERAL.

Scope of Weights and Measures Work.

Three factors enter into every commercial transaction—namely, quantity, quality, and price—and no transaction can be on a satisfactory basis until these three factors are expressed in definite and measurable terms. With this in mind the vital importance of accuracy in weights and measures is readily apparent, since the determination of quantity is directly dependent upon some form of weighing or measuring, and furthermore since in many cases the quality of a mechanism, as measured by performance, is also dependent upon the accuracy of measurement and nicety of fit of the parts.

LENGTH.

Investigation in Precision Length Measurements.

The precision 1-meter comparator has received considerable attention during the year. The temperature control of the comparator box has been developed and put into complete operation so that now the bath can be kept at a constant temperature to about 0°.01 C. for any desired length of time. Any temperature required for this work can be obtained very quickly by regulating the thermostat and auxiliary apparatus.

An investigation was made of several micrometer microscope screws used in precision work in this laboratory. Although more investigation is needed along this line, it is found that the micrometer screws in the laboratory are sufficiently accurate for all except the highest class of work One micrometer screw was found to have periodic and progressive errors of such small magnitude as never to require a correction to be made in any work done with it. Another instrument has errors several times as large but still of a negligible magnitude. This instrument is defective, however, in the mechanical construction of the micrometer and in the matter of rigidity of the microscope and freedom from lost motion which makes the instrument very much less reliable in actual use than the one first mentioned.

As a result of the improved apparatus now in use in the geodetic comparator for the test of precise base-line tapes, a greater accuracy and reliability in the test of these tapes is now obtained than heretofore. This is largely due to the elimination of friction and the ability to apply exactly the tension desired. Recent tests have shown that, with tapes in good condition and properly graduated, the length can be obtained with a probable error not exceeding one part in 3,000,000. These lengths are also correct in absolute value to nearly the same degree. It should be pointed out that careful examination of test records shows that previous work done on the geodetic comparator has been of such reliability as never to have been the source of serious error. The present apparatus can be regarded simply as a logical development of the work in precise tape testing along the lines so well laid out by L. A. Fischer, for many years chief of the weights and measures division.

The feasibility of standardizing tapes of a moderate degree of accuracy by direct comparison with standard tapes has been demonstrated and additional tapes have been ordered to make this method more effective and reliable.

Apparatus.

Besides the developments and improvements in apparatus already noted, the most important development is that of the sieve-projection apparatus. This is a very convenient method of testing sieves by measurements of the image of the sieve wires, magnified about 260 times on a ground-glass screen. The measurements can be made much more rapidly by this apparatus than in any other way, no dark room is needed, and eye strain is greatly reduced. A complete account of this has been prepared for publication.

For several years the need of the following three instruments has been felt: (*a*) Comparator for calibrating the intervals of a graduated standard; (*b*) a small comparator for calibrating sieves and small scales, etc; (*c*) projection apparatus for testing sieves. Of these, (*c*) has been built and has proved to be very much of a success. The need for (*a*) becomes increasingly great and should be filled by the purchase of a suitable instrument, a preliminary blue print of which is now in the files of the bureau. The small comparator (*b*) for the small scales and for testing the micrometer of micrometer microscopes can probably be supplied by an apparatus to be built at the bureau. The need for this apparatus in the testing of sieves has been successfully met by the projection apparatus.

Research in Screw Cutting and Precision Dividing Engines.

The principle of the interferometer has been applied to the determination of errors of screws and is giving excellent results. Periodic errors are accurately and rapidly detected. The progressive errors and other defects can also be detected with this testing apparatus. This has enabled the bureau to make substantial progress in the art of precision-screw cutting.

The success thus far justifies the enlargment of the work and plans are being made accordingly. The effects of lubrication, type of bearings, temperature, etc., are to be tried out on apparatus designed for these tests.

All the above problems are progressing rather slowly, but the accuracy of the work can not be sacrificed to satisfy the desire for greater speed.

Information on Length Measurements and Standards.

A rather complete bibliography on precision length measurements primarily and also on the miscellaneous work of the length section has been made. In gathering together this bibliography an effort has been made to find the primary sources of information relating to metrology and its historical development from the introduction of the micrometer microscope to the present methods of measurement in terms of light waves. It has been interesting to note that many metrologists seeking to establish the relation between the yard and the meter have neglected the fact of temperature—that the prototype meter has a length of 1 meter only at 0° C., and that the British imperial yard has a length of 1 yard only at 62° F. That is, they fail to distinguish clearly between the yard and meter as *units* of length, and specific yard and meter bars as *standards* of length. This bibliography, which is now in card index form, has already been of great assistance in answering correspondence and in supplying information needed in the laboratory. Cross indexing is now in progress to make this still more effective. It is also probable that this will serve as a basis on which a paper can be prepared on the subject of length standards and their measurement.

In order that information regarding the standard weights and measures which have been supplied to the States by the Federal Government might be more readily accessible for reference, this material has been collected from various sources and compiled in one volume. A copy of the information has been placed in the vault for preservation.

Further information is being gathered and measurements made on various standards in the possession of the bureau which are of historical interest.

Routine Testing.

The following articles were tested as to length during the year: 9 length standards and precision scales, 19 invar base line tapes, 157 steel tapes, 104 "metallic" tapes, 34 level rods, 40 level rod strips, 276 haemacytometers (blood-counting chambers), 540 extra cover glasses for haemacytometers, 111 sieves, 14 pieces of sieve cloth, and 73 miscellaneous articles tested for length or angle.

Among the length standards tested during the year, one of peculiar interest was a yard and ell standard from Alexandria, Va. This standard, which bore the inscription "County of Fairfax" and the date "1744," is the oldest length standard which has been submitted to this bureau for test. It was found to be correct within the usual tolerance for commercial measures.

As a result of the bureau's experiences in determining the coefficient of expansion of invar level-rod strips, a means for doing this accurately and quickly has been developed. There is the objectionable feature that it is necessary to change the temperature of the entire tape tunnel. On this account, the method as at present used can not be regarded as final.

It is apparent from the requests for the testing of sieves that the specifications for the United States standard series of sieves have now been well distributed, since in a majority of cases the test for compliance with these specifications is specifically requested.

In the haemacytometer testing, the most notable feature has been the testing of one-piece chambers on a quantity basis.

A standard temperature of 68° F. (20° C.) for all steel tapes has been agreed upon, effective July 1, 1922. This temperature is now very generally accepted in the United States as the standard temperature for all standards of length. Previously this has been the standard temperature for tapes graduated in metric units only, English tapes being ordinarily standard at 62° F. in accordance with English practice. The standard tension for tapes is under consideration with the manufacturers and it is expected that definite specifications will be agreed upon at an early date.

Visitors.

During the year there have been many visitors in the laboratory from various instrument firms and other companies making or using apparatus involving length measurements.

Statement of Present Condition of the Section and Recommendations for the Following Year.

1. At the present time all routine testing is practically up to date.

2. Suggested changes in routine testing:

(*a*) Development of a projection method, using the sieve-projection apparatus, for testing the rulings of haemacytometer chambers.

(*b*) Use of micrometer eyepiece microscope instead of micrometer microscope for the rough measurement of many capillary tubes.

(*c*) More scales on glass should be ruled for obtaining the mesh of finer sieves by the "picket-fence interference." The need for these is sufficient to warrant its having early attention.

3. Improvement in tape testing:

(*a*) Permanent, adjustable microscope holders especially designed for the work will avoid scratching the bench, will improve the appearance of the apparatus, and may still further increase the reliability of the results.

(*b*) It would be desirable to substitute weights for spring balances in the steel tape testing. No satisfactory arrangement has been devised as yet, however.

(*c*) Six additional tape supports for the geodetic comparator are recommended. This will enable comparisons of tapes to be made so near the condition of support throughout that the difference between the two cases as calculated by the formula would be so small as not to require any considerable refinement in the measurement of the weight per unit length of the tape. These supports would also be useful when a considerable number of supports are definitely specified.

(*d*) The most serious need in the tape testing is one which can not be remedied at once. The tape tunnel is not long enough. For geodetic tapes an increase in length of slightly over 5 meters is needed, but there is no way of providing this room in the present tunnel. A tape bench of 200 feet or longer is also an ideal to work for. It is hoped that these may in time be provided in a new metrology building.

Revision of Publications.

Two publications relating to work of this section have been out of print for a considerable length of time. These are—Circular 2 on Measurements of Length and Circular 39 on Measurement of Sieves. The first of these has been revised for republication. The second was revised nearly two years ago but has not yet been republished on account of certain questions as to specifications covering "sieving value." It is now proposed to rewrite the circular so as to deal with the standardization of sieves from the standpoint of standard dimensions only.

MASS.

Mass Standards of the Bureau.

Important calibrations of some of the standards of mass of the bureau have been made during the year; a set of platinum-iridium standards from 500 g to 1 mg have been made available for use, and a valuable old set of gold-plated brass standards was replated and readjusted. Some of these standards were compared directly with National Prototype Kilograms No. 20 and No. 4, whose values have been certified by the International Bureau of Weights and Measures. In the fundamental comparison of standards or sums of standards equaling 1 k, about 80 weighings were made, while many hundreds of weighings were made in the intercomparison of the weights of the various sets. In the fundamental comparisons each "weighing" included 4 interchangings of the standards and 2 determinations of the sensitiveness of the balance. These were so arranged as to give practically independent determinations of the difference between the standards being compared. The fundamental comparisons were made with a "calculated probable error" of 0.003 mg while in 19 pairs of weighings among the platinum and platinum-iridium standards the maximum discrepancy between the weighings was only 0.02 mg, or 1 part in 50,000,000.

One of the very gratifying features of the work was the close agreement of results based on the two national standards, the difference in the values derived from the one and from the other being less than the probable error of the results.

A secondary kilogram of pure platinum has shown a total loss relative to the national standards of about 0.1 mg, or of 1 part in 10,000,000 during the last 22 years.

Preliminary comparisons of some of the ordinary working standards with these newly calibrated standards show that the values of these working standards will be practically unchanged by the recalibration. The great benefit of the work is therefore the greater certainty with which values are known and in the assurance that the values of these working standards have been maintained on the proper basis during the past years.

Tests.

During the year more than 5,000 precision weights of various classes were tested by the bureau, the work being done for State governments, private laboratories, manufacturers, other departments of the Government, and other sections of the bureau. The number submitted for test was about equal to that submitted in 1920, which represented an increase of 60 per cent over any preceding year, although a decrease of 14 per cent from the number submitted last year was noted. This small decrease in the number of routine tests, taken together with the increased efficiency of the staff, has made it possible to devote time to a thorough recalibration of the standards of the bureau, work which was of urgent importance and which has been briefly described above.

State Standards.

Primary standards were tested for the States of Massachusetts, Michigan, North Dakota, and Wyoming.

Manufacturers' Standards.

Primary standards were tested for two large manufacturers of high-precision weights. In one case the standard tested was a high-grade one-piece weight of gold-plated brass and the result showed that this had not changed by more than a few parts in 10,000,000 since it was tested at this bureau 13 years ago. In the other case the standards were lacquered screw-knob weights, and these were found to have undergone serious changes within a few years.

Accuracy of American Weights.

The American-made weights submitted for test have shown marked improvement, the accuracy being the highest yet attained. Everyone of over 200 precision weights submitted by one maker during a period of several months were found accurate within the tolerances. Another maker submitted a somewhat smaller number during the latter part of the year, also without any rejections, and a third maker recently submitted 12 sets or nearly 250 weights, all of which were not in error by more than the tolerance allowed. Such records are striking examples of what can be accomplished by careful work and sufficiently thorough factory inspection.

Imported Weights.

Very few imported weights have been tested, but those tested showed 5 to 15 per cent in error by more than the tolerances for high-grade analytical weights. Some of the imported weights in the denominations just below 1 gram, instead of being made of platinum, were found to be of some magnetic material. Such weights are not suitable for many uses on account of the danger of errors arising from magnetic attraction when used on ordinary analytical balances and in connection with other weights or other objects.

Improvement in Types of Weights.

One maker has spent a large amount of time and effort in developing an improved sealing device for class C test weights such as are much used in factory work and in official tests of scales in commercial use. The device has now been developed to such a point that formal approval of this new form can soon be given by the bureau.

Two additional makers of standard weights are considering the manufacture of standards intermediate between ordinary test weights and the highest grade of gold-plated one-piece standards. These intermediate standards (called class B standard weights) are very useful since they make available better standards to some who would in the absence of these buy poorer standards than are required for the service to which they will be put, and money is saved to others who otherwise would be required to procure a better grade of weight than is necessary.

Repair of Analytical Weights.

Such great difficulty and expense were involved in the repair of worn sets of analytical weights when the work was done elsewhere that experiments have been concluded on relacquering and readjusting the brass weights of sets belonging to the chemistry division where a large number of such sets were in need of repairs. The saving was found to be so material that about 30 such sets have already been repaired in the bureau's laboratories, and arrangements are being made for handling such work regularly for all weights used in the bureau, and it is hoped to extend its scope so that other branches of the Government that may find it to their advantage may also be accommodated.

Equivalents.

A large number of equivalents between rare foreign weights and the metric or United States customary units have been checked up with a special view to ascertaining whether published values were really authoritative. This work has strongly emphasized the lack of reliability in many published tables and the need of getting such data directly from official sources in the country concerned.

At present a number of tables are being checked for an engineers' handbook. These involve not only checking and computations, but there will also be required careful consideration of the definitions of gravitational units of force, on which there is at present a great deal of disagreement and ambiguity.

Personnel.

This section has been very fortunate in having retained for nearly two years four of the five assistants now in the section, although the salaries paid can not be said to be large enough to be attractive ones. The amount of work found possible recently, when contrasted with the preceding few years, serves to emphasize very strongly the benefits of such continuous service, and proves that increasing salaries to a point where such assistance can generally be held will not, in the long run, result in an increase in total expense of operation.

TIME.

Research in Diurnal Variation of Clock Rates.

One of the leading astronomical observatories of the country recently announced that the rate of a clock has a diurnal variation: that is, that the rate is faster at one time of the day than at another. The maximum difference in rate between the extremes is said to be sufficient to make it of appreciable importance. It is not known whether the effect, if real, is due to the principle on which pendulum clocks operate, to faulty construction of clocks, or to some diurnal effect upon the supports of the clocks. This problem is being studied by the bureau with the cooperation of the Naval Observatory in so far as the available equipment and time will permit. This investigation may not conclusively prove or disprove the original statement, but may be expected to have some value relative to the problem.

Horological Institute of America.

The work of last year in aiding the National Research Council to form an association for improving conditions in the horological industry has continued actively during the present year. The association formed is known as the "Horological Institute of America." The major work which it has undertaken to date is the examination and certification of watch repairmen according to their proficiency. This work will be of benefit to all who are interested in the proper maintenance of timepieces. Part of the examination consists in testing a watch that has been repaired by the candidate for a proficiency certificate. The bureau is aiding this program considerably by testing the repaired watches and in other ways whenever possible, including aid in drawing up certification specifications. A member of the bureau serves on the executive committee of the institute and also as secretary of its certification committee.

Improvements in Equipment.

Arrangements have been completed for the installation of a radio chronographic-recording receiver for receiving the Arlington time signal. This apparatus will displace the permanently-connected pair of telephone wires leading to the Naval Observatory by means of which the time signal is now received. The receiver is being constructed by the bureau and will probably be ready for use shortly. The initial cost will be less than the annual rental of the telephone wires.

Testing.

The following tests have been completed during the year:

Railroad precision watches	181
Ship watches	145
Stop watches	51
Wrist watches (for Government service)	1,674
Miscellaneous	2
Total	2,053

Future Work.

A problem which needs solution is the development of a method for an accurate determination of the daily rate of a watch in a period of a few minutes. If a relatively inexpensive piece of equipment for accomplishing this can be developed, it will be of material advantage in other work which is contemplated. The principles upon which this instrument would be based are already developed. There remains merely the mechanical construction and development.

Additional Equipment.

A piece of needed equipment, to which attention was called last year, is an instrument for supplying a reliable time signal with a signal-interval of one-tenth or one-twentieth of a second.

An oscillograph is also needed for measuring with precision shorter time intervals than can be measured with an ordinary drum cronograph.

Travel.

The work of the bureau in the testing of watches has been described before several local and State jewelers' organizations. This has served to quicken the interest of the public and of the Horological Institute of America in this phase of the bureau's work. Two addresses of interest to the jewelry trade were made during the year by a member of the bureau and published in the Jewelers' Circular, February 1 and March 8, 1922.

CAPACITY AND DENSITY.

Research.

Considerable work has been done during the year on the density and thermal expansion of sodium chloride solutions. Additional observations are still to be made on the density of saturated solutions at 4° C., as considerable time appears to be necessary to reach a condition of equilibrium at that temperature. When satisfactory data can be obtained at that temperature the work can be prepared for publication, as all of the other necessary observations have been completed.

Hydrometer Scale for Petroleum Oils.

Confusion has existed for several years in regard to the hydrometer scales used in the measurement of petroleum oils. The so-called gravity of oils is ordinarily expressed in terms of an arbitrary scale which bears a certain relation to specific gravity. This arbitrary scale, commonly known as the Baumé scale for light liquids was originally based on the following relation to specific gravity:

$$\text{Baumé degrees} = \frac{140}{\text{specific gravity}} - 130.$$

It was discovered a few years ago that, unfortunately, many of the hydrometers in use in the petroleum-oil industry were not graduated in accordance with the above relation, but were more nearly in agreement with the relation expressed when the constants 140 and 130 were replaced by 141.5 and 131.5, respectively.

It was held by the bureau that this deviation from the original relation to specific gravity was the result of an error and that the error should be corrected by correcting the instruments. It was held by the manufacturer of these instruments, however, that they were in agreement with certain other instruments which had been adopted by the industry as standards and that they were, therefore, correct in spite of the fact that they did not agree with the formula on which they were originally based.

The result of this difference of opinion as to the correct basis of graduation was that both scales were widely used in the oil trade; one being known as the United States standard scale, and the other as the Tagliabue scale, and both as the Baumé scale. The confusion resulting from this situation was very great.

During the past two years it has become increasingly apparent that the question must be settled by the exclusive use in the oil trade of either the one scale or the other. The question was taken up by a joint committee composed of members from the American Petroleum Institute, the Bureau of Mines, and the Bureau of Standards in an attempt to arrive at a satisfactory settlement. It was the opinion of the bureau that the original scale, based on the modulus 140 should be adopted and used in the measurement of oils as well as other light liquids. The sentiment in the oil industry, however, appeared to be very strongly in favor of making an exception in the case of petroleum oils, and adopting the modified scale, based on the modulus 141.5.

After careful consideration of the relative extent to which the two scales were used, and the cost and inconvenience involved in changing to either scale, the committee agreed to recommend to the petroleum oil industry the adoption and exclusive use of the scale based on the modulus 141.5; this scale to be known as the American Petroleum Institute scale, and to be used exclusively in the petroleum-oil industry. This recommendation has been approved by the industry, and a long and profitless controversy has at last been settled. While it may be considered unfortunate that it could not have been settled by the adoption and exclusive use of the other scale, still it is better settled as at present than not at all. The bureau will now certify hydrometers graduated in accordance with this scale, and will lend its influence to secure the universal use of this scale in the petroleum industry.

Calibration of Horizontal Tanks.

The bureau is frequently called upon to supply a formula for computing the contents of a partially filled horizontal tank with bulged ends, such as a railroad tank car. The necessary formulas for this work have been developed and extended tables prepared for use in applying the formulas. A mimeographed circular will be available for distribution shortly.

Testing.

The following is a report of the testing done by the volumetric section for the year ended June 30, 1922:

Kind of apparatus.	Number submitted.	Number tested.	Number passed.	Percentage passed.
Glass volumetric:				
Burettes	2,246	1,939	1,622	72
Cylindrical graduates	620	565	242	39
Dilution pipettes	568	557	542	95
Flasks	6,021	5,000	3,811	63
Pipettes, transfer	4,226	3,858	3,393	80
Pipettes, measuring	647	631	596	92
Pipettes, Babcock	42	16	6	14
Specific gravity flasks	27	26	6	22
	14,397	12,592	10,218	71
Hydrometers	563	559	358	64
Metal capacity measures	105	105	85	81
	668	664	443	66
Calibrating bulbs		11		
Miscellaneous		72		
Total pieces of apparatus tested		13,339		
Other tests—Density determinations		114		
Total number of tests		13,453		

An examination of the above data shows that of the volumetric glassware submitted for test 87 per cent was eligible for test. The remaining 13 per cent was rejected upon preliminary examination. The rejections in the case of flasks were due to unsatisfactory blanks having striæ and bubbles, and some rejections were on account of the apparatus being unstable. The burette rejections were due to striæ and leaky stopcocks. The general quality of the glassware was very much improved over that submitted the previous year.

Seventy-one per cent of the glassware submitted passed the test, and of that actually tested 81 per cent passed test. This is a better showing than the previous year, due, no doubt, to better methods and closer attention to details on the part of American manufacturers of volumetric apparatus.

Sixty-four per cent of the hydrometers submitted passed the test. For the greater number of those not passing the test reports were issued giving corrections so that the instruments could still be used, even though not complying with all of the bureau specifications as to accuracy and inscriptions.

For the purpose of comparison, a summary of the work done by the section for the fiscal year ended June 30, 1921, with the present year is given:

	Number submitted.		Number tested.		Number passed.		Percentage passed.	
	1921	1922	1921	1922	1921	1922	1921	1922
Volumetric apparatus	10,353	14,937	7,932	12,592	6,339	10,218	61	71
Hydrometers	628	563	619	559	427	358	68	64
Metal capacity measures	210	105	210	105	161	85	77	81
Calibrating bulbs			60	11				
Miscellaneous			156	72				
Density determinations			55	114				
Total number of tests			9,032	13,453				

Examination of the above data shows that there was an increase of 39 per cent in the amount of glass volumetric apparatus submitted for the test over the previous year, while the number that passed test was 61 per cent more than for the previous year.

A decrease of 10 per cent in the number of hydrometers submitted is explained by the fact that the Internal Revenue Service no longer sends alcoholometers for test, as that department has little use for the instruments since prohibition has been in force. The hydrometers submitted were mainly on small orders and of varying ranges. This would indicate that the instruments now certified by the bureau are used principally in the industries and as working standards for manufacturers of hydrometers. The number of capacity measures submitted showed a decrease over the previous year. They were, however, found to be more accurately adjusted.

The density of a number of samples of steel prepared under different conditions was determined for the metallurgical division of the bureau in connection with their investigations, and of several samples of storage-battery plate material for the electrical division for their storage-battery investigation; also several determinations of the density of pure platinum were made to determine the presence of voids in the samples.

Apparatus on Hand July 1, 1922.

The following apparatus was on hand July 1, 1922: 168 flasks, 217 burettes, 594 pipettes, 110 cylinders, 2 specific-gravity flasks, and 3 pieces of special apparatus, a total of 1,094 pieces as compared with 3,155 pieces one year ago. The hydrometers are tested to date, and one capacity measure only is on hand. This condition is very gratifying to the bureau and is sure to be appreciated by those submitting apparatus for test, as the delay on apparatus submitted will be materially decreased.

Visitors.

A large number of representatives from the makers of glass volumetric apparatus visited the bureau during the year. These visits, which make possible an interchange of ideas, are very helpful in bringing about a better understanding and more cooperation between the bureau and the manufacturers than could be accomplished in any other way.

A meeting of the makers, dealers, and users of chemical glassware, especially beakers and flasks, was held at the bureau on January 28, 1922, for the purpose of standardizing sizes and shapes and eliminating unnecessary sizes. Good progress was made in the program of standardization.

GAS MEASUREMENT.

Research in Connection with Orifice Meters.

In response to an urgent demand from another department of the Federal Government, State governments, and several other sources the bureau is inaugurating an investigation to develop some fundamental data on orifice meters for the measurement of gas.

The commercial development of this type of meter has been due to a demand for a large-volume meter of relatively low initial cost and low upkeep cost, but which will have for commercial purposes a fairly high degree of accuracy, even under widely varying conditions of pressure and temperature. It has come to be extensively used, particularly in the natural-gas fields, for measuring enormous quantities of gas, and very large payments depend upon its reliability. For example, royalties received by the United States Government on natural gas, determined from orifice meter readings, amount to some $600,000 a year from one reservation alone.

Doubt and controversies often arise concerning the accuracy of orifice meters or the proper interpretations of their readings, and these can not be settled by reference to unimpeachable authority, nor is it possible, in general, to guarantee an accuracy of better than 5 per cent because no authoritative and sufficiently accurate experimental work has been done anywhere.

In the practical use of an orifice meter the quantities directly observed are the static pressure, the temperature in the line, and the differential or drop in pressure through the orifice. These quantities are usually obtained by automatic or recording devices.

From the static pressure and temperature, the density of the gas may be found, and from the density and differential pressure, together with the diameters of the pipe and orifice, the so-called theoretical rate of flow may be computed by a simple equation. The actual flow differs from the theoretical by an empirical factor or "discharge coefficient" which must be determined experimentally. The final accuracy of the meter indications is, therefore, very largely dependent upon the accuracy with which the discharge coefficients are determined.

The problem is, therefore, to determine the discharge coefficients under all the variable circumstances that may effect it, so that its value may be known a priori, with satisfactory accuracy, under any set of conditions that may reasonably occur within the range of commercial or engineering practice. To study this problem satisfactorily requires the use of a large volume of gas, preferably air, under conditions which may be altered as desired. Equipment capable of providing a large flow of air under a wide range of pressures is available at Edgewood Arsenal and arrangements have been made for carrying out an extensive series of experiments there. Work on setting up the experimental pipe line and preparing the compressors for the work is well under way and actual tests will be started within a few weeks.

Standard Methods for Determining and Rating the Capacities of Dry Meters.

Due to the many improvements in dry meter designs and the great expansion in the utilization of gas during the past two or three decades, the old method of rating gas meters according to their light capacity has become almost meaningless. This has caused considerable confusion and inefficiency in the use of gas meters. Therefore the consumers' meter committee of the American Gas Association and the bureau are cooperating in taking definite steps to improve this situation. This work has already resulted in the adoption by the committee of a uniform method for designating meter sizes and capacities. There is now being prepared by the bureau an outline of a method for testing gas meters for capacity, suitable for adoption as a standard method. This should not only meet all essential technical requirements, but should be so simply worded that it will be easy to understand and to carry out.

Measurement of Compressed Gases.

Steps are now being taken to assist in the establishment of nationally uniform methods for measuring compressed gases. This section is cooperating with a committee appointed by the Compressed Gas Manufacturers Association, and questions relating to the present practices followed in the measurement of compressed gases are being considered. It appears that there are some points on which closer agreement is desirable, and it is hoped that such agreements may be arrived at as a result of this work.

Gas-Measuring Instruments, Routine Tests.

The following is a summary of the tests made on which reports were issued by this section during the past fiscal year:

Dry meters	38
Wet meters	5
Portable cubic-foot standards, Stillman type	8
Orifice meters	22
Pitot tubes	6
Flow meters	1
Spirometers	9
Total	89

THERMAL EXPANSION.

Research in Dental Inlays.

Arrangements have been made whereby the bureau has been able to take up an investigation of dental inlay materials. While the work is far from completion, sufficient progress has been made to warrant the statement that it will be possible to supply accurate information on many disputed points connected with the inlay technique.

The questions of plaster behavior, wax manipulation, and gold casting are being studied, both from the standpoint of laboratory technique usually employed and fundamental relations.

Already the commercial laboratories have expressed their approval of the methods employed and are planning to install apparatus similar to that designed and used at the bureau. This work will result in enormous savings to the general public which has often been a victim of the mistakes of a comparatively new profession, hampered by inadequate information and experience.

The Ultra Micrometer.

With the cooperation of the electrical division an oscillating valve circuit for detecting small length changes has been constructed and calibrated. This micrometer was calibrated by measuring the change in frequency of the circuit, as determined by the use of tuning forks, and comparing this change with the fractional shift in wave lengths of light of one of two silvered glass capacity plates. These plates were so arranged that they formed the essential surfaces of an interferometer having a separation of about 1/100 mm, and accurately parallel.

The shift of the fringe served as an accurate measure of the actual change in separation of the capacity plates. While the apparatus is capable of detecting the most minute changes in length (one billionth of an inch, as claimed by the inventor) there are many sources of difficulty in its practical application. Unless a laboratory is prepared to provide constant temperature, extremely uniform electrical circuits and conditions, freedom from vibrations and other disturbances, it will not be possible to use the instrument to the limit stated above.

Tests.

The following tests were completed during the year: Thirty-two representative aluminum alloys, 10 nickel steels, 24 dental investments and waxes, 8 valve steels, and 17 enamels and glasses.

These are parts of series of researches on the corresponding materials or alloys. At the completion of the series the data will be assembled for publication.

The bureau has been unable to keep up with the demand for this class of work. The importance of this work is indicated by the fact that three commercial laboratories have sent representatives here during the year, each planning to duplicate the bureau's apparatus and carry out their own testing.

It is unfortunate that on account of inadequate funds the bureau is obliged to limit its activities along this line. In spite of the necessary limitations, however, good progress has been made in this work. The upper temperature limit for tests has been extended above 1,000° C. The use of neutral gas in the test chamber has made possible the testing of specimens at temperatures above their usual oxidizing points.

INVESTIGATIONS AND TESTS ON COMMERCIAL SCALES AND RELATED WORK.

Investigation of Railroad Track Scales.

Exceptional progress has been made during the year in the investigation of the condition of railroad track scales throughout the country. It was pointed out in the last annual report that during the year 1921 extensive repairs and replacements were made to railroad track scale-testing equipments Nos. 1 and 2, and that it was hoped thereby to keep them in efficient service. That the bureau's expectations in this regard have been fully realized is indicated by the fact that during the first 10 months of this year these equipments have been maintained in almost continuous service without the necessity of frequent repairs. It was necessary, however, to lay up these equipments during the greater part of May and June on account of lack of sufficient funds to keep them in the field.

Notwithstanding this lack of funds there were tested during the year 894 track scales as well as 17 master scales by these equipments and by equipment No. 3. The greatest number of track scales which have heretofore been tested in one year with these equipments was 681. Therefore there was an increase of 220 tests, or about 32 per cent, over the previous high record of a year's work. This has largely been made possible by the fact that the personnel has remained almost constant during the year, all of the men now in this work having been previously trained in this service. The efficient testing of track scales and the moving of the equipments are tasks requiring considerable experience, and when frequent changes in personnel occur the number of tests possible to obtain is very greatly reduced.

The work done was well distributed throughout the country, scales having been tested in the following 33 States and in the District of Columbia:

Alabama.	Louisiana.	Oklahoma.
Arkansas.	Maine.	Pennsylvania.
California.	Minnesota.	South Carolina.
Colorado.	Missouri.	Tennessee.
Florida.	Nebraska.	Texas.
Georgia.	Nevada.	Utah.
Illinois.	New Hampshire.	Vermont.
Indiana.	New Mexico.	Virginia.
Iowa.	New York.	West Virginia.
Kansas.	North Carolina.	Wisconsin.
Kentucky.	Ohio.	Wyoming.

The accompanying map shows in a general way the routes followed by the three testing equipments, and also the location of master scales throughout the country.

The distribution of tests among numerous owners also serves to make the figures representative, scales owned by 99 different railroads and by a very large number of industrial concerns being included.

A résumé of the results of the tests of railroad track scales is presented in the following table. This does not include the results of master-scale tests which are shown elsewhere. For the purpose of bringing out certain facts of interest the data have been arranged geographically, the country being divided into three sections which have been designated East, West, and South, the subdivision following closely that adopted by the Interstate Commerce Commission in its report on the statistics of railways. The table is also classified to show the ownership of the track scales whether by railroads, industries, or the Federal, State, and local governments. The mean numerical error on scales listed as incorrect is shown and a short analysis of the errors of such scales is included.

RESULTS OF TESTS ON TRACK SCALES.

Location and ownership.	Number.	Correct.		Incorrect.			Analysis of errors on incorrect scales.					
							Plus.			Minus.		
		Number.	Per cent of total scales	Number.	Per cent of total scales.	Mean numerical error in per cent.	Number.	Per cent of incorrect scales.	Mean plus error in per cent.	Number.	Per cent of incorrect scales.	Mean minus error in per cent.
East:												
Railroad	172	80	46.5	92	53.5	0.60	41	44.6	0.41	51	55.4	0.75
Industries	74	43	58.1	31	41.9	.64	15	48.4	.39	16	51.6	.88
Government	3	1	33.3	2	66.7	.22	2	100.0	.22	......	....	....
Total	249	124	49.8	125	50.2	.61	58	46.4	.40	67	53.6	.79
West:												
Railroad	251	152	60.6	99	39.4	[1].55	62	62.6	[1].43	37	37.4	.76
Industries	182	98	53.8	84	46.2	[1].53	44	52.4	[1].42	40	47.6	.64
Government	2	1	50.0	1	50.0	.70	......	00.0	....	1	100.0	.70
Total	435	251	57.7	184	42.3	[1].54	106	57.6	[1].42	78	42.4	.70
South:												
Railroad	182	50	27.5	132	72.5	.78	60	45.5	.62	72	54.5	.92
Industries	27	9	33.3	18	66.7	[1].55	5	27.8	.39	13	72.2	[1].62
Government	1	......	00.0	1	100.0	1.18	......	00.0	....	1	100.0	1.18
Total	210	59	28.1	151	71.9	[1].76	65	43.0	[1].60	86	57.0	.88
All sections:												
Railroad	605	202	46.6	323	53.4	[1].66	163	50.5	[1].49	160	49.5	.83
Industries	283	150	53.0	133	47.0	[1].56	64	48.1	[1].41	69	51.9	[1].70
Government	6	2	33.3	4	66.7	.58	2	50.0	.22	2	50.0	.94
Total	894	434	48.5	460	51.5	[1].63	229	49.8	[1].47	231	50.2	.79

[1] The errors of several scales have been omitted from the computation of these mean errors. See paragraph immediately following table for detailed information as to these.

The above table shows that 48.5 per cent of the scales tested were within the tolerances allowed, namely, 200 pounds per 100,000 pounds of applied load. By geographical subdivisions it is found that 57.7

Map showing territory served by Bureau of Standards track scale testing equipment for the fiscal year 1922.

Solid line, route of equipment No. 1. Dot-and-dash line, route of equipment No. 2. Dotted line, route of equipment No. 3. Heavy dots, location of master scales.

per cent were correct in the West, 49.8 per cent in the East, and 28.1 per cent in the South. The mean numerical errors of the incorrect scales in these sections were in the same order of merit, the West having the lowest percentage error, 0.54 per cent, the East being next with 0.61 per cent, and the South having the largest, 0.76 per cent, the general mean error for all sections being 0.63 per cent. (These figures exclude several scales having extremely abnormal errors, since the inclusion of these would have unduly influenced the averages. These scales are as follows: One railroad scale and one industrial scale in the western section having errors of +34.55 per cent and +11.55 per cent, respectively; and one industrial scale in the South having an error of −17.39 per cent.) The table also indicates that there was no preponderance of errors in either the plus (fast) or minus (slow) direction since 49.8 per cent of the scales were fast and 50.2 per cent were slow.

In general these figures seem to indicate that the advances of accuracy made heretofore in the railroad track-scale field were well maintained during the year. The general percentage figure for correct scales, 48.5 per cent, is higher than in any previous year with the exception of last year, former figures being 32 per cent in 1914 and 1915, when the work was inaugurated, 38.2 per cent in 1916, 44 per cent in 1917, 39.1 per cent in 1918, 46 per cent in 1919, and 41.8 per cent in 1920, the general average of these yearly figures being 39 per cent. The general figure on average correctness this year is noted as being somewhat lower than last year, when it was 53.2 per cent. Nevertheless consideration should be given to the fact that the figure this year includes the large number of 210 scales in the South having an average correctness of only 28.1 per cent, while but little work was done in this section last year, only 34 scales for an average correctness of 44.1 per cent being included.

Comparing the percentage of correct scales throughout the country, exclusive of the South, in 1921 and 1922 we find the figures to be practically identical, or 54.4 per cent and 54.8 per cent, respectively. The mean numerical error of incorrect scales is found to be identical, namely, 0.57 per cent. This maintaining of last year's percentages seems to be an excellent record in view of the widespread industrial depression which has existed, which in general has meant that considerably fewer men were employed by railroads and industries in the maintenance of scales than has formerly been the case.

It was found possible for the bureau's field force to adjust more scales found incorrect than in any preceding year, the errors on 99 scales having been thus reduced. This service is extended to the owners whenever the condition of the scale justifies it and it can be done without loss of time which could be utilized in making additional tests.

Calibration of Privately Owned Test Cars.

Thirty-eight test cars belonging to railroads and industries were calibrated. This service is extremely important, since it assures that a correct rather than an incorrect standard will be used in private adjustments of scales for the testing of which such test cars are utilized. A striking example encountered during the year of the use of an incorrect standard may be cited: A test car of a certain railroad was tested by one of the bureau's equipments and found to be in error by 160 pounds, the car being light. This car had been in service in this condition for some time and had been used in testing and adjusting a number of scales, 8 of which shortly thereafter were tested by the bureau. In the bureau's tests every one of these 8 scales showed a plus error, and 7 out of the 8 were outside the tolerance, the average error being 0.41 per cent. The character of these errors was such as would be expected if the scales had been sealed by a light test car. Further, when the error introduced by the test car as found on calibration, viz, +0.26 per cent, is deducted from the scale errors determined, it is found that 4 out of the 7 deficient scales will be within the tolerance and 1 will exceed it only by a scant margin. The dates on which the scales were tested by the incorrect test car and on which they were tested by the bureau happened to be so close together as to clearly prove that the incorrect performance of the scales reflected the defective condition of the test car.

Calibration of Master Scales.

The general arrangement for the testing of master scales throughout the United States has remained the same as it was last year and for several years before the control of the Railroad Administration, the agreement between this bureau and the American Railway Association still being in force. This agreement contemplates that the bureau will maintain the standard of weight for track scales by testing once in each year each master scale which is suitable for use and is being used by States, railroads, or industries in the calibration of test cars, and by adjusting those which require adjustment to bring them within the tolerance. In return for this service the American Railway Association furnishes free transportation for the track scale testing equipments when operating upon master-scale schedules, which are laid out in advance by mutual agreement. The necessity of this work is obvious. It has been pointed out above that serious errors in many scales may be caused by the inaccuracy of one test car. If then a master scale, which may be and often is used in the calibration of a number of test cars, were to be inaccurate all of these cars and the scales tested by them would be adjusted to an incorrect standard. Therefore, the bureau in its efforts to improve general weighing conditions throughout the country pays particular attention to this phase of the work and considers it of paramount importance. The bureau's equipments Nos. 1 and 2 are the only ones in the country which are suitable for work of this character. The master scales are located in all sections of the United States and the bureau's equipments are especially designed to transport 80,000 pounds of accurately sealed weights from place to place.

As an example of the precision with which master scales throughout the country are being adjusted and their accuracy maintained by the bureau's testing equipments, a recent instance of which the bureau was advised by the parties involved may be cited. A railroad-owned test car of a nominal weight of 80,000 pounds was adjusted by the builder on a master scale in Pennsylvania and shipped to Colorado for use by a western railroad. Upon arrival it was check weighed on a master scale there and a discrepancy in the weight of the car of only 5 pounds was found.

The yearly master-scale schedules are now coextensive with the fiscal years starting July 1. The bureau is pleased to report that all the suitable master scales in the country, 17 in number, were tested during the past 12 months and were left in proper weighing condition. It is encouraging to note that several new master scales have recently been installed either to furnish facilities in new locations or to replace former unsatisfactory scales, and that additional installations are already arranged for or are in contemplation.

Bureau of Standards Master Track Scale.

The master scale purchased by the bureau some years ago is now in storage, but the bureau has no proper site and is still without funds to install it and thus put it to the use for which it is intended. Until this scale can be installed for use the bureau can not realize upon its investment, its scale work can not be made of maximum efficiency, and the service which the bureau should render must necessarily be greatly curtailed.

As pointed out last year, this scale was contracted for in 1916 and it was intended to house it in a centrally located test depot. This has not yet been done, although since that time the track-scale work has broadened in scope and the need has consequently become more urgent. Track-scale testing equipment No. 3, contemplated at the time of the purchase of the scale and put into service at a more recent date, comprises test cars Nos. 3 and 4, these being 40,000 and 80,000 pound self-contained test units traveling on their own wheels. Therefore, they must be reweighed at intervals not exceeding two months in order to maintain and assure their accuracy, and this reweighing should be done on a scale operated and guaranteed by the bureau. Moreover, the 160,000 pounds of test weights (including the special trucks) carried on equipments Nos. 1 and 2, which are used in certifying to the accuracy of every master scale in the United States, must be repainted and adjusted from time to time and the equipments overhauled. The bureau has no present facilities for doing work of this character.

In addition to the needs of the bureau the proposed testing station would also be used for standardization of the test cars of all railroads in the vicinity of the scale, the calibration of weights carried thereon, as well as all heavy weights submitted for test by industries or railroads in that locality. The maintenance of a Government-owned master scale and testing depot at some central point would do more, perhaps, than any other thing to furnish a correct standard of weight to be transferred to railroad-owned and industrial scales, to quicken the appreciation of accurate weights and weighing, and to reduce claims, allay suspicions, and provide a more stable basis for all business carried on by weight.

In the opinion of the bureau, the city of Chicago is the most favorably situated in the country for the station. This location, being a central one, would most efficiently be reached by the several equipments, and it also would enable the bureau to serve a maximum number of railroads and industries.

Mine Scale Investigation.

The investigation of the condition and accuracy of the so-called tipple scales used at coal mines in determining the amount of coal mined by the individual miners. from which results the wages due the various workers are determined, was carried on during the year in so far as this was found possible. The equipments worked in the Illinois fields during the summer months until all urgent work there was completed. The work with the equipments was then discontinued as on account of the lateness of the season and road conditions movement into new territory would have been impracticable. It was intended at that time again to start active operations in the early spring, but the general strike in the organized fields rendered it impracticable to carry out this plan since in the unorganized fields, which were the only ones in which work could have been done, scales are not ordinarily employed in the determination of wages, the miners here being paid by measure rather than by weight. Work done this spring in connection with this investigation has therefore largely been confined to investigations necessary for the preparation of proper specifications for tipple scales and other similar scales. Such specifications have been practically completed and are nearly ready for publication.

One hundred and twenty-nine scales were tested in Illinois. Of this number only 21 scales, or 16.3 per cent of the total, were found to be correct, the remaining 108 scales, or 83.7 per cent, having errors in excess of the tolerance allowed scales of this type, namely, 0.4 per cent, or twice the tolerance allowed on track scales. This extremely unsatisfactory percentage of accuracy emphasizes the necessity of actively prosecuting this work and the bureau intends to resume it as soon as conditions warrant.

Miscellaneous Tests of Weighing and Measuring Devices.

These tests and examinations of weighing and measuring devices may be roughly divided into two classes, namely, those made at the request of a State or of some department or bureau of the Federal Government, and those made at the request of a manufacturer of such devices. The first class includes tests on the accuracy of individual devices to determine the acceptance or rejection of equipment purchased, or the corrections to be applied where unusual precision is demanded, and also retests of equipment in use to determine its fitness for continued service; in this class are also included tests of devices in which the object is not so much to determine the accuracy of the particular machine submitted as it is to determine the suitability of machines of that type for a particular service. Among the inspections and tests made during the past year falling into this group may be mentioned the following: Ten scales tested at Camp Humphreys and belonging to the Quartermaster Department of the Army; 11 dynamometers and 9 personal weighing scales tested for the Public Health Service; 7 dynamometers tested for the Bureau of Markets; motor-truck scale tested for the Navy Yard at Washington, D. C.; scales tested for the Post Office Department and for the Children's Bureau of the Department of Labor; 4 portable weighing devices, having a capacity of 15,000 pounds each, tested for the State of New York (designed for weighing trucks on the highways in the enforcement of the State road laws); several testing machines and paper scales and dynamometers for other sections of the bureau, etc.

The second class of tests—that is, those made at the request of a manufacturer—are performed for the information of the bureau and of State weights and measures officials and for the purpose of advising the manufacturer as to the performance of his product and its compliance or noncompliance with such weights and measures regulations as are applicable to it. This work is of especial importance in that it results in raising the general character of the weighing and measuring devices placed upon the market. Manufacturers in general have shown themselves willing and anxious to comply with the suggestions made by the bureau and this cooperation has resulted in benefit to all concerned. It is greatly to be regretted that the funds available for work of this character are so limited that only a relatively small amount of it may be undertaken. During the past year, however, it has been found possible to make very thorough inspections and tests of several types of gasoline-dispensing devices and attachments for such devices, a meter designed to vend liquids of various kinds, weighing scales, etc.

A considerable number of tests were made during the year in connection with the enforcement of the standard barrel law, on new types of barrels to be used for cranberries and apples. The manufacturers desired to develop new types of packages to contain one-half standard cranberry barrel and one-half standard barrel, respectively, and the bureau not only tested sample packages submitted but also assisted the manufacturers in computing the dimensions necessary to produce a package of the desired capacity.

Investigations Concerning Weights and Measures Tests and Practices.

At the request of the Fourteenth Annual Conference on Weights and Measures the bureau conducted two investigations to assist in standardizing testing procedure. The evaporation loss from the delivery hose used on gasoline-dispensing devices was determined in connection with elapsed-time tests on such devices, and also there was developed a simple and effective field-test method to be used in testing fabric-measuring devices used in retail dry goods stores in measuring cloth. Reports were rendered on both these matters to the fifteenth annual conference.

An investigation was also started to determine the hysteresis effect in connection with coiled steel springs such as are used in many types of weighing scales. The preliminary work done indicated that results of importance were to be anticipated from a complete investigation along these lines and it is hoped that this investigation may be completed during the coming year.

Upon complaint from a purchaser of smokeless powder the bureau made an investigation of the methods of sale used by different manufacturers of this product. The use of the so-called "bulk pound," which in reality was a more or less flexible unit of measure instead of weight, was found to be practically universal among powder manufacturers. Owing to the fact that the value of this unit was inconsistent with its nomenclature and that its use was misleading to the purchaser, the bureau recommended that its use be discontinued. Through concerted action by the manufacturers this was done.

A manufacturer submitted to the bureau 48 glazed kid skins, the area of which he desired to have measured. Half of the skins were imported and half of them were of domestic origin. It was found that the areas reported for the domestic skins agreed fairly closely with those found, whereas the areas given for the skins of foreign origin were very much greater than the areas actually found, the difference being almost 10 per cent.

Automatic-Dial Scales.

Automatic-dial scales were made the subject of a special investigation during the past year. This type of scale is being used to an increasing extent and is daily becoming a more common and important industrial device. In order to accumulate and add to the first-hand information and data respecting the existing condition of these scales in service a special investigation was conducted by the Bureau of Standards and participated in by representatives of the committee on specifications and tolerances of the Annual Conference on Weights and Measures and by a railroad which was a user of a number of these devices. A large number of scales were examined in several different cities and the results obtained permitted a good idea to be gained as to the actual conditions of scales of this character when used for various purposes. The percentage of scales which would pass inspection when different tolerances which have been suggested for use in testing these scales were applied was also studied.

Grain Scales.

The past year has disclosed the fact that much remains to be done in reference to scales used for weighing grain. However, a gradual adjustment of ideas is being effected and it is felt that before long a general agreement based upon carefully considered data respecting the design, use, and test of these scales will be arrived at. The bureau is studying this problem closely and has assisted in the solution of some of the phases of it by having a representative present at meetings of committees concerned with the subject. It is planned that a representative of the bureau make a special trip through the grain region in the continuation of the study of the general subject. Information so gained will be incorporated in a publication outlining the equipment required for testing grain scales which will assist in overcoming many of the typical difficulties experienced in the field.

Railroad Depot Scales.

The bureau is cooperating in the preparation of specifications of scales used by the railroads, such as motor-truck scales, depot scales, warehouse scales, and the like. This work is being done by a committee which in a joint capacity represents the American Railway Engineering Association and the American Railroad Association. The Bureau of Standards has a representative on this committee, and the committee is succeeding in drawing up specifications satisfactory to all interests.

An important economy can be achieved without any practical sacrifice in the choice of scales available for different weighing purposes by reducing the number of standard sizes manufactured, and thus reducing the number of patterns and the amount of stock which are now required to be maintained by the manufacturers.

Strength Specifications for Scales.

In the design of scales strength and stiffness are important factors. In past years the nominal capacity usually associated with a given design of scale often bore little or no relation to its actual weighing capacity. Through the insistence of the bureau that there be a reasonable and proper relation between the strength of a scale and its nominal capacity, and that the capacities of scales should be based upon sound engineering principles, much improvement has been made in the last 10 years. Many scales now have a nominal capacity corresponding to the actual weighing capacity where this was not the case before. This is particularly true in reference to railroad track scales.

The drafting of specifications which will serve to define the capacities of scales and the working stresses which should form the basis of scale design are matters of fundamental importance. In scale levers cast iron is employed in transverse bending, and this material appears to have certain practical advantages for such use, although it has proved to be a rather variable material in respect to strength. and consequently it has long been abandoned by most industries in favor of steel or other material.

The bureau is now cooperating in the study of this question of working stresses for cast iron. Specimen levers and specially prepared test bars have been broken, and other tests have been made under the supervision of a representative of the bureau. This work has just been completed. The bureau is making a study of the results, and the findings will be prepared in the form of a report which, it is believed, will have an important bearing on problems of scale design.

Specifications for Testing Machines.

Most testing machines, a large number of which are used in commercial and industrial laboratories, are essentially a special form of weighing scale in which the force applied to bend or break a specimen is weighed by means of a compound-lever scale system. The subject of the proper verification of such machines is now receiving the attention of many interested parties, including engineering societies, industrial and engineering concerns, railroads. schools, and other technical laboratories. and the Bureau of Standards.

The weights and measures division has already been able to make suggestions respecting the verification of these testing machines and to point out the undesirability of certain proposed provisions which were about to be accepted. Since a difference of opinion prevails among the users of testing machines as to what tolerances should be applied, during the coming year tests will be made and information gathered which it is expected will make possible the establishment of tolerances for standardizing testing machines.

Precision Test of Large Capacity Scales.

Grain-hopper scales and railroad master scales of large capacity are often necessarily tested and adjusted according to very exacting requirements. It is generally desired to reduce the errors to but a few pounds per 100,000 pounds. Different ideas prevail both in regard to methods of test and interpretation of the results obtained.

During the year a publication was issued. Technologic Paper 199, "Method for Precision Test of Large Capacity Scales," which explains the procedure to be followed in testing scales with great exactness. The plan used is one which was developed by the Bureau of Standards in the test of railroad master scales and grain-hopper scales, and represents the practical adaptation of laboratory methods to field work.

Weighing by Substitution.

In standardizing very heavy weights at the bureau, a method of weighing was developed whereby it became possible to obtain a high degree of accuracy in the adjustments by using a compound-lever scale according to laboratory methods. The plan developed is applicable in a large number of cases where it is necessary to make weighings, especially of large objects, with special accuracy, as in technical or industrial laboratories. This method of substitution weighing is described in a publication issued during the year as Technologic Paper 208, "Weighing by Substitution," which describes the plan in detail.

Mathematical Character of Scale Errors.

A continued study of the nature of scale errors shows that in many cases the errors found for large-capacity scales, such as grain-hopper scales, follow a fairly definite law which can be formulated in mathematical terms. As soon as an agreement, expressed in definite terms, can be reached among those interested as to just what should be accomplished in the test and adjustment of scales, the results of this study can be used in the formulation of specifications respecting the procedure of test and the tolerances and methods of adjustments to be observed. It has been demonstrated that up to this time certain practices in the adjustment of grain-hopper scales have been based upon wrong ideas, so that the supposed results were not being realized.

Correspondence.

The bureau answers many inquiries covering a wide range of subjects related to the general field of commercial weights and measures. These inquiries come from individuals, manufacturers, newspapers, trade associations, etc., as well as from weights and measures officials. In many cases the bureau has on file information of the nature desired, but quite as often the answers to these inquiries necessitate investigations or computations of a more or less involved character.

COOPERATION WITH STATE AND LOCAL OFFICIALS IN WEIGHTS AND MEASURES ADMINISTRATION.

General Cooperation with States.

The bureau has maintained close touch with the activities of the various State departments of weights and measures throughout the year and has frequently been called upon for information and advice by officials from all parts of the country. The assistance which the bureau has been able to give has been along lines of testing methods, new laws or ordinances, interpretations of existing laws, regulations, specifications, and tolerances, etc. Particularly valuable have been those opportunities when a representative of the bureau has attended meetings of weights and measures officials and discussed various matters relating to their work. Such State conferences at which the bureau was represented during the past year were held in Maine, Massachusetts, Michigan, New Jersey, New York, Pennsylvania, and Wisconsin.

Fifteenth Annual Conference on Weights and Measures.

The bureau has always considered one of its functions to be the promotion of uniformity and efficiency in the administration of weights and measures laws and regulations throughout the country. To this end there was organized, in 1905, a "Conference on the Weights and Measures of the United States," and except during the period of the war, meetings of this conference have been held annually. The conference is an unofficial body whose membership is made up of weights and measures officials, but its meetings and discussions are open to manufacturers and to all others who are interested in weights and measures matters. It is believed that the conference has been one of the most potent factors in the development, in the United States, of State and municipal activity in regulating commercial weighing and measuring and the securing of uniformity in this regard. This has been brought about through the exchange of ideas on the part of the officials themselves, through technical papers presented at the conferences by various authorities on subjects affecting the work of the officials, and through the adoption by the conference of model laws, specifications, tolerances, methods of test, etc., which are recommended for adoption by State and local jurisdictions. In other words, the conference is a clearing house for weights and measures information of all kinds.

The fifteenth annual conference was held at the bureau May 23-26, 1922, and there was a registered attendance of over 200 delegates and guests. Twenty-six States were represented by 111 weights and measures officials. Included in the program were papers on leather-measuring machines, testing of heavy capacity scales, methods of wholesaling gasoline, serialization of type of weighing and measuring devices, and the manufacture of precision standards of weight. Probably the most important matters before the conference, however, were the reports of the committee on specifications and tolerances on the subjects of automatic indicating scales and tolerances for loaves of bread. Owing to their importance and the desire on the part of the committee and the conference for further investigation, action on both of these matters was put over to the succeeding meeting, and additional data will be secured and studied during the year.

A record of the proceedings of the conference is published each year and this serves to place in the hands of those interested a permanent record of the papers and reports delivered and of the conclusions reached in the discussions.

Weights and Measures Laws.

A revised compilation of the weights and measures laws of the States and of the Federal Government was prepared for the printer in the fall of 1920, but it has not as yet been found possible to publish it. It is hoped that it will be possible to issue a new edition of this work during the present fiscal year, as the last edition (issued in 1912) is no longer of much value on account of the large number of changes in and additions to weights and measures legislation, both Federal and State.

A compilation of the weights and measures laws of the various States is indispensable to the bureau in carrying on its work of cooperation with and assistance to the weights and measures officials in the States. The two previous editions have been a great help to State and local officials, to manufacturers and merchants, and to other departments of the Federal Government. In the absence of this publication it becomes necessary to compile special data, which are needed from time to time by the bureau in answering correspondence and assisting weights and measures officials. Among these subjects may be mentioned net-weight laws, adoption of tolerances, and specifications; laws relating to berry baskets, hampers, barrels, and other containers for fruits, vegetables, etc.; laws relating to weights per gallon, pounds per cubic yard, definitions of the perch, cord, etc., and similar data.

Weights Per Bushel.

A revision of Circular 10, Legal Weights (in pounds) Per Bushel, has been commenced, the last edition having been printed in May, 1918. There is a constant demand for this publication, and it is important that it be kept available for distribution, and fairly well up to date. It is expected that the revision of this circular will be completed shortly.

Foreign Weights and Measures.

Considerable information on the subject of foreign weights and measueres has been accumulated by the bureau during a number of years, and it has been found very useful in answering correspondence. Requests for information along this line have been more frequent in recent years than formerly, due no doubt to the increasing interest since the war in the sale of American products abroad. It is a field of work in which a great deal of help can be given to American manufacturers, importers, exporters, etc.

There is comparatively little literature dealing with the subject in general, but a great deal of work has been done during the fiscal year in bringing together (in a separate folder for each country) letters, reports, pamphlets, etc., on the weights and measures of each country, and in listing separately for each country various references found in other publications, so that the general survey of the weights and measures of a particular country may be made with as little loss of time in searching as possible. About one thousand references on cards have been added to the index of units of foreign weights and measures. A bibliography of the literature on the subject is also under way.

GAUGES.

Investigation.

In cooperation with the paper section an investigation was made of dial micrometers used in measuring thickness of paper. In addition to determining the errors in the readings of the instruments, the static friction, area of contact, and contact pressure of each instrument were determined. Also a study was made of the mechanism of each instrument to determine how many commercial instruments could be altered as to have a standard contact pressure with a standard shape contact. The results of this investigation have been submitted for publication in a paper, "A Study of Commercial Dial Micrometers for Measuring Paper."

An investigation of the effect of errors in pipe threads on the strength and tightness of pipe joints has been carried on during the past six months. Specimens representing various thread errors in two sizes of pipe have been made and tested. Specimens for a third size are now being made. The results, showing the relative importance of errors in pitch, angle, taper and thread form, will soon be ready for publication.

An investigation of the suitability of stellite as a material for plug gauges has been carried on during the year. Because of the great resistence of this material to abrasion it was felt that a gauge made of stellite would show long life in use. A number of plain plug gauges of stellite were made to drawings submitted by various manufacturers, the plugs were sent to the manufacturers, and the rate of wear in use determined in comparision with steel gauges. The results received up to the present time show a longer life for stellite than for steel but the increase in life is not as great as was anticipated.

Tests and Studies for the National Screw Thread Commission.

The torque required to make up stud fits with dimensional interferences representing the practice of two automobile manufacturers was determined. The data obtained in this investigation were furnished to the National Screw Thread Commission for use in establishing specifications for wrench fits. Also information was collected for this commission as to whether bolts and nuts purchased in the usual hardware stores were within the free fit or the loose fit class as set down by the commission. A number of studies have also been prepared for this commission. Among these are tap drill sizes, lead errors and tolerance on commercial taps, compilation of table of dimensions of bolt heads and nuts, and standardization of widths across flats of bolt heads and nuts. Also the section compiled and issued a summary of answers to a question on tolerances and allowances for machine fits issued by the American Society of Mechanical Engineers committee on plain limit gauges.

Constant-Temperature Room.

During the past year the satisfactory temperature regulation of the constant temperature room for use in the test of precise end standards has been accomplished. While the regulating device is normally set to operate on a total temperature range of 0.05° C., between 22 and 22.5° C., nevertheless, when desired the room can be regulated much closer than 0.5° C., also a temperature of 20° C. can be attained.

Ordnance Gauge Shop.

Through cooperation with the War Department a small but thoroughly equipped shop is maintained at the bureau for such experimental work in gauge making as the War Department may have occasion to carry on. This shop has proven very useful in the working out of new designs in gauges and gauging equipment.

Design and Construction.

In addition to design and construction necessary to carry on the tests and investigations, a comparator was designed and built to measure small differences in gauge blocks and for other precision contact measurements to an accuracy of one-millionth of an inch. The indicating principle of this comparator consists of two mirrors which are rotated when the spindle of the instrument is moved. These mirrors are inserted between the objective and eyepiece of a microscope which is used as the projection-lens system to project the image of a cross hair on a scale in front of the observer. The rotation of the mirrors produces an angular displacement of the beam of light so that the movement of the spindle of the instrument of one-millionth of an inch gives a movement of the image of the cross hair of about 0.04 inch on the scale.

The work of the gauge shop during the past year also included the manufacture of a series of plain gauges, representing two types of construction made to standard proportions for both large and small plain gauges. Also a series of adjustable thread-ring gauges were made to illustrate the proposed standard design for this type of gauge. In addition, a series of thread plugs and rings were made to illustrate closest and loosest fit for the classes of fit adopted by the National Screw Thread Commission. Work on 25 sets of precision gauge blocks in metric sizes has been continued as opportunity would permit.

Routine Tests of Gauges.

The following routine tests have been made:

Thread gauges	238
Profile gauges	5
Precision gauge blocks	979
Plain gauges (plugs, rings, etc.)	1, 048
Miscellaneous measuring instruments	48
Total	2, 318

The total number of gauges tested during the year is considerably less than during the preceding year when 4,200 gauges were tested. The decrease was mainly in the number of polariscope tubes, of which there were nearly 1,000 tested last year, and in the number of gauge blocks submitted by one manufacturer. There has been a slight increase in the number of gauge blocks submitted by others. Usually these are either new sets of blocks submitted for standardization or used blocks the accuracy of which is questioned. In many instances serious errors, due to wear, have been found in such blocks.

Government Tests.

The laboratory has been called upon to make contact measurements of various kinds for other divisions of the bureau, in connection with their investigations, to a greater extent than in previous years. For example, the dynamometer laboratory in its investigation of power losses in truck transmissions for the Motor Transport Corps was in need of information relative to errors in form and dimensions of gears. The development of special attachments for the Saurer gear-testing machine made it possible to detect, locate, and measure these errors. Also variations in diameter of a series of die drawn-copper wires were determined for the electrical division in connection with its work on standards of inductance, and a device was designed for determining the length of lever arms in a dynamometer used in the investigation of power losses already mentioned.

A determination of the wear of gears and bearings of three truck transmissions, which were run under similar conditions with three kinds of lubrication, was completed during the year.

Tests for Commercial Concerns.

The laboratory has again been called upon frequently to settle disputes between the gauge maker and buyer as to the accuracy of gauges. The section has also been called upon to make tests or investigations involving contact measurements that are not strictly gauge work. For instance, a determination was made of the relative wear of two types of phonograph needles when run under similar conditions.

GENERAL STANDARDIZATION WORK.

National Screw Thread Commission.

The commission, which was authorized by Congress (40 Stats., ch. 156, p. 912, approved July 18, 1918) for the purpose of standardizing screw threads, and of which the Director of the Bureau of Standards is chairman, has continued its work, and is now considering special problems not covered in its original progress report. The questions that have been given attention during the past year are: Taps, tap drills, and wire gauges, standard dimensions for nuts, boltheads, and wrenches; instrument threads and threads cut on brass tubing; special threads, such as electrical fixture and fittings threads, conduit threads, and oil-well casing threads. Good progress has been made along these lines.

Special Committee Work.

The bureau is represented on several sectional committees under the American Engineering Standards Committee which are engaged in standardization work, each along a definite line. Among these may be mentioned (*a*) the sectional committee on plain gauges for general engineering work, (*b*) the sectional committee for the standardization and unification of screw threads, and (*c*) the sectional committee on bolt, nut, and rivet proportions. Of these committees the most substantial progress has been made by (*a*). Fundamental principles have been laid down, a classification of fits has been established for machine parts, and a complete system of allowances and tolerances has been approved by the committee and is now under detailed consideration by designers, manufacturers, and users of gauges and machine parts. The adoption and use of a consistent series of allowances and tolerances would add tremendously to the efficiency and economy of interchangeable manufacture, and the work of this committee should prove of great practical value. The manufacturing world is not yet fully awake to the advantages of this type of standardization, though great strides have been made within the past few years.

Standardization of Rig Irons.

A member of the bureau visited Tulsa, Okla., to confer with the standardization committee of the Purchasing Agents' Association of Tulsa, Okla. The conference had been called for the purpose of standardizing rig irons used in drilling oil wells. Manufacturers, purchasing agents, and users of rig irons were well represented at the conference, and very good progress was made toward rendering the product of various manfacturers interchangeable. If this is brought about, in the case of breakage of a part, it will be possible to replace it by a similar part from the same or any other manufacturer.

The bureau has agreed to outline a complete series of gauges to be used in connection with the standardized equipment.

The standardization of rig iron should serve as a beginning of much needed standardization of all equipment used in the oil fields, not only in well drilling but in the storage and transportation of oil. For example, there is now a wide variation in the threads used on oil well casing. This question is being taken up by the bureau in cooperation with the National Screw Thread Commission.

Adding Machines.

Upon the invitation of the Postmaster General, a member of the bureau served on the committee for the standardization of adding machines used in the Postal Service. The committee made a thorough investigation of the construction, durability, and reliability of a number of types of adding machines, and also their adaptability for use in the Postal Service. The conclusion of the committee was immediately put into effect with an appreciable saving to the service.

Publications.

The following publications, relating to the work of the division of weights and measures, have been issued during the year and may be obtained from the Superintendent of Documents:

Report of the annual conference on weights and measures, Mis. Pub. No. 48.
Graphic comparison of screw thread pitches (H. W. Bearce), Mis. Pub. No. 49.
Thermal expansion of nickel, monel-metal, stellite, stainless steel and aluminum, (W. H. Souder and P. Hidnert), Sci. Paper No. 433.
Thermal expansion of a few steels.
Method for precision test of large capacity scales (C. A. Briggs and E. D. Gordon), Tech. Paper No. 199.
Weighing by substitution (C. A. Briggs and E. D. Gordon), Tech. Paper No. 208.

The following papers have been submitted for printing or are practically ready for submission:

A study of commercial dial micrometers for measuring paper (prepared jointly with paper section, P. L. Huston and D. R. Miller).
The testing of hydrometers, Cir. No. 16 (revision).
Standard density and volumetric tables, Cir. 19 (revision).
Gas measuring instruments (H. S. Bean).
A paper prepared jointly with the ceramic division on the Cause and control of fish scaling of enamel (R. R. Danielson and W. H. Souder) was published in the Journal of American Ceramic Society, August, 1921.
A paper dealing with the formula for computing the volume of a partially filled horizontal cylindrical tank (by A. F. Beal) has been nearly completed and will be issued in mimeograph form.

ELECTRICITY.

The work of this division covers electrical units, standards, measuring instruments, and methods of measurement, including electromotive force, resistance, current, inductance, capacitance, conductivity, insulation, magnetic measurements and properties, radioactivity, radio communication, and properties and performance of electrical equipment, such as lamps and batteries. As a result of cooperation with technical societies, testing laboratories, electrical industries, public service companies, public utility commissions, municipalities, and engineers in problems of standardization, including standards of adequacy and safety of service, some of the work has been extended to cover more than strictly electrical service.

GENERAL.

Scope of Electrical Work.

One of the most important functions of the bureau is the establishment and maintenance of the fundamental standards upon which all electrical measurements in this country are based. This includes the intercomparison of standards, extensive research in methods of measurement, and the development and improvement of subsidiary and derived standards. These standards are utilized and the results of the researches are applied in the testing of reference standards and instruments for manufacturers, testing laboratories, universities, research institutions, electric utilities, utility commissions, engineering and other interests, and various agencies of the Government. Close contact is also maintained with similar institutions in other countries so as to secure international uniformity.

The testing of electrical instruments and apparatus is of two main classes. First, the standardization of reference standards and precision instruments for manufacturing and other institutions which themselves make or standardize instruments for commercial use or which conduct research work. It is through the work of such institutions that the measurements made in practice are referred back to the standards of the bureau. Second, a limited amount of testing of commercial electrical measuring instruments, radio and photometric apparatus, magnetic materials, etc., is done chiefly for the purpose of keeping the bureau in touch with the needs of the industries, of developing methods, and of improving apparatus and materials. The greater portion of this testing is conducted for the Government services and serves the double purpose of providing information to be used in formulating specifications and of determining the quality of materials furnished upon specifications.

The research work has mainly to do with methods of measurement, the determination of the electric and magnetic properties of materials, and the development of those phases of engineering science in which measurement plays an important rôle. In general, this investigational work deals with fundamental properties and principles, so that the results may be applicable to a class of problems rather than being limited to the one specific problem under investigation. The work on correlation of magnetic and mechanical properties of iron and steel and in the study of insulating materials are examples.

The research work in radio communication, magnetism, radioactivity, and photometry is along lines quite similar to that in the more purely electrical measurements. Standards have been and are being developed, methods of measurements are being improved, and important special problems of significance to the industries and in a number of cases of particular importance to the Government are being investigated. Specific examples of the projects in hand during the past year are given in the sections below.

Public Utility Investigations.

Another important activity of this division, including more of engineering and field work than most of the electrical work referred to above, is the investigation of problems arising in connection with various public utilities, particularly electric light and power, gas, street railway, and telephone services. The work includes (1) scientific and engineering research, (2) the study of the conditions which determine the quality of the public utility service of various kinds, (3) methods of testing and inspection employed by municipalities and commissions, (4) safety rules for use by the utility companies to safeguard their employees and the public, and (5) the collection and distribution of information by published papers and through correspondence.

This work is a natural outgrowth of the research and testing done by the Bureau of Standards for the public utility companies and commissions. The testing of electrical instruments and meters, of gas lamps and the standards employed in testing gas, the life testing of electric lamps, the testing of instruments used in telephone work, research on electrolysis mitigation, and similar investigations and tests connected with public utilities, have all involved questions of standards of service. The bureau has gradually accumulated a considerable amount of information on these questions and has been able to contribute materially to the establishment of standards of quality in several of these services. Furthermore, it has promoted with marked success the practice of settling disputed questions in this field on the basis of sound engineering and economic principles and of cooperation between interests rather than by legal controversy, and in so doing the bureau has attained a recognized position as an advisor and mediator in such questions.

The establishment and enforcement of regulations for utility services of the kinds covered by the bureau's work are recognized as proper functions of State or local governments, and the bureau neither has nor seeks any legal authority to control these services. However, the mere determination of the facts regarding the quality of service rendered often involves difficult technical or engineering questions. To say what constitutes reasonably good service and whether improvements are practicable is usually not easy. For most cities and many State commissions it is a difficult matter to judge the quality of service rendered by the utilities. Obviously, it will never be economical or desirable for each commission or city to handle these questions alone. Though they possess large and able engineering staffs or employ specialists for each separate problem, the question of what is good service or whether the service in any given case is adequate, safe, and satisfactory can usually be settled only by reference to what is done under similar circumstances elsewhere in the country. In other words, standards of good practice and good service are largely determined by general experience, and should be studied comparatively using the experience of the entire country. The bureau has been doing this for several years, and has done enough to demonstrate the practicability and acceptability of the method.

In many States the commissions have set standards of service for the different utilities, and most of those that have done so have been glad to make use of the bureau's assistance. It will conduce to fairness and a good understanding to have the subject studied further and to have specifications as definite and complete as possible made available for all branches of public-utility service. The present status of the utility work is summarized in the sections following those on electrical measurements.

General Condition of the Division.

During this year, as for the past three years, there has been a gradual reduction in the staff of the division, the total personnel of all classes assigned regularly to its work being 121 on June 30, 1922, as compared with 163, 148, and 128, respectively, at the close of the three preceding years. On the other hand, the number of changes in personnel has been relatively small in comparison with recent years, and the slight decrease in numbers has probably been more than counterbalanced by the added experience of the staff in general. It has, however, been necessary to extend the work into some new fields, and the amount of testing required has been very large. Consequently there is little progress to report on much of the fundamental work of the division. The character of the work done in years past has given the bureau an unquestioned supremacy in the field of electrical measurements and has put it in position to render service of great value to the country. Under present conditions, however, the demands for such service are so insistent that they threaten to undermine the foundations of the work.

The bureau's earlier electrical work was largely on fundamental problems of measurement; the results of these researches, in order to be of practical value, must be applied in commercial measurements and in industrial processes. To make such application possible, the bureau must calibrate laboratory and factory standards and instruments, and must make tests of electrical and magnetic materials; but all this work takes time and facilities, which have had to be diverted from the research previously carried on. If governmental and industrial needs are to be met, the work in testing and calibration must be given precedence, and it has now reached a magnitude which absorbs practically all the resources of the division and precludes research.

The bureau is consequently in a dilemma. If research is neglected the bureau can not hope to keep abreast of the needs for greater refinement in measurements, or to maintain either its physical standards or the caliber of its personnel. Men of large capacity will remain on relatively low salaries if the work is stimulating and affords opportunity for growth; they will not remain to do merely routine work. On the other hand, the finest researches are not profitable unless means are provided for their application. The only solutions for the difficulty appear to be either to obtain additional support for the work or else definitely to abandon some parts of it, and all parts are of such fundamental importance that this latter course can be considered only as a last resort.

RESISTANCE MEASUREMENTS.

Routine Testing.

The demand for the testing of precision resistance standards and resistance apparatus has been greater than for any previous year in the history of the bureau. There has, however, been a marked decrease in the number of tests of insulated wires and cables so that the total amount of routine testing in this section was about the same as for the year ended June 30, 1921.

Change in Resistanec of a Conductor with Change in Its Potential.

According to a paper by Prof. H. A. Perkins, read before the American Physical Society in April, 1921, when a conductor is at a negative potential with respect to its surroundings there is an abnormal number of electrons within it, and consequently its resistance is below normal. Likewise when a conductor is at a positive potential with respect to surroundings there is a deficiency of electrons within it, and consequently its resistance is above normal. It was claimed that in a particular case that the change in resistance on changing the potential by about 10,000 volts amounted to about 1 part in 5,000.

Inasmuch as this effect if real would require modification of the generally accepted ideas concerning metallic conductors, it seemed advisable to investigate this matter further. On repeating the experiment under conditions such that the effect, if real, should have been more pronounced, no change in resistance was observed, though the apparatus used was sufficiently sensitive and sufficiently reliable to have detected a change in the resistance of about 1 part in 5,000,000.

A short paper describing the experiment is ready for publication.

Galvanometers.

A method has been developed for producing at a distance a magnified record of mechanical motions. This method involves the use of (1) a magnet on one and a coil of insulated wire on the other of the two parts whose relative motion is to be recorded, (2) a galvanometer which, when short-circuited, is excessively damped by the current induced in its winding, (3) a fairly large inductance of low resistance in parallel with the galvanometer, (4) a line connecting the coil on the part whose motion is to be recorded to the galvanometer, and (5) a source of light, and photographic means for recording deflections of the galvanometer.

The inductance counteracts to a very considerable degree the lag of the deflection of the galvanometer, due to the inertia of its moving system. In fact the inductance gives to the galvanometer an extra period which may be very short in comparison with the period determined by its inertia and suspension constants. Further, the motion in this extra period may be either under damped, over damped, or critically damped.

The method is applicable in the case of motions taking place in from 0.02 second to 20 seconds or having effective periods in this range. It was developed particularly for use in the seismological work referred to in a later section of this report.

Fundamental Measurements of Resistance.

Work on the determination of the resistance of the bureau's resistance standards in ohms as distinguished from international ohms; that is, in terms of a unit of length and a unit of time, has been under way during most of the year. For this work it is necessary to have (1) a motor which can be operated at a very constant speed, and means for determining this speed accurately, (2) one or more self or mutual inductances so designed that their dimensions can be measured and inductances calculated accurately from the dimensions, (3) apparatus of such design and construction that the electromotive force induced in the inductances can be accurately balanced against the potential drop in a conductor whose resistance is to be measured.

The different methods used in making such measurements have been carefully studied and some new ones devised. One of these seems to be superior to any of the methods previously used, and has been selected as the first of possibly two or three methods which may be used.

Apparatus for the control and measurement of the speed of the driving motor has been designed and the construction is nearing completion. This apparatus will synchronize a motor with either a clock or chronometer having an electrical contacting device operating once per second. Some novel features in symchronism will be embodied in this apparatus. The mutual inductances needed, two in number, are to be designed by and constructed under the supervision of the inductance and capacitance section.

The design of the apparatus for balancing the induced electromotive force against the potential drop in the conductor whose resistance is to be determined is nearing completion.

Standard for the Conductivity of Aluminum.

Some work in cooperation with the Laboratoire Central d'Electricité, the National Physical Laboratory, and the Aluminum Co. of America has been done toward a determination of the electrical properties of the aluminum used for conductor purposes. The purpose of this investigation is the establishment of an international standard for the electrical conductivity and other properties of aluminum as was done some years ago for copper. Samples of aluminum conductor of American manufacture have been procured and tested in this bureau, the Laboratoire Central d'Electricité, and the National Physical Laboratory. Samples of French manufacture have been procured and samples of British manufacture are expected for use in this investigation.

The Aluminum Co. of America will cooperate at least to the extent of furnishing samples of exceptionally pure aluminum as well as samples of what is known as conductor aluminum.

INDUCTANCE AND CAPACITANCE.

Inductance and Capacitance Laboratory.

Work in this laboratory has been so systematized that all ordinary tests can be handled promptly, but there is an increasing demand for measurements of higher precision. Such measurements entail much added work, since the accuracy requested is sometimes greater than the constancy of the apparatus, and it is therefore necessary to keep the apparatus under observation for some time.

Inductance Research.

A theoretical and experimental investigation of the effect of frequency on the inductance and resistance of single-layer coils has been completed. It has been found that most of the existing formulas are considerably in error.

Progress has been made on the derivation of a formula for the alternating current inductance and resistance of a three-phase cable. While this is not yet completed, it has reached a point where it is possible to indicate the limitations on the size of power cables which can be economically used on 60-cycle current.

Capacitance Research.

A research on the determination of the capacitance and power factor of some 10-microfared paper condensers shows that there is considerable change in the power factor of these paper condensers with time.

An investigation was carried on under the direction of this laboratory to determine the change of the capacitance and power factor of some telephone condensers at low temperatures. The condensers investigated were paper and tinfoil impregnated with paraffin. Measurements were made at temperatures ranging from —40° C. to +25° C. The maximum value of the capacitance occurred at about +11° C. At —40° C. the capacitance was about 3 per cent less. The power factor showed a linear increase with decrease in temperature, the increase between +20 and —40° C. being about 100 per cent. The actual measurements in this investigation were made by members of the auronautic instruments section, the purpose being to determine how much variation might be expected in apparatus used on airplanes due to the change in temperature as the airplane ascends.

Methods of Measuring Dielectric Loss.

There have been a number of requests during the year for information concerning the best methods to be used in measuring the power loss in dielectrics subjected to alternating electromotive forces. The problem is a varied one, since in some cases the capacitance is large and the applied voltage relatively low, whereas in other cases the capacitance is small and the applied voltage may be very high. Also, measurements are sometimes wanted over a wide range of frequencies. In particular, some of the large manufacturing companies desire methods which they can use in their laboratories to make routine tests. Up to the present time the methods of different laboratories have not given consistent results. The bureau has, therefore, begun a systematic investigation of the different methods of measuring dielectric loss. It is expected to carry this over a considerable range of voltages and frequencies. A bridge method has been satisfactorily used in the bureau's laboratories but considerable difficulty has been found in adapting it for use in commercial establishments. Other methods will be tried in the near future.

Properties of Insulators for Submarine Cables.

At the request of the Signal Corps of the War Department an investigation of cable insulating materials has been undertaken, and for several months measurements have been made at frequent intervals of the insulation resistance, dielectric constant, and dielectric loss of samples of rubber and gutta-percha. While some conclusions have been reached, it is necessary to continue the investigation. It is hoped to try a wider range of materials.

Absolute Determination of the Ohm.

Since a resistance can be experimentally measured in terms of inductance and time, an absolute determination of resistance can be made if an inductance is constructed whose value can be computed from its dimensions. The inductance laboratory can make the necessary measurements with high accuracy, the main difficulty being the construction of the inductance coil. A number of coils have been constructed, but as yet coils have not been made which have the required stability. There are still a few theoretical considerations to be examined regarding the computation of the inductance, but the principal problem to be solved is the construction of an inductance which will be permanent and which will be of such form that its physical dimensions can be accurately measured.

ELECTRICAL MEASURING INSTRUMENTS.

Testing of Electrical Instruments.

The volume of testing of instruments for the Government was substantially the same as during the preceding year, while that for outside parties (public utility commissions, utility companies, and individuals) was only 40 per cent of that for the preceding year.

Cooperation with Associations.

The section has been represented on the following committees: Instruments and Measurements, American Institute of Electrical Engineers; Insulation, Engineering Division, National Research Council; Terminal Markings of Electrical Apparatus, Electric Power Club Sectional Committee, under American Engineering Standards Committee; Unbalance Factor, Standards Committee of the American Institute of Electrical Engineers; Standard Symbols for Electrical Equipment; Sectional Committee, American Engineering Standards Committee; Technical Committees on "Stranding" and on "Paper Insulation" of the Sectional Committee on Insulated Wires and Cables.

A number of committee meetings in New York were attended. The attention of the Instruments and Measurements Committee was called to the progress in instrument standardization abroad. The bureau's representative on this committee was thereupon designated as a subcommittee of one to make a canvass of the sentiment of American makers of electrical instruments. The French and German specifications were translated, and copies of these and of the British specifications were sent out to all the makers and to the members of the two national meter committees. This was supplemented by personal conferences with the makers at their works. It is hoped that as a result of this work a conference of makers, users, and independent authorities will be called to consider whether it is desirable to formulate American standard specifications.

A circular letter, summarizing the present confused state of definitions of "Power factor," and "Unbalance" in polyphase systems, was prepared and circulated by the Unbalance Factor Committee. Discussion stimulated by this is still in progress.

Assistance was given the N. E. L. A. meter committee in the revision of Chapter II of the Meterman's Handbook.

Federal Standard Specifications.

The chief of this section has served as chairman of the electrical supplies committee of the Federal Specifications Board. Six meetings have been held, conferences have been held with the underwriters' laboratories at Chicago and New York, 10 specifications have been recommended for adoption, and others are under consideration.

Cooperation with Manufacturers.

Assistance has been furnished to a number of firms in developing improvements in their product. Such work includes: (*a*) Suggesting a modification in the design of portable watt-hour meters in order to reduce the error resulting from internal heating; (*b*) measurements on the effect of variations in room temperature and of voltage on the accuracy of direct-current watt-hour meters constructed with monel and with german silver resistors, which showed that the use of monel reduced the errors very decidedly; (*c*) planning a new style of deflection potentiometer and studying the heating errors of the coils in the volt boxes used to extend the range of the potentiometer; (*d*) assisting in the development of a convenient portable apparatus for current transformer testing based on the method described in Scientific Paper No. 309; and (*e*) testing a radically new type of current transformer to determine its possibilities, and preparing a paper for the A. I. E. E. on the subject.

Development of Apparatus.

The work on instrument standardization, mentioned above, has required so much time that no progress has been made on the design and construction of the 250-kilovolt absolute electrometer referred to last year. It is hoped that work may soon be resumed on this project.

Some further progress has been made in standardizing the bureau's voltage transformers, and data have been obtained to indicate their constancy. Much work still remains to be done on this problem.

A variable resistance standard for current transformer testing, which will materially reduce the time required for such work, has been constructed and installed.

Ignition Apparatus.

The investigation of ignition apparatus has been continued in cooperation with the automotive section of the division of temperature and heat, and a full report on that work is given under that section. The experiments on the sparking voltage of spark gaps in which one electrode is decidedly hotter than the other have been continued and a report of the results has been made to the Air Service.

MAGNETIC MEASUREMENTS.

General Magnetic Measurements.

As time and resources permit, the magnetic laboratory is gradually extending the range of measurements which it is prepared to make. During the past year a method for testing small specimens has been developed which is capable of giving an accuracy sufficient for most research work on the properties of materials. This method will be especially valuable in the study of materials of exceptional purity which are generally available only in small quantities.

Attention has also been given to a general revision of routine testing methods to meet more exactly the needs of those submitting materials for magnetic tests.

Correlation of Properties.

Many practical problems involving the relationship between the magnetic properties of steel and other physical properties require for their solution a knowledge of the effect of various factors on the magnetic properties. These governing factors include chemical composition, previous heat treatment, cold work, stresses, etc.

During the past year a study has been made of the influence of composition and heat treatment on the magnetic properties of a series of iron-carbon alloys of exceptional purity. A paper presenting the results of this investigation is nearly completed.

An investigation is now under way to determine the effect of manganese on the magnetic properties of straight carbon steel. For this purpose a series of very pure alloys of iron, carbon, and manganese has been available.

Thermomagnetic Analysis.

One of the lines of investigation hitherto almost entirely untouched in this country is thermomagnetic analysis in which continuous observations are made of the intensity of magnetization of a specimen during heating or cooling. By this means much can be learned of the structural changes which take place in steel upon heating or cooling. Apparatus for such observations has been completed during the year and should prove extremely valuable in the study of magnetic materials.

Magnetic Compasses.

Cooperation with the Ordnance Department, United States Army, on the use of magnetic compasses in tanks was continued during the year and a final report has been rendered. It has been found possible under certain conditions to use magnetic compasses with satisfactory results.

Miscellaneous Activities.

The section has cooperated with various organizations on magnetic subjects, and particularly with the committee on magnetic properties of the American Society for Testing Materials, which is completely revising its specifications for magnetic testing.

PHOTOMETRY AND ILLUMINATING ENGINEERING.

Calibration of Standard Lamps.

The primary functions of this section are the maintenance of the standard lamps on which all candlepower and illumination measurements in the United States are based, and the provision for other laboratories of lamps calibrated by comparison with the bureau's reference standards. The latter function has involved an unusually large amount of work during the year. About 440 electric standard lamps have been calibrated for research, university, and testing laboratories, and lamp factories, and, in addition, measurements have been made on four large groups of lamps circulated among the more important factories in order to secure greater uniformity in the results of photometric measurements made by them. At the close of the year there still remain on hand about 125 standards to be calibrated, and two groups of lamps to be measured for the factory intercomparisons.

Miniature Standard Lamps.

In connection with attempts to obtain agreement on specifications for miniature lamps (including automobile lamps) comparisons were made last year between the candlepower and efficiency ratings assigned to such lamps by various factories. For this purpose a considerable number of lamps of various kinds were circulated and measured in different laboratories. As a result it was found that differences in the ratings assigned were as large as 10 per cent between different factories. Since that time standards have been interchanged between the different factories and between the bureau and the factories, and a considerable improvement in uniformity has been obtained. During the year it has developed, however, that there was an important outstanding discrepancy in values even of lamps issued by the bureau. This made it necessary to devote a considerable amount of time to checking up the measurements which had been made on miniature standards. The difficulty in establishing satisfactory values for miniature standards arises from three causes: (1) It is uncertain how well miniature lamps may be depended upon to maintain their values, and consequently the bureau has not felt justified in depending on miniature standards for the calibration of those which were sent out. (2) The miniatures, especially of the automobile type, operate at very high efficiency, being comparable in this respect to gas-filled lamps. This means that they differ very greatly in value from the standards which are of the same order of intensity as themselves. It is therefore advisable to calibrate these miniatures in terms of the large gas-filled standards. (3) This stepping down in intensity from the large lamps to the small ones involves measurements over a wide range of candlepowers, calling for a precise knowledge of the transmission of sectored disks and other devices used in cutting down the intensity over such ranges. In the checks which have been carried out the values for miniature standards have been obtained in several different ways, most of which have shown very satisfactory agreement. More recent checks between the various factories have also agreed fairly well.

Photometric Methods.

The most urgent practical problems in photometry at present are those arising from the development of coiled-filament lamps of high efficiency and correspondingly high temperature, which give more nearly white light than the older lamps. Because of the irregular arrangement of filaments these lamps can be satisfactorily measured only in an integrating sphere, and the tendency is now to measure all lamps in spheres, because such measurements give directly an indication of the total light output. The bureau has therefore continued to give special attention to problems connected with sphere measurements. A paper on the general theory, construction, and use of the sphere is now in press, and another is in preparation dealing particularly with errors arising from lack of perfect whiteness in sphere coatings.

No general agreement has been reached regarding the methods to be used in assigning candlepower values to lights differing in color from the fundamental reference standards. A committee on which the bureau is represented was appointed last year by the International Commission on Illumination to deal with this problem, and through this committee, as well as by direct dealings with the national laboratories of other countries, it is hoped that substantial progress can soon be made toward a settlement of this difficulty. Pending such a settlement the bureau is maintaining sets of reference standards representing the three most important types; that is, carbon lamps (the original basis of the unit), vacuum tungsten, and gas-filled tungsten. A paper dealing with these general problems of photometry was published in the Journal of the Optical Society for July, 1921.

Corrections for Flame Standards.

In work done at the bureau on flame standards of candlepower the factors found to represent the effect of atmospheric humidity have differed consistently from those found in England, particularly for the 10-candle Harcourt pentane lamp, which is the nominal basis of the British unit. Experimental work carried out several years ago indicated that the cause of the discrepancy was a small temperature effect. Recent comparisons of data obtained in England and in Japan with that obtained at the bureau have confirmed the earlier laboratory results, and consequently new correction factors have been proposed. Detailed data are given in the Journal of the Optical Society, September, 1921.

Specifications for Incandescent Electric Lamps.

A new edition of Circular 13, Standard Specifications for Large Incandescent Electric Lamps, issued during the year, marked a new departure in the test procedure for tungsten lamps. For about 15 years electric lamps have been purchased by the Federal Government under specifications published in Circular 13. Progress in the art of lamp manufacture has been so rapid that this circular has had to be revised nine times in order to keep the specification abreast of current developments. The original specifications covered only carbon filament lamps. In later editions metalized carbon and tantalum lamps were introduced and then discarded, as tungsten-filament lamps gradually displaced them in use. In connection with these radical changes in types of lamps, very great improvements were made in the efficiency and the life required, but no fundamental change was made in the form of the specifications or in the methods of testing until this latest edition was prepared. The most notable of the changes made is the abandonment of the long established provision that the life of test lamps shall be considered as ended when the candlepower has fallen to 80 per cent of the initial value. The specification of such an end point is convenient and reasonable in the testing of carbon lamps, because those lamps will often burn for a long period after they have become so blackened that they should not be continued in use. In tungsten lamps, however, means have been found to prevent excessive blackening of the bulbs, so that the lamps normally burn out before their efficiency has fallen enough to justify replacing them. The new tests are therefore based on the total life to the time of burn out, thus conforming more nearly to actual practice in the use of lamps.

The performance of the lamp throughout its life is also taken into account through two new provisions. One of these is the evaluation of life-test results on the basis of average efficiency throughout life, instead of the initial efficiency; the other is a requirement that the average light flux during the life of the lamp must not fall below a specified percentage of the initial flux.

Tests under these new specifications are intended to give a more complete indication of the performance of lamps than the former specifications did, and thus to discriminate more exactly between types of lamps. In the first application of the new specifications it was deemed wise to make the requirements moderate, and it was recognized that for the first year the application of the new requirements should be more or less experimental. In the application of the new specifications some difficulties have arisen with regard to details of procedure, but on the whole the use of the new tests has been inaugurated with very little confusion or misunderstanding. A new (tenth) edition of Circular 13 is in course of preparation, but in general its provisions for tungsten lamps will not differ essentially from those of the ninth edition. In the new edition, however, carbon lamps will be omitted, thus completing the transition from the early editions which included only this type.

Inspection and Life Tests of Electric Lamps Purchased by the Government.

Government lamp orders during the preceding year were abnormally large, and it is evident that many of these were for stock, since purchases during the current year have been abnormally small, aggregating only 1,380,000 lamps, having a total value of $420,000. Large tungsten lamps constituted 79 per cent of the total number, being a slightly larger proportion than last year. Large carbon lamps fell from 14.5 to 9 per cent of the total, while miniature tungstens and carbons comprised, respectively, 10 and 2 per cent. Of the large tungsten lamps 17 per cent were gas-filled, costing, however, 40 per cent of the amount spent for this group. It is understood that practically no large carbon lamps will be ordered during the coming year. They have heretofore been used on vessels of the Navy because of their mechanical strength, but the "mill type" tungsten lamps have now been found sufficiently strong for this purpose.

Because many lamps ordered during the preceding year were delivered later, the number inspected at the factories has been considerably greater than the number ordered. About 1,640,000 lamps were so inspected, and 2,350 samples representing them were run on the life test at the bureau. Of these 1,895 were vacuum tungsten, 180 gas-filled, and 275 carbon-filament lamps.

Automobile Headlights.

During this year the bureau has again taken up actively the problem of automobile headlight regulations particularly with a view to the promotion of uniformity among the States so far as this is feasible. Information regarding present laws and their enforcement has been obtained from nearly all the States. There is still considerable diversity in the laws, and there are also important differences of procedure in method of enforcement. In order to secure a satisfactory condition, it will be necessary to have (1) uniform laws, (2) uniform procedure, and (3) an extensive campaign of education both for enforcement officers and for garage men and drivers of automobiles.

So far as uniformity of legislation has been obtained, it has been based on the specifications formulated by the committee on motor vehicle lighting of the Illuminating Engineering Society, on which the bureau has been represented. These specifications have been adopted in practically the same form by nearly a dozen States. They were based on an extensive series of road and laboratory tests and were intended to provide for two things—(1) a reasonably good driving light and (2) the prevention of glare in the eyes of other drivers. These specifications have been revised by the committee during this year in order to bring them up to the requirements of the most advanced States. The bureau has installed special equipment for making tests in accordance with these specifications, and has been regularly making tests for New York State.

Miscellaneous Illumination Problems.

The bureau is called on by Government officers and others for advice and assistance in a great variety of problems involving illumination or its measurement. Some of these requests require considerable time. For example, instruments for measurement of light in connection with various tests or investigations have been calibrated for five different branches of the Government service during the year, brief surveys of illumination in two Government buildings have been made, samples have been tested as a basis for the choice of new luminaries for the House of Representatives Office Building, measurements of light reflected by several metal surfaces have been made for another division of the bureau, and equipment for similar measurements has been provided for the research laboratory of a manufacturer of metal paints.

An extensive test of kerosene oils was made at the request of the department offices in connection with the contract for oil for the Lighthouse Service. This test led to some studies of the behavior of the lens lanterns in which the oil was to be used, and measurements were also made on lenses in combination with electric lamps proposed as a substitute for the oil lamps.

RADIO COMMUNICATION.

Radio Research and Information.

During the past year there has been a remarkable increase in poplar interest in radio communication. This has been greatly stimulated by the fact that there has become available radio-telephone apparatus of satisfactory performance, by means of which market and crop reports and other news, music, and entertainments have been transmitted broadcast and received by many persons. This general interest has resulted in a large increase in the bureau's correspondence on radio subjects. Dozens of letters asking for radio information are received each day, and many of these are of considerable importance. In order to answer such inquiries, as well as to keep the bureau's staff informed on current developments, it has been necessary to devote much time to the maintenance of a radio information service. An unusually large number of visitors have called at the radio laboratory, and in order to avoid continual interruption of the regular work in progress special arrangements have been made for demonstrating the exhibits of most general interest. Members of the bureau have delivered a number of lectures on radio subjects.

While this necessity for maintaining an enlarged information service has had a direct deterrent effect on the research work in some respects, it has, on the other hand, stimulated the work on a number of research problems and made the need for results more urgent. In addition to the bureau's general program of radio research, attention has been given during the past year to special problems for the Air Service, the Signal Corps, and the Department of Agriculture. The work on the several lines of research is presented in later paragraphs.

Seven scientific papers and circulars prepared by this section have been issued by the bureau during the year, and two other publications were issued by other Government agencies. Twelve papers and nine abstracts were published in outside periodicals. Five Scientific Papers and Circulars are now in press besides four papers in outside periodicals. Eleven letter circulars were issued. Several of these were in response to the popular demand for information on the construction and use of simple radio receiving equipment. A second edition of "The Principles Underlying Radio Communication" was published. Both the first and second editions of this book were prepared by the Bureau of Standards for the Signal Corps, and issued as Signal Corps publications. The first edition was prepared during 1918 for use in training Signal Corps personnel for radio work. The second edition contains a considerable amount of new material, and is nearly double the size of the first edition. It is a comprehensive elementary textbook, and contains over 600 pages.

The Bureau of Standards has also contributed various news items concerning radio work and publications to the "Radio Service Bulletin," a monthly periodical published by the Bureau of Navigation of the Department of Commerce.

Many preliminary reports on radio work of the bureau are prepared in typewritten form as laboratory reports available for distribution to technical workers who have special need for them. During the year about 100 such reports were prepared.

Electron Tubes as Generators.

Theoretical and experimental investigations were conducted on the power output of electron-tube generators. A paper was prepared for publication on methods of testing and rating electron-tube generators.

A special form of electron-tube generator was developed for producing sparks of high frequency for use with recording apparatus for recording the pressure cycle in a gas engine cylinder.

Electron Tubes as Amplifiers.

Special amplifiers, using both radiofrequency and audiofrequency amplification, were developed for particular purposes, including direction finding, radiotelephone communication with surfboats of the Coast Guard service and reception of material sent broadcast by radiotelephony.

A 5-stage amplifier was developed which uses 60-cycle alternating current to supply power for the filaments and plates, instead of the usual storage and dry batteries. Both radiofrequency and audiofrequency amplification are used in connection with a crystal detector. This amplifier has aroused considerable interest, and is described in a paper which has been published. A special amplifier was developed for amplifying variations in direct current, or low-frequency alternating currents.

Radio Control.

A radio-operated relay has been developed which employs audiofrequency tuning and has been found effective for operating an ordinary telegraph tape recorder, and for operating other mechanisms. Such a relay can be used for the remote control of mechanisms by radio. The relay is rugged and highly selective, and is very useful when moderate strays or considerable interference exists. By proper audiofrequency tuning it has made clear tape records of messages when interference was so severe that an experienced operator could not copy the message at all by the use of telephones. It can be used for reception at fairly high speeds. Relays of this type have been constructed for various applications in the Signal Corps and other branches of the Government service.

Radiotelephony.

At the request of the Coast Guard, radiotelephone transmitting and receiving equipment was installed on a 36-foot motor-driven surfboat, and successful communication in both directions was maintained during a demonstration over a distance of about 5 miles from shore. The antenna used on the boat was a single-turn coil antenna, of which the hull of the boat formed a part. A special multistage amplifier was constructed for use in this work.

A scientific paper was issued describing the operation of the modulator tube in radiotelephone transmitting sets.

Arc Converters.

An investigation was conducted to determine the most satisfactory denaturing formula for alcohol used to supply hydrogen in the arc chamber of small arcs, and several kinds of denatured alcohol were found which gave more satisfactory operation than ethyl alcohol, which was used as a comparison standard.

Preliminary developments were made on a short-wave arc using electrodes submerged in alcohol.

Direction Finding.

Improvements were made in a method of locating an airplane in flight transmitting radio signals. Two trucks equipped with crossed-coil direction finders were used, and results of satisfactory accuracy were obtained. Other work has been done on direction finding and related problems for the Air Service which can not be covered in this report.

Interference Measurement.

The rapid growth of radiocommunication has made it more important than ever that the wave sent out by a radio transmitting station shall have such characteristics as will not interfere with waves sent out from other stations. Interference-producing qualities of radiotelegraph signals sent out by damped waves from spark transmitting stations have been studied for a number of years.

In the past few years the use of continuous waves has greatly increased. The problems of the interference-producing qualities of such waves, modulated either by keying in telegraph transmission or by the voice in radiotelephony, are quite different from those of the damped waves from a spark transmitter, and require careful study. The Paris conference of the Interallied Technical Committee gave consideration to this problem. The bureau is making theoretical studies of the problem, with a view to establishing a criterion for the interference-producing qualities of a modulated continuous wave.

Assistance was given to the radio inspection service of the Bureau of Navigation in connection with an investigation of a spark transmitting station which was using a special type of transmitting apparatus and was causing serious interference.

Radio Fog Signaling.

A scientific paper, describing the applications of the radio direction finder to navigation, was published during the year. A considerable number of manufacturers, prepared to make direction finders for installation on board ship, attended a conference with the Assistant Secretary of Commerce, the Commissioner of Lighthouses, and the Director of the Bureau of Standards, and expressed much active interest in the development of radio direction finding. The Bureau of Lighthouses is installing radio beacon equipment at five additional light stations, and direction finders are being installed on a considerable number of ships. The interest of shipowners in radio direction finding is increasing. A recalibration was made during the year of the direction finder on board the lighthouse tender *Tulip*, and it was found that the calibration was substantially the same as the one taken about a year previous. A direction finder installed on the U. S. Army transport *Cambrai* was calibrated.

Radio Receiving Sets.

A comprehensive investigation has been made on the construction, design, and performance of representative types of radio receiving sets. The rapid growth of popular interest in radio has caused a very large increase in the demand for receiving sets, and many new manufacturers have commenced to make receiving equipment. This investigation is, therefore, of immediate commercial importance. Methods of testing and standards of performance have been developed for receiving sets, and publications covering various classes of sets are in preparation. Some of this work has been conducted in cooperation with commercial testing laboratories and retail trade organizations.

Standardization of Radio Equipment.

The bureau has cooperated with the Institute of Radio Engineers and the American Society for Testing Materials in the standardization of radio terminology and definitions and in the preparation of specifications for insulating materials used in radio apparatus. Contact has been maintained with manufacturers of radio apparatus, in order that the bureau may, so far as possible, adapt its radio work to the needs of the industry. Information regarding available radio apparatus has been compiled, but the very rapid growth of the industry has made it impossible to keep this information up to date. This rapid growth has made the need of standardization even more imperative than heretofore.

The bureau has cooperated with the National Fire Protection Association in the preparation of a revised rule for radio installations for the National Electrical code.

Interdepartment Advisory Committee on Governmental Radio Broadcasting.

Members of the bureau represented the Department of Commerce on the Interdepartment Advisory Committee on Governmental Radio Broadcasting, which considers the problems involved in the broadcasting by radio of material emanating from various Government departments and other interdepartment phases of the radio work of the Government.

Radiotelephony Conference.

The number of radio telephone broadcasting stations in the United States increased very rapidly during the year. Interference between these stations threatened to become serious, and it was found impossible for every station to transmit according to its own convenience. The need of new laws and regulations to cover the development of radiotelephony, and broadcasting in particular, became imperative. The Secretary of Commerce in February called a conference of radio specialists to consider the legal and technical problems of broadcasting. The experts of the bureau gave assistance to the committees of the conference which considered technical problems.

International Conferences.

During the summer of 1921 there met at Paris representatives of the British Empire, France, Italy, Japan, and the United States to consider the technical problems involved in new international agreements on radio communication which have arisen because of many important advances since the International Radio Convention of 1912. The chief of the radio section of the Bureau of Standards attended the meeting of the committee as a delegate of the Department of Commerce.

The Conference on the Limitation of Armaments held in Washington during the past winter had the problems of communication on its agenda. In connection with this subject two members of the bureau served on the technical staff of the American delegation.

International Union of Scientific Radiotelegraphy.

Meetings of the International Union were held at Paris in connection with the meetings of the Interallied Technical Committee, and were attended by a member of the bureau. This organization organizes radio research on problems that are international in scope. A number of meetings of the American section of the International Union, of which a member of the bureau is the technical secretary, have been held during the year.

ELECTRIC BATTERIES.

Test of Batteries.

During the fiscal year 38 tests of routine nature have been made, comprising 554 batteries as follows: dry cells and batteries, 487; other forms of primary batteries, 10; battery materials, 4; storage batteries, 53. These included tests for the Panama Canal, Department of Commerce, Signal Corps, Quartermaster Corps, Post Office Department, General Supply Committee, Treasury Department, and Bureau of Ordnance of the Navy Department. One of the most important of the tests was on starting and lighting batteries for automobile service. Seventeen different makes of batteries were submitted for a competitive test to determine their compliance with the specifications which were prepared by this bureau, with the cooperation of manufacturers and the Society of Automotive Engineers, for the use of the Motor Transport Division of the Army. About one-half of these different makes were found to be satisfactory. Defects revealed by the tests were brought to the attention of the manufacturers, and in some cases they have been able to submit for retest new batteries that comply with the specifications.

In addition to these routine tests, a number of special ones have been made to obtain information required in writing specifications and for miscellaneous purposes. The conference for the standardization of dry cells mentioned below requested the bureau to make certain tests to determine the performance to be required of the standard sizes of dry batteries. The bureau accordingly obtained 676 representative samples on which a carefully planned series of measurements has been made. One hundred and seventy-six other batteries have been tested in connection with miscellaneous investigations. The total number of batteries tested during the fiscal year was, therefore, 1,406.

Standardization of Dry Cells.

During the past year the standardization of dry cells and flashlight batteries has been accomplished through the cordial cooperation of manufacturers and large users of dry cells. A conference to consider the standardization and specifications for dry cells was held at the Bureau of Standards December 5 and 6, 1921. This conference was attended by representatives of the largest manufacturers, the various Government departments, and the largest individual users of these batteries. The conference considered 17 different sizes of dry cells, and standardized 7. It considered 30 different sizes and kinds of flashlight batteries, and adopted 8 of these as standard. It considered assembled batteries containing larger sizes of cells, of which about 30 were being manufactured, and standardized 6. Two sizes of batteries for radio apparatus were standardized also. In addition to the standardization of sizes, the conference agreed on general requirements of performance for the sizes which were accepted as standard, and the bureau was requested to make tests to determine the minimum performance to be required in cases where sufficient information was not already available. These tests are now being made.

The bureau was also requested to revise its specifications for dry cells to conform with the standardization adopted by the conference. This revision has been made, and photostat copies of the specifications, showing the additions, omissions, and changes proposed, have been sent to all members of the conference for criticism.

Circular on Dry Cells.

In 1919 the bureau issued a circular on "The Electrical Characteristics and Testing of Dry Cells," containing also specifications for dry cells and batteries. The first edition of this circular was quickly exhausted. The bureau has obtained much additional information about the performance of dry cells, and a revised edition of the circular has now been prepared. This circular summarizes the available information on dry cells. A brief description of the materials and methods of construction and the elementary theory of the operation of the cells is given. Various sizes and kinds of dry cells on the market are described. The electrical characteristics of the cells and methods of testing them are discussed. In the appendix are given specifications for dry cells, which have been prepared by this bureau with the cooperation of the manufacturers and principal users of dry cells. At the close of the fiscal year the text of this revised circular was ready to be sent to the Printing Office.

Specifications for Airplane Batteries.

At the suggestion of the Navy Department, the Bureau of Standards called a conference of storage-battery manufacturers and others to discuss the standardization and specifications for airplane batteries. Very large currents are required from the battery in cranking airplane engines, particularly when the engines are cold, but the general conditions of airplane service require batteries of light weight having the maximum output. Because of the special requirements for batteries in this service, the conference designated a committee consisting of representatives of the Bureau of Aeronautics, Navy Department, the Air Service of the Army, and the Bureau of Standards to consider problems relating to the rating of these batteries, the tests to be required of them, and the physical characteristics of which a knowledge is necessary in preparing adequate specifications. This committee is preparing a report dealing with these subjects. A comprehensive series of experiments has been planned to obtain information about physical performance of storage batteries under the conditions peculiar to airplane service.

Cooperation with Technical Committees.

The bureau has cooperated with the standards committee of the American Institute of Electrical Engineers through the membership of a bureau representative on the subcommittee for storage batteries. The work of this committee consisted of a revision of the standard definitions and nomenclature dealing with storage batteries. A member of the bureau's staff was appointed conferee of the storage-battery division of the standards committee of the Society of Automotive Engineers. This work has been confined chiefly to standardization of starting and lighting batteries for automobile service. The bureau has acted as technical adviser of the battery committee of the signal division of the American Railway Association. This committee prepared specifications for dry cells and has submitted them for adoption by the signal division. These specifications are in conformity, both as to requirements and tests, with the specifications prepared by the bureau in accordance with the recommendations of the conference on dry cells mentioned above. The bureau has given assistance to the General Supply Committee in the matter of making awards for dry cells and storage batteries. In some cases extensive tests have been made especially for the Supply Committee, and the results of the various tests made by the bureau on different kinds of batteries have also been made available for the committee's use.

Electromotive Force of Cells at Low Temperatures.

The experiments mentioned in the report for last year have been extended to lower temperatures because of the theoretical interest of the problems presented. The practical importance of a knowledge of the electromotive behavior of dry cells and storage batteries at low temperatures has arisen from their use in the Arctic and at high altitudes. Two series of experiments have been made. In the first of these, dry cells and storage batteries were cooled to —72° C., and in the second to —170° C. The Gibbs-Helmholtz equation which deals with the thermodynamics of such cells was applied to the observations and excellent agreement between theory and observation was found. At the lowest temperatures unusually high values of the voltage were sometimes observed and the polarity was often reversed. An explanation of this unusual phenomenon was found on the basis of the Nernst equation. The experiments within the range of +25° C. to —72° C. answer completely the practical questions which prompted the investigation. A publication describing the results of these experiments has been issued.

Resistance and Potential Measurements of Dry Cells.

A study has been made of methods of measuring the internal resistance of dry cells and the potential relations that exist between the positive and negative electrodes. Both the direct and alternating current methods have been employed. Measurements by direct current do not agree with those made by alternating current even if the effects of polarization are reduced to a minimum. The most promising method employed has been a resonance bridge using alternating current. By means of this bridge it has been possible to follow the changes in resistance which take place within the cells during the course of their discharge on various standard tests. The internal resistance of these cells is a matter of importance since it determines in large measure the usefulness of the cell under ordinary conditions of service. A series of potential measurements which was made on cells during the course of their discharge was analyzed and the results computed. It was found that valuable information can be derived from measurements of the fall in potential at each electrode during the discharge. The results of these measurements, which have an important bearing on the design and testing of dry cells, are being prepared for publication.

Rate of Sulphation of Storage-Battery Plates.

Although numerous attempts have been made in the past to measure the rate of sulphation of storage-battery plates no convenient and accurate method has hitherto been devised. It is believed that this problem has now been solved by the method of weighing the plates when submerged in the electrolyte. It has been possible to make accurate measurements of the local action occurring at the positive and negative plates immersed in electrolyte of varying concentration, provided a balance of sufficient sensitivity is used and the temperature is maintained constant, as may be done by using a suitable thermostat bath. This work is expected to serve as the groundwork for a more extended investigation of the effect of impurities in storage-battery electrolytes. The experimental work on normal plates in pure solutions has been completed and the results are being prepared for publication.

Study of Storage-Battery Separators.

Experiments to determine the electrical resistance of storage-battery separators made of different kinds of wood and also the resistance of these separators and the action of acid of varying concentration have been made as the opportunity was afforded during the past year. This is part of a more general investigation to determine the relative merits of different kinds of storage battery separators. The experiments were incomplete at the close of the year.

Exhibit of Foreign Dry Cells.

The bureau has obtained dry cells manufactured in Denmark, Sweden, England, France, and Germany and has subjected these to the standard tests such as are made on American cells. These tests have continued throughout the year. An exhibit of foreign cells was prepared especially for those attending the conference on dry-cell standardization, but the exhibit has been continued as a permanent one. A summary is being prepared showing the comparative performance of the American and the foreign cells on the various standard tests.

Measurements of Current and Voltage in Starting an Airplane Engine.

At the request of the Air Service of the Army a series of experiments was undertaken to determine, by means of an oscillograph, the instantaneous values of current and voltage in the battery circuit during the cranking of a 12-cylinder Liberty airplane engine. Measurements of the current and voltage were made when the engine was at room temperatures and at various lower temperatures down to −29° C. Experiments were also made with different throttle openings and with the compression released in the cylinders from 1 to 12 successively. A report summarizing the measurements and showing the photographic reproductions of the oscillograms has been sent to the Air Service.

RADIOACTIVITY AND X-RAY MEASUREMENTS.

Gamma-Ray Measurements of Radioactive Preparations.

The amount of gamma-ray testing has been so great that there has been practically no opportunity for investigations in this field. Although the amount of radium tested has decreased during the last few months, the total for the year is approximately the same as that for the preceding year. Indications point to another increase in a short time. During the year gamma-ray measurements have been made of 2,070 radium preparations containing a total of 30,397 mg, and 17 mesothorium preparations containing a total of 1,010 mg. This material has a market value of about $3,500,000.

The proportions attained by this work during the eight and one-half years since routine gamma-ray testing was begun are shown in the following table:

Year.	Number of tests.	Equivalent milligrams of radium.	Year.	Number of tests.	Equivalent milligrams of radium.
1914 (half year)	28	486	1918–1919	1,068	13,367
1914–1915	98	2,097	1919–1920	1,413	25,278
1915–1916	177	4,531	1920–1921	2,129	35,565
1916–1917	292	6,638	1921–1922	2,087	31,407
1917–1918	1,248	5,376			

Because of inadequate facilities and lack of time it has been necessary to refuse a number of requests for tests of low-grade ores, of solutions, and of spring waters.

Work has been started, however, on the determination of radium content by the emanation method, and it is hoped that the bureau will soon be able to conduct such tests.

Self-Luminous Materials.

The quantity of luminous material measured for brightness far exceeded that of any previous year. Nearly all of the 2,389 tests made were on luminous tubes for various branches of the Government. On account of the large amount of this testing and also of the gamma-ray work, there has been no opportunity to continue investigations begun several years ago.

X Rays.

X-Ray investigations have been entirely discontinued. During the year only a few tests of protective materials have been made.

ELECTROLYSIS PREVENTION.

Scope of Current Electrolysis Work.

During the year the work of the electrolysis section has comprised four distinct phases of the subject of electrolysis and corrosion. These include the completion of the Report of the American Committee on Electrolysis, the further development and field application of the earth current meter, the carrying out of field researches jointly with the research subcommittee of the American Committee on Electrolysis with the special object of studying electrolysis mitigative measures, and the investigation of soil corrosion.

Report of American Committee on Electrolysis.

This report, which is a joint report issued by the committee representing all the national associations of utility companies and the Bureau of Standards, has been in preparation for nearly two years. The bureau took a very active part in preparing the text of the report, its engineers being chairmen of two of the four committees which prepared the report. After the text was completed the editorial work was undertaken by the bureau at the request of the committee, and arrangements for printing the report were also handled by the electrolysis section. This report was finally completed and issued to the public in October, 1921.

Earth Current Meter.

There has been under development by the bureau for more than two years past new methods and apparatus for making electrolysis surveys. This has resulted in the development of the earth-current meter, an apparatus for measuring the intensity of electric current discharged from a pipe at any particular point, and gives a more accurate measure of the rate of corrosion of the pipe surface than has heretofore been possible. During the past year some further development work was done on this apparatus, and this was supplemented by numerous field trials in Washington and near-by places. After these had yielded satisfactory results considerable work was done in a number of cities with the object of developing and standardizing the mode of procedure to be followed in the practical application of the method and instrument. These latter tests were carried on jointly with the research subcommittee of the American Committee on Electrolysis. The instrument has now been developed and standardized to a point where it meets all requirements in electrolysis testing, and has been adopted as the standard instrument for both routine testing and research work by the Bureau of Standards and the American Committee on Electrolysis. The instrument is now being introduced among utility companies for routine maintenance testing on pipe systems.

Work Carried on Jointly with the American Committee on Electrolysis.

For some years this bureau has been engaged jointly with the American Committee on Electrolysis in conducting research work, particularly with respect to mitigative measures that may be applied for the prevention of electrolysis troubles. During the past year the bureau carried on two extensive researches jointly with the committee, one in Atlanta and the other in New Orleans. These investigations were recently completed and reports have been prepared and submitted to the American Committee on Electrolysis, which, in turn, will submit them jointly with the bureau to the local utilities in the two cities mentioned above. Further investigations of this character are contemplated during the coming year.

Soil Corrosion.

The problem of protecting pipes from stray currents from electric railways has always been rendered much more difficult by the lack of adequate information regarding the extent of corrosion of buried pipe systems by ordinary soil influences, and the conditions under which such corrosion may occur. Because of this difficulty it became necessary for the bureau to undertake a comprehensive research in this field. In this investigation the Bureau of Standards has the cooperation of the Bureau of Soils of the Department of Agriculture, the pipe manufacturers, and the public utilities through the research subcommittee of the American Committee on Electrolysis. Forty-five locations have been selected as representative of the principal types of soils to be found throughout the United States and in them will be buried a number of samples of every kind of iron and steel pipe in commercial use. A few pieces of pipe coated with representative pipe coatings designed to prevent soil corrosion and a few pieces of lead sheath cable both plain and armored will also be buried in each locality. Some of the samples will be uncovered and examined from time to time to determine the rate of corrosion.

Complete data on the physical and chemical properties of the soils will be determined, and the chemical analyses of the pipes, their microstructure, and complete metallurgical history will be determined. Extensive laboratory experiments will be conducted to determine the effects of variations in individual characteristics of both soils and pipe materials.

Pipe owning companies and others who have metallic structures buried in the ground experience corrosion trouble in many localities throughout the United States, and the expense, on account of the replacement of pipes and the leakage of water, gas, and oil, due to corrosion of pipes probably reaches several millions of dollars annually. On account of the pipes being buried, the extent of damage can not readily be determined and is usually discovered only when serious leaks develop and the gas or water appears at the surface of the ground or in basements of buildings.

The results of the tests should be of great value in determining the causes and importance of soil corrosion and in selecting the kind of pipe best suited for use in any particular soil. It is expected that data as to the relative rates of corrosion of different kinds of pipes in the soils under observation will be obtained within 2 or 3 years, but the experiment will probably continue over a period of 8 or 10 years. Complete sets of specimens have now been buried in about 30 of the 45 locations, and the remaining sets will be buried during the present summer.

SAFETY ENGINEERING AND SAFETY STANDARDS.

National Electrical Safety Code.

The bureau has been engaged for nine years in a study of the life hazard in electrical practice and in the preparation and application of the National Electrical Safety Code. In this work it has had the cooperation and assistance of a large number of engineers, many of whom are connected with the electrical operating and manufacturing companies, others being engineers and inspectors of State commissions, municipalities, and insurance underwriters. The various national associations connected with the electrical industry have also cooperated effectively in this work. The importance of having a national code uniform in all the States is generally recognized, and also the advantage of having such a code prepared and presented by a national agency that can study the subject thoroughly and consult all the interests affected. The Electrical Safety Code consists of four principal parts, as follows:

1. Rules for the installation and maintenance of machinery, switchboards, and wiring in central stations and substations.
2. Rules for the construction and maintenance of overhead and underground lines for the transmission and distribution of electrical energy and intelligence.
3. Rules for the installation and maintenance of electrical apparatus and wiring in factories, residences, and wherever electricity is utilized for light, heat, or power.
4. Rules to be observed by operators in working on or near electrical machines or lines.

A supplementary section includes rules for the grounding of circuits and equipment.

The bureau's thorough study of the diverse conditions under which electricity is generated, distributed, and utilized and of the effect of the rules on operating and construction costs has secured a code which involves no unreasonable expense, but in general assures an adequate measure of safety and a useful standardization of practice. The large number of conferences held in all parts of the country for discussion of preliminary drafts of the code aided largely in its development. The varying conditions in different geographical sections and in thickly and thinly populated districts have been given careful attention.

The code was published originally in two installments for examination and criticism—the operating rules were published in August, 1914, and revised in May, 1915; the construction rules were published in April, 1915. Both operating and construction rules, again revised after a general conference of all interests in Chicago in the spring of 1916, were combined in a single volume, Circular No. 54, which was published in November, 1916, with a recommendation for actual field trial.

The third edition of the Electrical Safety Code was published under date of October 31, 1920, but was not actually issued until the early part of 1921. This edition is known as Handbook No. 3. The discussion was separated from the rules and issued as a separate volume known as Handbook No. 4. Both the rules and the discussion have ben extensively revised and amplified, and this edition of the rules is in suitable form for adoption by State commissions, municipalities, and other agencies having appropriate jurisdiction.

Such mandatory application of the rules is already being made, the States of Iowa, Nevada, North Dakota, Oklahoma, Tennessee, and Wisconsin having adopted rules based on the third edition and a number of others having them in course of preparation. Other administrative bodies had previously adopted rules comprising this code in whole or in part, and it is generally recognized as the most complete and satisfactory standard in its field. This code has now been approved by the American Engineering Standards Committee as an American standard.

A pictorial edition of the rules showing their application by illustrations is in course of preparation. The bureau also plans to publish a volume of engineering data on matters connected with the rules or with overhead-line construction. These data will include more extensive tables for the sags of conductors and will include tables regarding the supporting structures, such as wood and concrete poles and steel towers.

Electrical Safety Conference.

The Electrical Safety Conference has been organized to promote by cooperative action the orderly, consistent, and proper development of practice in electrical manufacturing and installation with regard to accident hazards. Its membership includes representatives of the Associated Manufacturers of Electrical Supplies, the Electric Power Club, the National Bureau of Casualty and Surety Underwriters, Underwriters' Laboratories, and the Bureau of Standards. Detailed standards for construction and installation of apparatus will be worked out in harmony with the Electrical Safety Code. The conference has already adopted standards for industrial control equipment, rotating machinery, switchboards, and oil switches and circuit breakers. Others are in course of preparation.

Lightning Protection.

A committee has been formed to assist in the preparation of standards for lightning protection. This work will consist of three parts: (1) the protection of buildings, live stock, ships, etc.; (2) the protection of structures containing inflammable liquids and gases; and (3) the protection of electrical lines and apparatus.

A tentative draft of rules for the protection of buildings, etc., has been prepared and is now under consideration by the sectional committee.

Combined Electrical Code.

In 1918 a tentative draft of an electrical code relating to both fire prevention and accident prevention in the interior wiring of buildings and the employment of electrical utilization apparatus was prepared. This consisted of the rearrangement and combination of the rules in part 3 of the Electrical Safety Code and the rules enforced by the fire insurance underwriters and known as the National Electrical Code. This was circulated for criticism and was the subject of considerable comment and discussion. In the State of Oregon it was adopted by statute and has been legally enforced. During the current year this code has been revised to conform with the 1920 editions of the two component codes.

Industrial Safety Standards.

As a result of the work on the National Electrical Safety Code and the numerous points of contact thus established with State authorities and others interested in safety work, the bureau has been called upon to enlarge the scope of this work and to consider safety requirements in other than the electrical industry. In order to arrange for more complete cooperation in this work and to insure the coordination of the efforts of all parties concerned, a conference was held at the bureau on January 15, 1919, which was attended by more than 100 representatives of different organizations concerned with safety standards.

On December 8, 1919, another conference on industrial safety codes was held at the bureau and was attended by representatives of all interests from many parts of the country. The conference voted in favor of having safety codes prepared under the auspices of the American Engineering Standards Committee. It also provided for the formation of a joint safety code committee to prepare a list of codes already in existence or urgently needed and to recommend sponsors for preparing and revising these codes. Such a committee was organized at the time and has since been succeeded by the Safety Code Correlating Committee, upon which the bureau is represented. Recommendations have been made to the American Engineering Standards Committee for a large number of safety codes and most of the recommendations have been approved by that body.

The Bureau of Standards has, upon invitation from the American Engineering Standards Committee, accepted sponsorship for the following Codes:

Electrical safety code.
Gas safety code (joint sponsorship with the American Gas Association).
Code for the protection of the heads and eyes of industrial workers.
Combined electrical fire and safety code.
Code for protection against lightning (joint sponsorship with American Institute of Electrical Engineers).
Safety code for logging and sawmill operations.
Safety code for aeronautics (joint sponsorship with the Society of Automotive Engineers).
Code for the colors of traffic signals (joint sponsorship with the National Safety Council).
Safety code for elevators (joint sponsorship with American Society of Mechanical Engineers and the American Institute of Architects).

A number of safety codes are being developed by sectional committees organized by other Federal bureaus and engineering societies as sponsors. The bureau is represented upon a number of these committees and is doing active work in cooperating with such committees in the development of these codes.

Code for Head and Eye Protection.

The National Safety Code for the Protection of the Heads and Eyes of Industrial Workers was first issued in 1921. During the current year it has been revised and a new edition is now ready for publication. This code states the type of protection needed in various groups of industries and includes specifications for the goggles, helmets, and other devices which provide such protection. It has been generally recognized as the most authoritative work upon this subject and has been approved by the American Engineering Standards Committee.

Logging and Sawmill Code.

A rough draft of this safety code was prepared from a study of existing requirements and the bureau's general knowledge of such operations. Field inspections were made by members of the staff in the Virginia woods, and later in the South as far as Louisiana, and in New York State, Michigan, Wisconsin, and New England. As a result of these field inspections a revised draft of this code was prepared and circulated among those interested in the subject as a tentative suggestion to be used as a basis for the complete code. Comments and criticisms upon this draft have been gathered and submitted to the sectional committee, which is cooperating in the completion of this code. Additional material has also been prepared and it is expected to issue a complete code during the forthcoming year. The sectional committee referred to has been organized according to the scheme of procedure of the American Engineering Standards Committee and contains representatives of all interests concerned with this code.

Aeronautical Safety Code.

A sectional committee has been organized to cooperate with the bureau and the Society of Automotive Engineers in the development of an aeronautical safety code, which will include the requirements for airplanes, balloons, landing fields, etc., and will specify the qualifications for aviators, and the traffic rules to be observed in the navigation of the air. A preliminary draft of such a code has already been prepared and has formed the basis of the committee work upon this subject. A revised draft is in preparation and parts of it are ready for circulation for the criticism of those concerned with this subject.

Elevator Code.

An elevator safety code has already been published by the American Society of Mechanical Engineers, members of the bureau's staff having taken an active part in its preparation. As joint sponsor the bureau will take an active part in the revision of this code. During the year an extensive survey of elevator conditions in the city of Baltimore was made and assistance was given to the officials of that city in the preparation of elevator rules which were later adopted. Interlocking devices will be approved for use in Baltimore only after passing tests which will be conducted at the Bureau of Standards.

GAS ENGINEERING.

Utilization of Gas.

Investigations covering utilization of gas have been continued from last year and have formed the principal part of the gas engineering section's work. Based upon experience gained in service investigations in several cities and on the results of laboratory work carried on during the past two years a short circular (No. 116) was issued entitled, "How to Get Better Service with Less Natural Gas in Domestic Gas Appliances." It was considered so valuable by the gas companies that a private printer has supplied 85,500 copies to different companies. It was also reprinted in gas journals and in several hundred newspapers in towns where natural gas is used, and the information in it was given wide publicity by the United States Chamber of Commerce.

In connection with an investigation conducted by the public service commission of Maryland to determine the most economic heating value standard for manufactured gas in the city of Baltimore, the bureau conducted an extensive series of laboratory tests to determine primarily: (1) the relative utilization efficiency of gases of different heating value; (2) the extent to which present appliances can be adapted to give good and efficient service with gases of different heating value and composition; and (3) what adjustment in appliances is necessary to give the consumers good and efficient service when different kinds of gases are mixed and there is a variation in the composition, heating value, and the specific gravity of the gas.

The laboratory tests of gases varying in heating value from 300 to 600 Btu per cubic foot indicated that the usefulness for top-burner cooking is dependent almost wholly upon the total heating value per cubic foot. Some change in the size of orifice and air-shutter adjustment of burners is necessary to secure the best service when a material change is made in heating value. Most existing burners can be readily adjusted to give good service with heating values as low as 450 Btu per cubic foot without alteration of the burners. Uniformity in heating value, specific gravity, and pressure are essential for the very best service, yet it is practicable to adjust burners to give satisfactory service in cities where different gases are mixed and there is considerable variation in the heating value or specific gravity.

Efficiency tests of burners were made as the distance of the utensil from the burner was varied and the rate of consumption and adjustment of burners were changed. The products of combustion were analyzed to determine how close a burner could be placed to a utensil without producing carbon monoxide.

A complete report of this investigation was rendered to the public service commission of Maryland and is being printed as a technologic paper of this bureau.

The increase in the price of gas, which began during the war, and the conservation programs sponsored by public and private organizations, have brought about the invention of so-called "gas-saving" devices to be used on top burners of gas ranges. A complete investigation has been made of the efficiency of four types of these devices and it was found that there is practically no increase in efficiency obtained by their use and they in no way justify the claims of economy made by the makers. By their use the secondary air necessary for complete combustion of the gas is excluded from the flame, which causes rapid liberation of carbon monoxide in sufficient quantity to be a positive menace to health. The leading gas journals are publishing the report of this work.

As a result of the bureau's publications on design of gas burners, manufacturers are applying the information given and some have submitted their improved burners for test and criticism.

The section had an exhibit at the convention of the Natural Gas Association of America held at Kansas City, Mo., in May. The exhibit showed the right and the wrong use of natural gas in domestic gas ranges and was very effective in showing the consumer how to use natural gas more efficiently.

Standards for Gas Service.

The section has continued to cooperate actively during the past year with municipalities and State public utility commissions in the establishment of proper standards for gas service. The suggested rules as contained in Circular No. 32, "Standards for Gas Service," continue to be a model for commissions adopting standards. The supply of the fourth edition of Circular No. 32 has been almost exhausted. The section dealing with State and municipal standards now in force is being revised for the new edition.

Gas Safety Code.

The sectional committee on the Gas Safety Code, organized under the rules of the American Engineering Standards Committee, is practically complete. The American Gas Association, the joint sponsor on the National Gas Safety Code, is making very good progress on the revision and enlargement of the material in the first draft of the five parts of the code submitted to them by the bureau.

ELECTRICAL AND RELATED SERVICE STANDARDS.

Standards for Electric Service.

For some years the bureau has been studying questions arising in connection with specifications for electric light and power service and the technical and engineering requirements that should be embodied by municipalities or by State public utility commissions in the ordinances and rules and regulations promulgated by them. Public service commissions in 40 States and in the District of Columbia are empowered by law to ascertain and fix adequate and reasonable standards for the measurement of quality and other conditions pertaining to the service rendered by any public utility and to prescribe reasonable regulations for examination and testing of such product or service and for its measurement.

In 1916 the bureau's Circular 56, "Standards for Electric Service," which covers the field of electric service, was published. This circular contained suggested rules for adoption by State commissions, three model ordinances for use of cities in States where no commission exists, or where cities have regulatory powers in addition to the State commission, and a complete and exhaustive digest of all regulatory rules and ordinances then in force. This circular has been out of print for some time and a new edition is now in press.

Since the first edition was published, the States of Alabama, Arkansas, Louisiana, North Dakota, South Carolina, Tennessee, and Utah have created new commissions or extended the jurisdiction of existing commissions and rules and regulations are now in force in 30 of the States and the District of Columbia. The new edition of the circular completed during the year includes the new laws, the new and amended rules, and a discussion of the engineering features of electric service regulation. It is, therefore, an exhaustive summary of the technical and engineering features of electric service regulation by commissions and municipalities.

Standards for Heating Service.

Central-station heating, either by hot water or by steam, is technically very closely related to electric central-station operation, and in 1918 a study of the requirements of central station hot-water heating service was undertaken at the request of the public service commission of Indiana. Field investigations were made in Ohio, Indiana, and Illinois, heating plants visited, and conferences held with operating engineers. The cordial cooperation of the educational committee of the National District Heating Association was obtained and has been of much value. A proposed set of rules for the regulation of central hot-water heating plants was formulated and submitted to the Indiana commission, and after public hearing and criticism was made the basis for the rules formally adopted by that commission.

The bureau has continued its studies of the engineering factors entering into the quality of central-station heating, and has the manuscript of a circular on standards for central-station heating partially prepared. This contains summaries of regulations so far adopted by States for both steam and hot water systems and proposed rules and regulations for commission adoption. Methods for calculating " radiation " (that is, customers' heating requirements), engineering phases of contracts with customers, and brief suggested contracts, are included in the study. It is hoped to complete this circular during the next fiscal year with the cooperation of the special committee of the National District Heating Association and other associations and engineers interested in central-station heating problems.

Street-Lighting Service.

Many requests for information are received from municipal engineers and city electricians with reference to street-lighting problems. For some years the bureau has collected information, contracts, and engineering data on street lighting and has made suggestions in numerous street lighting negotiations between municipalities and electric light and power companies.

Electrical Standardization.

A representative of the bureau has for some years been a member of the standards committee of the American Institute of Electrical Engineers. The electrical division of the bureau has several investigations under way in cooperation with the institute and there has been the fullest cooperation throughout the year.

TELEPHONY.

Quantity and Quality of Telephone Service.

The telephone section since its organization has been engaged in laying the necessary groundwork for the determination of standard measures for quantity and quality of telephone service applicable the country over. This involved the collection on a large scale of data regarding the design and operation of all types of telephone systems, manual, automatic and semiautomatic, and an analysis of telephone service into elementary parts to each of which measures are applicable.

The results of this work have been embodied in part in Circular No. 112, entitled "Telephone Service." This circular was released for publication late in August, 1921, when complimentary copies were forwarded to the State commissions, to telephone engineers, and to the electrical engineering departments of various universities. The demand for the circular has been quite large, the third printing having been found necessary before the end of the year, and requests for it are still being received.

The preparation of material for the above circular having been completed, work was immediately begun on the determination of the most suitable measures of quantity and quality of telephone service. Although a good start was made on this fundamentally important work, its postponement was found necessary because of a special assignment by the Bureau of the Budget.

General Survey of the Government's Telephone Systems.

In October the Bureau of Standards was requested by the Chief Coordinator for General Supply, acting for the Bureau of the Budget, to make a general survey of existing telephone systems in the various executive departments and independent establishments in the District of Columbia, to determine whether efficient service could not be maintained at lower cost. Since that time the bulk of the work of the telephone section has been in connection with this survey.

Each department and independent establishment, at the instance of the chief coordinator, appointed a representative to deal with the bureau regarding telephone matters. These and officials of the telephone company, who have struggled for years to learn the requirements of the various Government establishments sufficiently far in advance to meet them economically, have heartily cooperated in the survey.

The order of procedure, briefly stated, has been to determine, through analysis of monthly bills, the kind and quantity of facilities now serving each unit and the cost thereof; to determine through traffic studies the kind and quantity of equipment that would most economically meet the actual requirements without adversely affecting the service, and to advise the representative directly concerned as to what equipment changes, if any, should be made. During the survey the bureau was requested on numerous occasions to assist in special determinations requiring prompt consideration. These were, of course, given preference over the bureau's own plans.

As a result of the survey, thus far limited to local service only, there has been effected an actual annual economy approximating $50,000. Nearly one-half of this sum is the direct result of the elimination of excess equipment, the consolidation of switchboards, the rerouting of certain classes of calls, etc., all without adversely affecting the service. The balance resulted from rate reductions made as a consequence of this survey of facilities.

Revision of the Government Supply Schedule for Telephone Service.

Inaugurated previous to the present survey but carried on in conjunction therewith, a complete revision of the supply schedule for telephone service was made at the instance of the subcommittee on class 20 of the General Supply Committee. The occasion for this work arose from the fact that many items of the old schedule were difficult to interpret. The schedule as revised and accepted by the Supply Committee will be adopted as the Government's contract with the telephone company for the next fiscal year. It is a systematic arrangement of the various items, worded so as to minimize all chances of misinterpretation and numbered in a logical manner.

New Billing Forms for Telephone Service.

In the course of the survey of the Government's telephone facilities it was necessary to carefully analyze and check all bills in order to determine the layout of the whole network, the mileages involved, the kind and amount of facilities provided for each establishment, the volume of service rendered, etc. The telephone company now submits its bills for local service on 40 different Government voucher forms in addition to its own bill form which is accepted in some cases. The desirability of uniformity in the method and order of billing the numerous service items and the resulting economy in time and effort in checking and auditing the bills were immediately apparent.

By tabulating a large number of bills item by item in accordance with the newly assigned item numbers the frequency of occurrence of each item was determined. Data thus obtained were used in drafting a simple bill form, the advantages of which have been discussed with the telephone officials, with representatives of the departments, and with the coordinator for telephone service. It seems highly probable that all bills for local service will be rendered on identical forms during the new fiscal year.

Tests of Coast Defense Fire-Control Equipment.

Acting for the Signal Corps, a series of tests were made on telephone equipment representative of that in use at the Coast Defense stations to determine how best to modify the apparatus, designed for short distances only, so as to meet the present requirements for telephone service over somewhat greater distances.

Tests of Radio Receivers at Audible Frequencies.

A large number of radio head sets, representing the product of various manufacturers, was tested at audiofrequencies to determine their respective electromechanical efficiencies and other fundamental characteristics. This work was done in cooperation with the radio section which conducted similar tests at radiofrequencies.

Circular on Telephone Transmission.

Most of the material for the proposed circular on telephone transmission has been rewritten and expanded to include a section on filter circuits and circuits of optimum transmission. Some examples were worked out for typical standard circuits. The use of the complex variable and vector diagram in alternating current circuits, which has been a subject of dispute among teachers and engineers, has been exhaustively discussed.

Submarine Cable Problem.

The work on the problem of submarine cable signaling, set aside during the previous fiscal year for more urgent work, was resumed this year on a broadened basis. Substantial progress was made in several of its most difficult theoretical phases. A study was made of the relation between the mathematical methods of attack on the cable problem developed at the bureau and those used by Continental and American research engineers.

In particular, two basic subsidiary problems, for which no satisfactory solution seems to have been obtained heretofore, have been successfully solved. One is the determination of the natural oscillations of a cable with any receiving and sending apparatus. The other is the solution of general circuits associated with the cable in which the ordinarily fixed circuit constants are variable. Both solutions are grounded on very general processes of modern mathematical analysis, and admit of wide application to other forms of signaling circuits; as, for example, those containing microphones or audion amplifiers. This makes the solutions especially valuable in circuit design because of the widespread use of variable elements, in particular the vacuum tube, in electric circuits.

BALLISTICS AND OTHER SPECIAL PROBLEMS.

Cooperation with Navy Department.

The electrical method for recording short-time intervals, which was developed in connection with ballistic measurements, has been applied to a number of new problems. The majority of these problems have been undertaken at the request of the Navy Department, which has furnished the necessary facilities for carrying on the investigation. In each case the Bureau of Standards has designed the necessary apparatus, has cooperated in taking the data, and has prepared a report which includes the interpretation of the data obtained.

A Study of the Variation in Gun Pressure with Time.

Improvements have been made in the electrical gauge for measuring pressures in guns, which was mentioned in last year's report. The improved gauges have been used in several firings during the year and valuable results have been obtained. It is hoped that this gauge will soon be in such form that it can be made a standard testing apparatus at proving grounds.

Primer Explosion Times.

A report of the results obtained on a very large number of primers in the laboratory has been submitted to the Navy Department. These are all electrical primers and the report shows the effect of variations in the voltage at the time of firing the primers.

Ejection Velocities.

Measurements made at the proving ground show that the method of measuring ejection velocity will give an accuracy of at least one-half of 1 per cent. This is quite sufficient for battleship work. The bureau has been asked to consider the possibility of designing apparatus for installation on each battleship, so that velocity measurements can be made at any time.

Pressure in Recoil Cylinders.

Pressure gauges have been used in recoil cylinders to obtain the rise of pressure with time. These are considerably more accurate than the indicator diagram usually obtained, but have the disadvantage that they give a curve of pressure with time instead of a pressure-displacement curve. However, it is relatively simple to convert these, provided a satisfactory recoil curve has been taken.

Velocity of the Projectile Inside the Bore of the Gun.

An effort has been made to determine the time at which the projectile passes a given plane by observing the expansion of the gun at that plane. This method gives considerable promise, but has not yet reached a point where it can be definitely depended upon.

Photographs of Projectiles in Flight.

A camera capable of taking 250 pictures per second has been built for this purpose. It is believed that this method can be used to determine the velocity of the projectile at any part of its trajectory.

Movements and Stresses in Turrets and Turret Structures.

At the request of the Bureau of Construction and Repair, Navy Department, the Bureau of Standards made very extensive investigations of the movements and stresses in turrets on the U. S. S. *California* during gunfire. Preparations for this investigation were under way for over a year. The apparatus was installed and the data obtained during the month of November, 1921, by a party of 10 from this bureau. Eight oscillographs were used for recording the motions of the turret, and two special large photographic drums were used for recording the movements in connection with the turning gear mechanism. A large amount of auxiliary apparatus with complicated wiring was required, and it was necessary to install a fairly complete temporary laboratory in one of the ship's compartments. Measurements were made of the tangential, radial, and vertical motions of the turret at a number of points. In addition, measurements were made to determine the distortion of the turret foundation. Check measurements of the maximum motion and distortion were made by mechanical methods at practically all points. Measurements were made to show the distortion of various parts of the turning gear at each instant during the firing process. Curves have been plotted showing the relationship between all of these movements. While much has been done in the way of preparing a report, considerable time will yet be required to make a complete analysis of the data.

Torsional Vibrations of Crank Shafts.

At the request of the Bureau of Engineering, Navy Department, apparatus has been designed for the measurement of torsional vibrations in crank shafts. This consists of accurately made commutators placed at each end of the crankshaft so that the displacement can be determined at any instant. The apparatus is now being made at the New York Navy Yard and tests on an engine will be carried out as soon as this apparatus is completed.

Seismometry.

The bureau is working in cooperation with the Carnegie Institution of Washington, the California Institute of Technology, and various other institutions in the development of a device for the study of earth movements. The special requirement is that the apparatus record fairly quick motions such as occur in the vicinity of faults in action with sufficient accuracy so that from the records of near-by stations it will be possible to locate the origin by the triangulation method. The work of the bureau has been directed mainly along the line of the development of a seismometer suitable for use in this particular problem. The design of a pendulum type of seismometer for vertical motions has been completed, and it is now under construction in the California Institute of Technology. Other parts of the apparatus have also been designed and are under construction. In this apparatus photographic registration will be employed and the magnification obtained will be by the electromagnetic method developed by the bureau.

Electric Telemeter.

During the past two years this section has devoted considerable time and attention to the study of electric telemetric (remote recording) devices, more particularly with respect to their application to reading and recording of stresses and strains in bridges and other structural members. There has long been felt among structural engineers an urgent need for more accurate and reliable strain gauges than have heretofore been available, and more particularly for a strain gauge that could be read and made to give a graphic record at points more or less remote from the member, the strain in which is being measured. This is true in case of a test on bridges where the members are usually inaccessible, even for the attachment of recording apparatus. Heretofore only indicating strain gauges have been available, and these have been adapted only to give average stresses, so that it has not been possible to measure transient stresses due to live loading. These transient stresses are often of much greater magnitude than the average stresses, and it is therefore more important to determine these than it is to determine average load conditions. The telemeter strain gauge, therefore, permits one to obtain important information that it has not been possible to secure by any means heretofore available.

Prior to the initiation of the investigation here discussed, numerous attempts had been made by other investigators to utilize the property of carbon contacts in making pressure gauges and similar instruments. Systematic attempts in this direction had been made by the War Department and by numerous engineers interested in studying stresses in structural members, but all of these attempts resulted in failure. In general, three serious difficulties in all instruments of this kind were encountered, none of which were overcome prior to the initiation of the bureau's investigation. These difficulties were the lack of constancy of the apparatus, resulting in frequent changes in calibration, marked hysteresis effects, and a nonlinear relationship between pressures or displacements and the electrical resistance of the carbon contact devices. These difficulties have all been overcome and the instrument is now on a thoroughly practical basis for a number of important lines of engineering materials testing. A number of instruments with recorders have been built and delivered to the aircraft section of the Bureau of Construction and Repair of the Navy Department. A modified type of strain gauge has also been developed in cooperation with the sound section of the bureau for the War Department, to be used for the measurement of pressures developed in large-caliber guns when fired.

During the last few months a set of these instruments has been continuously in use in the bureau in connection with the testing of rigid girders for dirigibles. These trials have shown that the apparatus is not only thoroughly practical and reliable, but that for many purposes it is superior to any strain gauge heretofore available. Members of the bureau's staff connected with this work have stated without hesitation that it is the best strain gauge now available, and that so far as accuracy is concerned it approaches a precision instrument.

Careful tests have also been made in the laboratory to determine the ability of the instrument to record high frequency stresses and transients of short duration. These tests have established conclusively that high frequency stresses running up to many hundred cycles per second are recorded in their true proportions without amplification or reduction, regardless of their frequencies within this range. Transient stresses are also given their true value even though they persist for but a few thousandths of a second.

Another form of apparatus has recently been designed and built for measuring the stresses and stress distribution in bridges and other large structures. This apparatus is now ready for use and it is expected that some field researches will be made with it in the near future.

PUBLICATIONS.

The following papers relating to the work of the electrical division, have appeared during the year among the publications of the Bureau of Standards:

Mathematical theory of induced voltage in the high-tension magneto (F. B. Silsbee), Sci. Paper No. 424.
Standard specifications for large incandescent electric lamps, Circular No. 13 (ninth edition).
Operation of the modulator tube in radio telephone sets (E. S. Purington), Sci. Paper No. 423.
Some effects of the distributed capacity between inductance coils and the ground (G. Breit), Sci. Paper No. 427.
The radio direction finder and its application to navigation (F. A. Kolster and F. W. Dunmore), Sci. Paper No. 428.
The high-frequency resistance of inductance coils (G. Breit), Sci. Paper No. 430.
The field radiated from two horizontal coils (G. Breit), Sci. Paper No. 431.
The construction and operation of a simple homemade radio receiving outfit, Circular No. 120.
Sources of elementary radio information, Circular No. 122.
Results of a survey of elevator interlocks and an analysis of elevator accident statistics (C. E. Oakes and J. A. Dickinson), Tech. Paper No. 202.
Design of atmospheric gas burners (W. M. Berry, I. V. Brumbaugh, G. F. Moulton, and G. B. Shawn), Tech. Paper No. 193.
How to get better service with less natural gas in domestic gas appliances, Circular No. 116.
Carbon monoxide in the products of combustion from natural gas burners (I. V. Brumbaugh with G. W. Jones, of U. S. Bureau of Mines), Tech. Paper No. 212.
Electromotive force of cells at low temperatures (G. W. Vinal and F. W. Altrup), Sci. Paper No. 434.

The following mimeographed letter circulars were prepared:

No. 36. A list of bureau publications on public utility problems.
No. 39. List of sources of elementary radio information.
No. 40. Radio publications of the Bureau of Standards.
No. 41. Extension of the Dewey decimal classification applied to radio.

No. 43. Construction and operation of a very simple radio receiving equipment. (Superseded by Circular No. 120.)
No. 44. Construction and operation of a two-circuit radio receiving equipment with crystal detector. (Superseded by Circular No. 121.)
No. 45. Construction and operation of a simple radiotelegraphic code practice set.
No. 56. Methods of direction finding as an aid to navigation: The relative advantages of locating the direction finder on shore and on shipboard.
No. 60. A list of publications on accident prevention and safety.
No. 62. Proposed revision of rule 86 of the National Electrical Code on radio equipment.
No. 65. Electron tube amplifier using 60-cycle alternating current to supply power for the filaments and plates.
No. 66. List of manufacturers and sole United States distributors of radio receiving equipment.
No. 68. The common uses of electricity.

The papers listed below have appeared in current scientific and technical publications:

A galvanometer method for producing at a distance a magnified record of mechanical motions (F. Wenner), Phys. Rev., 19, p. 410, 1922 (abstract).
The two-stage current transformer (H. B. Brooks, with F. C. Holtz of Sangamo Electric Co.), Jour. Amer. Inst. Elect. Eng'rs., 41, p. 389, June, 1922.
Simplified theory of the magneto (F. B. Silsbee), Nat. Adv. Comm. for Aeronautics, Report No. 123.
Magnetic analysis of steel (R. L. Sanford), Amer. Machinist, 55, p. 836, 1921.
Some major problems in photometry (E. C. Crittenden and J. F. Skogland), Jour. Opt. Soc. Amer., 5, p. 366, 1921.
Atmospheric corrections for the Harcourt standard pentane lamp (E. B. Rosa, E. C. Crittenden, and A. H. Taylor), Jour. Opt. Soc. Amer., 5, p. 444, 1921.
A simple type of radio direction finder for use on shipboard—its application, construction, and operation (F. W. Dunmore), Radio Service Bulletin, October 1, 1921; Radio News, 3, p. 588, January, 1922.
The principles underlying radio communication (Signal Corps Radio Communication Pamphlet No. 40), book of 600 pages. Revised edition, March 23, 1922. Prepared by the Bureau of Standards.
A relay recorder for remote control by radio (F. W. Dunmore), Jour. Amer. Inst. Elect. Eng'rs., 41, p. 310, April, 1922; Radio News, 4, p. 51, July, 1922.
Standard radio wavemeter, Bureau of Standards Type R70–B (R. T. Cox), Jour. Opt. Soc. Amer., 6, pp. 162–168, March, 1922. Radio Topics, 1, p. 6, January, 1922. Aviation and Wireless News, 4, p. 16, February, 1922.
Portable wavemeter for shortwave radio (S. Kruse and R. T. Cox), Q. S. T., 5, p. 14, September, 1921.
An electron tube amplifier for amplifying direct current (H. A. Snow), Jour. Opt. Soc. Amer., 6, p. 186, March, 1922.
A high-voltage storage battery for use with electron tube generators of radio-frequency currents (E. L. Hall and J. L. Preston), Jour. Opt. Soc. Amer., 6, p. 177, March, 1922.
The development of radiotelephone communication between lifeboats and shore stations (F. W. Dunmore), Radio News, 3, p. 694, February, 1922.
The effective capacity of multilayer coils with square and circular section (G. Breit), Phil. Mag., 43, p. 963, May, 1922.
A method of measuring coil capacities and standardizing wavemeters (G. Breit), Radio Review, 3, p. 71, February, 1922.
Notation for electron tube circuits (J. H. Dellinger), Radio Review, 2, p. 454, September, 1921.
Objects that distort radio waves (L. E. Whittemore), Radio Broadcast, 1, p. 101, June, 1922.
Radio and timekeeping (L. E. Whittemore), Manufacturing Jeweler, 70, p. 1049, May 25, 1922.
Calculation of inductance of circular coils of rectangular cross section (brief abstract) (F. W. Grover), Phys. Rev., 18, pp. 136-139, August, 1921.
The high-frequency resistance of inductance coils (brief abstract) (G. Breit), Phys. Rev., 18, p. 135, August, 1921.
Method of measuring coil capacities and standardizing wavemeters (brief abstract) (G. Breit), Phys. Rev., 18, p. 136, August, 1921.

The distributed capacity of inductance coils (brief abstract) (G. Breit), Phys. Rev., 18, pp. 133–135, August, 1921.
Radio signal fading phenomena (brief abstract) (J. H. Dellinger and L. E. Whittemore), Phys. Rev., 18, pp. 148–149, August, 1921.
The radio research field (brief abstract) (J. H. Dellinger and L. E. Whittemore), Phys. Rev., 18, pp. 152–153, August, 1921.
The design of a standard wavemeter (brief abstract) (R. T. Cox), Phys. Rev., 18, p. 149, August, 1921.
Some physical problems of aircraft radio (brief abstract) (L. E. Whittemore), Phys. Rev., 18, p. 149, August, 1921.
The high-frequency impedance of radio telephone receivers (brief abstract) (C. T. Zahn), Phys. Rev., 18, p. 150, August, 1921.
The measurement of earth currents (Burton McCullom), Elect. Ry. Jour., 58, p. 809, November 5, 1921.
The work of the Bureau of Standards in cooperation with other organizations (M. G. Lloyd), Proc. 26th Annual Convention of International Association of Municipal Electricians, 1921, pp. 87–93.
Hazards in overhead construction (M. G. Lloyd), Telephony, 82, pp. 17–18, March 4, 1922.
Avoid overhead line perils (M. G. Lloyd), Telephone Engineer, 26, pp. 33–36, January, 1922.
Safety inspectors and inspections (J. A. Dickinson), American Machinist, December 1, 1921.
The dollars and cents value of safety (J. A. Dickinson), American Machinist, January 5, 1921.
The fundamental principles of safeguarding (J. A. Dickinson), Proceedings National Safety Council, October, 1921.
The national logging code (J. A. Dickinson), Proc. National Safety Council, October, 1921.
Electromotive force of cells at low temperatures (G. W. Vinal and F. W. Altrup), Jour. Wash. Acad. Sci. 12, p. 64, February 4, 1922.

The following papers are in press:

The magnetic susceptibility and iron content of tin red brass (L. H. Marshall and R. L. Sanford), Tech. Paper No. 221.
The testing and use of magnetic compasses for airplanes (R. L. Sanford), Part II of Nat. Adv. Comm. for Aeronautics, Report No. 128.
The theory, construction, and use of the photometric integrating sphere (E. B. Rosa and A. H. Taylor), Sci. Paper No. 447.
Tables for the calculation of inductance of circular coils of rectangular cross section (F. W. Grover), Sci. Paper.
Note on the development of an electron tube amplifier which uses 60-cycle alternating current to supply power for the filaments and plates (P. D. Lowell), Jour. Amer. Inst. Elect. Eng'rs., 41, pp. 488–490, July, 1922.
Radio-frequency amplifiers (P. D. Lowell), Sci. Paper No. 449.
An electron tube amplifier using 60-cycle alternating current to supply power for the filaments and plates (P. D. Lowell), Sci. Paper No. 450.
Properties of electrical insulating materials of the laminated, phenol-methylene type (J. H. Dellinger and J. L. Preston), Tech. Paper No. 216.
The construction and operation of a two-circuit radio receiving equipment with crystal detector, Circular No. 121.
A method for testing and rating electron tube generators (L. M. Hull), to appear in the procedings of the institute of radio engineers.
Recent developments in radio in the United States (J. H. Dellinger), to appear in the Pan-American Bulletin.
The effective capacity of a pancake coil (G. Breit), to appear in the Philosophical Magazine.
Some measurements of telephone sensitivity (Helen H. Smith) to appear in the Wireless Age.
Hazards of overhead line construction and methods of meeting them (M. G. Lloyd), Proceedings of Missouri Association of Public Utilities, May 4–6, 1922.
Overhead line construction for safety (M. G. Lloyd), Proceedings of Oklahoma Utilities Association, March 14–16, 1922.
National electrical safety code and its relation to distribution (M. G. Lloyd), Safety Engineering, July, 1922.

Elevator service and its relation to safety (J. A. Dickinson), Proceedings of National Building Owners and Managers Association, June 19–24, 1922.

Relative usefulness of gases of different heating value and adjustments of burners for changes in heating value and specific gravity (W. M. Berry, I. V. Brumbaugh, G. F. Moulton, J. H. Eiseman, and G. B. Shawn), Tech. Paper No. 222.

TEMPERATURE AND HEAT.

The work of this division includes establishment of the standard scales of temperature throughout the range of measurable temperatures; testing and standardization of thermometers, pyrometers, and other temperature-measuring instruments; determination of specific and latent heats, heats of reaction, melting and freezing points, and other properties of materials in the determination of which precise heat and temperature measurements are the principal requirements; standardization of calorimeters; production and distribution of standard heat and temperature samples; industrial applications of heat and temperature measurements; determination of fundamental engineering data involving thermal constants; determination of the fire-resistive properties of structural materials; investigations relating to automotive power plants, fuels, and lubricants.

GENERAL.

Functions of the Division.

A fundamental function of the division is the establishment, maintenance, and distribution of the standard scale of temperature from the lowest to the highest attainable temperature. The establishment of a satisfactory working scale covering the range of temperatures met with in research and testing has been emphasized, although the necessity of contributing to the fundamental data has been recognized and some work of this kind has been and is being conducted. In the determination of physical constants requiring precise temperature and heat measurements, a great deal of work in precision calorimetry has been carried out, special attention having been given during the last few years to the measurement of the thermodynamic properties of fluids. These investigations, while representing the highest type of research work, yield results which find immediate application in engineering.

In recent years there has been a marked extension in the direction of industrial and engineering applications of temperature and heat measurements as exemplified by the investigations in industrial pyrometry, of thermal conductivity and heat transmission of materials, investigations of the fire-resistive properties of structural materials, and the investigations of automotive power plants, fuels, and lubricants.

THERMOMETRY.

This section is concerned with researches on the standard scale of temperature and thermometric fixed points from the lowest attainable temperature up to about 500° C.; maintenance of working standards within the above range; methods of standardizing temperature-measuring instruments, such as liquid in glass thermometers, vapor-pressure thermometers, resistance thermometers, thermocouples; the testing and certification of temperature-measuring instruments; and methods of measuring temperatures.

Clinical Thermometers.

There has been a marked change in the character of the clinical thermometers submitted for test. While last year, over 95 per cent of some 26,000 thermometers submitted were for veterinary use, during the present year only about 10 per cent of the 15,085 submitted were for such use. While the number tested represents a considerable decrease as compared with last year, it shows an increase of about 12,000 thermometers intended for general medical and hospital use.

The question of compulsory testing of clinical thermometers has come up from time to time. Testing of clinical thermometers is compulsory in France, Germany, and Japan, and was in force in Great Britain for several years. A number of the States are beginning to show an interest in the subject, and the adoption of numerous forms of State regulation promises to develop a very unsatisfactory situation. The manufacturers and jobbers of clinical thermometers are about the only ones who have taken an active interest in national regulation, and their attitude, in general, is determined by business interests.

Laboratory Thermometers.

The section has cooperated with manufacturers and users of thermometers and with the American Society for Testing Materials in the standardization of specifications for laboratory thermometers.

New Testing Regulations and Fee Schedules.

With the publication of the third edition of Circular No. 8 on the testing of thermometers, new testing regulations and fee schedules have been put into effect. Thermometers which are free from defects and which are found correct within the tolerances established by the bureau receive certificates, while others receive reports of test with a statement as to why certification was refused. While the tolerances set by the bureau are, in general, more liberal than those proposed by some of the manufacturers in the preparation of specifications, the numerous cases in which thermometers were refused certification have resulted in some dissatisfaction and a much closer scrutiny of the results of the bureau's tests. In none of the cases in which results were questioned and retests were made has it been found that reports issued by the bureau were in error.

Tests of Pure Platinum.

The determination of the temperature coefficient of resistance is one of the most valuable tests of the purity of platinum. Such tests were made of a number of samples of pure material prepared in the chemistry division. The method of test was such as to minimize the introduction of strains and contamination into the wire under test.

Temperature Measurement and Control.

Some time has been given to the perfection of devices for automatic control of temperature, the construction of heating coils to meet special requirements, and to giving advice and assistance to other divisions and sections in problems involving temperature measurement and control. Considerable improvement in automatic temperature regulation has been made, although, in general, requirements in this field have kept ahead of developments.

Equipment.

A number of special resistance thermometers, much smaller than those ordinarily used, were made and are undergoing test. Additional resistance thermometers of the types already in use were constructed.

A new oil bath, replacing one which had become obsolete, was installed and has proved satisfactory. The ventilating system was improved, and it is now possible to keep the room in which the oil baths are installed both clean and comfortable.

HIGH TEMPERATURES.

This work includes researches on the standard scale and temperature and thermometric fixed points in the interval from 500° C. up to the highest attainable temperature; maintenance of working standards in the above range; standardization and distribution of standard samples for thermometric fixed points (for example, a series of pure metals of certified melting points); methods of standardization and testing and certification of pyrometers, such as thermocouples, resistance pyrometers, pyrometer galvanometers, optical pyrometers, including absorption glasses and color screens, radiation pyrometers, etc.; physical properties of materials at high temperatures, such as emissivity, monochromatic and total, specific heats, melting points of refractories, metals, fire brick, etc.; ionization and radiation in gases and vapors, etc.; industrial pyrometry; and the measurement of the temperatures in industrial processes.

Industrial Pyrometry.

The rare metal thermocouple, consisting of one wire of platinum and one wire of an alloy of 10 per cent rhodium with 90 per cent platinum, is used to such an extent in this country that a large group of manufacturers have been interested in the life tests of these couples, initiated last year. Formerly a large portion of the pure metal and alloy required by the industries for thermocouple manufacture was imported from Germany. Since the war, however, practically no metal has been obtained from this source for the reason that as good, if not better, material is now refined in both America and England.

As a result of the bureau's investigations, one manufacturer of an inferior grade of metal so rapidly improved his product that it is now equal to the best obtainable in the market. The report of the tests was published in Chemical and Metallurgical Engineering and has since been reprinted and widely distributed, one manufacturer purchasing 10,000 copies of the reprint.

Besides rendering aid in this manner to the manufacturers of thermocouples and pyrometric apparatus, the industrial public has been greatly benefited since reliable rare metal couples are now obtainable from every American manufacturer of pyrometric equipment. When errors of 50° C. may result, and have been encountered in general up to the present year, because of insufficient purity of the metals employed, the elimination of this source of error has been appreciated by all concerned.

The demand by the industries for greater accuracy in high-temperature measurement has affected the type of research problems undertaken by this laboratory during the past two years.

Standard Samples for Thermoelectric Fixed Points.

The work on the preparation of standard pyrometric samples, through the agency of which the temperature scale of this bureau is distributed to the industries, has been continued. In addition to samples of pure tin, zinc, lead, aluminum, and copper, the bureau is preparing to issue samples of gold, palladium, and platinum with certified melting points. These latter metals will be distributed probably in exchange for metal of commercial purity with a service charge of 50 per cent in weight to cover the cost of preparing pure materials. The samples will be prepared in the form of wire. The platinum already available is probably 99.999 per cent pure.

Research in Pyrometry.

It has become necessary to determine more accurately and to define by fixed points the "working" scale of high temperatures. Desirable fixed points between 1,500 and 1,800° C. are the melting points of palladium and platinum. Before this work could be attempted it was necessary to secure metals of the highest possible purity, and a great amount of time has been spent, in cooperation with the chemical and optics divisions, in preparing the materials in a sufficiently pure state. Supposedly pure metals from various sources have differed in their melting points by as much as 2° C. The bureau has now produced palladium and platinum of exceedingly high purity, and preliminary work on the former indicates that the melting point adopted by the bureau several years ago is in error by at least 5° C. It is hoped that this work will be completed during the early part of the coming year.

In order to measure accurately the melting points of these metals and to check their purity many new laboratory methods have been developed.

The thermoelectric method of measuring an impurity has proven to possess exceptional sensitivity. Platinum which shows no impurity whatever by the method of spectroscopic analysis may be satisfactorily graded by a measurement of its thermoelectric properties.

An optical pyrometer has been developed which is capable of a precision of 0.2° C. or better at 1,500° C. This instrument is of the standard disappearing filament type in which the errors, usually present on account of diffraction effects, have been eliminated. A considerable part of the past two years has been spent in the study and testing of this instrument, which presents problems in physical optics of considerable difficulty.

Investigations in Atomic Properties.

It is becoming more and more apparent that material progress in the development of efficient illuminants and of many important devices involving electron emission is conditioned by a thorough understanding of the nature of collisions between atoms and electrons. Any contribution to our knowledge of the mechanism of radiation and of the structure of atoms is certain to result in new applications of value from the utilitarian standpoint. Notable examples of such development are the Coolidge X-ray tube and the entire field of radio-bulb design, which have been an outgrowth in the past decade of the most academic type of research problem. This is a field of research upon which vast sums are now being expended by the technical industries and one to which this bureau should devote much more attention than it has been able to give in the past. At the present time the work on atomic structure has been confined to two or three members of the staff, whereas the opportunities in this field well justify a section of at least 20 scientifically trained men, with a specific appropriation of funds continued over a period of several years. Five papers have been published during the year and a book mentioned later is now in press.

Two papers have been published on enhanced spectra. From theoretical considerations the ordinary arc line spectrum of an element should arise in a neutral atom, while the enhanced spectrum should arise in an atom from which an electron has been removed. It may be shown that if this theory is correct the amount of energy required to excite enhanced spectra is comparatively small, and that the enhanced lines should appear in a low voltage arc, in general, below 50 volts. In the past it has been thought necessary to employ 10,000 volts or more in a spark discharge. The enhanced spectra of magnesium, sodium, and potassium have been investigated, and it was shown that these spectra are readily produced at precisely the low voltage predicted by theories of atomic structure.

An extensive investigation of X rays excited by low voltage electronic impact has been published. When this work was initiated the ultra-violet region of the spectrum had been extended to about 300A, while the longest X rays known had a wave length of about 12A. The ultra-violet region has been recently pushed to 130A, leaving a gap to be bridged between visible light and X rays, extending from 130 to 12A. The bureau has investigated the X rays lying in this heretofore inaccessible region and by a new method of measurement has observed characteristic X radiation of both gases and solids in the interval 700 to 26A. Work of a similar character has been carried on at Princeton University with solids, and characteristic radiation has been measured by the same general method of as short wave-length as 12A, so that we may now consider the great gap between visible light and X rays as satisfactorily bridged. On account of the fact that these rays are absorbed by the air, by glass, or by any intervening substance whatever, their therapeutic possibilities are of no interest. However, the work is of great importance from the standpoint of atomic structure, and an extensive development in this range of X-ray spectroscopy may be expected in the immediate future, both in America and abroad.

A book by Paul D. Foote and F. L. Mohler, entitled "The Origin of Spectra," has been submitted to the press. This work, which will print to possibly 350 pages and which is illustrated by about 50 half tones and zinc etchings, will appear as a volume in the monograph series of the American Chemical Society.

HEAT MEASUREMENTS.

Measurements are made in this section over a wide range of temperatures of thermal properties of materials, such as specific heats, latent heats, pressure-volume-temperature relations for liquids and gases; heats of reaction, particularly heats of combustion of solid, liquid, and gaseous fuels; and heat transmission and thermal conductivity. Work is also done on the development of calorimetric apparatus and methods and on methods for temperature control, pressure measurements, measurement of heat transmission, etc.

Practically all of the research work of this section during the year has been devoted to the determination of those fundamental physical constants of materials which find application in refrigeration engineering.

Specific Heat of Superheated Ammonia Vapor.

An elaborate series of measurements of the specific heat of superheated ammonia vapor was completed.

The experimental equipment was specially designed and constructed with reference to the particular requirements of this investigation, and its preparation has been in progress for the past two years. It includes a flow calorimeter and accessory elements for experimental operation and measurement. The novelty of the apparatus lies in the combination of two features, adequacy to cover the required range of temperature and pressure, and a high degree of accuracy in the measurments. Detailed descriptions of this apparatus and of its experimental operation form the subjects of scientific papers now in preparation.

While the phenomenon or physical process under observation is a simple one, its isolation from external disturbing influences and control of constancy to a degree insuring accurate results is not a simple problem, and the apparatus which has led to a satisfactory solution is extremely complicated.

The final series of measurements consisted of 90 complete experiments establishing the value of the specific heat of ammonia vapor at 35 different states in the range of temperature and pressure. The range covered was from —15° to +150° C. and from one-half to 20 atmospheres pressure. The results are accurate to a small fraction of a per cent, which is quite sufficient for engineering purposes.

While the preparation for this series of measurements has been slow and expensive it appears to have been justified in the completeness of the results, the excellence of their quality, the certainty of precision, and speed of experimentation. These attributes of the work as a whole constitute an advance in the technique of calorimetry of gases.

Specific Volume of Superheated Ammonia Vapor.

A series of measurements of the specific volume of superheated ammonia vapor, using a constant volume gas thermometer with a monel metal bulb having a capacity of about 900 ml. was completed. On account of absorption phenomena it was necessary to carry through a second series of measurements with another bulb, having a different ratio of area to volume. A second bulb, made of coiled tubing, was constructed, tested, and calibrated ready to begin a series of observations with ammonia. The data so far obtained cover a range of specific volumes from 85 to 1,300 milliliters per gram while the temperature range extends from a little above saturation temperature to +250° C.

Ammonia Tables and Mollier Chart.

The past year is a notable one in the history of the bureau's work in heat measurements in that it marks the completion, with a minor exception, of a series of investigations of the thermodynamic properties of ammonia, begun eight years ago. These investigations provide a basis for new, accurate, and authoritative tables of the properties of this important refrigerant. Each of the investigations has yielded as a result numerical values of a specific property of ammonia, and the complete series makes possible the calculation of the thermodynamic behavior of the fluid in any cycle in which it is likely to be used as a refrigerant. The last investigations are important as furnishing, in the chain of mutually related quantities, the link which makes possible a test of the consistency of the whole.

Although the preparation of complete ammonia tables must await the completion of the last of the experimental work and the careful correlation of the whole series of measurements, as well as the evaluation of data from other sources, one set of tables has already been issued in the form of a Mollier chart, thus making the results of the bureau's investigations available for engineering use. The accuracy of the chart is sufficient for all practical purposes, although allowing room for some readjustment in the final values.

The chart of thermodynamic properties thus embodies results of actual measurements made upon ammonia of known purity, in a single laboratory, in a program of individual investigations, each complete in itself, each planned and executed according to a high standard of accuracy, and all extending over or beyond the range of conditions to be encountered in practice. The data resulting from this series of investigations have been made mutually consistent, not so much by mutual adjustment of values or by arbitrary choice as by refinement of experimental work to the point where thermodynamic discrepancies are negligible.

The completion of the work will probably bring to ammonia the distinction of being better known as to its thermodynamic properties within its working range than any other substance, and the data available appear to be sufficiently reliable to meet all possible requirements for many years to come.

Properties of Steam.

Interest of mechanical engineers has lately been directed to improvement of tables of the thermodynamic properties of steam, both as to accuracy and extension of the range to keep pace with modern steam-turbine practice. The American Society of Mechanical Engineers, by its indorsement of the report of a conference of engineers and investigators on the subject of "Present State of Knowledge of the Properties of Steam," has sought the cooperation of the Bureau of Standards with several other suitably equipped institutions in a program of investigations leading to new data for the formulation of steam tables adequate to present needs.

The problem suggested as the appropriate initial work for the Bureau of Standards was the measurement of the *specific heat of water*. Two phases of this problem are presented. In one particular, data of greatest possible accuracy on the specific heat of water from 0 to 100° C. in terms of international units of energy are wanted to establish the fundamental heat unit to a better degree of certainty than it is known at present. In addition, data of a precision suitable to engineering purposes are wanted on the heat capacity of water from 100° C. to as much higher as is practicable, as a further basis of steam-table construction.

As a part of the preliminary survey of the problem, the theory of saturated fluid calorimetry has been further studied, with the result of more simply expressing the relations between the directly measurable heat quantities and the fundamental thermal properties of a fluid when saturated.

The previous work in determining the liquid total heat and heat of vaporization of ammonia has shown the practicability and expediency of making both types of measurement in the same apparatus. The recent further development of the theory of these processes (in preparation for publication) confirms the fact that from the experimental standpoint these two measurements, together with a third, are mutually complementary and therefore are appropriately undertaken in conjunction. Successful completion of a program of experimental work so planned would lead to the *direct* determination not only of the total heat function (E+pv) of the saturated liquid, but also the *heat of vaporization*, the *ratio* between the specific volumes of the *saturated liquid* and *vapor;* and thus indeed, except for the measurement of the vapor pressure and the specific volume of the liquid, would completely establish the thermodynamic properties of the fluid when saturated.

The instrumental equipment best suited to the three calorimetric measurements just referred to furnishes likewise a surrounding so well adapted to the measurement of the pressure and liquid volume that addition of supplementary means for observing these would be an obvious possibility to be considered in the general plan of work.

The design of a calorimeter for this investigation is now in progress. Because of the special nature of the problem much of the construction is tentative until its suitability is confirmed by experiment. Several features of the design involving novelty have already been the subjects of experiment and others are now in process of construction.

No useful object would be served in hastily conceived measurements carried out in crudely designed and roughly constructed apparatus. Only by strict attention to detail and patience in its thorough execution can calorimetric data of unquestionable reliability be obtained. This is one of the object lessons of the previous investigations of ammonia. For this reason no definite time can be set for completion of the work.

Thermal Conductivity and Heat Transmission.

This work had been suspended during the previous year on account of lack of personnel. The work was resumed early in the present fiscal year, attention being given chiefly to perfecting equipment partly completed several years ago for measurement of thermal conductivities of insulating materials at high temperatures. Installation of the apparatus and auxiliary equipment is well under way. This equipment will be available for measuring conductivities of insulators and refractories at temperatures up to 700 or 800° C.

In perfecting the design of this apparatus it became necessary to obtain data on the resistance to heat flow at surfaces in contact. The apparatus constructed for these special experiments proved to be suitable for measurements of conductivity of metals and alloys, to a moderate degree of accuracy, and it was used to measure the conductivities of a number of aluminum alloys submitted by the Air Service of the Army.

Late in the year work was started on measurement of heat transmission in building structures. Equipment was designed or purchased, test specimens have been prepared. and the equipment was practically ready for installation at the end of the year.

Preliminary designs for measurement of thermal conductivities at temperatures higher than can be used with the equipment mentioned above, for the measurement of conductivities of metals, and for measurement of heat transfer across air spaces have been worked out and work on these will be carried on as rapidly as the bureau's resources permit.

Equipment.

A new Wheatstone bridge for resistance thermometry was received during the year and equipped with apparatus for automatic temperature control. Two new piston gauges for precision measurement of pressure were nearly completed in the instrument shop and improvements made in an older one. The section is now well equipped for precision measurements of temperature. for pressure measurements except in the lower ranges, for measurement of electric power, production of high vacuum, and the production and maintenance of constant temperature.

CRYOGENIC LABORATORY.

This work is concerned with the production of low temperatures down to those of liquid-hydrogen (ultimately liquid helium), preparation and storage of pure gases, development of methods of producing and maintaining low temperatures. liquefaction and separation of gases at low temperature, and special tests requiring the facilities of the low-temperature plant.

Operation of Plant.

The plant has been operated as needed, for supplying liquid air to meet requirements of the bureau. and, to some extent, to supply the needs of scientific workers outside the bureau. Repairs made during the year have greatly increased the efficiency of the compressor.

Liquid Hydrogen.

One of the greatest difficulties in the production of liquid hydrogen is the result of traces of impurities in the gaseous hydrogen, which become solidified in the liquefier and clog it. The most troublesome impurity is nitrogen, because it is not readily removed. In this laboratory liquid hydrogen was made some time ago with a liquefier, the operation of which was frequently unsuccessful and always troublesome as the result of clogging. A new liquefier, which is larger and more elaborate, has given even more trouble with clogging and up to the present time has not been operated successfully. Part of the difficulty has resulted from the fact that the ordinary methods of gas analysis give entirely unreliable results in the determination of one-tenth per cent or less of nitrogen in hydrogen. A new method of analysis has just been developed which gives quite satisfactory results and permits a careful investigation of the sources of contamination. These sources are air dissolved in the water of the electrolytic generator, air dissolved in the oil or water used in the gas holder, air sucked in on the intake side of the hydrogen compressor, and air not completely removed from the equipment before hydrogen is introduced.

Experiments are also being made to find means of thoroughly removing from the hydrogen just before it enters the liquefier any trace of nitrogen or other impurities that can not otherwise be avoided.

Vacuum-Insulatd Containers.

A new type of vacuum-insulated container has been developed intended to hold liquefied gases, or for other purposes requiring especially good thermal insulation. A vessel has been completed which insulates five times as well as the best double-walled Dewar vessel of the same capacity. One is now under construction designed to have about 10 times the insulation efficiency of the best Dewar vessel.

FIRE-RESISTIVE PROPERTIES OF STRUCTURAL MATERIALS.

The object of the investigations on the fire-resistive properties of structural materials is to furnish architects, engineers, builders, State and city building bureaus, insurance interests, and others with fundamental engineering data relative to the behavior and safety under fire conditions of the various types of building materials and constructions. To this end fire tests of structural materials and structural members are conducted; investigations are made to develop engineering data relative to the general fire-resistive features of building construction; tests are made of fire prevention and fire retarding devices; testing conditions and testing methods are investigated with a view to standardization; and recommendations are made for proper provisions in building codes and fire codes.

Fire Tests of Brick Walls.

The program of fire tests of brick walls begun last year has been continued and is now nearing completion. This is the initial series of a number that it is proposed to carry out with this equipment, the intention being to include all the wall and partition materials in common use. It was deemed advisable to introduce the tests with brick first, because brick is a primary building material that has been in long and universal use, and the values obtained with each thickness can be used as a standard of comparison in interpreting the results with other materials. There is at present much demand for information on the fire values and stability under fire conditions of brick walls. Opinion as reflected in building ordinances varies greatly relative to wall thickness requirements, and while this is due in part to considerations other than those relating to fire, it is thought that a properly planned series of fire tests will help materially to determine the minimum thickness which is safe for use.

The panels are 11 feet high and 16 feet wide. They are built by a masonry contractor at a fixed price per panel, as determined by competitive bids. The series includes tests with brick made of two types of surface clay and one shale, and also with sand-lime and Portland-cement brick. Studies have been made on the effect of changing the cement and lime content of the mortar. The panels are either built solidly into their containing frames to approximate conditions of restraint sometimes present in practice or they are built free from the sides and top of the frame, some with stiffening pilasters at the ends, to simulate conditions of use in the upper stories of some buildings. Heat is applied to one side of the panel, using fuel oil atomized by jets of steam or compressed air, and temperatures are measured at a number of points in the furnace as well as on the exposed and unexposed faces of the panel and at intermediate points within it. The deflections of panel relative to the restraining frame are measured, as also the expansion of the unrestrained panels. The fire test is continued for six hours, provided failure does not occur earlier. Water will be applied in some of the tests after a one-hour fire exposure. Auxiliary strength tests are made of brick and masonry.

The series consists of 30 tests of solid and hollow walls, of which 23 have been completed. The tests were planned particularly to determine the effectiveness of the 8-inch wall, although tests of the 4-inch and 12-inch thickness are included. During the first half of the present year some modifications in equipment, found necessary consequent to the tests conducted last year, were made. As a result of the tests it can be stated that within limitations as to height and construction details the 8-inch wall is adequate for use in exterior walls, and also in party, division, and fire walls where the fire exposure is not too severe. The 12-inch thickness is apparently adequate for all uses and conditions as related to fires that ordinarily occur in buildings, although heavier thicknesses may be necessary under some conditions from the standpoint of strength and stability.

Hollow Tile Investigation.

The investigation of the fire-resistive and other properties of hollow building tile, conducted in cooperation with the Hollow Building Tile Association, has been continued and tests of tile representative of the types and classes now being manufactured have been completed. A large range in fire-resistive properties developed as between tile of different types and clays, and the present work is concerned with effecting improvements in this respect where needed. For this purpose tests have been made with tile made with various percentages of burnt clay (grog) additions to the raw clay. Panels have been built to determine the effectiveness of plaster protections on hollow tile and further tests are proposed to determine the effect of size and shape of unit. In order to obtain more representative conditions in the fire test, the equipment was rebuilt to accommodate a larger test panel. Provision is made for making the fire test under working load and also with the test panel fully restrained within the frame. Equipment has been provided for studying the weathering resistance by means of alternate freezing and thawing, in an effort to determine what relation it has to fire resisting properties.

Compressive strength and absorption determinations have been made of all the tile used in the fire tests. In connection therewith an investigation was made of proper materials and methods for use in capping tile for compresion tests, and also of the effectiveness of different methods of making absorption determinations. The results of the latter have been prepared for publication.

Fire Tests of Concrete Columns.

A brief summary of the nature of these tests, which were conducted at the Pittsburgh laboratories of the bureau, together with some of the more general conclusions, have been given in previous reports.

Detailed descriptions of the results of this investigation have been published in the Proceedings of the American Concrete Institute for 1918, 1919, and 1920. A complete report of the investigation will be published as a bureau technologic paper during the coming year.

Strength of Materials at High Temperatures.

Brief descriptions of an apparatus for determining the compressive strength and elastic properties of materials at temperatures up to 1,000° C. have been given in previous reports with notes on results obtained in tests on structural steel, concrete, and timber. Reassembly and calibration of the equipment, consequent on the transfer of the bureau's Chicago activities to Washington, have now been completed, and it is intended to continue the work during the coming year.

Building Codes.

A considerable amount of technical work relative to building-code requirements has been done in connection with the bureau's general activity in this field. At the request of the committee framing the code for residence construction, an examination was made of over 100 representative building codes relative to the requirements for thickness of walls of buildings of the residence class, which were tabulated, compared, and averaged. The use of these average values as bases for uniform requirements was discussed and applications made to the different types of walls. The properties of wall materials were outlined and relations indicated between the properties of the masonry and those of the individual units. Investigation was made of the functions of walls and criteria established for strength and stability.

The tentative recommendations of the committee were reviewed, as also proposed or revised codes of a number of cities that had been submitted for criticism. A number of conferences and committee meetings dealing with building regulations were attended. The building code library was brought up to date and now constitutes a fairly complete collection of State and city regulations.

A tentative classification of building construction was made from the standpoint of general fire resistive properties.

Safety to Life.

This work is concerned with building exits, inclosure of hazardous operations, and other items relating to life hazard under fire conditions in buildings. The bureau was represented on the American Engineering Standards sectional committee on building exits, a code for egress from school buildings being drafted.

At the request of Government units concerned with the use of motion pictures, examination of the hazards involved in the use of the various types of projectors was made, and recommendations submitted relative to operation and inclosure.

An investigation is being made of the fire resistance and safety of various types of theater fire curtains.

Standardization and Interpretation of Fire Tests.

In connection with the conduct of fire tests a standard pyrometer and mounting have been developed. The indications of this instrument are used in interpreting the time-temperature curve for fire exposure.

An investigation has been begun of the intensity and duration of fires in buildings, such data being necessary in order to properly apply the results of fire tests to the various types of buildings and occupancies. Examination of several buildings after fire has been made, the severity of the fire being judged by the effects on the materials exposed and the fusion of glass, metals, and alloys. A building is being constructed that will be fitted up to simulate typical occupancies, and burnt out, measurement of temperature being made at a number of points, as also observation of effects in building materials and devices.

Miscellaneous Fire Resistance Activities.

At the request of Treasury officials, an investigation was made of the cause of a recent fire on the roof of the Treasury Building, runs being made under representative conditions with the equipment thought to have caused the fire.

Tests were conducted of the fire resistance of concrete chimney blocks, at the request of the engineer department of the District of Columbia.

Investigation was made of an underground fire that had partly destroyed the foundations under a large industrial plant.

Response to frequent requests for information on the fire resistance or fire hazard of materials and constructions were made where it could be done without undue experimentation or research.

Ground was cleared and leveled for the erection of test structures and furnaces included in the program of work that should be undertaken within the coming few years.

AUTOMOTIVE POWER PLANTS, FUELS, AND LUBRICANTS.

This work includes the investigation of fundamental problems of a scientific and technical nature arising in connection with the design, operation, and testing of internal combustion engines and their accessories as applied to automotive purposes, and the qualities and characteristics of fuels, lubricants, etc., used in such power plants and accessories. Much of the work has been conducted in close cooperation with the military branches of the Government and with the National Advisory Committee for Aeronautics. Many investigations are sponsored directly by the engineering division of the

Air Service, McCook Field, Ohio, the motor transport division of the Quartermaster Corps of the Army, or by the Bureau of Aeronautics of the Navy Department, and are supported in whole or in part by funds transferred from their appropriations under the terms of the appropriation statutes. In such cases results are reported direct to sponsor and their publication is under its supervision.

Altitude Laboratory.

In the vacuum chambers, which simulate pressure and temperature conditions of flight, tests have been made of two engines, a 300-horsepower aircraft engine, the Packard 1237, and a 300-horsepower dirigible engine, the Packard 1551. The former engine was tested for the engineering division of the Air Service, and the latter for the Bureau of Aeronautics of the Navy Department. The test for the Army was made in accordance with the standard altitude laboratory test of engines outlined by the engineering division and previously followed in tests of the German Maybach and B. M. W., and the American Liberty and Hispano-Suiza engines. The program of tests followed in the case of the Navy engine was quite comprehensive and that department has requested similar tests on a number of engines during the coming year. The results of both series of tests have been reported to the departments requesting this work.

An aneroid type of automatic air fuel ratio control has been developed and calibrated. This work was done on a 300-horsepower Wright aircraft engine mounted in the altitude chamber. The results were reported to the engineering division of the Army Air Service for whom the work was done.

A series of indicator cards has been taken on an engine when operating under a wide variety of conditions typical of those met with in flight up to altitudes of about 25,000 feet. It is believed that this series of cards is the most complete ever obtained on an aviation engine. This work was carried out under the auspices of the engineering division of the Army Air Service and a report of the results has been submitted to them.

The investigation of the effect of changes in compression ratio on aircraft engine performance has been continued and a report will be prepared during the ensuing year.

Ignition.

Ignition problems have been handled jointly by this and the electrical division of the bureau and a portion of the work is described in the report of that division.

Tests have been made on a number of spark plugs and attachments to be used with them for various Government departments, municipalities, and, in special cases, for manufacturers.

Work is well under way on a series of measurements of the rate of combustion of mixtures of permanent gases ignited by sparks of different electrical quality. The results obtained so far give no evidence of any effect on the rate of combustion by even extreme variations in the energy in the igniting spark.

An investigation has been made of the liability of spark plugs to discharge over the outer surface of the insulator when used under conditions paralleling those in a supercharged engine at extremely high altitudes. This investigation was carried out under the auspices of the engineering division of the Air Service and the results have been submitted to them.

A compilation has been made of data now available on the voltage required to produce a spark under the various conditions of pressure, temperature, etc., met with in the cylinders of internal-combustion engines. This has been supplemented and the more important conclusions checked by a considerable number of measurements. The results of this work have been reported to the engineering division of the Air Service, for whom the work was done.

During some engine tests the engineering division of the Air Service found that the widening of a spark plug gap apparently decreased the tendency of the plug to preignite. The bureau was asked to investigate the causes for this behavior. The results of a series of tests indicated that an increase in the gap width of some spark plugs would cause the spark to occur at a different place in the plug and would thus reduce the effective spark advance. A report on this work has been submitted to the engineering division.

Carburetion.

Several methods for the inherent control of the fuel-air ratio supplied by aircraft carburetors have been tentatively tried out. An informal report on this work has been submitted to the engineering division, by whom this investigation was requested. It is hoped that the possibilities and limitations of these methods can be more completely determined during the coming year.

A short investigation has been made of the effect of changes in the viscosity and density of fuels on the metering of carburetors. A report on this work will be prepared during the ensuing year.

An investigation has been started of the differences in the fuel-air ratios supplied by carburetors when steady and pulsating air streams pass through them. A report giving the preliminary results obtained in this investigation is in preparation for submission to the engineering division of the Air Service, under whose auspices this work is being done.

An investigation of the disintegration of liquid jets into drops and the transportation of the drops by a moving air stream is in progress.

In connection with an investigation of the performance of carburetors and intake manifolds, with a view to increasing the fuel mileage of motor cars, apparatus has been devised for the measurement of the performance of engines in cars while being driven on the road. This apparatus gives synchronous records of (1) rate of fuel consumption; (2) car acceleration; (3) car speed; (4) relative air speed; (5) intake manifold pressure; (6) rate of air consumption of the engine; (7) inlet water temperature; (8) outlet water temperature; (9) engine oil temperature; (10) transmission oil temperature; (11) differential oil temperature, (12) air temperature, and (13) fuel temperature. By its use it should be possible to obtain data of great value to the automotive industry. A description of this apparatus has been presented before the Society of Automotive Engineers.

Fuels.

An investigation has been made to determine the most satisfactory benzol-gasoline blend for use as a fuel in a conventional type of aircraft engine having a compression ratio of 6. This involved an estimation of the supply of benzol available, its corrosive properties, the freezing point of benzol-gasoline blends, as well as the metering characteristics of carburetors and the performance of an engine when using these blends as a fuel. The Bureau of Mines cooperated in this investigation by preparing an estimate of the benzol available, and assisted in the determination of the corrosive properties of a number of samples. A report covering the results of this investigation and including recommended specifications for a fuel blend has been submitted to the Bureau of Aeronautics of the Navy Department, under the auspices of which the investigation was conducted.

The tendency of a fuel to detonate is of great importance in the determination of its suitability for use in high-compression engines. An analysis based on the work of many experiments has been incorporated in a technical note titled "The Background of Detonation," and published by the National Advisory Committee for Aeronautics.

From a considerable amount of miscellaneous information obtained incidental to the investigations in the altitude laboratory, it has become apparent that fuel conforming to the present United States Government specifications for aviation gasoline may be so volatile as to form vapor locks in the gasoline, thus making it impracticable for use in a gravity-feed fuel system. This question is being further investigated, and the results will be placed before the Interdepartmental Committee on Petroleum Specifications.

An investigation to determine the effect of definite changes in fuel volatility on the mileage obtained with motor vehicles in service has been conducted in cooperation with the Post Office Department. The results of this work have been presented before the Society of Automotive Engineers in a paper now in press. A further investigation on this subject is under way in cooperation with the Society of Automotive Engineers, the American Petroleum Institute, and the National Automobile Chamber of Commerce.

A short investigation of the effect of slight changes in the method of gasoline distillation as described in specifications has been made and reported to the Interdepartmental Committee on Petroleum Specifications.

Internal Combustion Engine Lubrication.

The greater proportion of the lubrication work of the section has been carried out under the auspices of the engineering division of the Air Service. These investigations, which are in progress, are outlined in the following paragraphs.

(1) The development of apparatus and the methods of manipulation for the more ready use and standardization of the Waters oxidation test. This test promises to be one of the most important means of specifying satisfactory oils for internal-combustion engines.

(2) The investigation of the relations between the values obtained from the present "cold test," and more direct measurements of plasticity at low temperatures for application in predicting the rate at

which oils will flow into the suction of engine oil pumps under severe winter conditions.

(3) The investigation of the friction losses in standard types of engine bearings with oils of varying characteristics under the severe condition of heavy loads and low speeds.

(4) The investigation of the action of lubricants under very high unit pressures, such as are encountered in ball bearings and gear teeth.

(5) The development of a method for the examination of finished lubricating oils by means of vacuum distillation and the examination of the properties of the several oil fractions so obtained.

As none of these investigations have been completed, no reports have been prepared; but a report covering all the engine tests on lubricants so far conducted at the bureau has been forwarded to the engineering division of the Air Service.

In addition to the above work a large number of special examinations of oils have been made for various departments of the Government.

Cooling Problems.

Under the auspices of the engineering division of the Air Service, an investigation was initiated to determine the ratio of power dissipated as heat by air-cooled engine cylinders to the power losses chargeable to their cooling fins. Only preliminary results had been obtained when the request for the investigation was withdrawn by the engineering division.

The cooling characteristics of several types of aircraft radiators have been measured as a continuation of work in previous years. A summary of the investigations at the bureau relative to aircraft radiators, which was compiled during the fiscal year 1921, was sent to press during the current year.

During the current year the radiator-test plant was moved to new quarters and extended in capacity.

A mathematical analysis of thermal conduction in the fins of air-cooled engine cylinders was completed and submitted to the engineering division of the Air Service. Although this report is a detailed mathematical treatment of the subject, a series of graphic charts are included which are so arranged as to avoid all necessity for reference to laborious mathematics and can serve as a guide for the designing engineer. This report is being published by the National Advisory Committee for Aeronautics.

An investigation has been started having as its object the determination of methods for the measurement of the distribution of air flow in the several tubes of a honeycomb radiator and around the fins of air-cooled engine cylinders. This work, which is being carried on under the auspices of the National Advisory Committee for Aeronautics, has not yet been completed.

Automobile Brake Linings.

The investigation of brake-lining materials begun two years ago at the request and with the assistance of the motor transport division, Quartermaster Corps, has been continued.

The extensive preliminary work necessary for developing a suitable method of testing these materials has been continued and considerable data of value obtained.

The tentative recommendations for test equipment and methods of test made by the bureau in the previous year have been modified in details.

While much remains to be done, the following has been accomplished:

(1) General agreement in the industry on the value of a standard method for testing brake linings.

(2) Very wide differences in performance have been shown to exist between the various brake linings on the market, although sold to the ultimate consumer at the same price for a given size.

(3) Manufacturers whose production totals probably 90 per cent of the gross output, have been led to give much thought to the improvement of their product and are availing themselves of the methods and equipment so far developed by the bureau. The admittedly more or less haphazard methods previously employed are giving way to systematic investigations.

(4) A very marked increase in durability has been found in the product of many manufacturers compared with their standard product of a year ago.

(5) Branches of the Government service are basing their purchases of brake linings on the bureau's tests and it is believed that the resulting saving to the Government will be considerable.

Service tests on passenger cars and trucks as a check on laboratory tests have been initiated and will be extended as rapidly as possible.

In view of the very large annual consumption of asbestos brake linings, the improvement in durability which manufacturers are bringing about as a result of the bureau's undertaking this investigation promises to lead to a very considerable saving to the automotive industry and the public.

Truck Rear Axles.

An investigation of the relative merits of the various types of rear axles for trucks which was begun during the preceding year under the auspices of the motor transport division, Quartermaster Corps, has been continued and it is believed will be concluded this coming year. This work has included the determination of (1) the efficiency of power transmission of a number of axles over the whole range of speeds and power for which the axles are suited, and (2) the relative strength of the various parts of the axles as determined by endurance runs under heavy loads.

The data obtained are expected (1) to assist in the selection of the most efficient and reliable axles for Government use; and (2) to make available information which should be of assistance to the industry in the improvement of its product.

Phenomena of Combustion.

This work, which was initiated several years ago, has been continued with the support of the National Advisory Committee for Aeronautics.

Apparatus has been developed for the measurement of flame velocities by two independent methods; one using an adaptation of the

Bunsen-Gouy method and the other a transparent constant pressure bomb. The second method has been developed entirely at the bureau and promises to yield results of great value.

A large number of measurements of the flame velocity of carbon monoxide and oxygen mixtures have been made at a number of temperatures and with varying amounts of inert gases present as diluents. The results of the several thousand observations taken have indicated that very reliable generalizations on the reaction rates at high temperatures may be possible. It is hoped to continue the work with fuels of more complex chemical structure and obtain information of a fundamental nature on the phenomena of combustion of internal combustion engine fuels.

Miscellaneous.

In some of the engine tests made at the bureau the fracture of thin metal diaphragms has been found very convenient as a means of comparing maximum cylinder pressures. The method of mounting the diaphragms and using them to compare maximum pressures has been described in a technical note published by the National Advisory Committee for Aeronautics under the title "Comparing Maximum Pressures in Internal Combustion Engines."

A technical note entitled "The Use of Multiplied Pressures for Automatic Altitude Adjustments" has been submitted to the National Advisory Committee for Aeronautics for publication. This note suggests a method of obtaining automatic adjustments of aircraft engine carburetor, variable pitch propellor, etc., that, so far as is known, has never been tried but which appears to have many very desirable characteristics.

At the request of an engine manufacturer a short investigation of a case of very rapid wear of exhaust valve seats has been made in cooperation with the metallurgical division.

TESTING, INFORMATION, AND PUBLICATIONS.

Thermometer, Pyrometer, and Heat Tests.

The tests completed in the division during the year are summarized as follows:

The number of liquid-in-glass thermometers of all kinds, exclusive of clinical thermometers, submitted for test was 3,008, of which 1,565 were certified and 472 received reports, the failure to receive certificates being due either to defects in design or construction or to the fact that the errors exceeded the established tolerances. In some cases a single report is rendered, giving results of tests of all thermometers in a given lot. Of the thermometers submitted 706 were reported in this way. Of the remaining thermometers 34 were received broken, 52 were broken in test, of which 9 were originally defective, and 146 were rejected as unsuitable for test. The percentage of thermometers broken in test, 1.4 per cent, is somewhat below the average of previous years. Among the thermometers submitted were 251 calorimetric thermometers, 115 Beckmann thermometers, and 66 clinical standards.

Of the 15,085 clinical thermometers submitted, 12,587 were certified, but only 6,689 received the certificate showing that the thermometer was without appreciable error. Of the remainder 933 were rejected on account of defects which could be detected by inspection while 1,486 were rejected due to defects which were found as the result of the tests. The 27 thermometers broken in test represent only about 0.2 per cent of those handled.

In addition to the above there were tested 29 resistance thermometers, 29 thermocouples, and a number of samples of platinum wire. A number of freezing-point determinations were also made.

In the high temperature laboratories tests were made of 106 thermocouples, 15 indicators for thermocouples, and 1 resistance thermometer. One radiation pyrometer and 9 optical pyrometers were tested, and, in addition, 5 lamps and 1 absorption glass for use in such pyrometers. Melting-point tests of 36 materials, such as fire brick, sand, fire clay, metals, etc., were made.

A number of tests completed in the sections dealing with the fire-resistive properties of structural materials and with automotive power plants, fuels, and lubricants were not of a routine character and have been summarized in the reports of these sections.

Information, Cooperation with Societies, etc.

An important part of the division's activities has consisted in furnishing information on scientific and technical subjects related to its work by extensive correspondence, reports, or directly to technical men visiting its several laboratories. Many of the requests for information relate to physical data which are readily accessible to anyone interested, but a considerable proportion relate to special equipment or information developed by the bureau, or they may require considerable investigation. Information has been given on such matters as the installation of a complete dynamometer equipment for engine testing, on equipment for testing brake linings, on a number of matters relating to fire protection and prevention.

Members of the division have cooperated in the activities of various scientific and technical societies and organizations including:

American Federation of Construction Industries, American Petroleum Institute, American Physical Society, American Society of Mechanical Engineers, American Society of Refrigerating Engineers, American Society for Testing Materials, Association of American Clinical Thermometer Manufacturers, Building Officials Conference, Common Brick Manufactures' Association, Hollow Building Tile Association, Interdepartmental Committee on Petroleum Specifications, National Advisory Committee for Aeronautics, National Brick Manufacturers' Association, National Fire Protection Association, Optical Society of America, and the Society of Automotive Engineers.

The division has been actively represented in the committee work of several of these societies, notably the American Society for Testing Materials, the National Fire Protection Association, the American Society of Refrigerating Engineers and the Society of Automotive Engineers. Numerous papers dealing with the work of the division have been presented before scientific and technical societies.

Publications.

The following publications relating to the work of the division have appeared during the year among the publications of the Bureau of Standards, and may be obtained from the office of the Superintendent of Documents, Government Printing Office, Washington, D. C. Prices are given in Bureau of Standards Circular 24:

The production of liquid air on a laboratory scale (J. W. Cook), Sci. Papers, 17 p. 277; 1921 (No. 419).
Specific volume of liquid ammonia (C. S. Cragoe and D. R. Harper, 3d), Sci. Papers, 17, p. 287; 1921 (No. 419).
Mathematical theory of induced voltage in the high-tension magneto (F. B. Silsbee), Sci. Papers, 17. p. 407; 1921 (No. 424).
Characteristic soft X rays from arcs in gases and vapors (F. L. Mohler and Paul D. Foote), Sci. Papers 17. p. 471; 1921 (No. 425).
Cutting fluids (E. C. Bingham), Tech. Paper No. 204; 1921.

The papers listed below have appeared in current scientific and technical publications:

Life tests of platinum, platinum-rhodium thermocouples (C. O. Fairchild and H. M. Schmitt), Chem. and Met. Eng., 26, pp. 158–160; 1922.
Characteristic soft X rays from arcs in gases and vapors (F. L. Mohler and Paul D. Foote), Sci. Papers, 17, p. 471; 1921 (No. 425). Abstracts in Jour. Wash. Acad. Sci., 11, p. 273; 1921, and in Jour. Opt. Soc. of Am., 5, p. 328; 1921.
The excitation of the enhanced spectrum of magnesium in a low voltage arc (Paul D. Foote, W. F. Meggers, and F. L. Mohler), Phil. Mag., 42, p. 1002; 1921.
The significance of the ½ terms in spectral series formulæ (Paul D. Foote and F. L. Mohler), Jour. Opt. Soc. of Am. and Rev. Sci. Insts., 6, p. 54; 1922.
A significant exception to the principle of selection (Paul D. Foote, F. L. Mohler, and W. F. Meggers), Phil. Mag., 43, p. 659; 1922.
The excitation of the enhanced spectra of sodium and potassium in a low voltage arc (Paul D. Foote, W. F. Meggers, and F. L. Mohler), Astrophys. Jour., 55, p. 145; 1922.
Properties of Ammonia (Mollier chart), published by Am. Soc. of Ref. Engs., 1922.
Lessons of fire tests (S. H. Ingberg), address before National Brick Manufacturers Association. Published in Clay-Worker, June, 1922.
Factors affecting fire resistance of building columns (S. H. Ingberg), Engineering News-Record, June 29, 1922.
The ideal wall construction (in conjunction with Div. VII-1), Letter-Circular No. 29.
The safety of portable motion picture projectors (jointly with Div. V-7), Letter Circular No. 70.
Tentative classification of building construction with reference to fire resistance, Letter Circular No. 71.
Radiators for Aircraft Engines (D. R. Harper, 3rd.), Jour. Wash Acad. Sci., Vol. II, No. 17; Jour. of Soc. of Automotive Engrs., October 19, 1921.
Developing a method for testing brake linings (S. von Ammon), Jour. of Soc. of Automotive Engrs., March, 1922.

REPORTS OF THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Performance of Maybach 300 horsepower airplane engine (S. W. Sparrow), Tech. Report 134.
Performance of B. M. W. 185 horsepower airplane engine (S. W. Sparrow), Tech. Report 135.
Simplified theory of the magneto (F. B. Silsbee), Tech. Report 123.

TECHNICAL NOTES OF THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

The background of detonation (S. W. Sparrow), Tech. Note 93.
Comparing maximum pressures in internal combustion engines (S. W. Sparrow and S. M. Lee), Tech. Note 101.

The following papers are in press or have been submitted for publication:

The origin of Spectra (Paul D. Foote and F. L. Mohler). book to appear in the Monograph Series of Am. Chem. Soc.

The effectiveness of different methods of making absorption determinations as applied to hollow building tile (H. D. Foster). Jour. Am. Cer. Soc.

OPTICS.

The work of the optical division includes: Radiation and absorption spectra, along with certain phases of qualitative and quantitative chemical analysis for which these are especially applicable, and the development of infra-red photography for astronomical observations and aviation purposes; investigations and tests involving measurements of polarized light and its application, especially in the testing, standardization, and technology of sugar, including the supervision of the sugar laboratories of the Customs Service; measurement of the factors which determine color, the optical transmissive and reflective properties of materials, and the color grading of light sources and materials; performance and development of optical instruments and materials, including refractive indices and dispersion measurements; the more general field of radiation, determination of the fundamental constants of radiation, the development of radiometric methods and instruments, and the determination of the emissive, reflective, and absorptive properties of materials for thermal radiation; application of the light wave as a standard unit for high-precision length measurements and development of interference methods; testing of photographic materials and devices, and general photographic investigations; optical investigation, and measuring of the physical properties of dispersoids, such as smoke, water supplies, etc.

GENERAL.

Outstanding Accomplishments.

From the large group of varied activities necessarily briefly described below certain accomplishments may be cited here which are of more than ordinary interest. The International Astronomical Union, which met during the year at Rome, adopted practically all of the bureau's measurements and recommendations concerning primary and auxiliary wave length standards. One of the greatest needs of color specialists, namely, a rigidly defined and accurately reproductible "white light," has been met by the development of a successful method for statistically fixing by test that which observers agree on as "white," and it is interesting to note that this approximates very closely to noon sunlight. A scale of color temperature ranging from the candle (approximately 1,900 centigrade absolute) through the common artificial light sources and sunlight to that of the blue sky (up to 24,000°) has been completed, and the same sources have been graded according to the wave lengths of their spectral center of gravity. The spectral energy distribution from a number of stars and several planets has been measured. Scales have for the first time been successfully ruled using light waves directly as measuring standards. One such, a 100-millimeter scale, was tested by the International Bureau of Weights and Measures at Paris and commended as being remarkably accurate. A method for deciphering completely obliterated ink records on charred carbon paper was successfully developed.

General Condition in the Division.

Many activities have been seriously handicapped through the impossibility of obtaining adequate equipment at present-day prices. It may be safely stated that productiveness in sugar standardization, spectroscopy, colorimetry, and optical instruments would have been distinctly greater had funds and facilities been available for obtaining needed equipment with greater dispatch.

The plan, undertaken at the beginning of the year, of merging the optical shop with the optical instruments section, has reduced "lost motion" in a satisfactory degree. With an optical instrument shop also in this section it is believed that the productivity will be commensurately enhanced.

SPECTROSCOPY.

Standard Wave Lengths.

After a lapse of nine years international cooperation in the perfection of a new system of standard wave lengths was to some extent revived in May, 1922, when the International Astronomical Union met in Rome and discussed this subject. Since 1913 the spectroscopy section of this bureau has considered its major duty to lie in the direction of precision measurements of wave lengths and each year it has contributed something along this line. It is not surprising, therefore, that this laboratory may now be credited with more work on standard wave lengths and spectra than has emanated from all other laboratories combined. The history and recent developments of this subject were summarized in two Reports on Standard Wave Lengths, published in the Journal of the Optical Society of America (5, p. 308; 1921, and 6, p. 135, 1922).

The International Astronomical Union has adopted practically all of the bureau's work and suggestions, including (1) the retention of the cadmium red line as the primary standard, (2) adoption of neon lines as an equivalent auxiliary standard (Sci. Paper No. 329), (3) additional measures on 12 cadmium lines suitable for secondary standards (Sci. Paper No. 441), (4) additional measures of argon wave lengths for secondary standards (Sci. Paper No. 414), (5) adoption of the tables of the Bureau of Standards for reducing wave-length measurements to standard conditions and for corrections to values in vacuo (Sci. Paper No. 327), and (6) adoption of tertiary standards among which the bureau's interferometer values of over 300 lines in the iron arc spectrum are included (Sci Papers Nos. 251 and 274).

Certain of the secondary standards previously adopted have been found to give slightly lower values when the light is taken from a more restricted central portion of a longer arc. The International Commission on Wave Lengths and Solar Spectrum Tables has changed the specifications of the iron arc as a source of secondary standards, thus making it necessary to redetermine the wave lengths in this spectrum. The bureau has accordingly made the required observations by taking photographs of the interference fringes produced by cadmium, neon, and iron lines. About 50 spectrograms were obtained with various interferometers. The range of wave lengths under observation extends from 3,000 to 9,000A. The results will be published during the coming year.

Investigation of Arc Spectra.

Previous annual reports and numerous publications show that this laboratory has been partially engaged for the past six years in describing the standard arc spectra of all the chemical elements, especially in the red and infra-red spectral regions for which special photographic technique has been perfected by the bureau. This work was continued during the past year, emphasis being placed upon the less common materials, such as the rare earths and the noble metals of the platinum family. Scientific Paper No. 421 describes the yellow, red, and infra-red arc spectra of yttrium, lanthanum, and cerium, while Scientific Paper No. 442 gives similar information for neodymium and samarium. In the case of the last two elements, the purest materials obtainable gave a considerable number of lines common to both. It is suspected that these may belong to the unknown element whose atomic number, 61, lies between those of neodymium and samarium. In addition to the above the arc spectra of gadolinium, dysprosium, columbium, and zirconium have been thoroughly investigated in the longer wave regions. The arc spectra of the entire group of platinum metals (ruthenium, rhodium, palladium, osmium, iridium, and platinum) have been photographed in the yellow, red, and infra-red, using the purest materials prepared by the chemistry division of this bureau. These results will be published in the near future.

Investigation of the red and infra-red emission spectra of oxygen and nitrogen have enabled the bureau to identify most of the "air lines" observed in the spectra of arcs and sparks operated in air. Up to the present time the longer wave portions of the arc spectra of about 75 of the chemical elements have been investigated.

Spectrographic Analysis.

Over 200 spectrochemical analyses were made last year on a large variety of materials including searchlight carbons, commutator carbons, defective platinum crucibles, bronze and brass castings, platinum metals, dental gold, colored glasses, precipitates and residues from reagents, etc. The spectograph has demonstrated its great value in supplementing chemical methods of analysis, and in certain cases it may replace the more tedious wet methods, both for qualitative and quantitative results. A paper entitled "Practical Spectrographic Analysis" is now in press, which describes empirical methods and is illustrated by examples of quantitative analysis of tin, gold, and platinum for impurities. The physical principles underlying spectrochemical analysis have been studied rather intensively and a paper on "The Physical Basis for Spectrographic Analysis" is being prepared.

Spectrum Tubes.

About 70 spectrum tubes of nitrogen, helium, neon, argon, mercury, or cadmium were prepared and furnished to various laboratories for optical testing or spectrum standards, and many additional requests for such tubes referred to other sources recently established in this country. Some notes on the preparation of spectrum tubes were included in Scientific Paper No. 441 so that research laboratories possessing the necessary equipment may be encouraged to make their own.

POLARIMETRY.

Cooperation with United States Customs Laboratories.

The bureau has continued to assist the Treasury Department in the maintenance and operation of its customs laboratories with excellent results. During the year more than 1,600 exchange samples of raw sugar were tested. Approximately 50 per cent were direct polariscopic determinations and the remainder were tested for the percentage of moisture in addition to sucrose content. The close agreement of the results obtained between the several customs laboratories and the bureau demonstrates the value of control analysis.

In view of the recent opening of a large refinery by the American Sugar Refining Co. at Baltimore, Md., the division of customs requested the bureau to design suitable laboratories and equipment to facilitate the additional testing incident to the appraisal of imported sugars. Although the appraiser's stores, in which it was necessary to place the laboratories, is an old building and somewhat unsuited for this purpose, an excellent and economical plan was devised, consisting of a chemical laboratory, polariscope laboratory, sampling and mixing room, together with suitable offices for the sugar examiner and the chemists. It was found necessary to modify the standard equipment to meet the peculiar requirements of the building. The installation of this equipment is well under way. The lack of facilities necessitated the installation of a separate boiler room in connection with the laboratories, which is equipped with a steam boiler, hot-water heater, vacuum and compressed air outfit, together with steam ovens for drying sugar buckets and sample cans.

At the suggestion of the bureau, an assistant chemist has been transferred from the bureau's staff to the Baltimore laboratory. The first cargo was received on March 17 and consisted of approximately 10,000,000 pounds of sugar. On the recommendation of the bureau, an experienced examiner was detailed from the customs service at Philadelphia to take charge of the sampling, and a member of the bureau was detailed for several days to supervise the testing.

Supplies for the Customs Service.

Additional facilities have been provided by the bureau for maintaining a stock of tested apparatus for the customs service of the Treasury Department. In the case of the needs of the new Baltimore laboratory it was thus possible to supply the necessary apparatus without the delay of obtaining the material and testing it. The various other customs laboratories have been promptly supplied with tested apparatus. A survey has been made of the weights used in the various laboratories in the testing of sugar, and at the suggestion of the bureau a supply of analytical and sugar weights was purchased and tested at the bureau. This permitted replacement of an equal number of weights in use at the ports. The tests of these replaced weights showed conclusively that frequent testing is necessary. In a number of cases the weights sent in were considerably in error. The regulations of the customs service require that these weights be tested at least once a year. Since this has not always been carried out in the past, the bureau has been authorized to replace and retest all such weights. The increased accuracy will well repay the effort involved.

The need of a pulp balance which will meet the requirements of the customs service as well as the industry has long been recognized. To meet this need the design of such a balance has been undertaken. An experimental balance of this type has been constructed and tried out in actual operation, and found to be a decided improvement over the stock balances for sugar work.

Experiments have been conducted on glass polariscope tubes of the standard design to meet the requirements for a tube for acid solutions. A noncorroding metal tube has been made for the same purpose.

Plans have been devised for increasing the scope of the bureau's activities in connection with the precision apparatus of the customs service. This work is of fundamental importance in the administration of the tariff law.

Testing of Cover Glasses.

Through the efforts of the bureau all of the cover glasses in use in the customs service are supplied by American manufacturers. During the year large numbers of glasses have been tested for the above service and also for private concerns. These glasses are tested for optical homogeneity and absence of optical activity.

Testing of Molasses.

The bureau continued to act as referee between buyers and sellers of molasses. Since a large proportion of the molasses for manufacturing purposes is bought on the basis of total sugar content and density, a number of manufacturers specify that settlement be made on the bureau's analysis. During the year over 20 analyses were made. The study of new methods of analysis has been continued with the object of increasing the precision of determination on molasses and other low-grade products. Cooperative analyses of ash in sirups and molasses have been made for the Association of Official Agricultural Chemists and a report issued to their referee. The above association voted at their last meeting to continue this work during this year. The several methods suggested are being further studied at various temperatures.

The Rare Sugars.

So far as the United States is concerned, the rare-sugar industry, in relation to the commercial production of these materials, is a new one. Until recently we were wholly dependent on Europe for our supplies. The bureau has already been of considerable assistance to the industries immediately interested in this group of compounds, and the quality and variety of the products produced have been increased. In addition, materials of a higher purity have been produced and important contributions to the knowledge of the sugar group have been made.

Most of the work previously reported as under way has been continued. In extending this work it was found necessary to devote considerable time to the development of special apparatus needed for specific purposes. Of this apparatus having general applicability may be mentioned a vacuum still used for the concentration of sugar solutions and allied products. The apparatus is so constructed that is has a large capacity and at the same time concentration takes place in glass—a necessary prerequisite for the preparation of exceptionally pure products. A report on the design and construction of this apparatus was made at the meeting of the American Chemical Society held at Birmingham, Ala.

Investigations have also been carried out with the object of developing convenient and economical methods of preparing the rare sugars. In this connection methods have been developed for the preparation of two more members of the sugar group, namely, mannose and fucose.

Work upon the more fundamental phases of carbohydrate chemistry has been undertaken, and, as a result, the complete structure of fucose has been determined. This is an important contribution, as the constitution of this sugar has heretofore been unknown. It also has a direct bearing upon 5 other sugars, i. e., rhodeose, the 2 methyl hexoses from rhodeose, and the 2 methyl hexoses from fucose. This is because rhodeose is known to be the optical isomeride of fucose, and, therefore, the knowledge of the structure of fucose gives at once the structure of rhodeose. This leads to the structure, with the exception of all but one point, of the other 4 sugars above mentioned. Work upon these problems is in progress. In the course of this work the methyl tetronic acid from fucose has been prepared and studied for the first time. This is of importance, since it is the second sugar derivative of this type that has been studied, and the experience gained with it gives promise of affording a means of determining the structure of any other methyl sugars that may be discovered in nature.

Raffinose in Beet-Sugar Products.

Raffinose is a complex member of the sugar group, which occurs as an impurity in beet-sugar products of the Middle Western States. It has a disturbing effect upon the process of manufacture and frequently prevents the recovery of much sugar from the molasses in which it has accumulated. It has long been a disputed question whether the impurity which the prevailing analytical methods indicate as raffinose is true raffinose or a positively rotating nonsugar. The only feasible method for the determination of true raffinose depends upon the use of the enzyme "melibiase," which is extracted from brewer's yeast. Analyses conducted with this agent upon several samples of beet molasses obtained from Colorado indicate that true raffinose is present in beet molasses and that aside from the raffinose the residual impurity is not dextro rotary, as previously supposed, but is actually lævo rotary.

In continuation of the research improved methods of making this difficult analysis are being investigated.

The effect of raffinose upon the crystallization of sucrose has been studied. It has been ascertained that a diminution of the solubility of sucrose results in addition to a profound effect upon its crystal form. Apparently, however, raffinose does not combine to form "mixed crystals."

Preparation of Levulose.

Levulose is the sweetest member of the sugar group and under various forms is one of the important articles of human diet. Its difficulty of preparation, however, has prevented its appearance on the market in a pure state except in small quantities and at a prohibitive cost. If it could be prepared at a relatively low cost, it would undoubtedly become a valuable national asset, as the material would serve a multitude of special purposes, due to its sweetness, wholesomeness, high solubility, and other particular properties. This end, although remote, is the aim at which the bureau is striving. During the past year a study has been made of the preparation of levulose from cane sugar, in which it occurs combined with dextrose; and from dahlia tubers, in which it occurs in the form of a starch known as "inulin." The conditions necessary for the conversion of the inulin to levulose have been studied with a view to obtaining complete conversion and the highest possible purity. Experiments have been made on the crystallization of the sugar from various solvents, and in many instances promising yields of the pure substance have been obtained.

The properties of the pure sugar have been, to some extent, studied. Among these have been the density of solution, refractive index, and optical rotation.

The Utilization of Molasses.

The rapid change of conditions in the sugar market during the past two years has forced American manufacturers to consider seriously the utilization of the waste molasses and waste waters which result in the processes of sugar manufacture. A formerly valuable by-product has decreased to less than one-fourth of its former value. Many valuable chemical compounds, known as nonsugars, may be produced from these wastes under the proper conditions. Such processes are known to be in use in Germany, but as yet none have been developed to meet the different conditions which exist in the industry in this country. The bureau, with the strong commendation of those in the industry, has undertaken the problem of devising means of utilizing the waste liquors. A thorough search of the patents and literature connected with the subject has been made and steps have been taken to assemble the necessary equipment to carry out research on the problem. There is little or no general scientific literature on this subject and the bureau has had to resort to the procedure of studying foreign patents. The search has proven difficult and taken much time. The chief difficulty has arisen from the fact that but a small fraction of the pertinent patents are classified under the heading of molasses. Twenty or more principal classes were found, in each of which it was necessary to create subclasses. The search has been conducted systematically and wherever possible by examining the full individual patent brief. It has been surprising to find that in an important commercial field in which there is practically no literature over 1,000 patents in German alone should be found. The unmistakable impression has been obtained that every legitimate means has been used by foreign patentees to create as many difficulties as possible in the trailing of patents, and it is exceedingly difficult to decide when a given patent is really of practical and specific economic importance.

Molasses Formation.

Molasses is one of the greatest sources of sugar loss in the manufacture of both beet and cane sugar; hence, a study of the various factors influencing the quantity produced is of primary importance to the industry as well as of great importance to the country at large. The work in this field which has been undertaken at the bureau includes, among others, a scientific study of the equilibria of the various complex chemical systems existing in the product.. It is hoped that by this study a rational theory of molasses may be developed. The work already indicates that the theory now most widely accepted by the industry is probably inadequate to explain the phenomena, and it seems quite possible that this theory may have been an important factor in retarding development along certain lines of sugar technology. The low prices of molasses during the last year have awakened some of the beet-sugar manufacturers to the importance of such studies; and they have urgently requested the bureau to undertake an extensive program of research on the general problem of molasses.

Saving of Waste Sugar.

Every year huge tonnages of sugar are lost through various deficiencies in the manufacturing operations whereby the sugar from beets and cane is extracted. One of the greatest sources of such losses is in the molasses, which is the residual sirup obtained from the last crystallization of sugar. It is a product from which no more sugar can be obtained by present methods of crystallization. In a beet-sugar factory each pound of impurities which is not eliminated in the process before the sugar reaches the stage of crystallization will necessitate the rehandling of some 8 or 10 pounds of sugar and impurities in the crystallization process, and, finally, will cause the loss of 1½ pounds of sugar in the form of molasses. Hence, any practicable increase in the quantity of impurities eliminated in the process before the crystallization stage will bring about the saving of at least an equivalent quantity of sugar. From a sugar manufacturer's standpoint this is preferable to any known means of utilizing the equivalent quantity of molasses. Therefore, the bureau has undertaken an investigation in this field. The work accomplished thus far has been confined to beet molasses. Unfortunately, the available literature on this subject is very widely scattered under different subjects and in various languages. Much time has, therefore, been spent during the current year in making a technical survey of existing knowledge on this subject. The collected material thus obtained will be of special value to the American industry and will save much time in attacking the experimental part of this work.

Commercial Production of Pure Dextrose.

In previous reports there have been given the results of the bureau's fundamental work in making possible the commercial production on a large scale of practically 100 per cent dextrose. This sugar, commonly known as glucose, is now produced in fine, white crystals very similar in appearance to granulated sugar. The bureau's connection with this work is again touched upon in order to call attention to the fact that the abstruse scientific laboratory experiment of to-day frequently becomes of great commercial importance to-morrow. The one and one-half million dollar plant built at Chicago for the manufacture of this material has now been completed and successfully operated, and a similar plant is in course of erection by the same American firm in Germany. Once a new material is available new uses on an extensive scale immediately spring up. The two most recent extensive applications in the use of dextrose are in the condensed-milk and ice-cream industries. In these industries it satisfactorily meets the demand for a material which heretofore has not been available.

The Laboratories of Sugar Technology.

The work of equipping these laboratories has been continued, but they are not yet complete. They will be used extensively in the coming year's work, however, and several pieces of work not previously attempted on account of lack of facilities will probably be carried out. The new vacuum equipment includes a glass enameled pan and a wet vacuum pump.

Special Sugar Apparatus.

Much of the special sugar equipment, consisting of commercial and semicommercial units mentioned in the previous report, has been received and partially erected during the year. Several new designs have also been completed during this period. The equipment will be used for the purpose of obtaining scientific data required for further work in certain lines of sugar technology and will permit of carrying out laboratory-scale operations connected with various projects.

Table Sirups of High Density.

A study of the solubilities of sugars in the presence of other sugars has shown that a sirup of maximum solubility of a sucrose-invert-sugar mixture is obtained if it contains 33.6 per cent sucrose and 45.4 per cent invert sugar. Such a sirup may be concentrated to 79 per cent total solids without danger of crystallization if the temperature is maintained at 30° C. This part of the investigation was completed during the previous fiscal year. During the past year the variation of this maximum solubility point with the temperature has been determined by computation and experiment. Many subsidiary data have been obtained, such as the contraction of volume upon inversion and the effect of such contraction upon the density of the solution.

The question of effecting the inversion of sugar to obtain an increase of solubility is still under investigation. It appears evident that when the enzyme "invertase" is available its inverting action is the most feasible one. Where this material is not available for isolated localities, it now appears possible that an acid method may be applied, which, however, is valid only for "open kettle" processes.

Viscosities of Sugar Sirups.

One of the most important properties of the liquors passing through the sugar factory is viscosity. Upon this depends, in a great measure, the facility of filtration, boiling, centrifugal separation, and many other operations. There is, therefore, a need of standardization in methods and an increased number of accurately known viscosities in order that measurements may rest on an absolute rather than merely a comparative basis. Although there are in existence reliable data on the viscosities of sugar at a few concentrations, these are so widely separated that interpolation is impossible. During the past year an interpolation formula has been devised which rests upon these few known viscosities, and it is important to establish this and other such formulæ by a greater number of accurately determined viscosities.

Decomposition of Invert Sugar in the Presence of Hydrochloric Acid.

The experimental data acquired in the study of table sirups of high density have made it possible to determine the time required under a given set of conditions to produce complete inversion of sucrose. It now becomes important to ascertain the effect of an excessive time of heating, or, in other words, the rate of decomposition of invert sugar in the presence of acid over the range of temperatures commonly employed. This work is well under way.

Crystallization.

A delicate thermostatic-control apparatus for growing large and perfect crystals has been in operation for a year. It has recently been improved in a number of details and has been successfully kept in continuous service over a period of six months with little or no attention. The process of growing large and perfect crystals is necessarily a very slow one covering considerable periods of time. The general problem of crystallization is an important one for industrial as well as purely scientific purposes. A number of relatively large and perfect crystals of some of the rare sugars and allied substances now being produced at this bureau have been successfully grown. An important development has resulted from the discovery that in some cases the purity of a substance can be judged by the character of the crystals it will produce. Raffinose, for instance, after purification by repeated recrystallization will readily grow in large clear crystals, while before recrystallization it would invariably precipitate as a mass of fine white crystals. The same may be said of mannite. Among the substances which have been grown may be mentioned dextrose, levulose, sucrose, raffinose, rhamnose, xylose, mannite, gulonic lactone (gulose itself has never been obtained in crystalline form), cadmium sulphate (for the production of pure metallic cadmium), nickel sulphate, Rochelle salt, and sodium nitrate.

Diffusion Process in Sugar Manufacture.

Some work was done on this problem during the year, including the construction of a small battery. This was described before the sugar division of the American Chemical Society at the New York meeting in September. The experimental results thus far obtained indicate that most of the work outlined in this field can not be completed without developing a more complete set of apparatus. It is planned to make some measurements of the relative diffusion rates of certain beet constitutents, using for the purpose a series of special glass cells which have been designed. It is believed that the result of this study when completed will provide data from which the present commercial practice may be improved.

Standardization of Commercial Sugars.

In the previous report attention has been directed to the importance of the problem of grading and preparing standard specifications for the various commercial sugars produced in the United States. With the completion of the greater portion of the experimental work incidental to this problem, the investigation has been extended during the year to devising a system of classification which will permit the grading of all classes of sugar products, from the highest, almost colorless fancy grades, to the most highly colored soft sugars. The results obtained have been satisfactory. A definite color scale, covering all these products, now seems available, including the small differences in tint of white sugars. The system of color grading is pliable and gives excellent promise of a color scale suitable for the entire sugar industry. There remains considerable work to be done in this investigation which can only be accomplished by consultation with representatives of the industry, to the end that the practical application may result in all cases to the benefit of the individual manufacturer.

Storage and Shipment of Sugar.

The caking of white, dry, granulated sugar during storage and shipment is a problem of great economic importance to the sugar industry, and while it has been studied more or less extensively with varying degrees of success by several of the leading producers, no satisfactory solution of the problem has been obtained. Inquiries which have been received relative to the work previously done in this field indicate that the various factories are still much interested and that they regard a further study of this problem an urgent matter. The past year's work has been confined largely to qualitative experiments and continued study of data previously obtained by one of the manufacturers.

Color Measurement in the Sugar Industry.

The principal object of all factory operations in the manufacture of sugar and its by-products is the ultimate removal as far as possible of all color. An accurate and convenient method of measuring the color that remains has been a basic problem in the sugar industry for many years. Of equal importance is the utilization of a system of color measurement to estimate the efficiency of the various steps in the removal of color during the progress of sugar manufacture. In the previous report, attention was directed to the nature of these problems, their importance, and the results which the bureau has accomplished in its efforts to apply modern research laboratory facilities to practical use in the industry. This work has been continued with gratifying results, the investigation entering new phases and aspects of the problem. These have compelled the acquisition of additional precision instruments and equipment. Considerable delay has necessarily resulted, as a part of these materials have had to be purchased from Europe.

In summarizing the results accomplished thus far, it may be said that a better definition and understanding of the nature of the color in impure sugar products has slowly developed. There is a peculiar intimate relationship between any color problem of the industry and all methods pertaining to purification, filtration, and decolorization.

The additional information which has been secured as to the nature of the color indigenous to cane and beet products is equivalent to opening up new possibilities for the refinement and improvement of all technical processes of manufacture. While the investigation is proceeding by the utilization of all available scientific refinement, it is hoped to attain the practical results in such form that they may be directly and conveniently applicable in sugar technology. As a valuable aid to this end, much time has already been spent in the design of instruments of a type directly applicable to use in the factories and to the scientific laboratories connected with the sugar industry.

Gradation of Sugars by Sieve Analysis.

No further experimental work has been carried on in this investigation, but excellent progress has been made in the correlation of the results of previous tests with other data obtained on the same samples of sugar.

Enzymic Estimation of Sucrose.

In previous investigations the bureau has studied the Clerget method for the analysis of sucrose and has suggested modifications of the method to eliminate errors caused by disturbing impurities. These methods have depended upon the inversion of sucrose by means of hydrochloric acid. During the past year a study has been made of the inversion of sucrose by means of the enzyme "invertase," an active agent extracted from yeast. The invertase method, while theoretically perfect, is apparently at present subject to greater errors than the acid method. A great diversity exists in the experimentally determined value of the inversion constants. The sources of these diversities have been investigated and the conclusion has been tentatively reached that they are to be ascribed to the preparation of the enzyme. This preparation has consequently been carefully investigated and preliminary determinations of the constants of the invertase inversion have shown that an accurate reproducibility is possible.

The importance of this research depends not only upon its application to the invertase method itself, but as corroborative evidence of the acid methods of analysis. The latter, when proven to be reliable for all products, may then be used for the daily control of sugar manufacture, and the invertase method for corroboration and examination of the performance of the acid method.

Decolorizing Agents.

So great is the demand for efficient decolorizing carbons in many lines of industry, including the sugar industry, that new carbons are continually being produced in many countries. The collection of samples by the bureau has now been extended to include the European product wherever conditions have permitted of a search of foreign industries. In the bureau's work the study of these materials is still confined to the removal of coloring matters in preference to that of ash and organic substances. This procedure has been followed because the decolorizing action is closely connected with the investigation of the color in sugar and sirups, reported elsewhere. The equipment which is being accumulated directly for the measurement of color is applicable to the present problem of estimating the performance of decolorizing carbons, and the results accomplished in both investigations are necessarily interwoven.

A further study of technical color-measuring devices has developed the necessity of supplying industrial laboratores with precision color-measuring devices which must be reasonably priced and simple in operation. Reliable results in decolorization practice can not be secured by methods and instruments which merely give approximations. Deductions drawn therefrom in industrial laboratories for practical problems are invalidated wherever such approximations are used. The technical demands for precise information have been pushed so energetically by technologists that only precision methods and instruments can produce the desired results. The bureau is, therefore, engaged in presenting the sugar color problem in forthcoming publications in such manner that scientific principles in methods of analysis and in interpretation of observed results will supplant the antiquated colorimetric practice, which has been proven unsatisfactory.

Adjustment and Standardization of Saccharimeters.

The work of adjusting and standardizing saccharimeters and polariscopes has been continued. Although several excellent types of instruments have been on the market for some time, the supply is still limited, as is evidenced by the fact that a large proportion of the instruments sent to this bureau for test are old types, many having a different basis of calibration from the newer ones. The bureau is constantly called upon to furnish information regarding the use of these instruments and has continued to render valuable service to the sugar industry. During the year 40 instruments were adjusted and standardized, 29 of which were submitted by various sugar companies, 5 by other Government departments, 2 by State universities, and 4 by industrial and research laboratories.

Basis of Saccharimeter Standardization.

The rotation of the normal sugar solution, which fixes the 100° point of the saccharimeter scale, is the most important of all polarimetric constants. In previous reports there has been chronicled the bureau's work in the accurate determination of this value and the discovery of an error in the accepted value of over one-tenth of a per cent. Owing to conditions which have prevailed for some years, it has been impossible to get the International Sugar Commission together in an effort to secure international agreement on the value of this constant. In view of the fact that the error discovered by the bureau was resulting in large losses to the Government from duty not collected on imported sugars, as well as in still larger losses to the producers of sugar, the bureau has for some time been standardizing all instruments and all quartz control plates on the corrected value. The most important development in the subject during the year has been the publication by a prominent European authority of an elaborate investigation on the determination of the 100° point. This work fully confirms the results obtained by the bureau and thereby greatly strengthens and justifies the policy previously adopted in introducing the correction for the North American industry.

Quartz-Control Plates.

The modern saccharimeter as developed for sugar-testing purposes is necessarily a complicated piece of apparatus and is, therefore, likely to show variations in its reading from day to day and thereby render inaccurate the test of a sugar. Inasmuch as all sugars are bought and sold upon the tests shown by this instrument, the highest available accuracy and reliability are essential. All inaccuracies, including those due to variations in temperature, can be corrected by means of quartz-control plates. A plate of crystalline quartz, properly cut with regard to the crystallographic axis, has the power of rotating the plane of polarization of a beam of polarized light in the same manner as a sugar solution. The control plate is placed in the saccharimeter in place of the sugar solution and the reading obtained compared to the standard value of the plate determined at this bureau. These plates are thus of fundamental importance throughout the sugar industry and in scientific laboratories as well. During the year over 100 have been tested, 40 per cent of which were rejected as being unfit for precise sugar work. Inaccuracies produced by improper mounting of the plates were so common that the bureau adopted the policy of remounting many that were sent in for test when such plates were already in the possession of the industry. On the other hand, when improperly mounted plates are submitted for test by the maker, they are rejected. The effect of this procedure has been most satisfactory, and as a result of the bureau's work in this field the average accuracy of the plates in use throughout the industry has been greatly increased.

Properties of Quartz at High Temperatures.

In carrying out an investigation of the optical activity of crystalline quartz at high temperatures, it was found necessary to carefully explore the region in the neighborhood of 573° C. At this temperature quartz undergoes a recrystallization with a consequent absorption of heat if the specimen is being heated, and a liberation of heat if the specimen is being cooled. From this study it was discovered that the transformation temperature is so sharp and reproducible that it is suitable for a fixed point on the high-temperature scale. All clear crystalline quartz is especially pure and the previous experiments in this investigation were made on material of that character. During the year a further study was made on colored quartz of the usual type occurring in Japan. Careful experiments on the Japanese quartz showed that recrystallization occurs at exactly the same temperature as the clear quartz, namely 573.3° C.

Owing to the importance of the utilization of quartz for the purposes mentioned above, the effect was studied in the powdered material. It was found to be much less suitable.

"Reaction" of Sugar Products.

In the sugar industry, as in many others, it is common practice to express an idea of the alkalinity or acidity of a product by indicating how much acid or alkali would be required to make the product "neutral." As one might state the quantity of heat in a product without stating the temperature, so this method expresses the quantity of acidity or alkalinity, but does not indicate its degree of intensity. This degree or intensity is termed the "reaction" and may be stated in terms of the hydrogen-ion concentration, just as temperature may be stated in terms of Fahrenheit or centigrade scales.

The recent work of many investigators has indicated that the behavior of a substance is controlled less often by its total quantity of alkalinity than by its reaction. The possible application of these facts to sugar products and processes seems to be very extensive, ranging from improving flavor and appearance of white sugar to better elimination of impurities in the process, and hence the production of less molasses and more sugar. Previous work in this field by the bureau has been carried on with indicators. Electrical equipment for the purpose has recently been acquired and an extensive program of work has been planned.

Polariscopic Determination of Double Refraction in Glass.

The usefulness of a glass is affected adversely by the presence of strains in the material. These strains are caused by improperly annealing the glass or by the application of external forces, and are accompanied by variations in the refractive index and by double refraction. Practically the only method of detecting these strains is by means of some test for double refraction.

As it has thus far been impossible to remove all trace of such strains by any practical method of annealing, it is necessary to determine the effect of their magnitude and distribution on the performance of the glass used in optical instruments. It is hoped eventually to establish standards for the fitness of glass for optical purposes. Much assistance in this work has been received from the optical glass and instruments sections of this bureau.

Polarimetry of Oils.

Oils of all classes are often naturally active; that is, they possess the property of rotating a beam of plane poliarized light, and all become active or doubly refracting in a magnetic or an electric field. Data on these properties aid in identifying the oils and determining their source. The commercial value of such data is great, as it is frequently possible through their use to detect adulterations and inferior quality. Investigations in this field are progressing and the bureau is now cooperating with those commercial laboratories where similar work has been undertaken. Special attention is being given to developing a technique used in making the tests.

Refractometer in Sugar Analysis.

The refractometer serves a useful purpose in sugar analyses by virtue of its ability to indicate in a very rapid and convenient manner the total solid content of a sirup submitted for analysis. The refractometric determination of solids is very precise when applied to pure sugar solutions, and gives a satisfactory approximation even when the dissolved substance does not consist exclusively of sugar. A necessary preliminary to the use of this instrument is that the refractive indices of sugar solutions be established with a degree of accuracy somewhat greater than that required for laboratory control. In response to this requirement the bureau is engaged in determining with as high a precision as possible the refractive indices of the pure sugar solutions over the complete range of concentrations and at varied temperatures. The available data are at present valid to the fourth decimal. It is now proposed to extend the accuracy at least to the fifth decimal. An improved method of measurement has been devised by the optical instruments section of the bureau which permits precise measurement of the accurately prepared sugar solutions and allows accurate temperature control at the same time, eliminating all evident sources of error.

This research is being conducted in response to a request by the American Chemical Society which has appointed a committee to investigate the technical uses of the refractometer. Application will be made not only to the cane and beet sugar industry, but to the glucose, maltose, and allied industries.

Rotation Dispersion of Sugars.

The necessity for additional knowledge regarding the variation in the rotation of plane polarized light for different colors (rotation dispersion) has long been noted from a theoretical standpoint, and has recently become of enhanced importance owing to the recent development of the rare-sugar industry in the United States. The use of the green line of the mercury spectrum as the standard individual wave-length for polariscopic constants, first proposed and adopted by the bureau, has now been almost universally adopted by the scientific world in place of the inferior sodium lines. It is now used in making measurements on the various sugars and allied substances as fast as they are prepared in a sufficiently pure state, and is always utilized as the most important wave length in all rotary-dispersion measurements. During the year additional measurements were made on raffinose, fucose, and some of the derivatives of the latter. It is expected to continue under this investigation the accurate measurement of the rotary dispersion of the various sugars which are now being produced by the bureau in a high state of purity. When this is accomplished manufacturers and investigators will have a defined guide for the purity of their products.

Monochromatic Light Sources.

The problem of monochromatic light sources is a fundamental one of great importance in sugar analysis and many lines of optical research. Such sources, as fast as they become available, are utilized in instruments requiring special illumination, and as accessories in other fields of practical work. There is thus needed a series of sources of monochromatic light waves fairly equally spaced throughout the visible spectrum and of great intensity. The bureau has made important contributions to this field from time to time. Recently a practical cadmium vapor arc lamp was developed by alloying the cadmium with gallium. During the year considerable experimental work has been done to develop a similar lamp, using other materials than cadmium. Both silver and zinc have very desirable intense lines in their spectrum, and lamps have been prepared in which they are used. Work has progressed to a point where there is every promise of success, so far as the development of a zinc lamp is concerned. Whether or not it is possible to produce a successful silver vapor lamp has not yet been determined, as material, sufficiently free from zinc, has not been obtained.

Saccharimeter Light Filters.

The investigation into the feasibility of substituting permanent light filters, such as colored glass, as the standard light filter for saccharimeters to replace the bichromate filter adopted as standard by the International Sugar Commission has been continued. If such a filter can be shown to give the same readings as are obtained when using the bichromate solution, a decided improvement will have been accomplished, as such a filter would be free from the many disadvantages inherent in the use of a solution. All observations to date tend to confirm the conclusion indicated in last year's report that there is no difference between the readings obtained with a standard bichromate filter and those obtained with a glass whose spectral transmission curve closely approximates that of the bichromate solution. Observations have been made and more are now under way to determine how far and in what manner the spectral transmission curve can depart from the transmission curve of the standard bichromate solution and not introduce any error in sugar determinations. The question of a light filter for saccharimeters is an important one because of the money involved in transactions based upon saccharimeter readings.

Standard Samples.

During the past year more than 100 samples of sucrose and about 20 samples of dextrose were distributed. These materials are used principally for industrial and scientific purposes, and the demand made upon the bureau for standard samples has steadily increased. During the year, additional equipment for preparing these samples, as well as for the issuing of samples of other sugars, has been designed and installed.

Society of Sugar Chemists and Technologists.

The national organization of sugar chemists and technologists, in the formation of which the bureau has taken an active interest and assisted in every way possible, has been made, during the year, a self-governing division of the American Chemical Society. It is known as the Division of Sugar Chemistry.

COLORIMETRY.

White Light.

For many years one of the greatest needs of color specialists has been a rigidly defined, accurately reproducible "white light." Such a standard is not only very essential in the work of color analysis, but it is indispensable to the absolute specification of certain very important color characteristics. Until the standard white can be adopted certain other problems must remain unsolved. Involving as it does physiological factors as well as physical, the standard for white or gray, or the "hueless" sensation, as it is named, is peculiarly difficult to attain. The color to be adopted must be that which the normal (average) eye will readily recognize as without hue.

A suitable physical stimulus of the hueless sensation must fulfill two requirements: (1) It must be exactly reproducible in the laboratory, so as to be available for those who require it; and (2) it must conform as closely as possible to the best contributions to the knowledge of this subject. These considerations have led to the choice of a source of light known as a complete radiator, the radiant energy of which for any given wave length and temperature conforms to a rigid mathematical (Planck) formula. The temperature of this source at which the energy distribution is such as to give the hueless or white sensation was found with four observers to be approximately 5,200° absolute centigrade—very like average noon sunlight at Washington, D. C. Although there is no known terrestrial source that can be heated to so high a temperature, the energy distribution characteristic of this temperature can be accurately reproduced by means of an ordinary gas-filled tungsten lamp and a proper light filter (quartz rotatory dispersion apparatus).

The method, with preliminary data, has been published in Scientific Paper No. 417, August, 1921. An extensive series of observations from many observers, however, is needed before this question of standard white can be considered settled; but so great is the need for this standard white that the preliminary data, scant as they are, have already been pressed into service by workers in color.

Color Grading of Artificial Illuminants and Daylight in Terms of Color Temperature.

The same device used in the determination of white light for producing a source of illumination of apparent temperature 5,200° absolute centigrade has been the means of extending the so-called color-temperature scale enormously. Thus the light proceeding from the incandescent lamp, modified by the filter, can be made to assume spectral energy distributions corresponding to those of a complete radiator as calculated for any temperature from about 1,500 to 24,000° absolute centigrade. This has made it possible to grade, by means of color temperature, many of the ordinary illuminants, including sky light and artificial daylight. The method is to color match the light from the unknown source with that from the standard incandescent lamp, suitably filtered. Among the illuminants that have been examined in this way are the Hefner lamp (the German standard candle), carbon filament lamp, vacuum-tungsten and gas-filled tungsten lamps, 10-ampere carbon arc, sunlight, and daylight under different conditions. When the color temperature of an incandescent source has been determined, its spectral distribution of energy is then known, to within farily narrow limits, in the visible part of the spectrum.

In this connection a great deal of work has been done on the color grading, by means of rotatory dispersion of a number of so-called daylight glasses. The problem of producing artificial daylight by means of filtering the light from a tungsten lamp through a blue glass, is a very important one commercially. The rotatory dispersion method of grading these glasses is far more rapid than the spectrophotometric method; but unless the spectral distribution of energy emerging from the glass conforms to the Planckian distribution, the slower method must be used.

Spectral Center of Gravity Scale for Color Grading of Illuminants.

The color temperature scale, convenient though it is for color grading many illuminants and artificial illuminants, has not been found quite as suitable as another scale, namely, the spectral center of gravity scale. The spectral center of gravity and its relation to color have been described in the Journal of the Optical Society of America, September, 1920, page 389. The great advantage of this scale over the color-temperature scale is that equal intervals on the former indicate approximately the same color difference at all points on the scale, while on a temperature scale a very slight color difference indicates a very large temperature interval as temperatures above 6,000° absolute centigrade are reached. A scientific paper describing in full the color grading of illuminants in terms of color temperature is in course of preparation.

Spectral Distribution of Energy from a Complete Radiator.

In the course of the work of color grading by means of color temperature it was found necessary to determine, as represented by the Planckian formula, the spectral distribution of energy for a complete radiator at various temperatures. The calculation of this energy at every 10 millimicrons for each temperature required involved a great deal of time and labor. In order to facilitate this work, certain curves have been plotted, with relative energy values along one axis and temperatures along the other, one curve for each of the required wave lengths. From these charts the reading of the energy value for any temperature desired can now be accomplished both rapidly and accurately. The practical use of the charts is to determine readily the spectral distribution of energy of any illuminant subject to the following conditions: (1) That the energy distribution resembles that of a complete radiator, and (2) that its color temperature be known.

The Visibility of Radiant Energy.

Two methods of photometry are in common use—the direct-comparison method and the flicker method. It is an open question whether or not results obtained by the two methods are consistent with each other. If there is a slight difference between them may this not be a result of a difference in the spectral sensibility of the eye to radiant energy as measured by the two methods? The exact values of this visability curve are important also in the determination of the mechanical equivalent of light in the use of colorimeters and in other problems.

In cooperation with the Nela research laboratory, the bureau has made a new investigation of the visibility of radiant energy by the so-called step-by-step method, a direct comparison method throughout the spectrum in which the color differences are almost eliminated. This investigation will afford an interesting comparison with a previous one by the step-by-step method made at the Nela research laboratory and another at this bureau by the flicker method, as several of the observers in the present investigation were observers in one or the other of these earlier determinations. The present investigation, with about 50 observers, is practically completed. The results will be published during the coming year as a Bureau of Standards Scientific Paper.

Physiologic Optics.

In cooperation with the Munsell Color Co., an extensive investigation into various outstanding problems of physiologic optics has been started. This will comprise a continuation of the determination of a standard white or gray, a determination of the hue sensibility of the average eye, and correlative data on the visibility of radiant energy.

The Spectral Transmissive Properties of Dyes.

The present pronounced interest in the development of the dyestuffs industry has emphasized the need of accurate and reliable data on the properties of dyes. One of the most important properties of a dye is, of course, its color. Like the colors of other substances, that of a dye can be completely specified by means of its spectral transmissive or reflective constants. The bureau is well equipped for such specification, but has been handicapped by lack of personnel to carry out such work. The following results have, however, been accomplished this last year:

(1) The cooperative investigation between the Bureau of Chemistry and the Bureau of Standards on the spectral transmissive properties of the seven permitted food dyes, mentioned in a previous report (1920, p. 135), has been completed and the results published in Bureau of Standards Scientific Paper No. 440. This publication, in addition to giving extensive data on the food dyes, describes in detail the methods which have been developed at the bureau for obtaining such data.

Four different methods have been used enabling the complete transmittancy curves to be obtained in ultra-violet, visible, and near infra-red. This affords accurate measurements upon the location and magnitude of the absorption bands—useful in theoretical studies as well as in analysis and identification. In addition carefully measured values of the specific transmissive indices for the homogeneous, visible spectral lines of mercury and helium are given, primarily for purposes of chemical analysis. The paper also illustrates the methods—graphs and tables—by means of which the results may be reported. Future publications will consist largely of data presented in this way.

(2) A cooperative investigation with the Calco Chemical Co. started the previous year has been continued. Data on about 15 dyes have been obtained in a manner similar to that used in the study of the food dyes. Further cooperative work is planned for the coming year.

(3) About 30 dyes have recently been prepared in the chemistry division at the Bureau of Standards. Visual measurements with

the homogeneous mercury and helium spectral lines have been made on the majority of these.

The Spectral Transmissive Properties of Vegetable Coloring Matters.

This cooperative investigation with the Bureau of Plant Industry, Department of Agriculture, referred to in the last annual report, has been continued. Measurements for xanthophyll, chlorophyll and carotin have been extended into the ultra-violet, and a study of the changes produced by oxidation is being made.

The Spectral Transmission of Spectrometers.

In connection with other investigations it has been necessary to know the spectral transmission of spectrometers, both prism and grating instruments. This has been measured for various instruments. Such data should be of general interest; it is, therefore, planned to extend the measurements to still other instruments and publish the data so obtained.

The Spectral Reflection of Enamels.

In connection with a cooperative investigation of the enameled metals section of the ceramics division, the spectral reflection of about 25 specimens of "white" enamel was measured. Results of the investigation will be published in a Bureau of Standards Technologic Paper.

REFRACTOMETRY AND OPTICAL INSTRUMENTS.

The Testing of Photographic Lenses.

Forty photographic lenses for use in airplane photography have been submitted to the Bureau of Standards for investigation by the Air Service, United States Army. These lenses are being subjected to a complete test, and all the different aberrations are quantitatively determined. The Air Service hopes by this means to determine what type of lens is most suitable for use in photographic mapping from a plane. During the course of this work new adaptations of older methods have been developed by which the different aberrations may be measured. The spherical aberration and departure from the sine conditions are determined by Hartmann's method, and a special piece of apparatus has been devised which considerably facilitates the production of the two exposures required for the test. A further advantage of this apparatus as constructed lies in the fact that both exposures are made on a single $2\frac{1}{4}$ by $3\frac{1}{4}$ plate, and a complete record is therefore in a convenient form for filing. The other aberrations are measured visually on an optical bench, and new nodal slides and other attachments are under design which will facilitate this type of work. The final results of the tests are represented graphically by methods which enable the comparative excellence with which the aberrations are eliminated to be determined easily. As a result of this work the bureau is accumulating a valuable record of the performance of different types of lenses upon which a standard of excellence may be based. In fact, some of these data have already served as a basis for performance specifications for photographic lenses.

Silvering Apparatus.

A new apparatus for silvering glass has been installed in order that the silvering may be accomplished without the failure and waste of time incident to the old method. In the method which is now employed the reducing solution and silvering solution drop at the proper rate from two glass tubes into a funnel, from which the mixture flows upon the surface to be silvered. The method has long been employed in commercial plants but seems to be relatively unknown in scientific laboratories. It enables half film or opaque coatings to be produced and appears to be much less open to the vicissitudes accompanying the more common laboratory method.

An addendum to circular letter No. 32 has been prepared which fully describes this apparatus.

Luminous Cross Wires.

At the request of the Navy Department, attention has been given to methods of illuminating cross wires on reticules of telescopic sights by means of radium luminous material. It has been found possible to illuminate broad lines satisfactorily, but the luminous material has not been successfully applied to the fine lines which are required in many cases.

Design of a Magnifying Stereoscope.

The Coast and Geodetic Survey has requested the Bureau of Standards to design and build a magnifying stereoscope to be used in viewing photographs taken from airplanes for the construction of maps. The design has been completed and the blue prints are in the shop ready for construction to begin. The stereoscope is of the variable power type and gives magnifications ranging from 3.3 to 10 diameters.

Design and Construction of a Field Telemeter.

This was in response to a request from the United States Geological Survey, which needs a light and easily portable instrument for measuring the distance from a plane-table station to near landmarks with an error not greater than 6 or 8 per cent. It consists of two small micrometer telescopes with pentaprism attachments adapted to be clasped, respectively, to the two ends of a stadia rod. Since the stadia rod is already carried by the surveying party, the additional weight of the two telescopes is not much greater than that of a pair of binoculars. With the two modified telescopes mounted on the stadia rod, a single self-contained range finder having a self-contained adjustment feature and a base length of 10 feet is formed. This instrument has been completed and gave satisfactory results when tested at the Bureau of Standards. The Geological Survey is now testing it in actual field use.

Study of Spherometer.

Arising from the closer affiliation of the optical shop and the optical instruments section, there has been a great increase in spherometric work. A careful investigation has been made of the errors of the ring spherometer, and various plans are being considered for increasing the precision of measurement. In particular, it has been found that the edges of the rings soon become so rounded that the effective diameter of the ring is a function of the curvature of the surface to be measured. So far the rings have been calibrated for convex surfaces over a limited range by means of the standard steel balls in the possession of the gauge section. It is expected to extend the calibration to concave surfaces and to surfaces of large radii by the use of glass match plates.

Redesign of Apparatus for Measuring Transmission of Optical Glass.

A new transmission apparatus has been constructed in which a Martens photometer head is used to secure the matched fields. The transmission of the unknown sample will be compared with the transmission of a similar known standard instead of making the measurement directly as has been done previously. By this method the correction for loss of light by reflection at the two surfaces is made more simply and all trouble due to lack of good color match in the two fields largely eliminated.

Optical Sytem for Horizontal Angle Meauring Instrument.

The optical instrument section has designed the optical system for the horizontal angle measuring instrument being developed by the aeronautical instrument section.

Modification of Special Cameras for the Navy.

Several small inclinometers for use in airplane cameras and adapted to automatically register the inclination of cameras at time of exposure upon the photographic plate were tested and installed in cameras for the Navy Department. Also an airplane camera was modified in accordance with plans prepared by the bureau to permit two views of the horizon to be made on the plate at time of exposure in addition to the view below the plane. From the view of the horizon the tilt of the camera may be obtained and thus data for the rectification of the image.

Standard Prism Drawings.

These have been prepared for the different types of optical prisms along with tables giving the proper dimensions and optical constants for any given size. The object is to facilitate the ordering of prisms and eliminate much computation which otherwise has to be done repeatedly in the design of optical instruments.

Standard Laboratory Telescopes.

Twelve standard 3-power laboratory telescopes have been manufactured for the storeroom, in accordance with the design prepared last year.

RADIOMETRY.

Roof Covering for Balloon Hangars.

Among the unusual radiation problems presented was that of the proper covering for balloon hangars. The problem arose as to the most effective covering for keeping the inside of the hangar at a minimum temperature. The solution is to have the outside of the roof made of material (asbestos) which reflects a maximum of the short wave lengths (solar radiation) and emits a maximum of long wave length radiation (the reradiation of the roofing material as it becomes warmed by the sun). On the other hand, it appears that (contrary to the general belief) the inside of the roof should be painted with a substance (aluminum) which emits a minimum of long wave length radiation.

On actual test of roofing materials exposed to the sun it was found that the sample which was covered with asbestos on the outside and painted with aluminum on the inside was far better than either of the samples having (1) both sides painted with aluminum, or (2) both sides covered with asbestos.

Radiation Characteristics of Quartz Mercury Vapor Lamps Used for Therapeutic Purposes.

Investigations were made for the United States Public Health Service on the radiation intensity, etc., of quartz mercury arc burners used for therapeutic purposes. In the air-cooled burners it was found that the ultra-violet component as well as the total radiation was the same for the two types of burners (the all-mercury electrode burner and the tungsten-mercury electrode burner) when operated on the same energy input.

The information obtained from an investigation of quartz mercury lamps, during the past five years, was given in a paper on "Some Physical Characteristics of the Radiation from Quartz Mercury Lamps," presented before the American Electrotherapeutic Association on September 9, 1921.

Stellar Radiation.

During the past year some time was spent at the Lowell Observatory, Flagstaff, Ariz., making new measurements of the total radiation from stars. In addition to this the spectral energy distribution of 16 stars was determined by means of transmission screens (described in last year's annual report), thus obtaining for the first time some knowledge of the radiation intensities in the complete spectrum of a star.

The results obtained verify previous observations made seven years ago showing that the red stars emit three to four times as much total radiation as blue stars of the same visual magnitude. The spectral radiation measurements indicate an energy distribution similar to that of a black body at 3,000° C. for red stars to 10,000 or 13,000° C. for blue stars.

Planetary Radiation.

By comparison of the water-cell transmission of the sun's rays coming directly to the earth with similar measurement of the radiations coming from the planets, it was found that the water-cell transmission of the total radiation from Jupiter was the same as that of the direct solar radiation. From this it appears that Jupiter's atmosphere does not reradiate energy as the result of warming by solar rays and that the atmosphere is sufficiently thick and opaque to trap all the energy reradiated as the result of warming of its surface by solar radiation.

The order of intensity of reradiation, as interpreted from the per cent water-cell transmissions (Tr. of Sun=70), is as follows: Jupiter, 0; Venus, 5; Saturn, 15; Mars, 30; and Moon, 80.

Measurements on the south and north polar regions of Mars are different and, quantitatively, in agreement with visual observations, which show a slight cloudiness in one polar region, that would tend to trap the reradiated energy of long-wave lengths (emanating from the surface) thus raising the water-cell transmissions, as observed.

Photoelectrical Investigations.

As these investigations progress it becomes more and more evident that the phenomenon of photoelectrical conduction in solids is very complex. Each newly discovered photosensitive substance yields new results. For example, in some substances (e. g., molybdenite and stibnite) the photosensitivity was found most marked along the intergrowth of two bundles of acicular crystals. In certain samples of molybdenite, radiation stimuli of certain wave lengths induce a counter e. m. f.

Argentite.—An examination was made and a paper was prepared on the "Spectrophotoelectrical Sensitivity of Argentite." This paper, considered in connection with previously published data (Scientific Paper No. 344) represents a study of the effect of crystal structure upon photoelectrical sensitivity, as observed in silver sulphide, Ag_2S, in the isometric form, *argentite*, and in the orthorhombic form, *acanthite*. The results obtained show that crystal structure affects the spectrophotoelectrical reaction, but is not the underlying cause of this phenomenon. For silver sulphide appears to have a characteristic response spectrum, just as is true of selenium, cupric oxide, etc.

Bournonite and pyrargyrite.—An examination was made and a paper written on the "Spectrophotoelectrical Sensitivity of Bournonite and Pyrargyrite."

This paper, in connection with previously published data on proustite (Scientific Paper No. 412), represents a study of the effect of chemical constitution upon spectrophotoelectrical sensitivity. In previous researches on absorption spectra it was found that the absorption bands of a compound are not the composite of the constituents. Similarly, in spectrophotoelectrical reaction spectra, the bands of selective reaction of the double sulphide of silver and of antimony (pyrargyrite) are not the sum of the spectral reactions of the individual sulphides of silver and of antimony, which react photoelectrically.

Various other substances.—Among other substances examined were some lead and silver salts, also the chloride, bromide, and iodide of thallium (some samples of which were kindly prepared by the Case research laboratory). From the results obtained it appears that the maximum of photoelectrical sensitivity, which is a sharp narrow line, shifts to the long wave lengths with increase in atomic weight of the acid element (TlCl at 0.37μ, TlBr at 0.41μ, TlI at 0.46μ, and PbI_2 at 0.52μ). This shift of the maximum is similar to the shift of the maximum of photoelectrical reaction in gasionic photoelectric cells of the alkali metals (Na, K, Ca, Sr, Ba).

Experiments on the Direct Transformation of Light Into Electric Current.

Several experiments are on record purporting to demonstrate the direct transformation of light into electric current. But a critical analysis of the procedure shows that the light waves were absorbed and transformed into heat at the juncture of two dissimilar substances and that the resulting current is ascribable to the well-known thermoelectric phenomenon.

Concerning the generation of an electric current from direct light, it may be said that numerous samples of molybdenite were found which generated a small electric current without an impressed potential and without any apparent photochemical action, when exposed to light.

These tests were made by connecting the molybdenite with a sensitive Thomson galvanometer and exposing different parts of the sample to an equal energy spectrum. It was found that, on exposure to some parts of the crystal (remote from the electrodes) to radiation, a small electric current is developed which is a function of the wave length of the light stimulus and of the thickness of the sample. The maximum effect is produced by wave lengths of 0.7 to 0.8μ and no effect by the wave lengths greater than 1μ. The effect may be "photopositive" or "photonegative" depending upon the wave length of the radiation stimulus, just as observed when there is an impressed potential. It is, therefore, an interesting question whether all photoelectrical reactions in solids are an amplification of the effects produced without an impressed e. m. f. The actual magnitude is too small to affect the customary photoelectrical reactions observed in molybdenite.

DISPERSOIDS.

Assistance to the District of Columbia Fire Department in Smoke-Mask Training.

In cooperation with the Bureau of Mines, the bureau has assisted in testing smoke masks for the District of Columbia fire department and in training the men in their use. In training, smoke from smoldering excelsior and fumes from an ammonia tank were used—the chief danger in fighting fires being carbon monoxide, which is odorless. A demonstration of the removal of the odor from illuminating gas by the ordinary army canister was also made to warn the men of the danger in using this canister, which gives practically no protection against carbon monoxide.

Turbidimetry.

The characteristics of the Kober nephelometer have been studied and published in the chemical press. Commercial 75 cm. turbidity tubes have been measured, to furnish the Scientific Utilities Co. with information for their manufacture.

The bureau is cooperating with Dr. W. G. Exton, of the Prudential Insurance Co., in placing an improved turbidimeter of the disappearance type upon the market.

Ultramicroscopy.

In cooperation with other sections of the bureau, ultramicroscopic examinations have been made on oils, paints, optical glass, ceramics, sugar, etc. Samples of thermatomic carbon, precipitated coagulum from automobile crank-case oil, "amalgam" in the Trent process for recovering coal from low-grade ores, etc., have been examined in the microscope and ultramicroscope.

Statistical Standards.

In studying dispersoids statistical methods must be used. For example, the large particles are graded according to size by sieves, the smaller particles by the rate of settling. The size distribution of ultramicroscopic particles is determined by the average displacement in Brownian movement. Such statistical methods, like any others, need to be standardized. These mathematical standards apply in every field of pure and applied science, so that the bureau is called upon to advise other departments of the Government and the public upon the general and mathematical questions involved in estimating by sampling.

As an example of such work, a cooperative study has been made with a biologist of the New York State Conservation Commission of the statistical advantages of the logarithm of the number of bacteria per liter as a standard bacterial index. This work is now being considered by the committee on revision of the United States Public Health Service standard of water quality.

Advice has also been given the committees of the American Society for Testing Materials, which have been considering the standardization of statistical constants and methods of sampling, and the division of vital statistics of the Census Bureau on correlation constants.

INTERFEROMETRY.

Thermal Expansion.

The extreme sensitivity of interference methods makes it possible to measure the dimensional changes of small samples with great precision. The thermal expansion of samples 1 to 10 millimeters in length can be determined with an uncertainty of not more than one-half of 1 per cent. Temperature control apparatus has been constructed with which measurements can be made in the temperature interval —150 to +1,000° C. For most of the work the Fizeau method is used, but in special cases, when it is necessary to determine the expansivity of specimens taken from different parts of the same sample, a method by which the expansivities of three pins can be measured simultaneously is employed. During the past year tests have been made on samples of commercial and optical glass, cast steel, amalgams, nickel, gauge steel, etc.

Index of Refraction.

Several different types of interferometers have been used to determine the absolute indices of refraction and the variation of index and dispersion with pressure, temperature, etc. Several gases, vapors, liquids, and transparent solids have been investigated. A paper on the changes of the index of glass with temperature is being prepared for publication.

Calibration of End Standards.

During the year several redeterminations of the bureau's end standard have been made by direct comparison with the standard light waves. These standards are used in the calibration of precision gauges.

The standards of concerns engaged in the manufacture of precision gauges have also been calibrated. Scientific Paper No. 436, describing the methods and apparatus for calibrating gauges, has been published during the year.

Ruling of Line Standards.

Several line scales have been ruled using a Michelson type of interferometer and the light waves as the fundamental length standard. Different scales with 100 millimeter divisions have been ruled with error for the total distance ranging from 0.2 to 1.0 micron. The error of any millimeter division was too small to be detected with the microscope. One such scale was sent to the International Bureau at Paris for calibration. The report stated that the results of the calibration were very remarkable—the largest error being 0.27 micron.

Apparatus is now being constructed for ruling scales up to 1 meter in length.

Dimensional Changes of Materials.

An investigation of the dimensional changes of materials with time and the effect of different treatments upon this stability has been undertaken. A single example of the value of such an investigation may be cited in the need of an exceedingly stable material length standard. New apparatus has been constructed which will measure samples at the rate of one per minute. Already quite extensive measurements have been made upon gauge steel and it is planned to extend the work to other materials.

PHOTOGRAPHIC TECHNOLOGY.

"Inertia" of Photographic Plates and Films.

Accurate speed determinations of photographic plates and films are very difficult to make because of the change of the inertia with the growth of contrast. Potassium bromide, either in the developer or emulsion, as is well known, causes the inertia to decrease (speed to increase) with an increase in contrast. In practically all the works on sensitometry it is stated or implied that the inertia remains constant for all times of development except when bromide is present. This, however, is not correct in all cases; in fact, with a majority of the photographic plates and films the inertia does change with a change in contrast, usually in just the opposite direction to the change caused by potassium bromide. The Bureau is of the opinion that these inertia movements are real and are a characteristic of the emulsion. This problem has been under investigation and the results will be published later as a scientific paper.

"The Sensitometry of Photographic Emulsions," Scientific Paper No. 439, has been issued. While this investigation reported two years ago has been completed some time, the pressure of other work prevented the preparation of the data for earlier publication.

Color Sensitizing of Photographic Plates by Bathing.

This work, mentioned in the last annual report, under the topic photosensitizing and hypersensitizing, was carried to completion and the results published in Scientific Paper No. 422 under the title "Studies in Color Sensitive Photographic Plates and Methods of Sensitizing by Bathing."

The Action of Charred Paper on the Photographic Plate.

An investigation for a method of deciphering the written and printed matter contained on papers which have been charred, shows that good results may be had by the use of photographic plates.

If the charred papers are placed in contact with the emulsion of fast or medium speed photographic plates, kept in this condition in total darkness for a period of from one to two weeks, then developed in the usual manner, it is found that the plate is blackened by the charred paper except in those places occupied by the ink.

It appears that the gases contained in the charred paper have the power to fog the photographic plate and that the ink acts as a screen to the emanation of the gas. Films are not nearly so well adapted to this purpose as plates. They require a much longer exposure to the charred paper, about two months, and then it is found that the ink is the active portion and the charred paper inactive—just the reverse of plates.

Washing a film in pure water for a short time and drying (all in darkness of course) before exposure, gives results similar to the photographic plate. Very slow plates such as "Process," and the enlarging and printing papers are comparatively insensitive. The results of this investigation will be published in detail under the above title.

Veterans' Bureau School of Photography.

At the request of the Veterans' Bureau, advice has been given on a course of study, laboratory equipment, and laboratory plans for their school of photography.

TESTING, INFORMATION, AND PUBLICATIONS.

Tests Completed During the Year.

Work of routine nature completed during the year, amounting to something over 4,500 articles tested, covered: Spectrum tubes, photosensitizing dyes, spectrochemical analyses; polariscopes and polariscope cover glasses, samples of raw sugar and molasses, quartz control plates; spectral transmission of glasses, tanning solutions, celluloid, prisms and plant pigments; spectral reflection of talc, paints, leather, and rope; relative radiant power and color temperature of lamps; binoculars, telescopes, microscopes, photographic lenses; refractive indices, dispersion and transmission of optical glass and other substances; refractometers, spectrographs, and prism angles; standard sources of radiation, photoelectric cells, eye-protective glasses; fading effects of ultra-violet light; thermal expansion, planeness of surfaces; and calibration of end standards.

Information, Cooperation with Societies, etc.

An important part of the division's activities has consisted in furnishing information on scientific and technical subjects related to its work, by extensive correspondence, reports, or directly to technical men visiting its laboratories.

Members of the division have cooperated in the activities of various scientific and technical societies, including: The Optical Society of America in the standardization of nomenclature and the compiling of standard data needed in spectroscopy, colorimetry, and radiometry; the International Astronomical Union in regard to standard wave lengths; the American Chemical Society on refractive index tables for sugar solutions; and the Illuminating Engineering Society on research.

Publications.

The following publications, relating to the work of the division, have appeared during the year among the publications of the Bureau of Standards, and they may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C.:

Interference measurements in the spectra of argon, krypton, and xenon (W. F. Meggers), Sci. Paper No. 414.

Wave lengths longer than 5,500 A in the arc spectra of yttrium, lanthanum and cerium, and the preparation of pure rare earth elements (in cooperation with the chemistry dept., University of Illinois), (C. C. Kiess, B. S. Hopkins, and H. C. Kremers), Sci. Paper No. 421.

Studies in color sensitive photographic plates and methods of sensitizing by bathing (in cooperation with the photographic shop of this bureau), (Francis M. Walters, jr., and Raymond Davis), Sci. Paper No. 422.

An atlas of photographic negative emulsions (in cooperation with the photographic shop), (Raymond Davis and F. M. Walters, jr.).

Notes on standard wave lengths, spectrographs and spectrum tubes (W. F. Meggers and Keivin Burns), Sci. Paper No. 441.

Arc Spectra of Neodymium and samarium (C. C. Kiess), Sci. Paper No. 442.

A significant exception to the principle of selection (in cooperation with the pyrometry section), Phil. Mag., 43, p. 659; 1922.

The excitation of the enhanced spectra of sodium and potassium in a low voltage arc (P. D. Foote, W. F. Meggers, and F. L. Mohler), Astrophy. Jour., 55, p. 145; 1922.

1921 report of the committee on standard wave lengths (in cooperation with a committee of the Optical Society of America), J. O. S. A., and R. S. I., 6, p. 135; 1922.

Practical spectrographic analysis (W. F. Meggers, C. C. Kiess, and F. J. Stimson), Sci. Paper (in press).

False spectra from diffraction gratings (Part I by W. F. Meggers and C. C. Kiess; II, by C. Runge; and III, by J. A. Anderson), to appear in the July number of J. O. S. A., and R. S. I.

Preparation of galactose (E. P. Clark), Sci. Paper No. 416.

Note on the preparation of mannose (E. P. Clark), Sci. Paper No. 429.

An improved method for preparing raffinose (E. P. Clark), Sci. Paper No. 432.

The solubility of dextrose in water (R. F. Jackson and C. G. Silsbee), Sci. Paper No. 437.

The spectral distribution of energy required to evoke the gray sensation (Irwin G. Priest), Sci. Paper No. 417.

The spectral transmissive properties of dyes—I, The seven permitted food dyes in the visible ultra-violet and infra-red (K. S. Gibson, H. J. McNicholas, E. P. T. Tyndall, M. K. Frehafer, and W. E. Mathewson), Sci. Paper No. 440.

Supplementary note on the frequencies of complementary hues (Irwin G. Priest), J. O. S. A., Vol. V, No. 6, pp. 513–514; 1921.

Measurement of the color temperature of the more efficient artificial light sources by the method of rotatory dispersion (Irwin G. Priest), J. O. S. A., Vol. VI, No. 1, pp. 27–41; 1922.

A field telemeter for approximate surveying (I. C. Gardner), J. O. S. A. (in press).

Method of designing an objective for an astronomical telescope, Letter Circular No. 67.

Spherical aberration in thin lenses (T. Townsend Smith), Sci. Paper (in press).

A portable vacuum thermopile (W. W. Coblentz), Sci. Paper No. 413.
Spectroradiometric investigation of the transmission of various substances, II (W. W. Coblentz), Sci. Paper No. 418.
Tests of stellar radiometers and measurements of the energy distribution in the spectra of 16 stars (W. W. Coblentz), Sci. Paper No. 438.
Spectrophotoelectrical sensitivity of argentite (W. W. Coblentz) (in press).
Spectrophotoelectrical sensitivity of bournonite and pyrargyrite (W. W. Coblentz and J. F. Eckford) (in press).
Some physical characteristics of the radiation from quartz mercury lamps (W. W. Coblentz), Jour. Electrotherapeutic association, 1922.
New stellar radiation measurements (W. W. Coblentz), Astrophys. Jour., January, 1922.
The effective temperature of 16 stars as estimated from the energy distribution in the complete spectrum (W. W. Coblentz), Proc. Nat. Acad. Sci., March, 1922.
Sur l'Epaisseur des Lames Stratifiees (P. V. Wells), Annals de Physique, 16, pp. 69–110; 1921.
A simple theory of the nephelometer (P. V. Wells), J. Am. Chem. Soc., 44, pp. 267–276; 1922.
Turbidimetry of water (P. V. Wells), Jour. Am. Water Works Ass'n., 9, pp. 488–490; 1922.
A standard bacterial index (P. V. Wells and W. F. Wells), Jour. Am. Water Works Ass'n., 9, pp. 502–527; 1922.
Interference methods for standardizing and testing precision gauge blocks (C. G. Peters and H. S. Boyd), Sci. Paper No. 436.
A new method for the measurement of photographic filter factors (Raymond Davis), Sci. Paper No. 409.

The papers listed below were presented before meetings of scientific societies during the year:

Spectrographic tests for the purity of some metals, presented before the Philosophical Society of Washington, February 11, 1922. (See Jour. of Wash. Acad. of Sciences, 12, p. 267; 1922.)
Decolorizing carbons (H. H. Peters), presented before the sugar division of the Am. Chem. Soc., New York, N. Y., September, 1921.
An inquiry into fundamentals of sugar colorimetry (H. H. Peters), presented before the sugar division of the Am. Chem. Soc., New York, N. Y., September, 1921.
The testing of quartz control plates (F. P. Phelps), presented before the sugar division of the Am. Chem. Soc., New York, N. Y., September, 1921.
The estimation of raffinose and sucrose in beet products (R. F. Jackson), presented before the sugar division of the Am. Chem. Soc., New York, N. Y., September, 1921.
A simple diffusion battery for laboratory and lecture room experiments (M. J. Proffitt), presented before the sugar division of the Am. Chem. Soc., New York, N. Y., September, 1921.
Modifications in the use and application of the Hess-Ives tint photometer (H. H. Peters and F. P. Phelps), presented before the sugar division of the Am. Chem. Soc., Birmingham, Ala., April, 1922.
Color values of high grade sugars (W. B. Newkirk and H. H. Peters), presented before the sugar division of the Am. Chem. Soc., Birmingham, Ala., April, 1922.
Note on a laboratory vacuum still (E. P. Clark), presented before the sugar division of Am. Chem. Soc., Birmingham, Ala., April, 1922.
Some thermal effects observed in chilled glass (A. Q. Tool and C. G. Eichlin), presented before the Optical Society of America, Rochester, N. Y., October, 1921.
Measurement of the color temperature of the more efficient artificial light sources by the method of rotatory dispersion (Irwin G. Priest), presented before the Optical Society of America, Rochester, N. Y., October 26, 1921.
The complete scale of color temperature and its application to the color grading of daylight and artificial illuminants (Irwin G. Priest), presented before the American Physical Society, Washington, D. C., April 22, 1922.
Some physical characteristics of the radiation from quartz mercury lamps (W. W. Coblentz), presented before the Washington meeting of the American Electrotherapeutic Association.

CHEMISTRY.

The work of this division includes the investigation of the chemical composition and purity of materials, studies of chemical properties and constants, researches in connection with methods of analysis, the preparation of specifications for technical materials for other departments of the Government and for industrial and scientific laboratories. The chemistry division has general supervision of all chemical work at the bureau. In practically all questions of standardization or research the purity of the materials involved is an important factor. Much of the work of this nature supervised by the chemistry division is described under the appropriate headings elsewhere in this report.

GENERAL.

Reorganization of Sections.

The death, in September, 1921, of Mr. S. S. Voorhees, chief of a section of the chemistry division, made advisable a reorganization of the sectional framework of the division. The net result was a reduction in the number of sections from nine to seven and considerable redistribution of work.

Cooperation with Technical Societies.

The chemistry division has, as in the past, cooperated extensively with committees of technical societies. The division is represented on many committees that are engaged in scientific work and in a number of instances its members are chairmen of committees.

ELECTROCHEMISTRY.

Included in this work are studies of electrodeposition used in electrotyping and electroplating, the latter being made up of investigations of zinc, lead, copper, silver plating, etc.

Nickel Deposition.

During the past fiscal year the electrochemistry section has devoted its efforts especially to a study of nickel deposition. Work has been conducted upon several phases of the subject. Some of these have been nearly completed and others will require considerable further study. The general purpose of these investigations has been to determine the fundamental principles regarding the operation and control of nickel depositing solutions and their application in commercial practice. It is hoped through such studies to define those conditions of operation which will yield the most uniformly satisfactory results with the least expense and loss due to inferior and defective work. In planning and conducting these studies the bureau has benefited greatly by the advice and cooperation of members of the American Electroplaters' Society, especially from George B. Hogaboom, electroplating adviser to the bureau, and members of the research committee. These persons have visited the bureau twice during the year and on each occasion have considered carefully the plans and progress of the bureau's researches and have made many helpful suggestions. In addition, they have communicated information and suggestions to the bureau on numerous occasions. It is only through such willing and earnest cooperation as the bureau has received from these persons that its work can be made directly applicable and useful to the electroplating industry.

The status of the various researches may be briefly summarized as follows:

Acidity.—A simple method of measuring the acidity of nickel-plating solutions has been developed and is being tested in eight commercial plants. Results so far obtained indicate that improper acidity is only one of several causes for defective nickel plating, but if it is controlled other conditions can be more uniformly maintained and other causes can be more readily detected and corrected.

Iron.—To the presence of iron in nickel deposits, defective plating has often been attributed. It is apparent that under some conditions the presence of iron is more detrimental than under others. A study of the effects of iron has just been commenced.

Anodes.—In order to prepare deposits free from or containing definite amounts of iron, it is necessary to secure nickel anodes of definite composition. The effects of various impurities and of the method of preparing nickel anodes has never been clearly established. A study of these factors is being made. From such a study it is hoped that simple reliable specifications for nickel anodes can be prepared.

Salts.—It is also necessary to secure nickel salts of reasonable commercial purity. The exact effect of each of the probable impurities has not yet been determined. Analyses have been made of a large number of samples and the advice and cooperation of manufacturers and dealers has been requested, in the effort to at least exclude from the electroplating trade salts that are grossly impure.

Conductivity.—The conductivity of solutions containing the usual constituents of nickel baths is being determined. Such information may be useful in permitting more rapid deposition.

Throwing power.—The ability of a plating solution to deposit uniformly on irregularly shaped articles is of great importance. Preliminary studies have led to the development of the underlying principles, which are now being tested out experimentally.

GAS CHEMISTRY.

Methods of purification, analysis, and testing of gases, including illuminating gas and special gases, such as hydrogen, oxygen, nitrogen, and argon, comprise the chief work of the section of gas chemistry.

The work of the section during the past year was carried on almost exclusively with funds transferred from the Air Services of the Army and Navy. These problems received the first attention of the section, and the work upon each originally contemplated has been practically completed. This work for the Air Services will be described first.

Investigation of Methods of Producing Hydrogen for Aeronautical Purposes.

The major problem of the section during the past year has been that of developing a more economical method for producing hydrogen under the conditions required for military aviation. Some time was devoted to each of eight radically different processes. Experimental work was done upon five processes, ranging from a few days' work in the laboratory to the experimental operation of a plant of commercial size requiring the services of approximately 10 men during four months.

Oil-cracking process.—The process first investigated was that of the thermal decomposition of a hydrocarbon oil by contact with a highly heated solid. The major part of the experimental work had been done before the last annual report was prepared and is partially covered in that report. The interpretation of the results and the preparation of a technical report required much time. The results of the investigation carried out in the experimental plant are covered in a report entitled "The Production of Hydrogen by the Thermal Decomposition of Oil," which was transmitted in October, 1921. The process was shown to be a valuable one, provided suitable refractories and an adequate supply of solid fuel having the necessary characteristics could be found. Both these requirements were made the subject of investigations.

The location of an adequate source of supply of dense carbon practically free from ash-forming constituents was undertaken by correspondence. Numerous samples of the products of various manufacturers were examined and satisfactory tentative proposals were finally obtained from several concerns. The results are included in the "Progress Report on the Investigation of Methods for the Production of Hydrogen," dated March 25, 1922.

The testing of refractories for use in the process presented more serious difficulties. An effort was made in cooperation with the ceramics division of this bureau to obtain samples of all refractories made commercially in this country which might be expected to meet the difficult requirements of the process. Thirteen of these products were subjected to test in a load furnace heated to temperatures as high as 1,750° C. Two refractories were found which could be used to advantage in the hydrogen plant, and several which had been highly recommended were definitely eliminated. The results of these tests were issued in the report entitled "High Temperature Load Tests of Commercial Refractory Brick," dated May 11, 1922.

A specification and drawings of a hydrogen plant employing this process were prepared under the title "General Specification for a Hydrogen Plant to Produce a Maximum of 120,000 Cubic Feet of Hydrogen per 24-hour Day," dated May 13, 1922. A contract for a plant costing approximately $40,000 to be located at Scott Field has just been let by the Air Service under this specification.

Steam-iron process.—Without doubt more than half the time of the section during the past year has been devoted to a study of the steam-iron process for producing hydrogen. An improved method, based upon the utilization of heat wasted in the older methods, has been developed. The experiments with this process, which were made upon a commercial scale, indicate an increase in thermal efficiency of 30 to 50 per cent over the methods of this class now employed, and a large saving in the cost of maintaining the plant. The process is not well suited to intermittent operation, however, and its future usefulness must be looked for in the field of industry rather than aviation. The report upon this process is still in preparation.

Ferrosilicon process.—Tests were made upon the first of 10 new hydrogen generators to employ the ferrosilicon process, which were being constructed for the Navy Department. These tests were made to determine the capacity of the plants, the efficiencies of the cooling systems under various conditions, and the characteristics of a new feeding mechanism which was being introduced. These tests and some supplementary experiments resulted in the development of an entirely different method of feeding, and in a modification of the cooling system. These changes not only improved the generators but accomplished a considerable financial saving to the Government in the cost of the plants. The results are given in a report entitled "Report of Tests of Ferrosilicon Hydrogen Plant," dated July 22, 1921.

A paper upon "The Production of Hydrogen by Use of Silicon and Sodium Hydroxide" was presented by invitation at the spring meeting of the American Electrochemical Society on April 29. This will be published in the proceedings of the society.

Miscellaneous work on the production of hydrogen.—An effort was made to accomplish the simultaneous production of hydrogen and of salable lampblack by the decomposition of oil in an electric arc. The process was a complete failure because practically all of the carbon separated in the arc is precipitated in a dense form at the ends of the arc. This work is described in the progress report for March 25.

An electrolytic hydrogen-oxygen generator in which the electrolyte was stirred for the purpose of freeing the electrodes from bubbles and thereby decreasing the resistance of the cell was submitted for test by the Air Service. This apparatus was tested with negative results. Since the question of the practicability of decreasing the resistance of a cell in this way had arisen several times, it seemed worth while to make an effort to settle the question once for all if possible. Consequently an apparatus was constructed in which the electrodes were vigorously brushed with mechanical brushes. The results were negative, the difference in resistance being almost inappreciable when the brushes were set in motion.

This work is described in the "Report on an Electrolytic Hydrogen Cell with Mechanical Depolarizer," dated July 27, 1921.

Two conferences were held to consider two new methods of hydrogen production proposed by different firms of consulting engineers. One of these processes was definitely eliminated from further consideration at the first conference. The other process is quite promising and it is possible that experimental work will be done upon it during the coming year if arrangements for such work can be made without excessive cost to the Government.

Balloon Fabrics.

The work upon balloon fabrics during the past year has been almost exclusively in the nature of routine testing. A total of 329 tests of various kinds were made upon 299 fabrics by the section during the year.

Portable Permeability Apparatus.

A portable instrument for determining the permeability of a segment of balloon fabric without removing from the balloon has been developed. This instrument permits a determination to be made in about one minute. The instrument has been tested in service with satisfactory results. The first one constructed is now in service at McCook Field. The development involved several months of experimental work and the construction of four or five unsatisfactory instruments before a successful one was made.

Balloon Gas-Purity Indicator.

An instrument believed to be satisfactory for indicating the purity of the gas in an airship has been developed. This instrument has not yet been tried out in service, but it is now ready for a service test. This instrument, which is not heavy, will permit a pilot to read the purity of his gas within a few seconds and without drawing any gas from the balloon.

Problems Not Connected with Aviation.

Automatic gas analysis apparatus.—Much work has been done upon automatic gas analysis apparatus other than the instruments developed in connection with aviation which have already been described.

Sulphur dioxide recorders.—Instruments were constructed for the purpose of recording the concentration of sulphur dioxide in the gas leaving the sulphur burners and the gas after absorption of the sulphur trioxide in the contact process for making sulphuric acid. These recorders were installed in the plant of the naval powder factory at Indianhead, Md., where they have been in use and have given satisfactory service for nearly a year. Similar recorders, built according to plans furnished by this laboratory, were installed several months ago by a large industrial concern, and they have just placed an order for a second set of instruments. The success of these two installations is the best evidence that the apparatus of this type can be made to give satisfactory service under plant conditions when in charge of men not especially trained for the use of them. This should answer the principal question which has been raised concerning the ultimate value of these instruments to industry. The possibility of using the apparatus successfully in the laboratory for a great variety of analyses was demonstrated several years ago.

Recording and control of composition of gases from electrolytic generators.—An instrument for recording the purity of electrolytic oxygen was made up and loaned to the Washington Navy Yard, where it gave perfect service for a little over a month. It was then brought back to this bureau because of the arrival of a much advertised recorder of another type, which the Navy had already purchased at a cost considerably greater than that of the instrument constructed at this bureau. After using the commercial instrument for several months, the navy yard decided to discard the instrument they had purchased and requested the bureau to build one of the thermal-conductivity type. Financial arrangements have not yet been completed to make this possible.

As a demonstration of the possibilities of automatic control of industrial processes, the section prepared a recorder with contacts which would automatically vary the gas composition through a closed cycle. Four operations were involved, each step taking place when the composition of the gas reached a certain predetermined figure. The entire cycle occupied about three minutes. The apparatus was sent to the Exposition of Chemical Industries at New

York, N. Y., and operated perfectly during the entire week, attracting much attention.

Some of the work which has been done along this line was described in a paper entitled "Gas Purity Recorder for Electrolytic Oxygen and Hydrogen," published as a bulletin of the Compressed Gas Manufacturers' Association on December 8, 1921.

Control of combustion gases.—A considerable amount of work has been done toward recording and controlling the composition of gases, especially flue gases and other products of combustion, on the basis of their oxygen content. Oxygen is really a better criterion of efficient combustion in boilers and furnaces than is carbon dioxide which is usually determined. In some cases where either the presence or absence of oxygen is required for chemical reasons, it is essential. An arrangement was made with one large industrial concern to cooperate in the development and trial of an instrument for the purpose of controlling the firing of a tunnel kiln, but lack of time has prevented much progress being made by the section on this particular problem.

In connection with the devolpment of instruments, which has been described, several improvements have been made in the thermostating of units, in the control of adjustment of voltage, and in simple and cheap methods of applying the gas analyzing units to recording and automatic control. Some of these devices may find other applications. A paper is now in preparation which will describe several of them.

Absorption of gases in liquids.—A study is being made of the absorption of gases in liquids. This problem is of fundamental importance in the design of scrubbers and absorbing apparatus of all kinds employed in many industries. It is also of importance in gas analysis. The present study is so far concerned with fundamental principles. A mathematical study was first made with the aid of simplifying assumptions where necessary, and the various problems reduced to simple terms involving only one important unknown quantity termed the "coefficient of absorption." A large amount of laboratory work has been done for the purpose of determining the value of this coefficient for various cases, and the effect of several variable conditions upon it. Some surprising phenomena have been observed, and the problem seems to have opened up a whole field of great scientific interest as well as practical importance.

Methods of gas analysis by combustion and by fractionation.—A study of the methods of gas analysis depending upon combustion is now being undertaken. For the purpose of this investigation it is necessary to prepare several of the hydrocarbon gases in a fairly pure state. This is most readily accomplished by the use of fractionation. While using fractionation in the preparation of gases it seems worth while also to study the use of fractionation in analysis. A considerable amount of apparatus has been designed and is now being constructed for this general purpose.

Circular on pressure-volume-temperature relations of gases.—The receipt of numerous inquiries, from both producers and consumers of compressed gases and from testing laboratories, which are sometimes called upon to settle disputes, led the section to initiate an effort to fix standards for the measurement of compressed gases.

The matter was taken up with other interested sections of the bureau and with the National Compressed Gas Manufacturers' Association and the Gas Products Association. A conference was held at the bureau at which substantial agreement was reached that compressed gases should be measured for sale on the basis of gas actually delivered at 20° C. and 760 mm. The determination of the corrections to be made to observed pressures and temperatures to reduce these conditions was left tentatively to the bureau. The first step necessary is an accurate summary of the present state of knowledge of the relations between pressure, volume, and temperature for all commercial gases. This section is endeavoring to prepare this summary and to put it in such form that, while giving the most accurate scientific data, it can also be easily used for making any computation involving these quantities by the untrained man.

REAGENTS AND APPARATUS.

In this work may be mentioned the study of methods of testing reagents and apparatus to be used in chemical apparatus, including study of chemical glassware, porcelain, platinum, and platinum substitutes.

Chemical Reagents and Apparatus.

Limited personnel and lack of funds have again prevented undertaking systematic work on chemical reagents. Owing to the urgent necessity of testing the reagents used in the bureau's laboratories, one man was assigned to this work during the last four months of the year. In this time the following reagents were examined: Sulphuric acid, hydrochloric acid, ammonium hydroxide, potassium pyrosulphate, calcium carbonate, sodium carbonate, ethyl alcohol, potassium nitrate, potassium hydroxide, sodium hydroxide, and sodium sulphate.

As has been pointed out in previous reports, a systematic study of "analyzed reagents" involves standards of quality and standardization of methods of test, and is therefore of direct value to science and the industries. For this reason means should be provided for prosecuting this work.

In the reorganization of the division which occurred in November, 1921, the branch of the bureau's work known as the preparation of pure substances was assigned to this section. Besides the routine purification of mercury 200 pounds of pure benzoic acid was prepared for issue as a standard sample. In addition, the sodium chloride content of several aqueous solutions of this salt was determined in cooperation with the division of weights and measures.

Platinum Metals Investigation.

The research upon the chemical and physical properties of the platinum metals has been continued. Much of the necessarily great amount of preliminary work on purification and preparation has been completed and several definite projects were initiated during the past year.

The preparation of pure platinum sponge has been reduced to a routine process and several hundred grams of such sponge were prepared. Much additional work on the melting and working of platinum without contamination has been done in cooperation with the heat division and the division of metallurgy. This involved the study of suitable refractories and the best practice in melting. Several samples of pure platinum wire have been issued to scientific laboratories for use as standards of comparison. The heat division has substituted rare metal thermocouples made at the bureau from its own preparations of platinum and rhodium for the thermocouples hitherto used as primary standards. The bureau has been consulted by American and British manufacturers of pure platinum and of rare metal thermocouples as to the methods used in the preparation of these couples. A short paper on the preparation of pure platinum was published in the Journal of the American Chemical Society. Additional data have been collected on the occurrence of calcium in platinum melted in lime.

In cooperation with the divisions previously mentioned, work was done on the preparation of satisfactory palladium wire from the palladium sponge previously made. Additional attention was given to the preparation of pure osmium and a very satisfactory procedure was developed. This will be published shortly.

Analyses were made of platinum crucibles of British, French, and German manufacture. These were found to have much the same composition as platinum ware of domestic manufacture except that the French crucible contained about 0.4 per cent of copper, which is ordinarily present in traces only. The rhodium content of the French ware was also higher than usual.

The preparation and study of alloys of the platinum metals has been begun. Series of platinum-rhodium and platinum-iridium alloys containing from 0.001 to 10 per cent of rhodium and iridium, respectively, have been prepared. Their thermo-electric behavior against platinum has been studied, and they were further used by the optics division in the study of the partial spectrum of rhodium and iridium.

Active work on the study of analytical methods in the platinum group was begun during the past year. The platinum-iridium alloys already referred to have served as material for a study of the determination of iridium in platinum alloys. This is probably the most important determination in the platinum group. The work thus far accomplished has been designed to determine the limitations of the method of Deville and Stas, which, although first used about 50 years ago, still is the most reliable method of which the bureau has knowledge.

Work was also undertaken on the methods of analysis for platinum ore. Most, if not all, of the platinum ore imported into this country (valued at over $4,000,000 in 1921 and over $7,000,000 in 1920) is sold on analysis. The bureau's study has revealed that the methods in use are quite lacking in accuracy and the bureau's purpose is to develop modifications of existing methods which will make possible much greater accuracy. In connection with this work the complete composition of two samples of Colombian ore has been determined.

The gold content of several Red Cross buttons was determined for the Society of the American Red Cross and of a sample of gold leaf for the State of Vermont. The bureau was called upon to render an opinion in two cases of controversy over the cause of failure of platinum ware.

By order of the Secretary of War, dated January 24, 1922, rhodium-iridium concentrates, reported to contain about 45 ounces of rhodium and 35 ounces of iridium, were transferred to this bureau.

METAL AND ORE ANALYSIS AND STANDARD SAMPLES.

These investigations cover general methods of chemical analysis, with special reference to methods of standardization and the preparation and analysis of standard samples of iron, steel, alloy steels, brasses, bronzes, bearing metals, melting-point metals, ores, cements, and pure chemicals.

Standard Analyzed Samples.

The number of standard samples called for during the fiscal year 1921–22 was 3,532, as against 4,016 in the year 1920–21. The distribution was as follows:

Irons and steels	2,019
Brass, bronze, and bearing metal	138
Metals for melting points	244
Ores	184
Cements	181
Sodium oxalate	247
Benzoic acid	320
Naphthalene	69
Sucrose	108
Dextrose	22
Total	3,532

The decrease in the number of standard samples issued during the fiscal year is due in large part to the depression in the industries, particularly in the iron and steel trade; this was particularly noticeable in the first half of the year; in the latter half a nearly normal sale was established. Another factor in the decrease was the curtailment of the standards normally issued to colleges and universities necessitated by the lack of funds and equipment to carry on the standard sample work. Steps have been taken to remedy this condition, in so far as metallurgical samples are involved, by issuing a limited number of 1,000-gram samples for student use. These are prepared from the chips, which are not of the standard 20–40 mesh size issued as standard samples; they are, however, of uniform composition and are well suited for use in student laboratories.

The fee value of the samples issued during the last three years has averaged close to $10,000 per year. These fees revert directly to the Treasury and are not available for use by the bureau for any purpose whatsoever. Consequently, when Congress discontinued the special appropriation for the work in 1919 and again failed to appropriate funds in 1920, the work was carried on under difficulties and at the expense of other bureau activities. The appropriation of $10,000 which has been made for the coming fiscal year will lighten this burden and permit the purchase of material and the preparation of needed standards.

One new sample was added to the list during the year—No. 54, tin-base bearing metal. Six exhausted standard samples were renewed as follows: Acid open-hearth steel 0.2 carbon steel, 19b; acid open-hearth 0.4 carbon steel, 20b; basic open-hearth 0.8 carbon steel, 14b; chrome-vanadium steel, 30b; cement, 46h; and a new benzoic acid sample, 39b, to replace the older samples 39a and 48a.

Cooperation in the Analysis of British Chemical Standards.

In addition to carrying on the analytical work dealing with the bureau's standard samples, considerable analytical work was done on the British chemical standards. In this work the bureau cooperated with British, Scotch, French, and Italian analysts in the analysis of the British standard pure iron "A_2," and carbon steels "U" 1.2 per cent carbon and "R" 0.8 per cent carbon.

Cooperation in the Development of Standard Analytical Methods.

During the year the section cooperated with the American Society for Testing Materials in the revision of their standard methods for the analysis of plain carbon steel and alloy steels and in the preparation of tentative methods for the analysis of brass ingots, sand castings, and bronze-bearing metal. The section also cooperated with the subcommittee on analysis of the Committee for the International Standardization of Zinc; methods for the determination of aluminum, bismuth, tin, and indium in spelter were developed at the bureau and tested by the cooperating analysts.

Umpire Analyses and Standardization of Various Metallurgical Materials.

The work in this field was considerably increased during the past year. Umpire analyses of several kinds were carried out where analysts had failed to agree and the bureau was asked to settle the dispute. The policy of the bureau of aiding firms in the standardization of material, of which no standards are available, was continued and considerable analytical work was done on the prepared samples which were submitted.

Routine Analysis of Ferrous and Nonferrous Materials.

This work includes the chemical analysis of such metallurgical products as irons, steel, alloy steel, ferros, brass, bronze-bearing metal, type metal, boiler plugs, solder, pure metal, and coated metals such as tin plate, galvanized metal, and silverware. Much routine work was done for a number of branches of the Government service.

Cooperation with the American Society for Testing Materials.

The following methods of analysis, in the compilation of which the section largely cooperated, are now published as preprints by the American Society for Testing Materials and will appear in the Proceedings for 1922: Proposed Tentative Methods of Chemical Analysis of Plain Carbon Steel; Proposed Tentative Methods of Chemical Analysis of Alloy Steels; Proposed Tentative Methods of Chemical Analysis of Brass Ingots and Sand Castings; and Proposed Tentative Methods of Chemical Analysis of Bronze Bearing Metal.

LUBRICATING OILS, RUBBER, PAPER, TEXTILES, INK, AND GLUE.

This section is concerned with chemical analysis and investigations of oils, rubber, paper, textiles, ink, glue, airplane dopes, etc., with special reference to meeting particular requirements.

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Airplane Dopes.

For nearly four years there has been comparatively little activity in the study of these materials. However, samples are received from time to time, and a few were tested during the year.

Balloon Fabrics.

The routine chemical examination of rubberized balloon fabrics continued throughout the year, but the number of samples was not very large.

In last year's report mention was made of the attempt to prepare a material for coating balloon cloth which would possess the best features of both rubber and goldbeaters' skin.

Rubber Chemistry.

During the year the rubber laboratory was never without samples that must be analyzed for one or another branch of the Government, yet time was found for work on analytical methods. This investigational work was largely in cooperation with the committee on methods of analysis of the rubber division, American Chemical Society. One of the chemists of this bureau is chairman of this committee.

It is gratifying to note that at the April, 1922, meeting of the Chemical Society the rubber division accepted the report of the above committee, which recommended with only a few changes the methods of analysis given in the fourth edition of Circular 38 of this bureau.

Textile Chemistry.

Even in the routine examination of textiles there is considerable variety in the tests made. The following determinations are made on one or more kinds of materials: Composition of wool-cotton mixture, percentage of starch or sizing in cotton goods, fastness of dyes to light, crocking, water and washing, oil content of rope and twine, color test for manila fiber, shrinkage of window shades, resistance of duck to the penetration of water, copper content of cloth intended for rubberized raincoats, absorptive power of mops and absorbent cotton, and percentage of asbestos in packings.

Sealskins.

In the annual report for 1921, page 153, mention was made of the examination of certain sealskins to determine how they had been dyed. The object was to obtain evidence in connection with a suit brought by an English corporation against certain individuals and firms in this country, who had established the business of dyeing the skins. The English dyers claimed their process as a secret one, imparted in confidence to their head dyer, and wrongfully used in this country when he was employed here. This dyer asserted that the process was his own secret, which he had never divulged, and that after he left them the English were forced to find a new one. The work done by the Bureau of Standards showed unmistakable differences in the dyes and mordants used. Afterward four of its chemists were witnesses at the trial before the United States District Court in September, 1921. The decision handed down in June, 1922, was in favor of the Americans, but it would probably have gone against them if it had not been for the chemical analyses made by this bureau.

Dyes.

In furtherance of a program for work on dyes, including their standardization by spectrophotometric measurements, a series of typical dyes of known purity was prepared. It is planned to continue this work.

Writing and Copying Inks.

Most of the many samples tested were received with bids made to the General Supply Committee and the Post Office Department. Comparatively few delivery samples were received for test during the year.

Stamping, Marking, and Related Inks.

Inks for use on stamp pads; for numbering, canceling, and duplicating machines; and for marking and stenciling were tested to determine their suitability for the purposes intended.

Typewriter and Similar Ribbons.

Large numbers of these were tested to aid the General Supply Committee and the Post Office Department in awarding contracts, as well as to check deliveries when purchases were made. Most of the ribbons were for typewriters.

Carbon Paper.

Many samples were examined during the year. Carbon paper is used in so many ways and under so many different conditions that no one grade is suitable for all purposes. A given grade may be entirely suitable for making only 1 or 2 copies on relatively heavy paper, and not do at all for 10 or 20 copies on very thin paper. Still another grade may be best for use with pen or pencil. In the latest proposals of the General Supply Committee more attention than ever before is paid to this phase of the subject. This makes the work of testing easier and should enable purchasers to secure the grades best suited to their needs.

Glue, Mucilage, and Paste.

Numerous samples of these were tested during the year. Many of the samples of paste and some of the mucilage were found to be very susceptible to the growth of mold. In some cases the trouble was due to the use of formaldehyde, an excellent antiseptic but one not suitable for this purpose. It is so volatile that it soon escapes from the surface layers of the paste. This is where it is most needed in order to kill or prevent the growth of mold spores that settle upon the paste when it is exposed to the air. Salicylic acid, sodium benzoate, thymol, and phenol are all more effective than formaldehyde because they are but slightly, or not at all, volatile. The essential oils, such as wintergreen, clove, and sassafras, have antiseptic properties. They can be used alone, or to mask the less pleasing odor of thymol or phenol.

Fingerprinting Device.

For various reasons a system of fingerprinting is used as a means of identification by the Postal Savings Division of the Post office Department. There are objections to inking the fingers, and the department was considering the purchase of special equipment which would cost a great deal in the aggregate. This bureau was asked to study the subject and if possible devise some easy and convenient way to make the prints. After some experimentation this was accomplished by an adaptation of the equipment which the department had been considering. This bureau's device is so convenient and cleanly, and costs so little, that a request was made for 12 sets to be given a practical trial in various post offices.

The fingers are first imperceptibly oiled by pressing them upon a sheet of heavy paper impregnated with mineral oil. Prints are then made upon the necessary documents, developed by dusting them with lampblack, and fixed by spraying them with a dilute solution of shellac from an atomizer. The improvement is to do away with the camel's-hair pencil for applying the black, and to use instead a small ball of absorbent cotton coated with lampblack or gas black, and tied up in a cover of organdie. When the oily prints, at first nearly invisible, are dabbed with this, enough black comes through the organdie to make them visible and to develop their characteristics. The slight excess of black is then blown away and the prints are fixed by spraying them with the shellac solution.

Lubricants.

The final test of a lubricating oil or grease is how well it reduces friction and how long it lasts without serious deterioration when used on the machine for which it is intended. In examining a series of samples in the laboratory it is not possible to study their behavior in actual use. The best that can be done is to make a number of physical and chemical tests that indicate, but do not prove, whether or not the lubricants are likely to be satisfactory.

During the year the usual large number of lubricants was analyzed for different branches of the Government service. In connection with investigations in progress in another division of the bureau, oils were tested and samples of oil sludge and of carbon deposits were analyzed.

Further progress was made in the study of the oxidation of petroleum oils. Oxidation is one of the causes, and possibly the chief cause, of the deterioration of oils in use. A paper on the effect of metals and their oxides upon the rate of oxidation of oils was mentioned in last year's report. It was published in the October, 1921, number of the Journal of Industrial and Engineering Chemistry, under the title "Catalytic oxidation of petroleum oils." A related paper on "Sulphur compounds and the oxidation of petroleum oils" appeared in the July, 1922, number of the same journal.

Specifications.

Members of the section cooperated with interdepartmental committees in drawing up specifications for rubber goods and specifications and methods of testing petroleum oils.

DETERGENTS, CEMENTS, CORROSION, ETC.

The field covered by this section includes the chemical analysis and testing of detergents, cement, lime, gypsum, coated metals (such as tin plate and galvanized metals), waters, etc.

Detergents.

Routine tests.—Many samples of soaps, washing sodas, cleansers, polishes, etc., were examined to guide the various Government departments in making awards to contractors. Throughout the year many delivery samples were also examined. Several materials were analyzed for the Federal Trade Commission.

Soap specifications.—In April, 1921, in response to an inquiry regarding the revision of soap specifications, a prominent soap manufacturer was advised that the bureau would welcome the cooperation of a small authoritative committee who could represent the soap manufacturers. Nothing definite was heard from this suggestion until August, 1921, when the bureau was advised that the soap section of the American Specialty Manufacturers' Association, said to represent 90 per cent of the soap manufacturers of the country, had appointed a committee to confer with the bureau relative to the revision of soap specifications as outlined by the Government. Although considerable correspondence was held with the committee, nothing definite was accomplished until the Federal Specifications Board was organized. The manufacturers' committee offered their services to the board, and the latter appointed a technical subcommittee, with a member of the bureau staff as chairman, to take the matter up. A conference of the two technical committees was held at this bureau, and it was agreed that the specifications listed below would give material of suitable quality to cover the general needs of the Government service and at the same time conform to commercial practice. Specifications for the following materials were submitted to the Federal Specifications Board and have been promulgated as United States Government standards: White floating soap, liquid soap, soap powder, salt-water soap, chip soap, ordinary laundry soap, automobile soap, grit cake soap, scouring compounds, and hand grit soap. These specifications are being printed as circulars of this bureau.

In addition to the specifications listed above, the manufacturers' committee submitted specifications for special grade laundry soap, hard-water grade laundry soap, and milled toilet soap. These specifications have not been recommended for adoption as Government standards, as there appears to be no demand at this time for such soaps by the various branches of the Government service. However, the specifications are believed to be satisfactory for the grades of soap indicated and will be included in a forthcoming revision of Circular 62. The methods of sampling and analysis given in the various specifications are essentially the same as those prepared by a committee of the American Chemical Society, but not yet promulgated. These methods were prepared by the American Chemical Society committee in cooperation with the two technical committees mentioned above.

Cements, Etc.

Interdepartmental conference on chemical lime.—After publication of the modified Scaife method for the determination of available lime in quick and hydrated limes (Chem. and Met. Eng., October 19, 1921) various comments were received. Additional tests were made where further information was required, and objections were apparently satisfactorily met. The method appears to be very generally approved, has been formally adopted by the Technical Association of the Pulp and Paper Industry, and recommended for publication as a tentative standard by the American Society for Testing Materials. At the request of the conference, tests were made which indicate that this method may be used for the determination of overburned lime.

Investigations.—Considerable work of a miscellaneous nature was done in cooperation with the structural materials division, consisting largely of furnishing special data for their investigations. This work included the analyses of samples of Canadian feldspar, alkali water and soil, waterproofing and composition flooring compounds, trass for hydraulic cement, proprietary cement compounds, and comparative analyses of Belgian, Italian, and other foreign Portland cements. Studies of certain analytical procedures were also carried out.

Corrosion, Waters, etc.

Cooperative tests.—Cooperative work on the "total immersion" tests of the committee on the corrosion of iron and steel of the American Society for Testing Materials, conducted in part at this bureau and begun nearly two years ago, is still in progress. The iron and steel sheets under test at this bureau, while considerably corroded and somewhat thinner, have as yet shown no failures. Reports of these tests will be found in the proceedings of the above-mentioned society.

Metallic coatings.—Owing to press of other work, no investigational work was done on methods of testing metallic coatings. Indications are that the salt spray test, as described in Circular No. 80, is still regarded as a valuable accelerated test. Numerous tests were made for the Government departments of zinc coatings, oxide coatings, lead-coated steel, and copper-clad steel. Preliminary tests indicated that, for the same thickness of coating, cadmium offers greater protection than zinc. For stripping cadmium-coated metal, warm ammonium nitrate solution was found more satisfactory than the baths in common use for other types of coating.

Waters.—The work done on waters consisted of the mineral analyses of waters submitted to determine the advisability of purification for industrial use and the means to be adopted; and after the installation of purification equipment, analyses of the treated waters to determine whether specification requirements have been met. Of the latter, the installations in Government hospitals at Chicago, Ill., and Dawsonsprings, Ky., may be cited. Periodic examinations of the treated waters are made. Analyses were made of waters from various localities for the Treasury and War Departments and the United States Shipping Board. At the request of the Secretary of the Treasury, a member of the bureau staff was designated to serve as a member of an advisory committee on drinking water standards for common carriers. The bureau, however, does not test waters as to potability.

Miscellaneous Work.

A large number of samples of materials was tested for the Steamboat Inspection Service to determine their fire hazard. A report was made to the Navy Department showing the amounts of the standard Navy boiler compound to be added to various mixtures of condensation and sea water, in order to give a definite degree of alkalinity. Advice was given the Post Office Department regarding metals suitable for use in the construction of street letter boxes. Various materials were examined for the Government departments—for example, graphite, insulating compositions, boiler compounds, chemicals for water purification, fire-extinguishing liquids, antifreezing solutions for automobile radiators, so-called carbon removers and gasoline accelerators, nondrying oils, etc. Cooperative work was done with the American Society for Testing Materials on the distillation test of gasoline. A tentative specification was prepared for plumbago for facing foundry molds. A specification for fire extinguishing liquid (carbon tetrachloride base) was prepared by a technical committee with a member of the bureau staff as chairman. This specification has been adopted by the Federal Specifications Board and will be published as a bureau circular.

PAINT, VARNISH, AND BITUMINOUS MATERIALS.

This section handles the analysis and testing of a great variety of paint and varnish materials and of bituminous materials for waterproofing and roofing purposes. It prepares specifications for such materials and collects information relative to the service that may be expected from them.

As in past years, the greater part of the work done by this section consisted in the testing of paints, varnishes, and bituminous materials submitted by various branches of the Government service. The major part of this work in the fiscal year just past came from the Shipping Board, whose first estimate of the amount of work to be expected from it was more than five times exceeded in the amount actually sent.

Federal Specifications Board.

The committee formerly known as interdepartmental committee on paint specification standardization has been made the technical committee on paint materials by the Federal Specifications Board, and the various paint specifications published as Bureau of Standards circulars have been adopted as United States Government specifications. Representatives of this section of the chemistry division are also serving on the technical committees on (*a*) bituminous roofing, and (*b*) floor coverings—nontextile.

American Society for Testing Materials.

Cooperation has continued with the society's committee on protective coatings for structural materials. The report of that committee for the year 1922 contains contributions from more than one section of the chemistry division. The revised "tentative specifications" of the society for a number of pigments and paints are all based on the bureau's specifications.

The bureau cooperated actively also with the society's committee on waterproofing materials and to some extent with the committee on drain tile.

Researches.

Some improvements in the technique of testing paints were made, and work on the physical properties of paint was vigorously prosecuted. The field is almost untouched but the progress made is encouraging.

Investigation of built-up roofing has occupied much time. At the request of the Board of Education of Cleveland, Ohio, much of the information collected by the bureau on this subject was made available in preparing specifications for roofing for school buildings in Cleveland.

Experimental work on waterproofing shotgun shells for the War Department indicated that a coat of shellac was quite efficient. A number of shells so treated have been returned to the War Department for a service test.

The work on concrete drain tile, mentioned in last year's report, was continued but no conclusions have been reached. The work on mastic flooring, also mentioned last year, was continued and specifications have been prepared for regular mastic to be submitted to the Federal Specifications Board technical committee on floor coverings—nontextile and acid-proof mastic.

Considerable work has been done toward providing material for a circular of general information on bituminous waterproofing of concrete and masonry structures.

CHEMICAL TESTING.

The number of chemical tests made in the chemical laboratories during the fiscal year was 8,495. Distributed by types of materials the tests were as follows: Ferrous metals (irons and steels), 596; nonferrous metals, alloys, and coated metals, 649; cement and cement materials, 814; bituminous products (including creosotes, etc.), 488; varnish materials (including shellacs), 445; paint materials, 1,131; lubricants, 608; soaps, nondrying oils, and metal polishes, 614; inks and related office supplies, 1,068; balloon fabrics, 223; rubber, 667; textiles, 571; and miscellaneous, 621.

The tests were made for very many Government bureaus and establishments and for States, municipalities, and private parties, as follows: Agriculture, 20; Commerce, 2,967 (this includes samples received from other divisions of the bureau for chemical tests); Interior, 21; Labor, 5; Navy, 425; Post Office, 973; Treasury, 521; War, 464; United States commissions and committees, 1,500 (including United States Shipping Board, 1,310); General Supply Committee, 778; Panama Canal, 391; other independent establishments, 311; State and municipal institutions, 41; and private parties, 78.

PUBLICATIONS.

The following papers emanating wholly or in part from the chemistry division were published during the year:

Technologic Paper No. 195, Zinc cyanide plating solutions.
Circular No. 38, fourth edition, The testing of rubber goods.
Circular No. 90, second edition, United States Government specification for red lead.
Circular No. 97, second edition, United States Government specification for green paint, semipaste, and ready mixed.
Circular No. 103, second edition, United States Government specification for water-resisting spar varnish.
Circular No. 111, Recommended specification for flat interior lithopone paint—white and light tints.
Circular No. 114, Recommended specification for cotton rubber-lined fire hose.
Circular No. 115, Recommended specification for pneumatic tires, solid tires, and inner tubes.
Circular No. 117, United States Government specification for interior varnish.
Some physical properties of paints, Proc. A. S. T. M., 1922.
Determination of the acid number of tung and other vegetable oils, published in Jour. Ind. and Eng. Chem., 14, p. 57, 1922.
Abietic acid and certain metallic abietates, published in Jour. Am. Chem. Soc., 44, p. 1333, 1922.
Catalytic oxidation of petroleum oils, published in Jour. Ind. Eng. Chem., 13, p. 901, 1921.
Sulphur compounds and the oxidation of petroleum oils, published in Jour. Ind. Eng. Chem., 14, p. 725, 1922.
Determination of available quicklime and hydrated lime, published in Chem. Met. Eng., 25, p. 740, 1921.
Equilibria in the systems carbon disulphide; methyl alcohol and carbon disulphide; ethyl alcohol, published in Jour. Am. Chem. Soc., 44, p. 105, 1922.
Gas purity recorder for electrolytic oxygen and hydrogen, published in Bull. Comp. Gas Mfrs.' Assn., December 8, 1921.
The production of hydrogen by the use of silicon and sodium hydroxide, published in Trans. Am. Electrochem. Soc., 41, p. 15, 1922.
The electrodeposition of lead-tin alloys, published in Trans. Am. Electrochem. Soc., 40, p. 147, 1921.
The structure and properties of alternately deposited metals, published in Trans. Am. Electrochem. Soc., 40, p. 137, 1921.
The acidity of nickel depositing solutions, published in Trans. Am. Electrochem. Soc., 41, p. 233, 1922.
The electrolytic reproduction of engraved printing plates, published in Chem. and Met. Eng., 25, p. 320, 1921.
Coprecipitation of vanadium with ammonium phosphomolybdate, published in Jour. Am. Chem. Soc., 43, p. 2552, 1922.
Notes on the analysis of cast bronze, published in Jour. Ind. Eng. Chem., 14, p. 426, 1922.
Modified method for the determination of iron and vanadium after reduction by hydrogen sulphide, published in Jour. Am. Chem. Soc., 43, p. 1560, 1921.
The determination of aluminum as phosphate, published in Jour. Ind. Eng. Chem., 14, 1922.

The following are in preparation or in press:

The analysis of chrome-vanadium steel.
Notes on the determination of phosphorus.
Quantitative precipitation by ammonia of phosphorus pentoxide in combination with aluminum hydroxide.
Specifications for soap.
Standardization of solutions employed in the evolution method for sulphur.
Specifications for rubber goods.

ENGINEERING PHYSICS.

Investigations relating to mechanics, sound, and properties of matter; testing and development of engineering instruments; performance standards of mechanical appliances; sound ranging; investigation of soundproofing properties of building materials; analysis and correction of acoustical defects of assembly rooms; elastic properties of diaphragms and springs; investigation, testing, and experimental development of aircraft instruments; ballistics; and aerodynamical testing and research.

GENERAL.

The engineering physics division includes sections dealing with (1) engineering instruments and mechanical appliances, (2) sound investigations, (3) aeronautic instruments, and (4) aerodynamical physics. In addition, special experimental and theoretical researches are carried on by a staff of engineering physicists. The activities of the division in testing and research are described in the following pages. An equally important feature of the work is to be found in the advisory relationships which have been established with other technical branches of the Government and with the industries. This is illustrated by the participation by the bureau (1) in the formulation of several of the power-test codes of the American Society of Mechanical Engineers, and in the work of the American Engineering Standards Committee and the A. S. M. E. Fluid Meters Research Committee; (2) in the work of the aerodynamics committee of the National Advisory Committee for Aeronautics; and (3) in numerous conferences with representatives of the Army and Navy, particularly in connection with problems in aerodynamics, ballistics, and aerial navigation.

ENGINEERING INSTRUMENTS AND APPLIANCES.

Current Meter Rating Station.

An adequate installation for the accurate calibration of water current meters used in measuring the discharge of rivers and other open channels is too extensive and costly to be provided by private enterprise. A hydraulic laboratory, designed and equipped especially for this purpose and housed in so as to be available throughout the year is maintained by the bureau to supply this necessary service. During the past fiscal year 376 current meters of various types were calibrated for the engineering bureaus of the Government, instrument manufacturers, and engineers in private practice.

Calibration of Instruments.

During the past fiscal year 601 instruments were tested, including pressure gauges of various descriptions, current meters, anemometers, speedometers, and miscellaneous engineering instruments.

Fire Extinguishers.

At the request of the Steamboat Inspection Service the investigation and testing of chemical fire extinguishers submitted to that bureau for its approval for use on vessels under its jurisdiction was continued. During the past year 25 fire extinguishers, including one 40-gallon chemical engine, were investigated. Several of the devices tested represented new principles of construction and operation.

Radiator Return-Line Valves.

The successful operation of the heating systems generally employed in public buildings is principally dependent on thermostatic valves placed at the outlet of each radiator. At the request of the Supervising Architect of the Treasury Department performance tests are made of all such devices presented to that office for its approval for use in buildings under its jurisdiction. Nine valves of this description were tested during the past year for compliance with performance standards previously developed.

Miscellaneous Engineering Tests.

A variety of miscellaneous engineering tests were made, such as hydrostatic tests of condenser tubing, tests to determine the tow-line tension of sounding apparatus, tests of high pressure gas cylinder valves, discharge tests of a radiator modulation valve, tests of a safety device for gasoline containers, and the like.

Safety Release Devices for Hydrogen Cylinders.

At the request of the Chief of the Air Service of the Army, an investigation was undertaken of the safety devices used on hydrogen cylinders to safeguard them against explosion should extraordinary pressures be developed within the cylinder. The devices now in use successfully perform this function but frequently fail under ordinary service conditions, causing an appreciable loss of hydrogen. An investigation of the possibilities of a modification of the present form of safety cap for use with a fusible alloy plug has been completed, resulting in a design of a device of this description which promises to meet the needs of the service. An experimental study of frangible copper disks has been concurrently in progress. The necessary preliminary work in determining the separate effect on the bursting strength of the disk, under the conditions of use, of the dimensions of the disk and orifice and of the quality of the copper, has been completed and the investigation of the effect of continued loading on the bursting strength of the disk was in progress at the close of the fiscal year.

Investigation of Elevator Safety Devices.

A survey of available statistics shows that approximately 74 per cent of all fatal elevator accidents to the public occur at the hoistway door. A well-designed reliable interlocking device should practically eliminate all such accidents. An investigation of the interlocking devices now available was recently undertaken for the purpose of determining their reliability and of developing performance specifications for use in connection with elevator safety codes. The design and construction of automatically operated testing apparatus has been practically completed and the testing of commercial devices will be shortly under way.

SOUND MEASUREMENTS.

Sound Sources.

The electrical system devised last year as a sound source has been improved to provide for more ready control. The energy losses in the loud-speaking telephone instrument have been studied for systematic measurement under varying conditions of operation. Sound absorption and transmission are functions of the intensity. Sound intensity at a given position relative to the source is determined by (*a*) the emitting mechanism, (*b*) the environment of the source, and (*c*) the reaction of the environment upon the emitting mechanism.

It is, therefore, important that the output of the source should be measured in a series of experiments which involve alterations in its environment. A method has been devised and apparatus is being developed for this purpose.

Sound-Intensity Measurements.

The apparatus and method described last year has been further developed so as to cover a much wider intensity range. A substitution method has been devised which will make the intensity measurements comparable, regardless of changes which may have been made in the measuring apparatus, or of the variations in the amplifier system between experiments.

Sound Chamber.

In response to the widespread demand from associations of building material manufacturers and other building interests, a sound chamber has been designed and constructed for the purpose of providing suitable facilities for making sound-transmission measurements. Data on sound transmission and absorption in order to be really valuable to the architect and builder should include at least the more common materials and constructions. The data now available provide only a very limited amount of this information.

The sound chamber is built massively of concrete. Two measuring rooms are located, respectively, above and beside a source room, the latter being separated from the remaining structure by air space. Panel openings are so designed that the transmitting panels when sealed into position form the only bond between the two parts of the structure, excepting the common ground on which they stand. The vertical panel opening is to be used for the study of wall structures, the horizontal panel opening for the study of floor and ceiling structures. The panels are to be built 6 feet by 7 feet 6 inches. When sealed into position, the effective transmission area will be 5 feet by 6 feet 6 inches. These panels are larger than any for which transmission data have so far been found. The arrangements and the program of work are such that information covering a wide range of materials and construction can be developed rather rapidly after the preliminary difficulties have been cleared up.

Auditorium Acoustics.

Analyses have been made of the acoustical conditions in the auditoria of a number of public buildings and recommendations made for their improvement. In a few cases analyses of plans have been made in advance of construction. The preponderance of the former cases over the latter indicates clearly that architects and builders do not appreciate the importance of providing for satisfactory acoustics or do not know that they may be planned nearly if not quite as definitely as ventilation, illumination, and other essentials of an entirely satisfactory building.

Voice-Tube Experiments.

A series of experiments has been begun in cooperation with the Bureau of Construction and Repair of the Navy Department to determine the causes of difficulties encountered in voice-tube communication on vessels of the Navy and to develop information of value in designing installations of this kind. This work is still in the preliminary stages.

Fog-Landing Experiments.

In cooperation with the Air Service of the United States Army, some experiments have been made to determine the feasibility of determining altitude of aircraft above ground level by means of sound reflections from the ground as an aid in landing in foggy weather.

The interval between the transmission of a sound pulse from a plane and its reception after reflection from the ground would provide a means of estimating the ground disturbance. The difficulty lies in the reception of the feeble reflected sounds in the presence of the noises attending air navigation. A selective sound-receiving system has been developed with a view to overcoming this, but the service trials thus far made have not been very promising.

Sound Ranging.

The sound laboratory has continued to cooperate with the Signal Corps in the development of apparatus for artillery sound ranging. A sound-ranging system has been developed for the technical staff of the Army Ordnance Department and installed at the Aberdeen Proving Grounds. This system is designed to secure the muzzle velocity, range, and time of flight of each projectile from a machine gun during a burst of fire. The method has the further advantage that the three quantities are all obtained for the same shot instead of obtaining them separately from different rounds. The installation combines the desirable features of several sound-ranging systems developed during the World War and is believed to be superior to any apparatus available at that time. The field work is still in progress.

High-Speed Oscillograph Camera.

Several of the projects on which work has been done in the sound laboratory have involved the use of a high-speed oscillograph camera. Such a camera was developed last year. During the present year the tuning-fork time-scale apparatus was made an integral part of the camera, so that it is available for use with any type of oscillograph. This obviates the necessity of equipping each oscillograph in the laboratory with a time-scale apparatus.

In the 4-inch camera referred to above the exposure is limited to a half-inch strip if it is to be prolonged beyond a single revolution. An 8-inch camera has been developed which increases this strip width to 2 inches. In this development the laboratory had the effective cooperation of Maj. W. P. Wilson of the Coast Artillery, to whom the bureau is indebted for many essential features of the design.

Precision Time Scale for Oscillograph Measurements.

A G. E. oscillograph vibrator with the axis horizontal is tuned to the frequency of a 500-cycle fork. The vibrator is operated by current derived from the plate circuit of a 500-cycle tuning fork, the vibrations of which are maintained by means of the electron-tube drive. The light beam sweeps past the cylindrical lens of the oscillograph camera at its maximum speed and sharp time index marks result on the moving film. A number of vibrators can be operated from the same fork. This affords a means of correlating oscillograms obtained simultaneously on a number of oscillographs.

The sound laboratory has cooperated with six other sections of the bureau by providing suitable time-scale apparatus involving the use of tuning forks for both mechanical and photographic recording systems.

Radio Time Recorder.

In cooperation with the United States Coast and Geodetic Survey two radio time-recording sets have been developed and built for their longitude work. These instruments are now in the field.

Solenoid Chronograph.

The development of this apparatus for the technical staff, Army Ordnance, has been continued. The instrument provides a means of measuring projectile speeds with an accuracy at least ten times as great as any hitherto available in America. An automatic device has been added to the photographic instrument which makes it possible to make velocity firings more rapidly than with any of the chronograph types currently used.

Experimental work aiming at the elimination of the photographic method of recording has been progressing slowly and no definite results can be reported at this time.

Pressures in Guns.

The piezo-electric gauge developed last year has been subjected to actual test in a gun. The results obtained are in satisfactory agreement with other data obtained at the same time. The feasibility of the method and the adequateness of the apparatus have, therefore, been established.

A carbon disk gauge for measuring pressures in guns is being developed in cooperation with the electrical division of this bureau. It is an adaptation of the strain gauges and other telemetric devices similar in principle which have been developed in that division during the last year or two.

In connection with the program of interior and exterior ballistics being worked out by the technical staff at the Aberdeen Proving Grounds, considerable time has been given to the development of apparatus and the oscillographic recording of various events incident to the firing of the gun.

Small-Arms Projectiles.

A suitable method and apparatus for the convenient experimental determination of the principal moment of inertia of small-arms projectiles have been developed. Such measurements are of importance in estimating the stability of experimental projectiles. The apparatus may also be used to determine the degree of uniformity of a random selection of projectiles of the same type.

Yaw Instrument.

It is customary to study the yaw motion of a projectile by firing through suitable screens and measuring the maximum diameter of the perforation. An instrument for establishing the relation between this magnitude and the yaw angle for any projectile type has been constructed, and provides a convenient means for establishing the relation between the measured quantity and the significant yaw angle, from which calibration curves may be plotted for each type of projectile.

Measurement of Linear and Angular Speeds and of Torsional Oscillations.

An instrument is being constructed for the purpose of recording instantaneous values of linear and angular speed. It is of the homopolar dynamo type in which the electromotive force is strictly proportional to the speed at any instant. This instrument is designed to replace instruments used for obtaining time-displacement relations from which time velocity and time acceleration curves are usually deduced by graphical differentiation. The precise direct recording of a time-velocity curve has obvious advantages both in convenience and accuracy. It is proposed to use a pair of such instruments attached to opposite ends of a rotating shaft to record simultaneously the angular speed of the rotating system and the period and amplitude of existing torsional oscillations.

AERONAUTIC INSTRUMENTS.

The research and development work which the aeronautic instruments section has been carrying on for several years with the Army, the Navy, and the National Advisory Committee for Aeronautics on funds furnished by these organizations has been continued, together with a more limited program with other Government departments and private concerns. In addition a large amount of routine work on instruments submitted for tests has been carried out. In this report the research work which involves the experimental investigation of the fundamental principles of instrument design will be described first, followed by the development work which concerns the practical design and construction of new types of aircraft instruments.

Altitude Effect on Air-Speed Indicators.

A second report on the effect of altitude on air-speed indicator readings has been submitted to the National Advisory Committee for Aeronautics for publication. In this report are presented the results of tests in a specially constructed low-pressure wind tunnel on the Venturi and Pitot-Venturi air-speed nozzles in common use. The tests were conducted at air pressures ranging from atmospheric pressure to approximately 220 millimeters of mercury, which corresponds to an isothermal altitude of 33,000 feet. Curves giving the density and viscosity corrections for the Zahm Pitot-Venturi nozzles used by the United States Army and Navy are included in this report. The viscosity correction, which this work has made available for the first time, is particularly important in connection with the low-speed flight of dirigibles where serious errors might be made if the density correction alone were applied, as has been done in the past. It is also shown in this report that the effect of compressibility of the atmosphere on the performance of Venturi nozzles can be neglected over the speed range of present day aircraft. A cup anemometer air-speed indicator was tested in the low-pressure wind tunnel and was found to have approximately a 3 per cent altitude effect at an altitude of 33,000 feet.

Diaphragm Investigation.

The investigation of instrument diaphragms has been continued. Further information has been obtained as to the laws of deflection of corrugated diaphragms. It is found that the corrugations make a diaphragm much more flexible than a flat diaphragm of the same size. Apparatus for measuring the drift and hysteresis of metallic diaphragms has been developed. Hysteresis loops have been accurately measured for flat and corrugated diaphragms of various diameters and thicknesses of different materials, and for different ranges of loading. Evidence has been obtained tending to support the view that directional hysteresis, as distinguished from elastic hysteresis, exists. It is found that corrugated diaphragms exhibit much less hysteresis than do flat diaphragms under the same conditions. The investigation of materials for use in nonmetallic diaphragms has been continued. The effect of temperature and humidity on a number of leathers, rubberized and treated fabrics, and on rubber dam have been studied. The theory of the performance of Sylphon diaphragms has been developed and published as a technical note of the National Advisory Committee for Aeronautics.

Tension Experiments on Metallic Strips.

In connection with the investigation of the elastic properties of metals suitable for instrument diaphragms, measurements of the drift and recovery characteristics of metallic ribbons under tension have been continued and extended to include other metals and a wider range of loading. An interferometer method was used. The samples tested include German silver, nickel, silver, duralumin, phosphor bronze, and brass. The results indicate that German silver and nickel are the most suitable of the materials tested for instrument diaphragms. Phosphor bronze and brass show the least satisfactory results.

Bourdon Tubes.

The mathematical treatment of the deflection of Bourdon tubes as presented in various published papers has been coordinated and amplified for publication in a single report. Apparatus for measuring the deflection and hysteresis of Bourdon tubes has been developed in which an optical-lever method is used to obtain the required magnification.

Compass Investigation.

Extensive laboratory tests have been made on 43 types of airplane compasses comprising British, French, German, Italian, and American service and experimental instruments. Flight tests are in progress on each of the different types, the object being to determine by actual comparative tests which is the most desirable for use on aircraft. A careful magnetic survey of each available type of airplane is also being made. These data are very important and must be known before intelligent compass development can be undertaken. Laboratory investigations are in progress on the theory of compass performance, the damping effect of various liquids, card markings and interior bowl finishes, magnet steels, and pivots.

Ground Speed and Drift Indicator.

A ground speed and drift indicator of the optical-synchronized type has been completed and tested both in the laboratory and in flight. The instrument is easy to install and operate and no difficulty has been experienced in making satisfactory observations at altitudes above 3,000 feet. A new model embodying certain modifications of the mechanical drive system is now under construction.

Air-Speed Indicator.

The cup anemometer type air-speed indicator which was developed at this bureau for dirigibles has been improved and adapted for use on airplanes. The cups have been replaced by a small propeller, since it is found possible by this means to make the instrument start at a much lower air speed. Four of these air-speed indicators have now been built at the Bureau of Standards, two for the United States Navy and two for the United States Army. Tests of one of these instruments at altitudes up to 17,500 feet have revealed no measurable altitude effect; in other words, the instrument reads the true air speed at all altitudes up to this limit and probably still higher. A simple voltage adjustment corrects for the effect on the readings of changing the position of the instrument propeller on the airplane.

Water-Speed Indicator.

An instrument for measuring the taking-off and landing speeds of sea planes has been developed. This instrument consists of a small stream-lined body carrying a propeller which is rotated by the motion of the water relative to the plane. The propeller shaft carries a commutator which closes an electrical circuit each time the shaft revolves, thus operating a chronograph. The exposed parts of the instrument are constructed entirely of monel metal to avoid corrosion from immersion in sea water.

Turn Indicators.

A new electrically driven gyroscopic-turn indicator has been designed and made. It consists of a small, specially constructed battery motor in which the armature rotates about the field on ball bearings, forming the rotor of a gyroscope. The gyroscope is mounted in such a way that it may precess about only one axis, fore and aft, when mounted in the airplane. The turning movement of the airplane causes precession about this axis which is indicated on the dial by a suitable mechanism. The instrument has the advantage over the air-driven types that it operates always at the same sensitivity regardless of air speed, whereas the air-driven type does not perform satisfactorily at speeds lower than 50 miles per hour. It is much more compact and simple than other types of electric-turn indicators. The investigation of existing types of turn indicators has been continued. Tests on a propeller pump for driving turn and pitching indicators proved this device to be unsatisfactory.

Turn Meters.

Preliminary work on the design of a turn meter has been completed. The purpose of this instrument is to indicate quantitatively the rate at which the aircraft is turning from a given course.

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Angle of Incidence Recorder.

This instrument gives a permanent record of the angles of incidence of an airplane during flight. It consists of a specially constructed multiple surface wind vane which operates a series of electrical contacts in circuit with a set of minature electric lamps in the recording apparatus. These lamps record on a moving photographic film the angle of incidence, the lamp lighted at a given moment being determined by the position of the wind vane element. The vane is located on one of the airplane struts. The recording device is placed in the cockpit.

Precision Barometer.

An improved model of precision barometer has been completed and delivered. This instrument was given a number of flight tests which showed the desirability of making certain changes, particularly in the indicating mechanism. These modifications have been carried out and the instrument will soon be ready for further flight tests.

Temperature-Compensated Altimeter.

This instrument, which corrects automatically for the effect of air temperature on the altitude readings, has been completed and given laboratory and flight tests. These tests indicate that the method of temperature compensation used causes an appreciable amount of thermometric lag, and it is proposed in future instruments to provide an external thermal pressure element such as a Bourdon tube for air temperature compensation instead of the bimetallic device used in this instrument.

Temperature-Compensated Thermobarograph.

This instrument is similar in principle to the temperature-compensated altimeter described above, but is provided in addition with a recording mechanism. It gives a record of the altitude corrected for air temperature and in addition a record of the air temperature itself. The air temperature correction is computed on the assumption that the average temperature of the air column from the ground to the instrument is equal to the arithmetic mean of the temperature at the ground and at the altitude where the instrument is situated.

Temperature-Compensated Barograph.

This instrument is similar to the temperature-compensated thermobarograph, except that it is not provided with the temperature-recording element.

Precision Barograph.

Laboratory tests on this instrument indicate a satisfactory performance and show that it gives much more precise readings than ordinary barographs. As a result of this development it has been found to be possible to make a combined altimeter and barograph provided with an indicating dial like an ordinary altimeter and a recording device similar to that of the precision barograph. The pilot would thus be able to read the indication of the instrument as he would that of the altimeter and at the same time obtain a permanent record on the chart of the altitude throughout the flight. This combined instrument would obviate the necessity of carrying both an altimeter and barograph.

Statoscope.

A new type of statoscope has been designed in which an automatic electrically operated valve is substituted for the breaking bubble or hand operated valve ordinarily used in statoscopes. This method is much more accurate than that of using a breaking bubble and automatically protects the instrument against excessive pressure such as would occur if the pilot is careless in the use of the hand-operated valve. The electric current required is supplied by a dry battery inclosed in the case of the instrument itself.

Combined Statoscope and Rate-of-Climb Indicator.

This instrument is a combination of the automatic electrically operated valve statoscope described above and an improved rate-of-climb indicator which uses a Sylphon diaphragm for the rate-of-climb indicating element. When the instrument operates as a statoscope the air chamber and capillary leak tube are shut off from the Sylphon diaphragm by a valve which is operated from outside the case. At the same time a subdial with the legend " Statoscope " printed on it is rotated to expose this word through a slot in the dial thus indicating that the instrument is operating as a statoscope. When used as a rate-of-climb indicator the capillary tube is connected to the outside air, the air chamber connected to the Sylphon element, the contact device, which controls the electrically operated device, shifted so as to be thrown out of action and the subdial rotated so that the legend " Rate-of-climb indicator " shows that the instrument is functioning as a rate-of-climb indicator. The change is accomplished by simply turning a knurled knob.

Rate-of-Climb Recorder.

An improved type of rate-of-climb recorder has been constructed, which is more compact than the model referred to in last year's report. The film-propelling mechanism has been changed to permit the use of a long film which is of ordinary post-card camera size. This is effected by rolling the film by clockwork from one bobbin to another. Means are also provided for varying the speed of the film from one-half to 2 centimeters per minute.

Astronomical-Position Finder.

An experimental model of this instrument, the fundamental principles of which were suggested by the Air Service, has been designed and constructed to study the feasibility of an aircraft instrument of this type for indicating geographical position directly by the simultaneous observation of any two stars. Extended tests have been made with this experimental instrument. The essential features of an aircraft instrument have been determined and the design is now in progress.

Aircraft Sextants.

In connection with the instrument-development program, practically every type of aircraft sextant has been studied and tested.

An investigation of the properties of bubble levels and pendulums, regarding their use as artificial horizons for aircraft sextants, has been completed. A new bubble sextant has been constructed and the design of an improved model is now under consideration.

Airplane Compasses.

An experimental compass of new design has been made and tested in the laboratory and in flight. A novel feature of the instrument is the card element which is very light (weight 3 grams) and which is damped by radial supporting wires. This card recovers quickly, the time being 12.5 seconds for a deflection of 45° from its position of rest, with but one swing through zero.

Distant Reading Compass.

A study has been made of methods of indicating at a distance the readings of the magnetic compass. The problem is a very difficult one since no power whatever is available directly, the directive force of the compass magnets being so small that the least friction causes serious error. Systems employing selenium and other photoelectric cells and thermoelectric units have been tried but have not as yet proven entirely satisfactory. A method now being tested experimentally is one in which a high-tension spark jumps a gap on a repeater, the position of the spark corresponding to the position of the compass card. In connection with this method it is necessary to develop a suitable air-damped compass.

Earth Inductor Compass.

A model for airplane use has been produced and satisfactorily tested in flight. The inductor consists of a cross-shaped armature carrying a closed coil of wire which is rapidly revolved in the magnetic field of the earth, thus generating a current, the intensity of which depends upon the orientation of the coil with respect to the magnetic field. The pilot has before him on his instrument board a movable dial bearing compass graduations on which the desired compass course is set off. When the airplane is on this course the needle of a small galvanometer on the instrument board continuously points to zero. A deflection of the needle to one side or the other indicates a corresponding deviation from the predetermined course. The earth inductor itself is located in the fuselage back of the rear cockpit where it is free from magnetic disturbances due to the engine. It is driven by a small cup propeller projecting through the fuselage.

For this device the American Philosophical Society has awarded its Magellan medal to the two members of the bureau staff concerned in its development. Experiments are now being carried out with a view to producing an earth inductor compass suitable for ship use.

Latitude Indicator for Airplanes.

Study has been given the problem of the determination of latitude in airplane flights by the measurement of the magnetic dip. Considerable progress has been made but the difficulties of such measurements are obvious. A special form of dip needle seems to be the most promising type of instrument.

Altitude and Azimuth Indicator.

The problem of a complete determination of position by observation of a single star, the sun for example, is being studied. Several apparently promising methods have been eliminated as impracticable. The studies are being continued.

Maps, Map Boards, and Methods of Reducing Observations.

Since the nautical methods of finding position from astronomical observations demand rather involved computations requiring considerable time, the problem of devising some simple mechanical or graphical method for aircraft use is under consideration. A study of all the more promising methods which have been proposed is nearing completion. The related question of maps is also being studied, as well as the necessary equipment of map boards, map cases, and plotting instruments.

Horizontal-Angle Indicator.

An instrument for measuring horizontal angles between any two points, and simultaneously the depression angles to each point, is needed in range finding from captive balloons and dirigibles. A number of alternative designs have been worked out and from a comparative study of these, the most promising selected. Complete working drawings have been prepared and an instrument is now under construction and rapidly nearing completion.

Bomb Sights.

A comprehensive study of existing types of bomb sights has been made and an optical sight is in process of design. Attention is being directed toward making the operation of the instrument as simple as possible, thus giving the bomber more time for such adjustments as must be made. Plans for adjustment of the optical ground speed and drift indicator to the instrument have been developed. Experiments are also now in progress on a new type of gyro for the bomb sight, compensated by magnetic means for the effects of acceleration and the earth's rotation.

Aircraft Electric-Resistance Thermometer.

This instrument was designed primarily to determine the gas and air temperature in lighter-than-air craft. The temperature elements consist of resistance coils of fine nickel wire. The indicating element is an ohm meter graduated directly in degrees centigrade. Several resistance elements located at different parts of the ship may be connected to the indicator and the temperature at each point determined in succession by pressing a button on the indicator.

Ballonet Volume Indicator for Dirigibles.

The purpose of this instrument is to indicate the volume of air in the ballonets on nonrigid dirigible balloons. It is particularly desirable to have such an instrument on ships inflated with helium gas, since it will tend to prevent waste of this comparatively expensive gas by keeping the pilot informed as to the volume of air in his ballonets. The theory of a volume indicator based on the difference in pressure between the ballonet and the gas bag has been developed and has been confirmed by tests on the ballonets of several dirigibles. The development of a manometer for measuring extremely small pressures will be required for this purpose.

Balloon and Airship Manometers.

An investigation of the available mechanical types of balloon manometers has been conducted. As these instruments make use of nonmetallic diaphragms and these diaphragms are responsible for the most serious defects of the instruments, it has been found necessary to conduct an investigation of the materials available for use in this connection. Tests to determine the porosity of the material and the effect of temperature and humidity have been conducted.

Kymograph or Airplane Oscillation Recorder.

The purpose of this instrument is to record the oscillations of an airplane in flight by focusing the sun's rays on a moving photographic film in the instrument. An improved type of instrument has been developed which gives an exceptionally sharp, narrow trace. The film is driven by an electric motor and the bobbins have sufficient capacity for 3 meters of moving-picture film, which corresponds to a flight of three hours.

Standard Testing Sets.

A set of standard airplane instruments has been prepared for field use. This is made up of carefully calibrated instruments to be used in checking other similar instruments in the field. It contains an altimeter, an air-speed indicator, a tachometer, an oil pressure gauge, an air pressure gauge, a radiator thermometer, a cockpit thermometer, and a set of correction curves. The instruments are all arranged conveniently for transportation in a mahogany case.

Aircraft Chronograph.

A chronograph for use on airplanes has been extensively modified and improved. The record is made on motion-picture film. Electromagnetic shutters are provided to intercept the beam of light from a miniature electric lamp. The record consists of spots or short dashes on the film which is driven by a small electric motor. There is also an electromagnetic timing device for the film. Twenty-five impressions per second can easily be recorded with this instrument.

Sphygmomanometers.

The investigation of sphygmomanometers has been continued and standard tests and tolerances have been established for these instruments. The testing apparatus has been improved so that large numbers of instruments can be handled.

Routine Testing.

The usual amount of routine testing work on aeronautic instruments submitted for test by Government departments and private concerns has been carried out. This includes tests on 26 altimeters, 24 air-speed indicators, 16 tachometers, 11 turn indicators, 10 rate-of-climb indicators, 10 aneroid barometers, 5 barographs, 3 mercurial barometers, 3 airplane thermometers, 1 manometer, 1 oil pressure gauge, 1 air pressure gauge, and 5 sphygmomanometers.

Flight Tests on Aeronautic Instruments.

A large number of flight tests have been carried out by members of the bureau in connection with the development of new types of instruments. These have been made possible through the courtesy of the Army and Navy, who have provided the necessary facilities in both lighter and heavier than air craft for these tests.

Aeronautic Instrument Collection.

The collection of aeronautic instruments maintained by the Bureau of Standards, which is very complete and contains representative instruments of all the principal types from most of the more prominent manufacturers, not only in this country but also abroad, has been further extended by the addition of new instruments, including a Wimperis course-setting sight, a Power position finder, a Bygrave calculator, a Goerz course calculator, two sextants, a turn indicator, a maximum altimeter, a statoscope, and a rate-of-climb indicator.

AERODYNAMICAL PHYSICS.

Three wind tunnels are now available at the bureau for aerodynamical work. The tunnels differ in size and speed range and are adapted to a great variety of work.

The 54-inch tunnel, located in the wind-tunnel building, is of the British National Physical Laboratory type, octagonal in cross section, the 54-inch dimension being between opposite faces. The faired entrance of the tunnel is about 4 feet long, the parallel portion 25 feet long, and the exhaust cone 15 feet long. The diameter at the propeller end is 9 feet. The tunnel room is 68.4 feet long, 28.5 feet wide, and 18 feet high. The room is divided transversely near the exit end of the tunnel by a wall honeycomb, consisting of pasteboard tubes 1.5 inches in diameter and 4 inches long, packed in a light framework, which is covered on both sides by mosquito bar. This open honeycomb structure serves to damp out the swirl and eddies in the air stream as it returns from the fan to the tunnel entrance. A speed range of 17 to 90 miles per hour is attained in the tunnel with the expenditure of from 2 to 90 horsepower. Two balances are available, the first being a modified N. P. L. balance with an auxiliary balance for pitching moments, used chiefly for work on aerofoils and airplane models; the second balance is designed for very heavy models, such as radiator sections, engine cylinders, etc., and is adapted chiefly to head-resistance measurements. For very accurate work at low speeds storage battery current may be used.

The 36-inch tunnel is of the Venturi type, circular in cross section. The entrance cone is 12 feet long, the working portion 6 feet long, and the exit cone 33 feet long. The diameter at the end of the exit cone and the front of the entrance cone is 7 feet. The tunnel room is 106.7 feet long, 25.2 feet wide, and 10.2 feet high. Two wall honeycombs, consisting of hollow tile covered with mosquito bar, extend entirely across the room in the path of the returning air stream. A speed range of 11 to 180 miles per hour may be attained in this tunnel with an expenditure of from 1 to 110 horsepower. Speeds over 150 miles per hour may be maintained for short intervals of time only. The tunnel is steady and relatively free from turbulence. A modified National Physical Laboratory balance is available, but deflection methods have been much used in the past. The tunnel is well adapted to the calibration of airplane instruments at airplane speeds and to the investigation of devices functioning in a wind stream of high speed.

The third tunnel is 10 feet in diameter and is not housed. The faired entrance is 4 feet long, the parallel portion 50 feet long, and the exit cone 34 feet long. It is of circular section, 14 feet in diameter at the propeller end. A maximum speed of 75 miles per hour has been obtained with an expenditure of 250 horsepower.

Apparatus is thus available for practically all kinds of aerodynamic testing except propeller and windmill torque and thrust measurements.

Aerodynamical Characteristics of Aircraft Bombs.

The general investigation of the aerodynamical properties of aircraft bombs has been in progress for three years. An excellent series of aluminum models of ogives and bodies was delivered by the Ordnance Department in the early part of last year and these models have been supplemented by models of fins of various areas and shapes. Progress this year has been along two lines, namely, the investigation of the damping of an oscillating bomb and measurements of the forces, moments, and damping on certain models equipped with the various forms of fins. The first investigation required the development of the necessary apparatus, various difficulties being met and overcome in new designs. The apparatus in present use consists of two seven-sixteenths inch rods attached to the bomb in the same line passing through the center of gravity and connected to the supports on the tunnel walls by thin steel strips. The strips have sufficient stiffness to cause the bomb to oscillate. The frictional damping is very small. The fin form tests have progressed sufficiently far as to enable very definite statements to be made as to the desirability of the use of various forms.

In addition to the general program a finned trench mortar projectile was carried through the same tests as the bomb models. The projectile was then modified in various ways in an attempt to improve its stability.

Forces on an Airship Shielded by Wind Screens.

The preliminary work on this problem was reported last year, in which tests were made in cooperation with the balloon and airship division of the Air Service of the flow about models placed in the 54-inch wind tunnel. This past year experiments were made in cooperation with the engineering division of the Air Service in the open air, first in the slip stream of a propeller driven by a Liberty motor, secondly, in a natural wind at Langley Field, Va., and finally in the stream from an electrically driven propeller. Force measurements were found practicable only in the last-mentioned stream. The general flow was studied by means of anemometers and fine threads. Enough data were secured to specify the general design of a full-scale wind screen which with proper maneuvering of the airship would enable landing and ascents in high winds. The forces on the ship when shielded are a very small percentage of the unshielded values.

Resistance of Ice-Coated Electric Wires to Wind.

In connection with the preparation of safety codes and for the purpose of providing data for the specification of proper loading factors to be used in design, a series of tests was made on a smooth 1-inch cylinder, which represents approximately the form of an ice-coated electric wire, at various angles to the wind.

Studies of Wind Tunnel Air Streams.

At the request of the National Advisory Committee for Aeronautics, a number of studies have been made of the air streams of the wind tunnels. The two principal investigations concern the effects of turbulence and the absolute measurement of velocity.

An absolute measurement of velocity has been made by the use of hydrogen-filled balloons of the same average density as air, which were allowed to float in the air stream. The balloons traversed a beam of light reflected across the stream three times, the times taken to traverse the distances between successive reflections being measured by means of the camera developed by the sound section. Time signals were obtained from a tuning fork previously calibrated against a standard clock. The speed determined from Pitot tube readings was found to equal the speed of the balloons to within one-half of 1 per cent, the accuracy being limited by the unsteadiness of the air stream.

The turbulence tests were made on a stream-line model. Wire screens have been used previously as a source of artificial turbulence, but recent tests have shown the velocity distribution behind such screens to be extremely irregular and unsteady. The work was interrupted due to the pressure of other tests.

One attempt was made to measure the temperature of the air stream by means of thermocouple junctions placed parallel to the stream. The few measurements made show that the air does not undergo adiabatic expansion, but that the heat transfer due to turbulence is an important factor.

Cooperative Tests with Weather Bureau.

Assistance has been given to representatives of the Weather Bureau in the calibration of existing types of Robinson anemometers used at official stations for recording wind speeds. The corrections of these instruments at very high speeds are not well known. Some development work on new types designed to give a more constant correction factor has also been done.

Resistance Measurements in a High-Speed Air Stream.

Work for the Ordnance Department on the head resistance and cross-wind forces of models of projectiles and aircraft bombs in a wind stream of high velocity has been continued. These measurements have been made possible through the courtesy of the General Electric Co., which has provided facilities for carrying on the work in connection with the testing of large centrifugal air compressors at Lynn, Mass. A fairly steady air stream of high velocity is obtained by allowing the compressed air to escape continuously through an orifice 12 inches in diameter. The models are supported in this air stream on suitably designed balances of various types. Resistance measurements for air speeds up to 1,200 feet per second have been obtained in this way.

Jet Propulsion for Airplanes.

A theoretical investigation of this subject was undertaken and a report prepared about two years ago at the request of the Army Air Service. This investigation has now been revised and made more complete, and the results have been prepared for publication by the National Advisory Committee for Aeronautics.

There is no present prospect that jet propulsion can be used successfully and the publication of these results may prevent engineers or inventors from attempting impossibilities.

Orifice Meter Investigations.

Flow meters of the differential pressure type are of constantly increasing importance in the commercial measurement of water, oil, gas, etc., and many requests are received for information regarding them. In particular, very large quantities of natural gas are sold on the basis of orifice meter readings, and the Government is interested as receiving large royalties, determined in this way, from gas produced on public lands.

A considerable part of the literature on flow meters has been examined, in connection with preliminary reports prepared by the A. S. M. E. Fluid Meters Committee, and a further report has been submitted to that committee.

At present the division of engineering physics and the division of weights and measures are starting an experimental research on orifice gas meters. This is in answer to various requests and has the cordial approval, accompanied by offers of cooperation, of the Natural Gas Association and numerous meter manufacturers.

GENERAL INVESTIGATIONS.

Plumbing Investigations.

The plumbing subcommittee of the building code committee of the Department of Commerce is engaged in the formulation of simplified plumbing practices and regulations, especially as applied to small-house installations. Experimental work has been carried on at the bureau to determine the effectiveness of various simplified systems of venting and the effectiveness of smaller sizes of soil and drain pipes than are now commonly employed, with a view to reducing the cost of plumbing installations. Experiments have been conducted on the determination of rates of discharge from various plumbing fixtures with different methods of water supply; on the carrying capacities of the 3-inch soil stack and 4-inch house drain; on designs for the installation of plumbing fixtures on the stack system; on the variation of air pressure and air flow within the stacks and branch drains during service; and on the effect of external conditions, such as frost closure of stack tops, wind over stack tops, and rain water in a combined sewer system. Plumbing installations, employing 3-inch soil stacks, representative of different types of dwelling house construction, have also been erected and tested.

Conclusions from the experiments and tests have been made the basis of a preliminary report covering dwelling house construction by the plumbing subcommittee. The work is being continued with a view to publishing a final complete report during the ensuing year.

Hardware Standardization.

The purpose of this work is to accelerate the standardization of hardware for Government as well as private use; to carry out such laboratory tests as may be necessary to insure the adoption of articles having requisite characteristics regarding durability and performance; and to make surveys of hardware as manufactured in order that the items adopted as standard will be those found in general commercial production. Special attention has been given toward furthering the work of the interdepartmental advisory committee on standardization of hardware, appointed by the Federal Specifications Board. Illustrated specifications for 279 items of builders' hardware are now ready for submission to manufacturers for comment and criticism. A survey was made of the methods used by manufacturers in measuring the length of nails, tacks, and screws, and a digest of the replies was sent to the industries concerned. Several irregularities in the methods of measuring lengths have been eliminated.

Following the above survey two conferences were held at the bureau with representatives of the wood-screw manufacturers, at which dimensional standards for wood screws were adopted and the number of sizes manufactured as standard were very materially reduced. The new standard sizes have been put into effect by the makers and the trade notified accordingly. A specification for wood screws embodying the new standards has been written by the advisory committee on standardization of hardware for adoption by the Federal Specifications Board.

Plasticity of Soft Materials.

The determination of plasticity is of technical importance for specifying such materials as clays, paints, and greases, but no satisfactory methods have been developed. This subject has been under investigation in connection with experimental work in other divisions of the bureau. A paper on the subject is in preparation.

PUBLICATIONS.

The following papers have been published during the year:

N. A. C. A. Report No. 125, general classification of instruments and problems (M. D. Hersey).
N. A. C. A. Report No. 126, altimeters and barographs (A. H. Mears, H. B. Henrickson, and W. G. Brombacher).
Precision altimeter design (J. B. Peterson and J. R. Freeman, jr.).
Statoscopes and rate-of-climb indicator (A. H. Mears).
Aerographic instruments (J. A. C. Warner).
N. A. C. A. Report No. 127, air-speed indicators (F. L. Hunt).
Testing methods for air-speed indicators (H. O. Stearns).
Principles of ground-speed measurement (F. L. Hunt).
N. A. C. A. Report No. 128, inclinometers and banking indicators (W. S. Franklin and M. H. Stillman).
Aircraft compasses and turn indicators (J. A. C. Warner).
Testing of magnetic compasses (R. L. Sanford).[1]

[1] Contribution from electrical division.

N. A. C. A. Report No. 129, aircraft tachometers (G. E. Washburn).
Testing methods for tachometers (R. C. Sylvander).
Thermometers for aircraft engines (E. F. Mueller and R. M. Wilhelm).[2]
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STRUCTURAL, ENGINEERING, AND MISCELLANEOUS MATERIALS.

This division is concerned with the investigation of the properties, uses, design, and fabrication of structural, engineering, and miscellaneous materials. This includes metal of all kinds, and wood, especially when fabricated into structures or structural parts, cement, concrete, lime, gypsum, sand, stone, and sand-lime brick. Under miscellaneous materials are included leather, rubber, and composition materials used in place of these, textiles, paper, and lubricating oils. To make the study of these products complete it is desirable to take into consideration the processes by which they are manufactured. Hence, the equipment includes an experimental rubber mill, textile mill, paper machine, cement plant, etc. The division is also concerned in the improvement of the present and the development of new methods of testing and the establishment of standards covering the use of the materials concerned.

GENERAL.

The outstanding feature of the year has been the marked increase in the contacts which have been secured with the industries interested in the various lines of work covered by this division. This interest has been brought about by the increased activity in the matter of standardization. The war activities demanded the concentration of efforts along either routine testing or investigational lines to develop a definite product. The vast fund of information thus obtained has been of inestimable value in bringing to the attention of both producers and consumers the qualities of the products on the market and the possibilities of their improvement.

At the same time both the producing and consuming public have appreciated the need of extensive standardization as a result of the voluntary efforts in that line during the war. When, therefore, the matter of the extension and amplification of these had been brought to their attention, there was a very gratifying cooperation shown by all concerned. The producing interests have, through their representative organizations, appointed special committees on standards or technical problems. These have met with the experts of the bureau on the respective problems and gone thoroughly into the sug-

[2] Contribution from heat division.

gested standard—in certain cases approving it as prepared, in other cases taking it under advisement and study in private laboratories of the industry, and in still other cases drawing up a program of further cooperative research.

The bringing together of the producing and consuming interests concerned in any product has resulted in either party obtaining the other's viewpoint. The producers have learned that the consumer is interested in the manufacture of the commodity he uses, especially in how the materials entering into it and the methods of production affect the service, and the consumer has learned that the producer is just as interested in how different phases of service affect the manufacture. This mutual understanding of the problem by all concerned, when brought together on mutual ground, has been of very marked value to both and has hastened the work and the obtaining of results materially.

The bureau, in bringing together the interested parties, acts not only as a neutral agent or arbiter, but also to a certain extent as the representative of the Government as a consumer, always, however, with the advice and cooperation of those governmental departments actively interested in the product under consideration.

More detailed examples of this more active cooperation along technical lines and the preparing of standards, especially in the paper, textile, leather, and rubber industries, will be found under these respective headings.

STRUCTURAL AND ENGINEERING MATERIALS.

In these laboratories measurements are made of the resistance of engineering materials, particularly of metals and wood when fabricated into structural units, under tensile, compressive, and torsional stresses. The fatigue and impact resistance of materials, as well as their hardness, are subjects of careful study. Special attention is given to the design of testing apparatus and to testing methods in general in order that these may be improved. The properties of new materials are determined so that they may be used successfully by all branches of the Government and by American industries. Attention is given to the alloys of aluminum having low weight because of their importance in the construction of aircraft. Engineering structures are also designed and tested to determine the construction most suitable for a given purpose. Many of these are loaded to observe the behavior of their parts. Tests of this kind are made upon machine and airplane parts as well as on buildings and cranes.

Theory of Columns.

The design of columns or compression members in steel structures, such as bridges or steel-frame buildings, is in a much less satisfactory condition than the design of tension members or of girders. Instead of rational column formulæ giving the column strength in terms of the dimensions of the column and the properties of the material, it is the general practice to use empirical formulæ whose constants have been determined from tests on actual columns, and which are as a rule not related to the properties of the material of which the columns are made. As a consequence compression members are often designed with an unduly large factor of safety resulting in waste of material, and sometimes are of inadequate strength, resulting in failure.

This unsatisfactory condition has been due to the lack of an adequate theory of column behavior, verified by a sufficiently wide range of experimental data.

The work of other investigators in this field has been reviewed by the bureau, especial attention being paid to the work in foreign laboratories, and much valuable information has been obtained.

A mathematical analysis of the problem has been made and it seems probable that some of the results will be of practical application.

This theoretical work has been compared with the results of column tests made at the bureau, as well as those reported by other laboratories and in all cases where sufficient data were available the experimental results are consistent with the theory.

In order to verify the general applicability of the theory, a series of tests on small compression members has been undertaken. A wide range of physical properties of the material has been obtained by securing, through the courtesy of a number of manufacturers, specimens of ingot irons, carbon and alloy steel, brass, and monel metal. These will be tested in widely varying lengths to cover the slenderness ratios usual in practice, from the ordinary structural column to the slender latticing used in tower construction and the struts used in aircraft.

Fatigue Resistance of Metals.

The investigation to determine the fatigue resistance of sheet metals has been continued throughout the year. The metals used are those suitable for aircraft construction, the thickness varying from 0.020 to 0.120 inch.

Flexural fatigue.—Four machines have been designed and constructed for the work on flexural fatigue of thin sheet duralumin. They have many features which are novel and which may be found to have advantages for fatigue tests on thicker specimens.

The specimen, a small rectangular piece of the rolled sheet, is held along opposite edges by clamps. The bending stress is set up in the specimen by a lever and connecting rod driven by a variable speed electric motor.

The bending moment in the specimen is measured by the torsional deformation of flat steel springs held at their ends and to the middle of which the specimen is attached. The deformation of the springs is measured by a simple optical system consisting of a single filament electric lamp, a concave mirror attached to the springs near the specimen, and a graduated glass scale. A counter records the number of revolutions made by the motor before rupture occurs, as the motor is automatically stopped when the specimen breaks.

Preliminary tests on these machines indicated that their rigid construction, which it was believed would entirely eliminate undesirable vibrations, had not entirely accomplished its object. The dynamometer and crank system was, therefore, progressively redesigned to obtain the highest possible free frequencies consistent with the requisite sensibility. After setting up the machines as redesigned a preliminary series of tests on very thin material was made at relatively high stresses to see if the machines were giving consistent results. The first results showed considerable variation for the same stress range. It was found that the clamping stresses were responsible for the lower readings. After reducing the clamping stresses to a negligible amount further tests gave results well within the limits of variation of fatigue requirements.

The investigation has not been carried far enough to allow any conclusions to be drawn as to the magnitude of the endurance limit or even as to the probability of its existence in this thin sheet duralumin. Although specimens have been run for more than 10,000,000 alternations of stress without failure, other investigations have shown that it is not safe to draw general conclusions for series stopping short of 100,000,000 alternations of stress.

There is no reason to believe that the work will not proceed smoothly. Because of the speed limits imposed by the thinness of the specimens the tests will necessarily take a considerable length of time, but this difficulty is inherent in all fatigue testing.

Impact fatigue.—The machines designed for this investigation consist of heavy cast-iron anvils mounted on blocks of concrete. The specimens clamped at their ends are struck at the middle by a tilting hammer raised by a cam and which falls freely from a fixed height. The height of fall and the weight of the hammer can both be varied. Three of these machines were set up on separate bases of concrete to prevent the vibrations from one machine affecting the results obtained on another.

A number of preliminary tests have been made on specimens of the bureau's tentative standard size. It is proposed to use hammers whose weights are proportioned to the thickness of the material tested.

The three machines can apparently be used interchangeably as the results of most of the tests indicate little difference between them.

The machines can now be used satisfactorily for the thinner sheet metal, and with the solution of problems connected with methods of bending the machines will be ready for continuous use in securing data on this important problem.

Verification of Testing Machines.

A careful study of this problem is being made and much valuable information has been obtained, some of it from European laboratories. Because of the interest in this subject and its importance in commercial work committee E-1 on methods of testing of the American Society for Testing Materials undertook a revision of their standard methods of calibration, which have never proven entirely satisfactory. At the invitation of the chairman members of the bureau's staff attended meetings of this committee and were requested to submit a revision of the portion of the tentative report dealing with this subject. The experience of the bureau's engineers in the use of testing machines and particularly with commercial and other weighing scales was of great assistance in this work. The report met with the approval of the committee after some revision.

Machines have been designed for applying dead loads to apparatus for verifying testing machines. Several portable instruments have also been designed, and it is probable that experience with these will lead to the design of an instrument which will be practicable for verifying commercial machines.

Investigation of the Physical Properties of Dental Alloys.

Although dental science has probably been carried further in this country than elsewhere, much difficulty has been found with the metallic alloys used for fillings, inlays, crowns, and bridges. Many of these alloys now in use by the Public Health Service fail, due to deformation in use. This makes it necessary to replace the damaged ones at frequent intervals, with the great economic loss which this involves.

Tests of the physical properties of these alloys are not usually made and little is known about the relative merits of the alloys now on the market.

In cooperation with the thermal expansion laboratory this section is undertaking tests of these materials, which will give reliable information on their properties.

A Francke flexural testing machine has been donated for this work, and has the advantage that it allows a very small specimen to be used and is very sensitive. Loading the specimen as a beam approximates service conditions and makes it practicable to test wire, sheet, and other forms of the material in the form in which it is used for dental work. The tests on the Francke machine will be supplemented by tensile hardness and other tests whenever possible.

It is believed that this is the first investigation of this kind the results of which will be generally available.

Crinkling Stresses in Steel Tubing.

In cooperation with the Bureau of Aeronautics of the Navy Department the bureau is investigating the axial compressive loads which will cause failure of the steel tubing used for airplanes. Special compression blocks have been constructed having many small steel balls between the spherical end block for the tube and its seat in the testing machine. Tubes of different diameters and wall thicknesses and of different lengths have been tested and the results compared with theory and also with the experimental work of others. This investigation will allow the strength of tubular struts for airplanes to be computed for design purposes if the material is uniform.

Shrapnel Diaphragms.

At the request of the Bureau of Ordnance of the Navy Department, tests have been made of the steel diaphragms used in shrapnel shells.

These diaphragms are placed between the shrapnel and the explosive charge in the base of the shell. If too thin they deform when the gun is fired, and the charge in the base of the shell may also explode. The diaphragms were loaded in special fixtures and the deflection at the center measured. The tests showed that a thinner diaphragm could be safely used.

Marine Glue Specifications.

Marine glue is used in the construction of the pontoons of flying boats to cement the fabric used between the inner and the outer skin and elsewhere.

To supplement a large amount of investigational work done by the chemistry division on these glues, this section made a large number of experiments to determine the most practicable tests for the physical properties of this material.

Tungsten Carbide Balls for Brinell Hardness Tests.

For measuring the hardness of metals the Brinell test, using a ball to indent the material, is the most reliable and practicable. The ordinary hardened steel ball, such as is used for ball bearings, is satisfactory if the hardness of the material being tested does not exceed 500 Brinell hardness number. If the hardness exceeds this value the ball is deformed and the hardness is not accurately determined.

In an attempt to secure harder and stronger balls, tungsten carbide has been secured in small quantities, and its suitability for this work studied. Although this material appears to have some advantages over steel, the samples so far obtained have not been entirely satisfactory.

Investigation of Motor-Truck Wheels.

An investigation of the strength of several types of motor-truck wheels was made for the motor transport division of the Quartermaster Department, Camp Holabird, Baltimore, Md. The wheels tested in this investigation were a standard wood wheel, a cushion wood wheel, a cast-steel wheel, a special steel disk wheel, and an aluminum wheel. The tests made on the wheels were a static radial compression and a static side-thrust test, a wheel of each type being used for each test. From the results, the proportional limit, the strength, resiliency, stiffness, and other physical properties were obtained under static loading. The determination of these properties makes possible a comparison of the different types of wheels.

Tests of Oil-Well Material.

In the drilling of oil wells or in the salvaging of the fittings in exhausted wells it sometimes happens that the joints of the casing may separate at the couplings entailing considerable delay and financial loss. As the weak point in a string of casing is at the threads where they are joined by pipe couplings, tensile tests were made in cooperation with oil companies and manufacturers to obtain information on this important point. Apparently the strength of the threads could be increased to advantage. The material used is also an important factor in the strength of these casings.

Strength of Large Columns of H-Shaped Cross Section.

A report of the tests of large steel columns made at Pittsburgh was prepared and submitted for criticism to persons interested in the manufacture of these columns. As a result a number of conferences were held and it was decided to make further tests of large columns before publication of these results. In cooperation with the Bethlehem Steel Co. material of low and high yield point is being selected meeting American Society for Testing Materials and American Steel Manufacturers' Association, class B, specifications, respectively.

Seventy-two columns will be tested, including heavy and light comparable H-shaped sections of solid rolled and fabricated (plate and angle) construction of approximately 85 and 36 square inches cross-sectional area, respectively, and carrying loads up to 4,000,000 pounds.

The properties of the material used are being carefully determined by means of tests on a large number of coupons cut from the columns averaging over 10 specimens per column. These coupon results will be compared with the results of the column tests. Twelve of the columns have already been tested at the Pittsburgh laboratory, giving results consistent with those previously obtained. The tests will be continued during the coming year.

Investigation of the Strength of Brick Walls.

In cooperation with the Common Brick Manufacturers' Association of America and other interested organizations the bureau has made tests on the strength of brick walls. The program included many variables which are of practical importance in building construction. To avoid the criticism that laboratory tests of brickwork are usually made on specimens which are very much better than commercial brickwork, every effort was used to obtain average material and workmanship. The brick from the Cleveland district were of ordinary quality, and their physical properties have been carefully determined, both flatwise and on edge. The mortars used were cement, lime and cement, and lime. The walls were 8 inches thick in most cases and all of them 9 feet high by 6 feet long. The tests included compression, both axial and eccentric, and transverse tests to measure the resistance to lateral loads such as wind pressure.

Tests of Girder Hooks.

In cooperation with the American Bridge Co. tests have been made on the steel hooks used in handling rolled I beams and other structural shapes during fabrication.

The methods at present in use for the design of these hooks are not considered satisfactory, and the tests were undertaken to determine the actual strength of the hooks being used and, if possible, to obtain formulas which can be used for design.

Three each of the 5, 10, and 15 ton hooks were tested, many strain-gauge readings being obtained to show the behavior of the material.

These hooks are an important case of the curved beam and it is believed that the measurement of the stress by means of the strain-gauge will allow a comparison to be made between the actual and the theoretical stresses.

Welded Structural Members.

In cooperation with the American Bridge Co. tests have been made of columns, girders, and tensile specimens fabricated from structural steel. For the columns and girders three of each were riveted and three of each were electric spot welded. A large number of tensile specimens were made. All specimens were tested so as to show the relative strength and other properties of the members. A direct comparison in this way of members which are used in actual construction is very valuable in determining the suitability of a new method of fastening such as this. More elaborate experiments can then be planned to obtain additional information.

The results are very encouraging, as the strength of the welded specimen was, in most cases, at least, equal to the strength of those which had been riveted. It is probable that in the future both electric spot welding and also gas and electric fusion welding will be used for many purposes for which other processes are now employed. Before this is done, however, it should be proven that their use is not dangerous.

Cooperation.

The bureau has been cooperating actively with the various scientific and technical societies, assisting in the preparation of specifications, safety codes, and in the standardization of methods of testing.

CEMENT, CONCRETE, STONE, GRAVEL, AND SAND.

Specifications for Concrete and Reinforced Concrete.

Publication of the tentative specifications of the Joint Committee on Concrete and Reinforced Concrete, referred to in the annual report for 1921, page 185, has brought out severe criticism of certain parts of the report, especially those dealing with (*a*) the methods of proportioning the ingredients of concrete, (*b*) the use of reinforcing bars rolled from old rails, and (*c*) the use for waterproofing purposes of admixtures in concrete. A number of largely attended sessions of the American Society of Civil Engineers, the American Concrete Institute, and American Society for Testing Materials have been devoted to the discussion of these questions. The Bureau of Standards has participated in this standardization work, and a member of the staff is serving on committees which have prepared programs of investigation intended to settle the questions regarding proportioning of concrete and the use of rerolled bars as reinforcement.

Floor-Slab Tests.

The concrete and hollow-tile floor slab tested at Waynesboro, Ohio, is still under loads of 1,413, 1,184, and 920 pounds per square foot on three panels, respectively, as described in the annual report for 1921, page 185. It is reported, however, that these loads have recently caused severe deflections and cracking of the slabs. This is to be expected, since the loads applied are many times as great as are permitted by present standards. The report of the showing from this test up to October 21, 1921, forms the basis of a technologic paper, which has gone to press.

Effect of Direction of Reinforcement on Strength of Slabs Supported on Two Edges.

A technologic paper has been prepared in which is included (*a*) an analysis of the stresses and deflections of slab beams in which the reinforcement makes an angle with the direction of the span, and (*b*) results of tests of such beams using bars and of beams using expanded metal as reinforcement. The analysis indicates a smaller strength and a greater deflection for the beams with diagonal reinforcement than for beams having reinforcement parallel to the direction of the span. The slab beams tested were very shallow and the reinforcement was in two layers in all cases. The thinness of the slabs causes small errors in placing the reinforcement and in measuring its position to assume considerable importance in the test results. The fact that the reinforcement was in two layers offers opportunity for the entrance of errors in interpretation of the results. The tests show a distinct trend in the direction indicated by the analysis, but for final conclusions as to the effect of variation in details of the reinforcement on the behavior of the beams more tests are necessary.

Rerolled Steel Investigation.

Owing to the fact that concrete reinforcement made from salvaged steel, usually old rails, is prohibited in nearly all public and private work now going on, an investigation was made to determine the suitability of such reinforcement. One of the main objections entered against rerolled steel is that it is subject to too much breakage in handling, and the tests made were such as would show brittleness, lack of ductility and the tensile properties of the materials.

Lots of steel from 10 different sources—5 rerolled steel and 5 bought under the specification that they be hard-grade new billet steel—were tested. The tests made were: (1) Tension tests of straight specimens; (2) and (3) tension tests of bent specimens; (4) impact tests; (5) bend tests made in an Olsen cold-bend testing machine; and (6) bend tests in a special bending machine. The tension tests of bent specimens were made on specimens from the same bars but bent in different bending machines to study the effect of the manner of bending on the strength of the steel.

With the exception of one lot of bars the rerolled steel showed tensile strengths which met the A. S. T. M. specifications for such material. The yield points and tensile strength of the new billet steel were generally too low to classify them as hard grade. The method of bending appeared to have generally only a small effect on the tensile strength and was generally less for specimens bent in the special bending machine than for those bent in the ordinary way. Only one lot of $\frac{7}{8}$-inch square rail steel bars failed to meet the bend test. Out of 21 bars of the lot nine broke before bending through 90°. The impact test was used to test the bars for brittleness. The blow used was sufficient to stress the bars well beyond their yield points. In no case did the bars break, but after the impact each showed a decided bend at the point where the blow was applied. The amount of the measured permanent deflection was approximately inversely proportional to the square of the yield point of the bars.

From the tests made it appeared that either rerolled or new billet steel with yield points up to 60,000 pounds per square inch which meets the tension and bend tests would be satisfactory for concrete reinforcement. From these tests it appears doubtful if rerolled steel having a yield point greater than 60,000 pounds per square inch can be bent to meet conditions in practice, but reinforcement not required to be bent should be satisfactory if it meets the tension test and suitable impact or bending tests to detect brittleness. No data were secured which indicated whether or not the same conclusion would apply to new billet steel of high yield point. While the tests were quite clear in their indications, the finality of the conclusions is limited by the fact that steel bars from only 10 sources were tested. To justify a more positive statement it is desirable that an investigation be made on specimens from a large number of sources.

Durability of Concrete in Alkali and Sea Water.

The third progress report on Durability of Cement Drain Tile in Concrete and Alkali Soils was issued as Technologic Paper No. 214 at the close of the fiscal year. This paper is now available for distribution.

An opportunity was taken during the year to inspect some of the concrete structures in sea water on the Pacific coast; the experimental concrete blocks installed in alkali sloughs at Montrose and Grand Junction, Col., in 1915, were also examined. The present condition of these blocks, as well as of the sea-water concrete, indicates the marked superiority of strong, impermeable concrete in resisting attack by these destructive agencies.

General Investigation of Building Stones.

Several years ago the bureau started an investigation to determine the physical properties of all the important stone deposits in this country. The object of this study is to establish reliable data on the various types, deposits, etc., for use in specifications. This work has necessarily proceeded rather slowly, due to the fact that only a limited amount of time could be given the subject. Considerable work has been done on limestone, sandstone, and marble.

The greatest problem in connection with the testing of stone is that of preparing the test specimens from the rough quarry blocks which are submitted as samples. Recently some very important improvements have been made in the bureau's stone-cutting equipment which makes possible the preparation of specimens with more facility, hence the cost of this part of the work is considerably reduced and the tests can be accomplished more expeditiously.

The work done during the past year has been concerned principally with granite, slate, and limestone. About 30 specimens of slate from the slate district of Pennsylvania have been tested for transverse strength, elasticity in bending, absorption, and effect of freezing. Granites from the following localities have been tested: Rion and Mount Airy, S. C.; Salisbury and Raleigh, N. C.; Lithonia, Pine Mountain, and Stone Mountain, Ga.; St. Cloud, Minn.; West Compton, N. H.; Graniteville, Mo.; Lincolnville and Vinal Haven, Me.; Prescott, Ariz.; Bethesda, Md.; and Cheland, Wash.

Freezing tests have been made on a considerable number of limestone samples. In these tests a sufficient number of freezings were made to practically destroy the stone. Some of the weaker specimens were disintegrated by 100 freezings, while others were not visibly affected by 500 freezings.

Another problem which has been started in connection with building stones is the cause and effect of efflorescence on masonry. Cases have been noted where disintegration occurred in connection with efflorescence, and it is believed that this is due to the formation of crystals in the pores of the stone near the surface. The effect of allowing a few different salts to crystallize in the pores of the stone has been studied and all have shown a tendency to disintegrate the stone.

Exposure Tests on Colorless Waterproofing Materials.

This class of materials is used principally for exterior application to masonry walls where it is desirable to prevent the penetration of water. There are numerous brands of these materials on the market and the bureau is frequently called upon for information concerning their value and relative merits. More than a year ago a series of tests was started to determine their effectiveness on limestone and their relative durability when exposed to the weather. A report was published on this series after six months exposure and the tests are still in progress. Recently the scope of the work has been extended to include three types of sandstone which vary in texture from coarse-grained stone to very fine-grained, compact stone. The object of this study is to determine if a given waterproofing material is equally effective on different textures or if it is necessary to vary the composition to suit the texture of the stone.

Elastic Pointing and Calking Materials.

These materials are for the purpose of permanently sealing up joints in masonry which are subject to slight movements from settlement of the building or thermal expansion. Ordinary Portland cement or lime mortars usually crack under such conditions, thus permitting the entrance of water. Seven commercial compounds which are claimed to remain plastic enough to take care of such structural movements are being tested on panels of limestone which are continually exposed to the weather. One course of the stone is so arranged that small relative movements can be produced, thus bringing a stress upon the pointing material. These tests are made on the exposed panels about once each month and the effect on the materials is noted. Other observations are made on the materials, such as their tendency to stain the stone, their ability to maintain a waterproof joint, weathering qualities, and general appearance.

Discoloration of Indiana Limestone.

The frequent occurrence of ugly discolorations on new limestone buildings has long been a source of annoyance to users as well as the producers of this popular building material. While it is not of general occurrence, its effect in marring the beauty of the structure has greatly detracted from the value of the stone, in the opinion of many architects. This bureau has been carrying out various experiments in the laboratory and on exposed panels of the stone for the past two years trying to determine a practical method of overcoming the trouble. The bureau's work along this line has developed some important facts in connection with the stain, as follows:

1. The brown discolorations which are frequently called iron stains are really due to the organic impurities in the limestone.

2. The impurities in the stone which give rise to the stains are not uniformly distributed throughout the entire limestone deposits or even in one ledge or one quarry. Hence, it is not possible to say that certain quarries produce stone which will not stain.

3. Some properties of the cement used in setting up the stone are largely responsible for the appearance of the staining element on the surface of the stone.

4. So-called nonstaining cements sometimes possess this property to a greater degree than normal cements.

5. Stains do not occur to an appreciable extent if water is prevented from leaching through the masonry.

The work along this line is now concerned with: (*a*) The study of the properties of various types of cement, (*b*) the feasibility of preventing the leaching process by means of colorless waterproofing materials, and (*c*) the study of the chemical phases of the staining process. The bureau's experiments indicate that the trouble may be overcome by the use of colorless waterproofing materials, but a more economical solution may possibly be found in a specially prepared or treated cement for setting the stone.

Concrete Tanks for Oil Storage.

This investigation was brought to a close in the early part of the fiscal year owing to lack of funds for its further continuance. The chief aim of the work, however, was acocmplished and reported briefly in the last annual report. Further work of value in connection with oilproofing treatments might have been carried out, but aside from a few long-time tests on one or two special treatments, the test of oilproofings was abandoned.

Stucco.

An investigation of the comparative value of various types of metal lath and wire fabric as a base of stucco has been undertaken during this fiscal year. Ten of the large stucco panels erected in 1916 have been replaced with new panels, on which an extensive series of strain-gauge measurements are being made. Some very interesting results have been obtained from these measurements, but a complete report will not be made until the panels are a year old. As a matter of interest it may be stated that a few minute cracks have developed on the new panels in such manner as to indicate that they result from strains set up by the movement of the underlying diagonal sheathing, notwithstanding the fact that the frame and sheathing were erected six years ago and are now thoroughly seasoned. This furnishes additional evidence in support of the bureau's recommendation that sheathing of frame houses which are to be covered with stucco should not be laid diagonally.

Study of Concrete-House Construction.

Supplementing the activities of the division of housing, the bureau has made an extensive study of concrete-house construction. The majority of the larger projects have been visited, and numerous smaller projects and individual houses have been inspected. The data are now largely at hand for a comprehensive report on the subject, in which the advantages and disadvantages of the concrete house will be fully discussed. From the information which has been gathered it is believed that the concrete house is worthy of more general consideration on the part of architects, owners, and builders, and that within the next few years the merits of this type of construction will be widely recognized.

Investigation of Sewer Pipe in the City of Los Angeles.

In the latter part of the fiscal year the bureau began an investigation of the condition of sewer pipes in the city of Los Angeles for the purpose of studying the effects of sewage and sewer gases on clay and cement pipes, both of which are now being extensively used in that city. In this work it is cooperating with the clay and cement pipe manufacturers and the office of the city engineer.

The program of the investigation involves the excavation and inspection of sections of pipe from laterals in various parts of the city, and the replacement of these with tested pipe for further examination. The major part of the work, however, consists in the installation of small sections of pipe in manholes in such manner that a part of the specimens will be submerged in the sewage and a part exposed only to the action of sewer gases. The exposure points have been selected in such manner as to cover typical conditions throughout the system, and at these points periodic analyses of the sewage and sewer gases will be made for the purpose of determining the concentration of ingredients which may be injurious to the pipes.

The real object of the investigation is to determine, from the chemical survey as outlined above, general relations between rate or extent of deterioration of pipes and concentration of damaging elements in the sewage and gases. The problem is a difficult one, not only on account of the extent of the work involved but more particularly because the field which it enters is as yet unexplored.

Air Analyzer.

The modified form of air analyzer as described in the last annual report has been found to extend the range of fineness determinations to a minimum size of separation of 0.01 mm. The most important work carried out during the year with the apparatus was the mechanical analysis of a series of English and American whitings for the ceramic division of the bureau.

United States Standard Sieve Series.

Some progress has been made in the selection of a suitable material for checking up the "sieving values" of the finer sieves of the series to supplement the microscopic measurements of the sieve cloth. It is probable that the standard cement-fineness samples will be entirely satisfactory for sieves finer than the No. 200. For sieves coarser than the No. 200 it has been found that samples of fine quartz sand can be prepared with the necessary uniformity, but the desirable range in gradation has not yet been established with certainty. The new circular describing these sieves will probably be issued during the coming year and will contain matter descriptive of their manufacture, use, and testing.

Standard Samples.

The bureau prepares and keeps on hand for issue standard-fineness samples of cement for checking up No. 200 sieves. They are supplied in two degrees of fineness and are issued in sealed glass jars, each jar containing about 160 grams, enough for three 50-gram sieve tests. Each sample is accompanied by full directions for its use. A nominal price of 50 cents, sufficient only to cover the cost of preparation, is charged for each jar. With these samples No. 200 sieves may be compared with the standards of the Government and correction factors determined. These samples are also used by the bureau in checking up its own sieves and in the standardization of No. 200 sieves submitted for certification. The two samples on hand at present are 46h–78.6 per cent passing the No. 200 sieve and 47c–89.2 per cent passing the No. 200 sieve. While there has been in the last year a decrease in the number of No. 200 sieves submitted for standardization, there has been a 50 per cent increase in the number of standard cement-fineness samples issued. This would indicate that the users of sieves are taking advantage of the standard samples to make their own standardization tests.

Caustic Magnesia Cement.

The calcinations of certain lots of foreign and domestic magnesites referred to in last year's report was completed during the early part of this year. All specimens were made and all but a few of the long-time specimens have been tested. All results confirm the earlier conclusions of the sensitiveness of this cement to the action of the aggregates. They also show that until a satisfactory regulator of setting has been developed it will be necessary to overcalcine the ore, as an ore calcined at such a low temperature as to produce maximum activity reacts so energetically with the chloride solution as to be valueless for cementing purposes.

During the year five large test panels of commercial magnesite stuccos were erected and are under observation. While being placed, laboratory test pieces of the stucco as used were made as well as test pieces made of the dry mixtures used, but gauged with 22° Baumé chloride solution in the laboratory.

All of the manufacturers known to the bureau were also requested to furnish samples of the various floorings manufactured by them which were to be used in determining the various physical properties of the commercial floorings. A generous reply was received and a large number of samples were obtained, on which all test pieces have been made. They are now being tested, and from the results it is hoped it will be possible to prepare specifications for resilient composition floorings.

Constitution of Portland Cement.

Some few tests were made on admixtures of calcium monoaluminate with Portland cement. It was thought that as the former had the property of very rapid hardening with a consequent high early strength, it would materially increase the early strength of the Portland cement. However, it was found that until about equal amounts of the two were used, the Portland cement gave the mixture a flash set unless about twice the usual amount of gypsum was used. When the latter procedure was followed in using a 90 per cent Portland and 10 per cent monoaluminate mixture, it was possible to increase the 24-hour strength of a Portland cement mortar about 100 per cent.

An investigation is now under way at a commercial cement plant in which the conditions of burning in one 125-foot kiln are being closely observed and at the same time the composition is being varied over wide limits. The resulting cement, if it meets the specifications, is going in with the other output of the plant. At the same time a large number and variety of test pieces are being made at the plant and duplicates will be made at different later periods at the bureau. The entire investigation is an attempt to study the effect of different degrees of burning in bringing about a different constitution from raw mixes of the same composition and to study the effects of the different constitutions and compositions on the physical properties of the cement.

General Concrete Investigations.

In cooperation with eight other laboratories and the American Society for Testing Materials an extensive series of concrete tests has been made to determine the effects of various accelerators. The one-year tests will be completed this summer.

The San Francisco branch has cooperated with the Bureau of Public Roads in studies of alkali soils and their effect on concrete roads. In particular, an intensive study was made of the Glenn County, Calif., alkali district, and a special report thereon was prepared for the Bureau of Public Roads.

Extensive tests have been made in studying the effect of hydrated lime in concrete subjected to various storage conditions. The results were embodied in a paper presented before the National Lime Association in June, 1922.

Test pieces have been made of various clays mixed with a special cement which has been placed on the market as a cement suitable for building roads from roadside clays. This test has not been completed.

Periodic examinations are being made of mortar specimens prepared last year from an aggregate of partially decomposed feldspar. This aggregate gave satisfactory tests at the end of the usual 28-day period, but at the end of one year the disintegration of some of the specimens is becoming very marked.

Various laboratories have requested information and working drawings of the flow table, an apparatus designed to measure the consistency of concrete mixtures. Further investigations are planned with a view to improving this device, and a table embodying certain new and desirable features is now being constructed.

Testing and Shipment of Cement for Government Purposes.

The quantity of certified cement packed and shipped under the supervision of the bureau's inspectors to Government projects was smaller than in the preceding year. The cement was used in connection with the usual building operations of the Government, such as river development, irrigation projects, bridges, Army camps and buildings, naval bases, Panama Canal, island possessions, hospitals, educational institutions, fisheries, public roads, lighthouses, scientific buildings, and District of Columbia construction.

Among the branches of the Government served were: The War, Navy, Treasury, Interior, Agricultural, Commerce, and Labor Departments; the Marine Corps; the Office of Public Buildings and Grounds; the government of the District of Columbia; the Panama Canal; the Shipping Board; the Piscataqua River Bridge Commission; and the Smithsonian Institution.

SHIPMENTS OF TESTED CEMENT (BARRELS).

Month.	1919–20	1920–21	1921–22
July	144,421	99,849	71,416
August	168,141	63,625	63,853
September	138,164	52,460	67,528
October	133,462	93,532	72,355
November	118,648	75,305	46,809
December	80,939	59,389	44,625
January	79,894	24,890	27,624
February	66,285	29,605	21,476
March	70,835	57,515	42,969
April	75,590	54,054	43,970
May	53,798	59,129	45,156
June	56,605	89,698	46,064
Total	1,186,782	759,051	593,845
Rejections	125,919	86,652	[1] 51,124

[1] In addition, 6,200 barrels were withdrawn by manufacturers when the early test results were available.

Inspection was made at 40 shipping points located in the District of Columbia and the following 15 States: California, Colorado, Indiana, Iowa, Maryland, Montana, New Jersey, New York, Oklahoma, Pennsylvania, Texas, Utah, Virginia, Washington, and West Virginia.

The foregoing inspection does not cover all the mills furnishing cement on Government orders, but only those where conditions and location permit the service.

In addition to the approximately 1,100 samples tested in connection with the foregoing inspection, the laboratories tested 186 samples submitted by Government offices for specification tests. Ten samples were received for comparative tests and special investigations. Two imported cements and 10 special cements were tested.

Samples of cement submitted from an official source represented several large lots of cement which had been in storage for some months. A portion of these samples developed a tensile strength considerably below the specification requirements. On the assumption that the cement was satisfactory when purchased, this case emphasizes the need of making a retest after any considerable storage period.

LIME, GYPSUM, AND SAND-LIME BRICK.

Hydrated Lime in Concrete.

The outstanding feature of the year's work on this subject is the determination of the fact that when lime, but no water, is added to concrete the strength is increased and the flow is decreased. These effects are exactly the opposite of those obtained when water, but no lime, is added. When both lime and water are added, they tend to neutralize each other, so that the net effect may be plus, minus, or zero. This work has been done in cooperation with the cement section. A new machine for measuring the effect of lime on the workability of concrete has been developed and turned over to the cement section for further experiment.

Panel Tests of Lime Plaster.

In order to ascertain the impurities which may cause unsoundness of plaster, several suspected materials were prepared and screened to predetermined sizes. These were then mixed with hydrated lime and used as the finish coats of plaster panels. Ninety-eight such panels have been erected and are now under observation at the bureau. The materials for this work were furnished by the National Lime Association, the labor by the International Plasterers Union, and the supervision by the National Association of Plastering Contractors.

Measurement of Plasticity.

The plasticimeter designed by the bureau to measure the plasticity of lime is now on the market. Four of these instruments have been sold, to date, and the bureau is calibrating them.

Measurement of Sand-Carrying Capacity.

Where sand is added to lime to make plaster or mortar, it is the usual custom to continue adding sand until the mixture " feels right." The plasticity of the mortar seems to be the final criterion. The plasticimeter has therefore been made use of as a means of measuring the sand-carrying capacity of lime. The results obtained to date are quite satisfactory, so that all that now remains is to obtain a sufficient quantity of data to warrant a recommendation.

Making Hydrate Plastic.

Hydrates which are sufficiently plastic to be used for finish coats differ in plasticity only from those which are not so plastic; no chemical or physical differences can be detected. The bureau has found that by grinding a nonplastic hydrate with 1 per cent of a desiccating agent, such as quicklime, it can be made plastic. A patent on this method, taken out by F. C. Welch, has been dedicated to the free use of the public.

The Constitution of Hydrated Lime.

It is known that the maximum temperature reached during the slaking of lime has a profound effect on the physical properties of the hydrate. An investigation has been undertaken to ascertain whether the properties noted are dependent upon the way in which the water is contained in the hydrate. No results are available as yet.

Properties of Commercial Limes.

In order that the bureau may assist manufacturers by giving them a fair report on the quality of their products, and assist the users in the proper selection of the material they need, the bureau has undertaken to measure the more important physical properties of all commercial limes. These properties include plasticity, sand-carrying capacity, time of set, yield, shrinkage, and tensile strength. Some 20 samples have been tested to date.

Action of Lime on Clay.

It is known that lime sometimes changes the properties of a clay soil so that it will not bake when dry or get sticky when wet. This reaction is being investigated to see if it can be brought under efficient control.

Properties of Lime-Cement-Sand Mortars.

The addition of lime to cement mortars is becoming quite customary, but how much lime to use is still an open question. To answer it, measurements are being made of the plasticity, time of set, yield, shrinkage, and tensile strength of mixtures of lime, cement, and sand in many different proportions.

Quick Setting of Lime Plaster.

It is sometimes desirable to be able to exercise some control over the time of set of lime plaster. Five or six ways of doing this have been worked out, and are now being investigated as to their relative costs and the keeping qualities of the product.

Adhesion of Gypsum Plaster to Concrete.

Preliminary investigations led to the belief that any lack of adhesion of gypsum plaster to concrete is probably due to a difference in the coefficients of expansion of the two materials. A study of the expansion of gypsum plaster as affected by its content of sand, its consistency, and other factors was, therefore, made. The data so obtained made possible the production of a gypsum plaster having the same expansion as a given concrete. Such a plaster has been applied to concrete and is now being tested to see that it adheres properly.

Effect of Temperature of Calcination on the Properties of Calcined Gypsum.

This research has been under way for some years. This year it has taken the form of an investigation of the properties of dead-burned gypsum. Under the name of Estrich gypsum this material is widely used in Europe, but the nearest approach to it on the United States market is Keene's cement. Further information about this material may lead to the development of its manufacture in this country.

Pottery Plaster.

This is a form of calcined gypsum which is used in making molds for casting pottery. Some time ago the bureau was asked by a user of this plaster to develop a way to utilize his worn-out molds. This can be done by regrinding and recalcining the material, but, under ordinary conditions, it is cheaper to buy fresh material than to work up the old. The problem was, therefore, transformed into one of "casehardening" the molds, to make them last longer. Several methods of doing this have been developed and are now being tried out in the ceramic division.

Determination of Anhydrite.

Anhydrite is an impurity frequently found in gypsum, but the quantity of it is not accurately indicated by ordinary chemical analysis. Since small amounts of it may be quite harmful where the gypsum is to be used for certain purposes, a simple and accurate means for its determination becomes desirable. The heavy liquid method of separation, and also the petrographic estimation, are being tried.

Effect of Clay in Gypsum.

It is the custom in some localities to add a small amount of clay to calcined gypsum in the manufacture of wall plaster in order to make it work more smoothly. Opponents of this practice claim that the clay is deleterious to the quality of the hardened plaster. The bureau has undertaken to ascertain the facts in the case.

Measurement of Consistency.

There are almost as many ways of measuring the consistency of a plastic material as there are materials. Much confusion would be eliminated if one instrument could be used for this test, even though the different consistencies desired might require different readings on the instrument. Furthermore, it is generally conceded that no instrument now in use measures consistency only, but always consistency plus something else. Under these circumstances, the need for standardization is obvious and the bureau is engaged in a preliminary study of the subject.

Weatherproof Gypsum.

Gypsum has been used for exterior work, but is not recommended for permanent structures. A great many ways of making it weather proof have been developed, and samples treated in these ways are now exposed to the weather.

Tests of Gypsum Plaster Boards and Wall Boards.

In order to obtain the data necessary to prepare specifications for these materials samples from nearly every manufacturer were collected and tested for strength, weight, and thickness.

Properties of Plastering Sands.

The attempt to write a specification for plastering sand was finally abandoned as economically futile. Instead the bureau has undertaken an investigation of the properties of plastering sands, with a view toward guiding the contractor in the best utilization of the materials available. This has led to the measurement of the physical properties of lime and gypsum plasters, made with different kinds of sand.

Cooperation.

American Society for Testing Materials.—This section holds the secretaryship of the brick committee of the American Society for Testing Materials, and the incumbent was designated to represent the society at the conference of the Department of Commerce on the simplification of sizes and types of paving brick.

The lime committee, in which this section holds two subcommittee chairmanships, has revised its specifications for structural quicklime and structural hydrate, and brought out five new specifications for different kinds of chemical lime.

This section holds the chair of the gypsum committee, which has this year revised all of the seven specifications it has issued, and has started an investigation of the use of anhydrite in Portland cement, and of the fire resistance of gypsum products. One of the meetings of the committee was held at the bureau.

As a member of the committee on testing methods, this section has taken an active part in the discussion of the measurement of consistency.

Bureau of Standards plastering conference.—This body, composed of representatives of the various industries involved in plastering, was formed to assist the bureau in the preparation of a national plastering code. A great deal of correspondence, and several meetings, placed much valuable information at the bureau's disposal. This year this information has been worked up into a report, which is nearly ready to be submitted in tentative form to the members.

Interdepartmental conference on chemical lime.—This body, composed of Government employees from the various bureaus interested, is organized to assist the Bureau of Standards in preparing specifications for, and collecting information about, the quality of lime required for different chemical uses. It has published two specifications, has five or six more in preparation, and has commenced the preparation of four technical articles.

National Lime Association.—The bureau keeps in close touch with this association of manufacturers, which maintains a fellowship in the laboratory. Their board of directors met here in December. A member of the section attended their annual meeting in Cleveland in June.

Gypsum Industries Association.—The fellowship which this association maintains at the bureau assures close cooperation between the two organizations. Many of the members of the association are active in the work of the gypsum committee of the American Society for Testing Materials, which met at the bureau in October, and in conjunction with a monthly meeting of the association in Chicago in March.

Sand-lime Brick Association.—Contact with this association has been maintained through the brick committee of the American Society for Testing Materials and through the attendance of a representative of this section at the annual meeting of the association at Dayton in February.

Visits to plants.—During the year members of the section have visited 1 lime plant, 4 gypsum plants, and 2 sand-lime brick plants.

RUBBER.

New Equipment.

The bureau's experimental rubber mixing mill was inadequate for the amount of work necessary, and a mill with a much greater capacity is now being installed. This addition will make it possible to do experimental compounding on a much larger and more accurate scale.

A sifting machine was installed so that all the ingredients used can be of the proper fineness.

A new machine for buffing rubber samples was installed, which was designed in the laboratory and built at the bureau. It is now possible to prepare test samples of all grades of rubber goods satisfactorily and more efficiently.

Power Losses in Automobile Tires.

The investigation of the power losses in automobile tires has been continued. A preliminary report covering the results obtained will be published as Technologic Paper No. 213.

An endurance tire-testing machine has been installed and is in continuous operation. Data are being compiled from the results of the dynamometer and endurance machine tests with the intention of working out a service test for tires which can be incorporated in the Government specifications.

This work is being done in cooperation with a committee representing the Rubber Association of America.

Asbestos Packing.

At the request of the Panama Canal the properties of compressed asbestos sheet packing were studied. The results are to be used by the Federal Specifications Board in preparing specifications for this class of material.

Insulating Tape.

An investigation of the properties of rubber and cloth-frictioned tape is now being made in conjunction with the electrical division. The results of all this work are to be used in cooperation with the Federal Specifications Board for the development of standard specifications.

Insulated Wire.

The Signal Corps of the Army requested that a complete study of insulated wire be made, and this work is in progress.

Rubber Heels and Soles.

In cooperation with the leather section standard heel and sole compounds made at the bureau are being compared with commercial samples. A complete series of artificial and normal aging tests is being conducted.

Rubber Tubing.

The experimental rubber laboratory has been very successful in making all sizes of tubing to meet the bureau's needs. About 500 pounds was made this last year. In addition, this work has made it possible to accumulate data of value in the drawing up of standard specifications for rubber tubing.

Jar Rings for Canning.

This investigation is now continuing into the second year. Its object is to determine the aging qualities of jar rings in actual use and in storage, and to revise the existing specifications as found necessary. This work is being done in cooperation with the States Relations Service, Department of Agriculture, and a graphical report of the results to date was sent out to the cooperating manufacturers.

Compounding Ingredients.

One of the most vital problems that confront the rubber manufacturers is to find a rapid method for determining the life of a rubber compound. About eight years ago the bureau started some work on the Geer test, which consists in exposing samples to the effect of heat in a properly ventilated oven for varying periods. The results, which are contained in the new edition of Circular 38, The Testing of Rubber Goods, indicate that it is desirable to continue this work.

As a result the bureau has planned an extensive investigation of the properties of rubber and the effect of ingredients on the life of rubber compounds, under various conditions of storage. Some preliminary work was started in which the value of some substances that have not been used in the compounding of rubber is to be determined. One of these is slate dust, submitted by the Bureau of Mines, Department of the Interior. A preliminary report was made, which indicates that it can be used as a rubber filler.

Rubber Analysis.

An important part of the bureau's work is the analysis of rubber goods purchased by the various Government departments. The number of substances that can be used is constantly increasing. The properties of many of these are such that the usual methods of analysis give incorrect results, thus necessitating additions to or revisions of the existing methods.

The bureau has done considerable work the past few years in attempting to evolve a method of analysis which will give accurate results in all cases. It is hoped to find a solvent which will dissolve the rubber compound and permit of the separation of the fillers unchanged. At first cresol was used, but, in addition to being poisonous, inaccurate results were obtained. Later cymene was used and much better results obtained. At the present time a mixture of oils seems to be most satisfactory.

In cooperation with the committee on methods of analysis of the rubber division, American Chemical Society, the bureau has been doing considerable work on the determination of alcoholic-alkali extracts and the proper drying temperature for the different extracts. The bureau's methods formed the basis of those recommended by the committee for adoption by the rubber division and eventually by the society.

Miscellaneous Materials.

Under this heading are included not only a large number of rubber articles, such as hose of various kinds, belting, valves, packings, rubber-covered wire, jar rings, rubber bands, etc., but also many materials other than rubber. As typical examples of the latter may be mentioned asbestos gaskets, canvas belting, linoleum, flax shot lines used by the Coast Guard, sash cords, hack-saw blades, shoe laces, etc. Special equipment has been developed for testing some of these materials and in such cases similar tests are made for manufacturers upon request. The usual tests of miscellaneous materials were made for the General Supply Committee, the results being used as a basis for the award of contracts covering the fiscal year 1922–23. At the present time the bureau is cooperating with the rubber committees of the Federal Specifications Board.

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Cooperation.

It is the bureau's policy to cooperate to the fullest extent with manufacturers with the view of having the requirements of specifications conform in every way to the best manufacturing practice. When all available sources of information have been utilized a specification is prepared in tentative form and presented for discussion and final adoption at a conference of the Federal Specifications Board. In this way the requirements of a specification when approved are such as to insure a commercial product of satisfactory quality and well adapted to meet the conditions of service imposed by the Government.

The following examples illustrate the service rendered the various Government offices by the bureau acting in an advisory capacity.

The bureau has been cooperating with the Bureau of Engraving and Printing in the development of more suitable rubber-covered inking rolls. Considerable work was done for the Chemical Warfare Service on the artificial aging of gas-mask material. An investigation of the necessary properties of teat-cup rubbers has been started for the Dairy Division, Department of Agriculture.

In addition the bureau works in close cooperation with the Rubber Association of America.

Specifications.

Bureau of Standards Circular No. 155, Specifications for Pneumatic Tires, Solid Tires, and Inner Tubes, was adopted by the Federal Specifications Board for use by all Government departments.

The bureau assisted the Federal Specification Board in drawing up the following specifications:

- General specifications for mechanical rubber goods.
- Cotton rubber-lined fire hose.
- Rubber bands.
- Rubber tubing.
- Rubber jar rings.
- Water and wash deck hose.
- Gas hose:
  - *a*. Acetylene-hydrogen hose.
  - *b*. Oxygen hose.
- Engine tender hose.
- Air-brake and signal hose and gaskets.
- Steam hose.
- Suction hose.
- Pneumatic hose:
  - *a*. Rock-drill hose.
  - *b*. Pneumatic-tool hose.
- Diver's hose.
- Dredging sleeves.
- Chemical engine hose.
- Spray hose.

LEATHER.

Sole Leather.

The investigation to determine the comparative durability of sole leather filled with sulphite cellulose extract and sole leather filled with the ordinary tanning materials was completed and the results will be published as Technologic Paper No. 215.

As a result of these tests the following observations can be made regarding the sulphite cellulose extracts used in this investigation as fillers for sole leathers. (1) Leather filled either partially or entirely with sulphite cellulose extract is as durable as leather filled with the ordinary tanning materials, such as chestnut and quebracho. (2) As reflected by the chemical analyses this extract is as firmly fixed in the leather as these vegetable tanning materials. (3) The use of such a material instead of chestnut and quebracho would conserve these materials for use in the actual tanning process for which they are suitable and for which sulphite cellulose extract has not been successfully used. (4) It is probable that this material could be used as a filler in place of the more soluble glucose, thereby producing a more waterproof leather. (5) Leather filled with this material can be made of as light and uniform color as leather filled with the ordinary materials. This was the case for lots Nos. 1 and 2. There was a slight difference in the color in lots Nos. 3 and 4, the leather filled with sulphite cellulose extract was a little darker. (6) Using this material as a filler has no more effect on the aging of the leather than the ordinary materials, since samples of these leathers, which have been in the laboratory for over two years, are still in a satisfactory and pliable condition.

A detailed study is being made of the relative merits of chrome-tanned and vegetable-tanned sole leather. This investigation has included the securing of information and data regarding the water resisting qualities of differently treated chrome sole leathers, the ability to take an edge finish, comparative yields for the two types of leather, and a study of the variation in chemical composition of chrome sole leather. In addition, a large number of service tests are in progress to determine: (1) The comparative durability of vegetable and untreated chrome sole leather tanned from the same hides; (2) the comparative durability of untreated chrome sole leather and the same leather treated with paraffin; (3) the comparative durability of vegetable leather and chrome sole leather treated with paraffin; and (4) the comparative durability of vegetable-tanned sole leather and chrome-tanned sole leather made from the same hides when the latter is filled with greases and mineral matter.

Additional machines have been secured during the fiscal year so that it is now possible to receive the whole sides of sole leather for test and die out, skive, and attach the soles to shoes under close laboratory observation. An expert repair man has been employed in the laboratory during the greater part of the year.

Synthetic Tanning Materials.

Investigations were started to determine the suitability of various synthetic tanning materials for use in the making of leather. This work is being done by actual tanning experiments. Among the points being considered are the soluble effects of the various materials, their evaluation, penetration under different conditions, and their effects upon the physical quality of different leathers.

Shark Leather.

The work on this subject has been completed and the results are to be published as a joint publication with the Bureau of Fisheries. It is considered that the purpose of this work has been accomplished and the facts will be presented for such commercial application as may seem desirable to those interested. As a general conclusion it can be stated that the shark leather has considerable merit.

Rubber Heels.

The use of rubber heels on shoes has increased to such an extent that the matter is of vital interest to the shoe manufacturer. At the request of manufacturers the matter of the standardization of shapes and sizes for rubber heels was proposed by this bureau. Through its efforts the rubber heel manufacturers and shoe manufacturers have been brought together and considerable progress has been made toward standardization.

Experimental Tannery.

During the year laboratory tanning equipment has been designed and built at the bureau. This equipment consists of 20 rockers, 30 layaway vats, 4 paddles, 4 drums, beam, soaks, drying loft, and miscellaneous materials. Pieces of heavy leather 8 by 10 inches can be used in experiments and whole skins can be used for experiment with light leathers.

Specifications.

Specifications for shoulder straps and carrier's tie straps were developed for the Post Office Department.

A specification for vegetable-tanned leather belting developed in cooperation with the manufacturers was presented to the Federal Specifications Board. After some revision by the subcommittee on leather it has been adopted for use by the departments and independent establishments of the Government. In connection with the development of this specification considerable data were obtained regarding the physical properties of belting leather and the requirements of existing specifications were studied. It is hoped that large corporations and municipalities will seriously consider the use of this specification as a step toward standardization.

Specifications for lace leather and upholstery leather are now being developed.

Sole leather is a difficult product to cover satisfactorily by a specification. Work has been started on the subject in cooperation with the tanners, and special leather is being furnished by the Tanners' Council for investigations in this connection.

Cooperation.

The Tanners' Council, the Leather Belting Exchange, the National Boot and Shoe Manufacturers' Association, and the Rubber Heel Club of America have actively cooperated with the bureau during the fiscal year.

Committee work on the analysis of chrome leather has been done in cooperation with the American Leather Chemists' Association.

In addition, a large number of manufacturers and tanners have furnished materials for use in the experimental tannery and also furnished leather for special investigations. This cooperation has been greatly appreciated.

TEXTILES.

Standardization of Textiles.

The progress made on work classified under this general heading was very satisfactory, considering the number of items taken up, due to the degree of cooperation extended by the manufacturers and users of the materials. It is necessary to view the subject from the standpoint of the individual materials in the textile trade, hence no one group of manufacturers could materially assist in the standardization of textiles in general. The materials under consideration were selected either as a result of the direct requests of a group of manufacturers or to assist the Government in the purchase of textile materials. In either case the first move has been to establish direct contact between the user and manufacturer, so that their opinions could be collected and an outline of the work established which would be of maximum helpfulness. This, in itself, has been a difficult task in some cases because of the necessity of obtaining unanimity of opinion as to what is desired and required. Approximately 10 committees have been named especially by the manufacturers to work with the bureau on this subject, while others are being developed.

Aside from the projects for standardization discussed in the subsequent pages, the following products have been considered but have not progressed to the same degree of completion: Knit goods, electrical cotton yarn, cement bags, sugar bags, shade cloth, brushes and brooms, and sash cord. The work on these projects will, of necessity, continue until more data are available and until some of the work almost completed can be finished.

Generally speaking, the project of standardization has been taken very favorably by the entire trade.

Numbered Duck.

The first material considered for standardization was numbered duck. A committee was appointed from the Cotton Duck Association; samples were submitted from the stock of a number of manufacturers; these samples were tested at the bureau; and results of tests were made available for a series of conferences held at the bureau. Specifications were finally drawn up which were considered ideal for both commercial and Government purchases. These specifications have been finished and accepted both by this bureau and the Cotton Duck Association and are now ready for the printer. The specifications will be presented to the Federal Specifications Board for adoption, completing final action by the Government as a whole on these specifications. The Cotton Duck Association has taken the initiative in having the general form of the specifications and results of tests accepted by the entire trade. The final work along this line will produce specifications and methods of test which will be considered standard, giving, perhaps, the only good example of combined standard material and test in the textile trade.

Hosiery.

Hosiery is next in importance in the standardization project, considered from the standpoint of the amount of work performed and the degree of cooperation and interest shown throughout the trade. The National Association of Hosiery and Underwear Manufacturers welcomed the project and are following the matter very closely. Due to the present condition of the trade, in which no methods of test and no information on the technical manufacture of hosiery are now available, the project will take considerable time for investigation before satisfactory standards can be adopted.

Cordage.

A direct request from the Cordage Institute, which includes about 85 per cent of the hard-fiber manufacturers, led the bureau to take up the standardization of cordage. This work will cover standard specifications for commercial and Government use, standard methods of test, and development and standardization of a series of further tests to indicate the performance of the rope in actual service. This work will not only bring about satisfactory standardization, but it is a step toward proper selection of a material for a definite service.

Sheeting.

From direct contact with the manufacturers, users, and laundries it was found that the question of the standardization of sheetings was very important and vital to those interested. At a conference held in New York there were represented organizations of manufacturers, laundries, selling agents, dyers and cleaners, and hotel men. The meeting was not successful in the formation of a joint committee to consider the problem. The laundry men are especially interested in improving the quality of domestic sheeting in conjunction with the effort of the Government to standardize sheetings bought by the Government. The manufacturers have submitted a large number of samples as individuals, which have been tested. A recheck is now being made on the physical properties. Results of these tests will enable the Government to draw up a satisfactory specification for Government use.

A suggested problem in connection with this work is the development of a standard test to indicate the probable life or number of washings that any one sheeting can stand. This is being done in cooperation with the Laundry Owners' National Association.

The American Home Economics Association is interested in the project for educational reasons.

Press Cloth.

The results of the bureau's work on the determination of standards of moisture content and oil percentage of hair press cloths which were requested by a large user of this cloth were presented to a committee of manufacturers and users appointed by the president of the Interstate Cotton Seed Crushers' Association, the membership of which includes most of the users and manufacturers of this product. The members of this committee were located at different parts of the country and at first the work was carried on through correspondence, which lengthened the time required to bring the problem to a close. In an effort to settle the matter, the bureau invited the committee to come to its laboratory for a conference. Their work was correlated and submitted to the annual meeting of the association. The bureau's final report, which was later prepared, reviews the need for the problem, the difficulties involved, then outlines a method of procedure, and suggests standards for oil and moisture content. It also presents a form for insertion in contracts which will enable adjusting penalties for noncompliance in accordance with the use and price.

Conveyor Belting.

This work was taken up at the request of the Post Office Department in order to obtain data which would enable the Postal Service to select the most suitable belting for their service. The question of the number of stitches, the stretch, and surface impregnation appears to be of great importance.

In connection with the purchase of 7 miles of belting for the Chicago post office by the Post Office Department, samples were submitted to determine a few of their physical properties. The results of this work will be of great assistance in connection with the whole subject.

Heat-Retaining Properties of Fabrics.

Apparatus has been designed and set up in the bureau's humidity room for determining the comforting value of blankets. So far it has been found necessary not only to measure heat transmission but also air permeability and water-vapor permeability of the specimens, for each has an important bearing on the final solution of the problems involved. Thus apparatus of new design, which has been planned to eliminate errors of former apparatus and for greater range of application and flexibility of use, has been set up for obtaining data on all three of these interrelated properties of blankets.

Among the features of this apparatus is provision for compensating for edge and bottom heat loss, tensioning the specimen under test to bring it to a state of tautness which will make the results on different specimens comparable, and adjustability for testing in horizontal, vertical, or other positions. This latter provision has much to do with the freedom of mobility of the enmeshed air.

Blankets or textile products should be thought of as being relatively loosely constructed fabrics, enmeshing air and a certain degree of moisture content, which is relatively free to move or circulate, thus causing the different fabrics to vary widely in their capacity to retain heat or transmit heat.

The outstanding considerations which have been borne in mind dealing with this research fall into three phases of the problem, viz., (1) the human side in which the natural temperature of, and matter and heat dissipated from, the human body has to be reckoned upon as governing the comfort of the individual; (2) the weather or humidity conditions from without, which have to be insulated effectively from rendering discomfort to the individual; and (3) the blanket, covering, or fabric itself, which acts as the protector or insulator between the body and the elements, has to be studied physically and structurally to obtain the reason for its characteristic functioning in rendering its service as bedding or clothing. A correlation of data obtained on these three phases of the subject will lead finally to a satisfactory solution of the problems involved and to ratings which manufacturer or mechant may cite as standards in disposing of his products.

Thus far this research has been more useful in the direction of standardization of apparatus for developing satisfactory test methods than in the furnishing of results which can be applied immediately for purposes of the industry.

However, certain fundamental considerations have been studied and cared for in the new apparatus which have been partially or totally omitted in similar investigations heretofore conducted and will undoubtedly lead to more concordant results in the future. A preliminary publication is being worked up at present which will present the plan, progress, and some test data pertaining to this subject. The investigation is of wide commercial and domestic importance.

Physics of Balloon Fabrics.

At the request of the engineering division of the Air Service an investigation was carried out on the physical properties of cotton cloth to determine what factors in the manufacturing processes affect such properties as are of importance in a cloth to be used in the production of balloon fabrics. In the course of the work, 70 different specimens of cotton cloth were woven in the experimental cotton mill, where the details of manufacture could be completely supervised.

The same fiber was used to spin yarns, differing in yarn size, ply, and twist, and these yarns were woven into cloths containing various numbers of threads to the inch. The effect of these various factors on the properties of the cloth was studied and applied as far as possible to the present standard grades of balloon cloth.

Low-Grade Cotton.

The progress on the investigation of uses for low-grade cotton can be considered very satisfactory, as the problem is a difficult one and requires not only laboratory tests but the cooperation of the producer, machine builder, manufacturer, and user. It is now the practice in some foreign countries to use not only the by-product of the manufacturing processes but also the low-grade material produced in the fields, and for several years past there have been unsuccessful efforts made to introduce it in this country. The principal reason for failure is a lack of understanding of the possibilities of this material, brought about because the parties interested have never come together as a unit to discuss the problem.

A number of fabrics have been made from low-grade cotton introduced for different purposes, but these have failed because of the price of the material, which has been manufactured on the same machines and with the identical organizations used for high-grade fabrics. The cost of manufacturing, which is one of the important factors, thus became prohibitive.

The preliminary work in the laboratory can be considered complete. The bureau's plan is to secure large quantities of the materials to be manufactured in a commercial way. At first considerable lack of cooperation was manifested on the part of the grower; accordingly the work has been delayed so that it will be necessary to continue it into the next fiscal year. The bureau has now obtained the aid of the cotton growers through the Interstate Cotton Seed Crushers' Association.

Tent and Awning Duck.

In line with the bureau's policy of aiding in settling disputes caused by misunderstandings between various industrial organizations, the Cotton Duck Association and the National Association of Tent and Awning Manufacturers were asked to attend a joint conference in Washington to clear up a misunderstanding which has existed for some time on the question of a standard method of expressing the weight of a fabric. The existing method of expressing weight has caused considerable confusion to the tent and awning manufacturers, and they have attempted to secure legislation which would enable them to base the weight of material on their standard width of 29 inches. Reports of the two conferences which these associations have held in New York following the conference in Washington indicate that the suggestion of the bureau to adopt a standard basis of 36 inches for width would be accepted.

Pima Cotton.

A direct request was received from growers of Arizona Egyptian cotton (usually called Pima cotton) for physical tests and actual manufacturing data. Such information would enable them not only to submit facts to prospective users but also lead to an understanding as to just what their fibers were capable of, and probably to improved methods of growing. This unusual request indicated the desire of this group of growers to improve and to understand their material. The investigation is a long one and will probably continue for a period of two years. Such an investigation must take into consideration all other fibers, domestic and foreign, and any other facts which are likely to be of value.

The bureau's preliminary investigation was started using the fiber in a material and in a place where actual data could be collected. The fibers were spun and fabric made in the experimental cotton mill, producing a duck made according to the specifications of the Post Office Department. The material is now undergoing a service test for one year as railway package pouches. The purpose of this investigation in connection with the Post Office Department is to get a relation between the serviceability of the usual average staple cotton and this long-staple Pima cotton. The construction of the two materials is identical, the only variable being the length of the fiber. This will give a relative value in regard to the increased serviceability obtainable with increase in staple length.

The second step taken in this investigation was to obtain relative figures on the spinnability and serviceability of yarns of very high yarn numbers. The bureau succeeded in reaching a 200s yarn, though of course yarn of this number has no commercial value. The usual limit of ring-spun yarns in this country is approximately 80s, and this has been reduced in recent years to approximately 60s, the limit of fineness being determined by the desire of the public for fine materials.

The objectionable feature of this material has been the neppy nature of the yarns when spun. It is noted that the matter of settings speeds, and adjustment of machine parts affects to a very large extent the degree of neppiness of these yarns, making it necessary for the manufacturer to have exact information on the organization (machine adjustments, etc.) for this particular cotton. Actual figures are now being obtained.

Data are being collected from mills now using this cotton which it is hoped will in another year enable the bureau to submit a report containing experimental and commercial data and a standard outline for testing the uniformity of and degree of satisfaction which can be obtained from all long-staple cottons.

Abrasion of Fabrics.

An investigation of the workability of the design of apparatus used for obtaining the abrasive properties of fabrics is now under way and facts concerning the machine are being obtained. Most of these data are not of a sufficiently exhaustive nature to warrant definite conclusions. Few of the bureau's developments in the line of testing have caused such widespread interest as this abrasion test, and, because of this interest, it is thought that only work of an exhaustive character should be published. It is found that the abrasion test, besides forming an individual study itself, may be combined with a number of other investigations, thus securing additional facts.

The first publication on the subject will be prepared and submitted to a technical committee for criticism and for a discussion of the advisability of adopting it as a standard abrasion test.

Cloth for Federal Trade Commission.

In the course of the fiscal year the Federal Trade Commission requested determination of the actual per cent cotton and wool in approximately 1,100 samples of clothing material. The samples were collected by the Federal Trade Commission from various manufacturers and retailers in different parts of the country. The reason for the collection of the data is not definitely known, but it is understood that the Federal Trade Commission is desirous of obtaining data on the actual amount of mixed and pure wool goods now made and purchased by the public.

Cartridge Bag Cloth.

An investigation was made on a large quantity of silk fabric used in cartridge bags to determine whether or not the stock held by the Government would deteriorate in storage. Information was needed as to whether the material should be held to avoid great financial loss because of the lack of a sufficient market, or whether it should be sold at a very low figure because of future deterioration. Approximately 9,000,000 yards, worth $6,000,000, were involved. No conclusions were drawn from the material because the samples submitted were not taken at periods sufficiently far apart to indicate whether or not the material would deteriorate. In December a large number of tests were made on the material, and it was suggested that further tests be made in six months and in a year. It is expected that additional samples will be received for test, and at that time exact statements as to the deterioration of the material can be made.

Fishlines.

At the request of the Bureau of Fisheries a short study was made to find a better treatment of fish nets to increase the resistance to water deterioration and to develop technique for testing the relative merits of the various preservatives. The investigation included shrinkage, stiffness or pliability, increase in weight, stretch, strength, and wearing qualities. A number of these tests are being made in the laboratory of the Bureau of Fisheries, where the data will be compiled. This study should result in a better quality of net as well as a financial saving to the fishing industry.

Fasteners for Cartridge Belts.

As the request of the Quartermaster General of the Army an investigation was carried out to determine the usefulness of two types of cartridge-belt fasteners. The essential difference in the two types was in the formation of the spring. Special apparatus was designed to reproduce the actual action of fastening and unfastening the two parts in service. Results of tests showed that one type was greatly superior to the other in respect to the total number of fastenings and unfastenings. This investigation points out the great value of special tests and actual investigation before reaching conclusions.

Lead Lines.

Another short investigation was carried out in cooperation with the Coast and Geodetic Survey on the comparative endurance of several types of lead lines used in that service. These lead lines are usually made from flax fiber and are used to obtain soundings when a ship is entering a port or coming to anchor. Very complete tests were made to indicate the construction and physical properties under different conditions.

Effect of Washing on Sheeting.

An investigation was made for the American Laundry Machinery Co. to determine the effect of sours used in the laundering process on the physical properties of sheeting. The tests were for construction, breaking strength, and resistance to tear for different types of sours and for 3, 5, 10, 15, and 20 treatments. Results of this work are to be compiled by the company as a purely research matter.

A second part of the investigation was to determine if the joint use of sizing with the sours had any greatly deteriorating effect on the physical properties. Because of the great distortion of the samples submitted no definite conclusions could be derived.

Suiting.

A short investigation for a large manufacturer of suitings was made to determine the effect on woolen fabrics of sponging and drying at high temperatures. The investigation was made to ascertain if it was possible to decrease the time necessary for sponging and drying by increasing the temperature of the dryers. The maximum temperature used was 220° F., and results showed that no marked depreciation in properties of the material had taken place. A report was sent showing the results of tests, methods of test, and conclusions.

Printers' Blankets.

This investigation was started during the last fiscal year to devise some method of measurement which would assist the Bureau of Engraving and Printing to describe the desirable properties of felts used for the printing of paper money. The specifications at that time did not call for a test which would indicate performance of the material, for the specifications were drawn up from an analysis of the construction and fiber content of the material. The resilience test formulated showed that an index could be obtained which would measure the property of suitability for the purpose of printing, and that this would vary for different mixtures. It was then possible to use this index as a measure of practicability of the material. Results were submitted to the Bureau of Engraving and Printing about the middle of the fiscal year.

Bandages.

At a request from the Surgeon General's Office an investigation was made on the variation in length of a large number of 2, 2½, and 3 inch gauze bandages which were purchased during the war. This department had available for sale after the war an enormous amount of bandages which were declared surplus. On selling to private individuals it was found that there was a wide variation in length, some coming materially short of the length stamped on the package wrapping.

The purchaser took the stand that he was defrauding his customers by selling materials which were not as represented on the label and accordingly took steps to return the material to the Government. The Government in turn went back to the original manufacturer seeking adjustments and corrections. Results of the investigation showed variation in care and exactness in cutting bandages by the different manufacturers, also lack of information as to exact tolerances and effect of humidity on such material. The investigation involved the consideration of approximately $1,000,000 worth of bandages and illustrates the importance of the bureau's work to other Government departments.

Conferences.

The following textile conferences in which the bureau took part were held during the year at the places indicated:

Conference on—	Date.	Place.
Standardization of numbered duck	Aug. 1, 1921	Bureau of Standards.
	Mar. 15, 1922	Do.
	June 14, 1922	New York, N. Y.
Standardization of sheeting	Nov., 1921	Do.
	Feb. 3, 1922	Do.
Standardization of cordage	Dec. 21, 1921	Bureau of Standards.
	Mar. 9, 1922	Do.
	Apr. 18, 1922	Do.
	Apr. 19, 1922	Do.
	Apr. 26, 1922	Do.
	May 26, 1922	New York, N. Y.
Standardization of hosiery	May 1-7, 1922	Philadelphia, Pa.; Chicago, Ill.; Reading, Pa.; and Milwaukee, Wis.
	May 15, 1922	Philadelphia, Pa.
	June 14, 1922	New York, N. Y.
Textile research committee	Apr. 20, 1922	Bureau of Standards.
Tent and awning duck	Apr. 19, 1922	Do.
Standardization of shade cloth	Apr. 21, 1922	Do.
Press cloth	Apr. 24, 1922	Do.

PAPER.

The functions of this section are the study and development of methods of testing paper, the investigation of paper-making materials, the experimental production of special types of paper, the study of paper-making processes, the development of standards and specifications for papers and the testing of paper, both for the Government and for the public.

General Conditions.

It has not been necessary to purchase any large pieces of equipment during the year and there has been little change in the facilities for this work. Minor pieces of apparatus have been obtained, for the testing laboratories and especially for the paper mill, such as an electric conditioning oven, centrifuge, wire guide, large deckle straps, new lower press roll, torsion balance, glarimeter, etc. Every effort has been made to concentrate on the testing apparatus and equipment available and to standardize test methods as much as possible. The flexibility of the conditioning apparatus in the physical testing laboratory was demonstrated during a series of tests under conditions of relative humidity varying from 15 to 85 per cent. Some difficulties are, however, still experienced in maintaining exactly 70° temperature in the hot part of the summer, due to lack of insulation of the walls of the test room. The power supply has improved and there have been less delays due to that cause.

Tearing Strength of Paper.

As indicated in the last annual report, two studies were continued during the year in regard to the tearing strength of paper. Two publications (Technologic Paper No. 194, and Paper Trade Journal, March 9, 1922) have been issued, giving the results of these studies. It has not been possible as yet to recommend a standard method for determining this quality of paper, chiefly because of certain unknown factors introduced when more than one sheet is torn at one time. It is believed that the apparatus available at this time will give important information in connection with mill-control work and that each of the types are of some such value. It is doubtful, however, whether any results are of an absolute nature, and it is thought desirable to continue this study in the hope that a method may be developed which will give a true value to the tearing quality of paper. This quality is of very great importance in connection with wrapping and envelope paper and also in the case of paper for books, magazines, etc. However, the chief reason for continuing this research is to develop a method which compares with the common practice of tearing a corner of a sheet of paper to determine its quality and to have a check on the other test methods which do not give sufficient information. It is believed that a suitable test may be developed to give a true value of the tearing strength of a single sheet of paper.

Thickness of Paper.

In cooperation with the gauge section, an investigation of commercial dial micrometers for measuring the thickness of paper has been completed. This problem was taken up because of the differences existing at this time in the various types available and because of the fact that check results can not be obtained in many cases, when using micrometers of different types. For this reason controversies have arisen and it was believed necessary to thoroughly investigate the subject in order that definite data might be available. This study was made of the mechanism and performance of 12 different micrometers, with 14 different kinds of paper. Measurements were made of the area and parallelism of the contact surfaces and the static contact pressures of the instruments. It was found that there were radical differences in the various types of micrometers and that the thickness of paper as measured by various instruments was in some cases quite different. These differences were most apparent where a bulky, loosely formed sheet was used, due to the differences of the static pressure in the various types of micrometers. It has been possible to develop specifications for a standard instrument and for a procedure to determine the mean thickness of paper samples. Such an instrument should be of great value, because of the varying compressibility of different papers and the different pressures exerted by the various types of dial micrometers now used for determining the thickness of paper.

Blotting Quality of Paper.

Considerable difficulty has been experienced in determining the blotting quality of paper by the Klemm strip method, which does not sufficiently take into account the thickness of the sample, nor the value of the sample in connection with repeated blottings. In the case of some papers, a high initial absorption will be obtained but subsequent application of the sample to ink will often produce a blot, due to lack of further absorption. Twelve samples of commercial blotting papers were examined and tested by four different methods. These results were studied in connection with the bulk of the sample, the fiber content, and the amount of ash present. It was found that, although the amount of bulk is an indication of the value of the sample, the fiber content and the amount of ash present are of great importance and should be considered. The best results were obtained with samples having less than 10 per cent of ash present and with a high percentage of cotton or rag fiber. The absorptive value of the paper is due to the air spaces between and within the fibers and, since the long rag fibers are cut up in the beater, there are a large number of ends to permit absorption within the fiber. The fibers of the broad leaf woods are bulky but are short and have not so many open ends, which probably accounts for their lesser absorptive quality. For determining the value of a blotting paper, a practical test was developed which will give relative results and also indicates which of several samples may be considered the best. It should be noted that the samples used in this investigation were those to be used for blotting writing inks and were not the type of paper used as desk covers, which are less absorptive, more compact, and more durable.

Effect of Relative Humidity on Paper.

Data appearing in various publications and developed by different laboratories have indicated that it is necessary to control the atmospheric conditions in the testing laboratory, in order to obtain accurate and reliable information as to the physical qualities of paper. This is due to the fact that changes of relative humidity markedly affect the moisture content of paper, which in turn affects most of the physical characteristics of a sheet. In order to check work done at this bureau 10 years ago and to widen the scope of the information, a series of tests on 11 samples of different kinds of paper were made at relative humidities from 15 to 85 per cent. These tests included weight, bursting strength, moisture content, folding endurance, breaking strength, tearing strength, expansion, and stretch. An examination of these data indicate that the bursting and breaking strength increase with increase of relative humidity from 15 to 35 per cent and decrease as the relative humidity increases from 35 to 85 per cent. Weight and moisture content increase regularly with increase of relative humidity, as do the stretch of the paper under load and the expansion without load. Both the tearing and folding qualities of paper are markedly affected by changes of relative humidity, increasing in value with increase of relative humidity; however, this effect is not so regular with the different kinds of paper. It is shown by the data obtained that the tendencies indicated above are not the same for all kinds of paper and that it is probably impossible to develop a suitable conversion factor for the various tests. It is recommended, however, whenever possible, that some definite conditions of relative humidity be maintained within close limits, in order that test data obtained on similar samples of paper may be comparable. A full report of the data obtained in this investigation will be published in the near future.

Paper for Cement Bags.

In connection with specifications for paper for lime and cement bags, published in Technologic Paper No. 187, tests were made on 10 samples of bags obtained from several shipments of cement to determine whether commercial bags conform to these specifications. Complete tests were made on these samples, and it was found that only 1 bag would entirely conform to the specifications. Nine bags had a bursting strength equal to the specifications, 5 bags had the necessary ratio of bursting strength to weight, 7 bags contained 50 per cent or more of manila and jute stock, 8 bags passed the folding endurance specification, 5 bags had a breaking strength equal or greater than the specifications, but only 2 bags conformed to the breaking strength specifications. Data are being collected as to the value of the bags under service conditions of shipment, and a study of these data will indicate whether the specifications as developed will be satisfactory for paper for this purpose.

Blue-Print Paper.

For several years paper manufacturers in this country have been developing a paper for blue-print purposes which has seemed to give complete satisfaction. The requirements for this type of paper are somewhat severe, for it must properly absorb the sensitizing solution, must resist rough handling when the blue print is in use, and must have sufficient strength when wet to permit of handling in the washing bath. In order to determine the relative value of such paper made in this country and abroad, a number of samples were obtained and complete tests are being made. A comparison of the test data with specifications covering various uses of blue-print paper will indicate whether commercial papers are equal to these specifications and whether foreign-made papers have any superior qualities over such paper made in this country.

Carbon Paper.

As indicated in the last annual report, a study of carbon paper was being made in cooperation with the chemistry division. It has not been found possible to specify any but a practical test to indicate the value of carbon paper, but it has been possible to standardize the method of making this test in order to obtain relative values of carbon paper. For the purpose of Government specifications, carbon paper was divided into three classes or weights in connection with the number of copies to be made at one time on the typewriter. The kind and quality of paper to be used in making these tests have also been specified, as well as the kind of typewriter, type, etc. Data obtained in this manner on a large number of samples and correlation with actual use in the Government service should permit the development of definite specification of carbon paper for use with the typewriter.

Sizing Quality of Paper.

Over a year's study of the electrical conductivity methods of measuring the sizing quality of paper indicates that, although the data curves obtained are consistent and regular, it is not possible to evaluate these curves in order to obtain a numerical value for this quality. The problem is of considerable importance, since there is little or no uniformity in determining this quality and the present methods used do not give results that indicate the true value of the sample. A reliable method is essential before an investigation of the sizing process can be undertaken. A new method has been developed and published in a trade journal which has the advantage of requiring very little equipment and of giving consistent results which may be given a numerical value. The test depends on the time of curl of a small sample of the paper floating on water at a definite temperature. This time of curl is very consistent for a given sample of paper and by properly taking into consideration the thickness of the sample when completely saturated with water a numerical value is obtained which indicates the degree of resistance to absorption of the sample. This method is being tried out by several paper-mill laboratories and such data will aid in determining its actual value.

Herzberg Stain.

In the microscopic examination of paper to determine the proportions of the various fibers of which it is composed, it has been customary to make use of a selective stain composed of zinc chloride, potassium iodide, and iodine. The stain has the property of coloring cotton, chemical wood pulp, and mechanical pulp differently, which permits of greater ease in differentiating these fibers. Considerable difficulty has been experienced, however, in preparing this stain so that the color differences are correct and it is the general practice to "doctor" the stain to get the proper colors with known fibers. A careful study of this problem has developed a formula and manipulation which produces the necessary color differences and has eliminated the necessity of modifying, from time to time, the proportions of the ingredients of the stain. Such a formula is of great value to the various paper-testing laboratories which are equipped to make misroscopic examinations and will assist in obtaining greater accuracy, due to greater uniformity of color.

Photomicrography.

During the past two or three years extensive data have been collected on methods of making photomicrographs of vegetable fibers used in the manufacture of paper. An increasing number of technical laboratory workers and others are availing themselves of the possibilities of this means of studying problems and it is believed that a publication on this subject would be timely. Various phases of this subject are considered in a report that is now in press which gives data and methods of manipulation as follows: Source of illumination, light filters, use of condensers, use of substage diaphragm, choice of camera and objective, photographic plates and their development, value of representative field of fibers, value of staining, and photomicrographs as permanent records. The publication is replete with diagrams and photomicrographs which illustrate the various points to be brought out.

Color of Paper.

There has been a demand for a method which would satisfactorily measure and give a numerical value for the color of paper. Apparatus of this character is of importance in the study of such problems as the use of various clays as fillers in paper and also in connection with the color values and bleaching of the various pulps used in white printing and writing paper. Likewise a means of measuring the color of paper would be of great importance in assisting manufacturers to maintain uniformity of color, something of great importance in making fine papers. Through the cooperation and assistance of the optics division, an apparatus has been installed, the chief portion of which is a spectrophotometer. Delays in securing the parts necessary for this apparatus have made it impossible to determine at this time whether such an equipment will be satisfactory for slight differences of tints of white paper but with certain modifications, a suitable method for distinct color differences is being developed.

Flax Straw and Tow.

Many attempts, both laboratory and commercial, have been made to utilize the million tons of seed flax straw which are produced annually in this country and of which 80 per cent are wasted. Most of the attempts have had in mind the production of a strong paper from the bast fiber attached to the straw, by the elimination of the woody straw fiber, which is short and of little strength. Mechanical separation of the woody straw fiber from the long bast fiber is necessary, as well as a solvent for the ligneous and pectous binding compounds which will not weaken the bast fibers. In most cases, alkaline solvents, such as milk of lime, caustic soda, etc., have been used, but it has not been possible to eliminate all the woody shive by these processes. In the work carried on at the bureau, the "sulphate" process of cooking wood was used, both in the preliminary experimental work and the cooking trials under mill conditions. The process was found satisfactory for the separation of the bast fibers, and paper was made both from the flax straw and the flax tow which had a strength equal to a good grade of wrapping paper and bond paper. Difficulty was experienced in eliminating extraneous dirt which had been introduced by careless handling of the tow and straw and because of unfavorable conditions during the cooking trials under mill conditions. No difficulty was experienced, however, in handling the stock on the paper machine at the Bureau of Standards where all the cooked fiber was converted into paper, both that produced in the experimental rotary and in the mill cooking trials. Complete data are not yet available as to the actual yield of paper from the straw and tow, but about 7 tons of whole flax straw are required for 1 ton of pulp for wrapping purposes. In general, it may be said that a fair quality of wrapping paper can be made from whole seed flax straw, that a good quality of writing paper can be made from seed flax tow, provided especial care is taken to eliminate specks, that pulp prepared from seed flax tow can be readily bleached, that the chemical consumption for the preparation of pulp from the whole straw is about double that required for wood, that the chemical consumption for the pulping of a good quality of seed flax tow is only slightly in excess of that required for wood, and that, at the present time, it is not economically feasible to use seed flax fiber for the making of paper unless a solvent can be developed which will not weaken the bast fiber during the process of separation from the pectous and ligno-cellulose material combined with it. A full report of this investigation is in preparation and will be published in the near future.

Clay in Paper as Filler.

In cooperation with the ceramic division, an investigation was undertaken as to the relative value of foreign and domestic clays when used as fillers in printing papers. This material is added to the fiber stock during the process of manufacture of paper to produce a smooth, even surface, by filling up the interstices between the fibers, to permit of half-tone printing, etc. Foreign clays, chiefly from Cornwall, are used to a large extent for this purpose in this country, and this investigation was undertaken to determine what qualities of the foreign clays produced the better results. In general, color, grit, and retention on the paper machine are the factors to be considered. Complete physical tests have been finished by the ceramic division on a number of domestic and foreign clays, and preliminary work on the paper machine is under way to standardize the conditions of making the comparative runs. A considerable amount of preliminary work has been necessary to determine the closeness of check runs and a suitable method of determining the value for retention of filler. The problem has been made more difficult by the shortness of the runs and by the lack of uniformity among the paper mills as to a method of determining retention. This work will, however, be continued, and as soon as definite data are available, which may be used as the basis for tentative conclusions, cooperative tests are to be made with several book paper mills under commercial conditions.

Clay for Coating Wall Paper.

The bureau cooperated in a series of mill experiments in which four domestic clays were used successively in connection with the coating for wall paper. The problem under consideration was whether these domestic clays would be satisfactory when used with a special gum as adhesive. The tests indicated that all four clays worked satisfactorily, and difficulties experienced in this connection are probably due to lack of care in heating the gum or in obtaining the proper proportions.

Standardization of Paper.

During the past year the question of the standardization of paper has been taken up with representative manufacturers and users. In view of the very large number of kinds of paper and uses for paper, certain general phases of the subject are being considered by several committees which are collecting information and data on which to base recommendations. Because of the necessity for obtaining a uniform classification of the kinds of paper for the purpose of properly tabulating statistics, a grouping of the various similar types of paper is being accomplished. Such a classification will be of great value to all agencies engaged in the collection of statistics of the paper industry and should make it possible to compare accurately data obtained through different sources. The use of terms and names of kinds and grades of paper is very indefinite in many cases. Definitions are being developed for about 600 such terms and names, and this is being done with the assistance of manufacturers, users, and technical men of the industry. The acceptance of such terms and their arrangement in the form of a glossary or dictionary will be of great assistance in eliminating certain misunderstandings between buyer and seller and will have considerable significance in connection with export trade. A large economy may be obtained by the reduction in the number of sizes and qualities of paper, both as to the large-size sheets as sold and in the number of sizes of printed matter. An exhaustive survey is now well under way by a committee of large users of paper and a report and recommendations will be available in the near future. This phase of the subject is of great economic importance and will result in benefits to the manufacturer, distributor, and user of paper. A technical committee is considering the following subjects: Specifications of quality, standard methods of testing and sampling, and tolerance to be permitted on deliveries. Because of the lack of such standardization these phases of the subject must first be considered in a general way and later particular kinds of paper can be considered in relation to their uses. This investigation will progress more rapidly after some of these general aspects of the problem have been settled.

Government Specifications.

Assistance has been given various Government offices in connection with the development of proper specifications for the purchase of paper. In many cases a large number of tests were necessary, but in this work an attempt has been made to bring more closely together the specifications as used in the various bureaus and offices. Changes have been recommended in the standards for the District of Columbia, with special reference to terminology and conformity to good practice. Recommendations have been made in connection with the specifications used by the Government Printing Office, although the necessary changes in them are minor in character at this time, with the exception of light-weight printing paper used in the bureau's publications. It has, however, been suggested from time to time that the tolerances as to weight should conform somewhat more closely to good commercial practice. In connection with the General Supply Commitee, some additional items have been placed under the "standard sample" group. Such an arrangement permits the prospective bidder to have definite information as to the kind of paper desired. The specifications of the Post Office Department for official envelopes, shipping tags, and stamped envelopes have been revised. It has been possible to have included standard samples for color and finish for the paper for official envelopes, which will provide greater uniformity and also a closer match between the envelope and the contents.

Lime for Sulphite Pulp.

In connection with the Interdepartmental Conference on Chemical Lime, specifications were prepared for a suitable lime and limestone used in the preparation of the liquor used for cooking wood chips by the "sulphite" process. These specifications were based largely on data obtained during the war from a questionnaire and reflects the opinion of experienced technical men of the pulp industry.

LUBRICATING OILS.

Reclaiming Used Petroleum Lubricating Oils.

An investigation has been started on the methods necessary to restore used lubricating oils to a condition in which they may be of further service. It has been found that the completeness as well as the rapidity of separation of an oil from an emulsion with water must be considered, as the relation between emulsification and organic acidity is important. Some work has already been done in this connection. The methods of making the emulsion and demulsibility tests have been modified accordingly.

Standardization of Viscosimeters.

In continuation of the work of standardization of viscosimeters, equations and conversion tables have been derived for three additional instruments—the Saybolt Furol and Redwood Admiralty for measuring the viscosity of fuel oil, and the Redwood No. 1 for testing lubricating oils. The Redwood instruments are standard in England and are of importance in the export trade.

Closely related to this work were investigations of the drainage error in the Bingham viscometer, and the change in viscosity of oils with temperature, upon which papers have been prepared for outside publication. The Bingham instrument is an especially accurate instrument for determining the viscosity of liquids used to calibrate the technical instruments in everyday use.

An improved viscosimeter, with interchangeable outlet tubes has been designed and adopted for use in determining "Saybolt viscosity." The novel features are the stainless steel outlet tubes and the enlargement of the oil tube to permit leaving the thermometer in place during the run.

Oil Friction Testing Machine.

As a result of many tests on an oil friction testing machine with a journal partly surrounded by the bearing, the conclusion was reached that a machine of this type was unsatisfactory because the smoothness of the rubbing surfaces could not be kept constant. Tests were accordingly discontinued, and a new machine was designed, using flat rubbing surfaces, and is now being built. A journal can not be polished without changing the radius of curvature, but flat disks may be polished when necessary.

Cooperative Work.

Work has been continued on the consistency of fats used in cooking, in cooperation with the Bureau of Home Economics, Department of Agriculture.

Members of the division have cooperated in the activities of various societies and associations, including the American Society for Testing Materials, the National Electric Light Association, the American Petroleum Institute, and the Society of Automotive Engineers. All these societies are vitally interested in standard methods of testing and specifications for lubricants.

TESTING INFORMATION AND PUBLICATIONS.

Tests Completed During the Year.

During the year, the following tests have been completed by the various sections of this division:

Structural and miscellaneous materials.—The amount of test work of a routine nature completed during the fiscal year is listed below. The list includes materials tested for other divisions of the bureau, other Government departments, and for the general public.

SUMMARY OF TESTS: MATERIAL.

	Number of specimens.
Iron and steel:	
Malleable iron	12
Steel	330
	342
Aluminum and aluminum alloys:	
Aluminum alloy	8
Aluminum alloy, duralumin	40
	48
Copper, brass, and bronze:	
Brass	11
Bronze	22
Copper	3
	36

SUMMARY OF TESTS: MATERIAL—Continued.

	Number of specimens.
Miscellaneous metals and alloys:	
Dental amalgam	24
Monel metal	9
Magna metal	4
	37
Fiber rope and wire rope:	
Rope, fiber	60
Rope, wire	6
	66

CALIBRATION OF TESTING MACHINES.

Riehle, 50,000 pounds	1
Riehle, 100,000 pounds	1
	2

MISCELLANEOUS.

Asbestos sheet packing	16
Bearings	10
Bolts and nuts	5
Bomb points	7
Bomb lugs	2
Bones, hog	21
Cans	2
Chain	1
Cups	2
Crayons	12
Fiber, hard	4
Glass, wire inserted	12
Gears	15
Insulator, porcelain	1
Jacks	3
Lead lines	6
Metal, lead clad	15
Nails	6
Nickel	2
Pipe sections, threaded	48
Rubber hard	48
Shackles, anchor chair	4
Spoons, aluminum	9
Springs, automobile	4
Tubes, condenser	28
Tubes, boiler	2
Tubes, copper	2
Webbing	6
Wire, magnet	1
Wire, monel	1
Wire, sounding	4
Wood, storage battery separators	160
Wheels, roller-skate	2
Wheels, truck	12
Wheels, veneer disk	3
Veneer, 3-ply for airplanes	140
	617

Cement, concrete, stone, gravel, and sand.—In addition to sampling and testing approximately 600,000 barrels of cement for Government purchases, tests were made of more than 200 samples of miscellaneous materials, comprising silica sands, concrete fence posts, accelerators for concrete, building stones and slates, disintegrated stone, rock for riprap, special cements for stonework, concrete building blocks, floor hardeners, concrete aggregates, cement brick, clay brick, elastic cements, clay tile, trass, waterproofing materials, paints and coatings, filter sands, drinking water, boiler water, paints, limes, galvanized coatings, steel, copper, reinforcing rods, culvert pipe, lubricating oils, alkali, miscellaneous fine materials for separation by the air analyzer. The tests of aggregate included study of the materials submitted by some of the reclamation projects and a hospital project. In addition to the tests, inspection was made of a shipment of 540 feet of metal culvert pipe. Numerous specimens of concrete were tested for the United States Engineer projects, for one of which there were tested 561 specimens. From another there were received 1,242 specimens, some of which are for long time tests. Some of the other miscellaneous materials were submitted by Reclamation Service, Army, Bureau of Lighthouses, Public Roads, Navy, State Highways, Panama Canal, Forest Service, District of Columbia, and Supervising Architect.

Lime, gypsum, and sand-lime brick.—During this fiscal year this section has made routine tests on 5 samples of lime for other branches of the Government, and on 65 samples of lime, 18 samples of gypsum, and 12 samples of sand-lime brick for private individuals.

Rubber.—Seven hundred and seventy-six samples of miscellaneous materials, including pneumatic tires, inner tubes, solid tires, hose of all kinds, rubber bands, rubber rings, dredging sleeves, and rubber hospital equipment were tested for the Post Office Department, War Department, Panama Canal, General Supply Committee, Marine Corps, and other Government departments.

Leather.—Eighty-two samples of leather were tested for the various Government departments during the year. These included sole, flat and round belting, bookbinding and chamois leathers, also ledger binding straps, leather leggins, strap leathers, and leather preservatives. One item in the above consisted of the inspection of 400 pairs of leather leggins for the Porto Rican Government.

Textiles.—About 4,500 samples were tested for the various Government departments, chiefly the Panama Canal, Post Office Department, Federal Trade Commission, and Navy Department. The work done for these departments consisted of the testing of duck, twine, aircraft cloth, and suiting materials.

	Number of samples.
Government samples	4,406
Non-Government	119
Bureau investigations	1,285
Total	5,810

Paper.—Although the chief functions in connection with paper are the development of standard test methods and specifications of quality, a considerable amount of time is devoted to the testing of paper to determine the quality of such paper when delivery is made on contract to the Government. In addition to this, a certain limited amount of testing is done for the public, but this work is kept at a minimum, as there are several reputable commercial testing laboratories equipped for this type of work. All tests of this nature are made by the bureau at 65 per cent relative humidity and 70° temperature.

	Number of samples.
Government Printing Office	1,331
Post Office Department	777
General Supply Committee	404
New York State	149
Department of Commerce	155
Interior Department	50
Department of Agriculture	30
War Department	23
Panama Canal	21
Treasury Department	14
District of Columbia	12
Library of Congress	4
Navy Department	4
Department of Labor	2
Bureau of Standards	422
For the public	206

SUMMARY.

For the Government	3,398
For the public	206
Grand total	3,604

Lubricating oils.—During the year routine tests were made on 551 samples for Government departments. Special tests for private parties included determinations of viscosity on 64 samples, demulsibility on 29, and the examination of 33 viscosimeter tubes. These tubes were all of the Saybolt type, with the exception of one Engler.

In order to increase the accuracy of standardization of viscosimeters, and to obtain better agreement between different laboratories, a new form of certificate has been adopted based upon flow tests, instead of upon the less accurate measurement of the diameter of the outlet tube. (See report of committee D–2, Proceedings American Society for Testing Materials, 1922.)

Cooperation.

The division has continued to cooperate with the industries through their organizations and members of its staff have held positions on numerous important committees. A list of the societies interested in structural and other materials with which the bureau has cooperated is as follows:

American Concrete Institute.
American Society for Testing Materials.
American Society of Mechanical Engineers.
American Bureau of Welding.
National Research Council.
American Engineering Standards Committee.
National Advisory Committee for Aeronautics.
American Society of Civil Engineers.
American Association of Engineers.
Engineering Foundation.
Associated General Contractors.
Joint Committee on Concrete and Reinforced Concrete.
National Lime Association.
Gypsum Industries Association.
Sand-Lime Brick Association.

National Electric Light Assocation.
American Petroleum Institute.
Society of Automotive Engineers.
United Typothetæ of America.
National Paper Trade Association.
American Paper and Pulp Association.
Technical Association of Paper and Pulp Industries.
Association of National Advertisers.
National Association of Purchasing Agents.
Book Paper Manufacturing Association.
Tanners' Council.
Leather Belting Exchange.
National Boot and Shoe Manufacturers' Association.
Rubber Association of America.
Rubber Heel Club.
American Leather Chemists' Association.
Cordage Institute.
Cotton Duck Association.
National Association of Hosiery and Underwear Manufacturers.
American Home Economics Association.
Inter-State Cotton Seed Crushers' Association.
National Association of Tent and Awning Manufacturers.

Publications.

During the fiscal year the following material has appeared as publications of the Bureau of Standards:

Investigation of oxy-acetylene welding and cutting blowpipes, Tech. Paper 200 (R. S. Johnston).
The friction and carrying capacity of ball and roller bearings, Tech. Paper 201 (H. L. Whittemore and S. N. Petrenko).
Results of some tests of manila rope, Tech. Paper 198 (A. H. Stang and L. R. Strickenberg).
Durability of cement drain tile and concrete in alkali soils, Tech. Paper 214 (G. M. Williams).
Cementing qualities of the calcium aluminates. Tech. Paper 197 (P. H. Bates).
Preliminary report of exposure tests on colorless waterproofing materials—mimeographed circular—published in Jour. Am. Inst. of Architects; October, 1921.
Blast-furnace slag as concrete aggregate—mimeographed circular.
A preliminary study of tearing instruments and tearing-test methods for paper testing, Tech. Paper 194 (P. L. Houston).
The Redwood viscosimeter, Tech. Paper 210 (Winslow H. Herschel).
Recommended specifications for limestone, quicklime, and hydrated lime for use in the manufacture of glass, Circular 118.
The testing of rubber goods (4th edition), Circular 38.
Specification for cotton rubber-lined fire hose, Circular 114.
Specifications for pneumatic tires, solid tires, and inner tubes, Circular 115.
Power losses in automobile tires, Tech. Paper 213 (W. L. Holt and P. L. Wormeley).
The durability of sole leather filled with sulphite cellulose extract, Tech. Paper 215 (Roy C. Bowker); also published in Hide and Leather Magazine; April 22, 1922.

The following are in press and will shortly be available:

Specifications for numbered duck for commercial and Government use.—Circular. Was prepared for publication and has been submitted to the editorial committee.
A study of commercial dial micrometers for measuring the thickness of paper (P. L. Houston and D. R. Miller).
The photomicrography of paper fibers (R. E. Lofton).

The following papers by members of the bureau's staff have appeared in outside journals:

Tests of rotary-drill pipes, Iron Age; September 29, 1921, and February 2, 1922. (A. H. Stang.)

Experimental use of liquid air and explosives for tightening body-bound bolts, American Machinist; April 6, 1922. (H. L. Whittemore.)
Moments and stresses in slabs, reprint and circular series of the National Research Council, No. 32. (H. M. Westergard and W. A. Slater.)
Concrete by strength—Austrian specifications, translation and comments, Concrete, 19, 231; December, 1921. (W. A. Slater.)
Girderless floors in Malmo, Sweden, translation and comments, Concrete, 20, 264; June, 1922. (W. A. Slater.)
The application of the fundamental knowledge of Portland cement to its manufacture and use.—Reprinted from the Journal of the Franklin Institute, March, 1922. (P. H. Bates.)
Standardization of textiles (F. R. McGowan). This was presented to the National Association of Cotton Manufacturers and will appear in their bulletin. It has been published in most of the textile periodicals.
Standardization of cordage (F. R. McGowan). This was published in the Cord Age.
Tentative outline of Bureau of Standards Textile Committee on Cooperation and Research (F. R. McGowan). This was written for the July issue of the Manufacturers' Club of Philadelphia.
The standardization of paper, Paper Trade Journal; October 27, 1921. (F. A. Curtis.)
A supplementary study of commercial instruments for determining the tearing strength of paper, Paper Trade Journal; March 9, 1922. (P. L. Houston.)
The testing of blotting paper, Paper Trade Journal; November 10, 1921. (P. L. Houston and R. Ledig.)
The determination of sizing quality, Paper Trade Journal; April 6, 1922. (F. T. Carson.)
Improvements in methods of making the Herzberg stain used in fiber analysis, Paper Trade Journal. (M. F. Merritt.)
Viscosity and friction, Jour. S. A. E., 10, pp. 31, 369; 1922. (Winslow H. Herschel.)
Fuel oil viscosimeters, Chem. and Met. Eng., 26, p. 1175; 1922. (Winslow H. Herschel.)
Effect of grading of sand upon absorption and transverse strength of sand-lime brick, Rock Products; January 28, 1922. (Emley and Johnson.)
Manufacture of lime, Proc. Sand-Lime Brick Assn. (1922), p. 52. (W. E. Emley.)
Sampling of leather for chemical analysis, Jour. of Am. Leather Chemists' Assn., May, 1922. (Roy C. Bowker and E. L. Wallace.)

METALLURGY.

The metallurgical division concerns itself with research, investigation, and testing as related to metals and alloys, except built-up metal structures and the processes of extraction of metals from their ores. Its functions include the production of metals and alloys, both of the highest attainable purity and of commercial grades; the preparation and study of auxiliary metallurgical products such as slags, included gases, molding sands, refractories and deoxidizers; the development of apparatus, instruments, and manufacturing appliances for metallurgical processes, research, and testing; the formulation and maintenance of those standards and specifications of interest to metallurgy; the determination of metallurgical constants and properties; the investigation of the performance of manufacturing units; the determination of the causes of failure and the study of the improvement of metal products; and the development of economical metal substitutes. The division has equipment for metallographic examinations of metals such as microscopic analyses, including determinations of constitution, structure, and causes of failure; for thermal analyses including determination of heating and cooling curves for location of critical points; for the various heat treatments such as annealing, quenching, cementation, tempering; for various operations for the hot and cold working of metals such as forging, rolling, and drawing, and for miscellaneous physical tests; for the usual foundry operations of molding and casting ferrous and nonferrous metals; and for other metallurgical processes such as production of pure metals, electrodeposition and plating, welding, and determination of gases in metals.

GENERAL.

Among the important problems which have engaged the attention of the metallurgical division during the past year may be mentioned a study of the methods of analysis for gases in metals and a determination of the effect of these entrained gases on the behavior of metals at various stages of manufacture and on the properties of the finished metal products. The main object of this work has been to devise procedures suitable for the elimination of the harmful effects of gases in metals. This was accompanied by a study of deoxidation processes in steel and iron manufacture.

Work on several problems relating to railroad materials has been completed, particularly the investigation of thermal stresses in chilled iron and steel car wheels, a problem of great importance in connection with wheel design, weight of cars, and speed of trains. The effect of using titanium in the manufacture of steel rails has been studied, and there was also published the results of the investigation on sound ingot practice.

The present program relating to bearing metals has been completed, and methods of abrasion testing will next be considered. Papers have been published on alloy steels containing zirconium and other elements, properties of steels at elevated temperatures, and tests of centrifugally cast steel; the development of methods of metallographic etching for various metals has been studied, and there were prepared for publication several papers dealing with microconstituents and structures.

The investigation being carried out by a joint committee on the effect of sulphur on several grades of steel has led to a preliminary publication dealing with the relation of the sulphur content to the properties of rivet steel. A study of the rolling characteristics of medium carbon steel, the properties of pure alloys of iron, carbon, and manganese, and the testing of wrought iron is ready for publication. The standard tests for molding sands are being developed with a joint committee representing the industry.

Some of the investigations started are the corrosion of rust-resisting chromium and other steels; a comparison of the cutting qualities of high-speed steels, the preparation of platinum alloys of the highest purity, and several investigations principally of military interest.

Mention should also be made of the work of the research associates in metallurgy, relating to investigations in nickel and monel metal, malleable iron embrittlement by sherardizing, magnetic estimation of iron in brass, and the hot working of ingot iron as affected by sulphur, oxygen, and copper.

A notable event was the establishment of a committee advisory to the bureau on ferrous metals. This committee consists of delegates from technical societies interested in steel and iron and is representative of the entire industry, and will enable the bureau to keep in closer touch with the needs of industry.

The organization of a committee on metals under the Federal Specifications Board, in which the metallurgical division is taking an active part, was also an important matter.

Other activities started the past year through the instrumentality of joint committees are investigations relating to gauge steels, mine drill steels, molding sands, welded rail joints, and thermal stresses in steel wheels.

The most important instrumental development was the design and construction of an automatic apparatus for thermal analysis, permitting the elimination of one operator in taking heating and cooling curves.

RESEARCHES IN COOPERATION WITH TECHNICAL COMMITTEES.

Investigation of the Effect of Sulphur and Phosphorus in Steel.

The joint committee on this subject, of which committee the chief of the division of metallurgy is chairman, has finished its program relating to the effect of sulphur on rivet steel, and the bureau released for publication a preliminary report presented at the June meeting of the American Society for Testing Materials. The complete report will be issued as a technologic paper of the Bureau of Standards. In this investigation of rivet steels, material was used from fourteen 75-ton heats of sulphur contents ranging from 0.03 to 0.18 per cent. There were 19 kinds of tests made, amounting to 5,230 physical tests and over 1,000 chemical analyses, mostly at Watertown and Annapolis. Progress also has been made on tests of sheet steel of various sulphur content, as well as on a series of steels so made as to compare the effects of residual and added sulphur. The work is being extended to include forging steels for the coming year.

Molding Sand Research.

The bureau is actively represented on the joint committee on molding sand research recently organized by the American Foundrymen's Association and the National Research Council, and in cooperation with this committee is engaged in an investigation on the establishment of standard tests for molding sands. This work requires a considerable amount of experimental research; substantial progress has been made the past year in specifying the details of physical tests, the work on fineness and cohesiveness being practically completed.

Welded Rail Joints.

There was organized the past year by the American Bureau of Welding, at the suggestion of the committee on way matters of the American Electric Railway Association, a committee with the chief of the division of metallurgy as chairman, for the study and improvement of the several types of welded rail joints. The committee is composed of some 36 representatives of street railways, manufacturers of welding appliances, steel companies' engineers, and the Bureau of Standards. By means of meetings and successfully conducted questionnaires there has been mapped out a research program relating to types of weld such as cast iron, electric resistance, including bar and butt welds, seam, both carbon and metallic arc, and thermite welds.

The bureau has also carried out some experimental work along lines of interest in development of these welding problems.

Bearing Metals.

The program of tests, to be executed by the bureau, as mapped out by the nonferrous advisory committee and committee B–2 of the American Society for Testing Materials has been completed and reported through a paper at the June meeting of the American Society for Testing Materials. The following properties of the 12 tentative standard white metal bearing alloys of the American Society for Testing Materials have been determined: Compressive strength and Brinell hardness at normal temperature and 100° C., the melting point and temperature of complete liquation. The Brinell hardness at both temperatures was also determined on two series of alloys made up to meet the proposed specifications by two independent manufacturers in order to compare them to the similar series of alloys prepared at the bureau under careful laboratory control from pure metals.

Car-Wheel Investigations.

The investigation of thermal stresses in chilled-iron car wheels, outlined in cooperation with representatives of the Association of Manufacturers of Chilled Iron Car Wheels, has been completed and published as Technologic Paper 209. Further work is being planned on the properties at ordinary and elevated temperatures of irons of car-wheel composition with a view to providing data for the establishment of chemical specifications for chilled-iron wheels.

In cooperation with a group representing all the manufacturers of steel railway wheels an investigation has been completed and is ready for publication on thermal stresses developed in steel wheels by the heat caused by brake applications. The behavior of all the types of steel wheels in use was studied along the identical lines followed in the investigation of iron wheels, except it was found possible to reach higher temperatures with the steel without harmful effects. Both of these investigations are of interest in relation to design and weight of wheels, weight, speed, and braking of trains.

Corrosion of Metals.

The bureau is represented on the newly formed correlating committee on corrosion organized by the National Research Council and on the nonferrous corrosion committee of the American Society for Testing Materials and expects to conduct its researches in this subject along lines to best fit in with the programs now being outlined.

Gauge Steels.

The construction of all high-grade machines of precision depends on the use of gauges whose metallurgical and geometrical requirements are very severe, and which have not as yet been satisfactorily met. A joint committee has been formed consisting of representatives of all the manufacturers of gauges, certain steel manufacturers and large users, the Ordnance Department of the Army and the Bureau of Ordnance of the Navy, as well as the Bureau of Standards. A survey has been taken of the situation and a start made on a comprehensive program of research at the bureau in cooperation with the other interested parties under the joint committee's supervision. The funds for work at the bureau are provided in part from an allotment from the War Department. The main features of the problem involve a study of the properties and behavior of a selected series of steels, including the technique of manufacture into gauges, especially the relation of heat treatment to permanence of dimensions, resistance to abrasion, and corrosion.

Mine-Drill Steel.

A committee advisory to the Bureaus of Mines and Standards has been formed on the subject of mining-drill steels, their composition, treatment, thermal and mechanical, and reclamation, together with causes of breakage as related to standardization of design and practice, properties, manufacture, and preparation, with the object of eliminating waste and delays in mining operations. Several meetings have been held, a preliminary program mapped out, and the bureau has made a survey of drill-steel practice in the metal mines of some 10 Western States, obtaining data which will be of use in suggestions as to standardization of design, heat treatment, and practice generally as relating to drills and auxiliary mining machinery. Reports of this survey are in preparation.

Deoxidation of Steel.

The committee of the National Research Council on this subject is being reorganized, and the advisory committee to the bureau on ferrous metals approved the bureau studying "the general principles, physical and chemical, of the cause and prevention of oxidation of steel."

Metals Committee, Federal Specifications Board.

Under this board there has been organized a committee on metals, with the chief of the division of metallurgy as chairman and the chief of the section on mechanical metallurgy as technical secretary, with representatives from the various Government departments, which has undertaken the task of preparing unified Government specifications for metal products. It is planned, where possible, to use existing specifications, whether governmental or of the technical societies, with the purpose of bringing about as complete uniformity as practicable. The subjects are being taken up in the order, generally, of ingot, cast, wrought, fabricated, and special metal products.

Conferences.

The committee advisory to the bureau on nonferrous alloys held two meetings at the bureau, going over in detail the bureau's work in that field.

On June 2 was held the first meeting of the newly organized advisory commitee on ferrous metals, at which were present all but two of the official delegates apointed by the several technical societies interested in steel and iron.

Several conferences were held with the representatives of the manufacturers of iron and steel wheels, and one on metallurgical refractories.

Committee Memberships.

A large part of the work of the metallurgical division is planned by keeping in touch, through membership in technical societies and committees, with the needs of science and industry as expressed by these activities. The following is a list of such cooperating bodies: The National Advisory Committee for Aeronautics; National Research Council, American Institute of Mining and Metallurgical Engineers, American Society for Testing Materials, Joint Committee on Sulphur and Phosphorus in Steel, American Physical Society, American Engineering Standards Committee, Society of Automotive Engineers, American Society for Steel Treating, American Foundrymen's Association, and Advisory Committee on the Critical Table of Constants.

Circulars of Information.

The circulars of information, dealing with the properties of different metals and with other metallurgical subjects, which have been issued from time to time during the past few years have proved to be among the most useful of the division's publications. During the past year two new ones were added. Circular 42 on metallographic testing summarizes in a general way the bureau's activities along the line of physical metallurgy. Circular 113 on the structure and related properties of metals is based upon the bureau's experience in the microscopy of metals and shows by the means of typical examinations the need for and the use of such examinations in the study of engineering and metallurgical problems.

Several of the other circulars have received considerable revision. Circular 58 on invar and related nickel steels has been largely rewritten and a good deal of new material included. Circular 73 on copper and Circular 80 on protective metallic coatings for the rustproofing of iron and steel have been revised and brought up to date. Circular 76 on aluminum is under revision at the present time.

OPTICAL METALLURGY.

Crystallinity in Wrought Iron.

Most specifications for wrought iron require specimens of the material to pass satisfactorily a "nick-bend" test. the absence or the occurrence of crystalline areas in the fracture being the criterion by which the material is to be judged. Numerous requests have been received from time to time concerning this test, and in order to furnish reliable information for answering such requests a study was made of the behavior of different grades of wrought iron, donated for the purpose by five manufacturers, when tested in various manners after nicking. The results were presented before the American Society for Testing Materials at its last annual meeting, the aim being to show that the clause covering this test in most current American specifications should be rewritten so as to define this test more strictly. A nicked bar of wrought iron subjected to impact stresses usually shows a crystalline break upon fracturing, whereas the same material moderately stressed will show a fibrous appearance. The presence of "steel" in wrought iron is usually conducive to a crystalline fracture, although the converse is not necessarily true. Two types of crystalline areas are often found in the fractures of wrought-iron bars after the "nick-bend" test; one, which is the result of transcrystalline fracture usually by impact, is to be considered as revealing certain characteristics of the iron, whereas the second, which always occurs on the side of the tested specimen which is in compression during the test, results from the plastic deformation of the grains by compression and should be considered as a characteristic of the method of testing rather than of the material.

Corrosion of Special Steels.

The increasing use of "noncorrodible" steels and irons and the lack of information concerning the behavior and limitations of the various grades, as evidenced by the numerous requests received by the bureau for information, appeared to warrant a rather extensive investigation of this subject. During the past year various grades of chromium steels, differing in their relative carbon and chromium contents—carbon, 0.04 to 1.07 per cent; chromimum, 3.9 to 13.7 per cent—were prepared and tested. Small ingots of the alloys were melted in the high-frequency induction furnace, rolled into plates and cut into suitable size for corrosion tests. The behavior of these specimens, when subjected to hydrochloric-acid corrosion and in a simulated weather test, was studied. In general, the order of resistance of the alloys to acid attack was found to be quite different from that under atmospheric corrosion. A relatively high chromium content is necessary for the latter, whereas in the series of simple chromium steels subjected to acid the high-chromium specimens were the least resistant.

Further tests are being made in the endeavor to show the influence of added elements in chromium steels, such as nickel, silicon, and manganese. Apparatus is also being constructed for the oxidation tests so that the conditions can be much more carefully controlled than hitherto. By an automatic arrangement the specimens will be alternately immersed in the corroding medium and then withdrawn into the air. The results of the experiments are being published from time to time.

Microstructural Changes Accompanying the Tempering of Martensitic Steels.

This investigation was completed during the year and the results assembled for publication. The structure of martensite, as illustrated by quenched steels varying in carbon content from 0.07 to 1.12 per cent, and the visible microstructural changes which occur during the tempering of such steels are described by means of typical micrographs. A structural change corresponding to the transformation at approximately 250° C. as determined by thermal analysis and other means of investigation was shown to exist. The variation in the mechanical properties corresponding to different structural conditions was determined by means of scleroscope hardness measurements.

Metallographic Etching Reagents for Nonferrous Alloys.

During the past year the second scientific paper summarizing results obtained in this investigation was published. This dealt with the common alloys of copper and with nickel and its alloys. The etching characteristics of aluminum and its alloys have also received attention during the past year. As material for study and for the preparation of necessary alloys, aluminum of an exceptionally high degree of purity (99.97 per cent), furnished by the manufacturers for the purpose, was used. In the preparation of the various alloys, preference was given to those which have some industrial use. The results will be published shortly.

Metallographic Etching for the Identification of Carbides, Tungstides, and Other Compounds in Alloy Steels.

When etching alloy steels with the acid reagents usually employed for steels, no apparent distinction is obtained between the carbides, tungstides, and other compounds that may be present in the free or undissolved state, in the microstructure developed by the etching.

Various investigators had in the past proposed special etching reagents, some of them being known to be present. It appeared, however, that coordination among these results was lacking and no clearly established rationale underlay the procedure. This investigation has been undertaken in the endeavor to establish upon a systematic basis the identification of the various constituents of alloy steels by means of comparative results obtained on the constituent in question with the already known etching reagents and any new ones or methods of etching that might suggest themselves during the course of the investigation. It was seen early in the work that solutions of an alkaline nature did not offer much hope in this direction. Attention has been directed to the rationale of the behavior of the several alkaline solutions used to the various constituents of the chromium, tungsten, and plain carbon steels. Ternary alloy steels, containing varying amounts of carbon and the alloying element as chromium or tungsten, have been in part prepared in the laboratory and in part obtained from steel manufacturers. Other special substances, such as tungsten carbide, have been prepared for study. Specimens of these steels have been given different heat treatments as quenching from a high temperature to retain in solid solution as much as practicable of the constituent, ordinary furnace cooling, and extremely slow cooling from a high temperature to precipitate as far as possible the constituents out of solid solution and at the same time agglomerate them into larger masses for the easier concentration of the etching effects upon the otherwise very small-sized constituents. A method of sequence etching, involving the etching of the microsection with two or more different etching reagents in succession without any repolishing of the section being undertaken between the etchings, has been developed for high speed steels, and the results obtained so far indicate that there are at least three different constituents present in this complex alloy which may be identified from one another, although their identity has not yet been established with certainty. The investigation is in progress, and it is proposed to extend the work to include in the study molybdenum, vanadium, and possibly other alloying elements.

Embrittlement of Steel by Hydrogen.

Low-carbon steel of the grade used as boiler plate at times becomes embrittled in service so that cracks develop and leaks in the boiler occur. The explanation is now very generally accepted that the concentration of the "caustic products" resulting from the "treatment" of the boiler water, or initially present in the feed water is responsible for the failure of the steel, the evolved hydrogen being the immediate cause. Several cases of failure of this kind were submitted for metallographic examination during the past year. A means for the metallographic determination of steel affected in this way is being sought at present.

Graphitization of White and Gray Cast Iron.

These experiments were conducted to determine the maximum allowable temperature for the annealing or "pitting" of cast-iron car wheels. The wheels should be annealed at the highest temperature that will not cause any graphitization of the chilled treads. Previously it was generally supposed that no graphitization occurred below 700° C. The work of the bureau, however, has shown that for periods of annealing as long as 12 days there is appreciable graphitization at temperatures as low as 600° C. Because of the excessive time required for graphitization at 600° C. the actual practice in the annealing of car wheels may not be affected. The results, however, are of considerable theoretical interest, as they may aid in explaining the mechanism of graphitization, which phenomenon is extremely complicated and which must be understood to control exactly such processes as the annealing of chilled-iron car wheels and the production of malleable castings. Micrographs were taken showing the progressive changes in microstructure of white and gray cast-iron with variations in time and temperature of annealing.

Relation of Grain Size to the Mechanical Properties of Steel.

The subject of the shock-resisting properties of annealed steel received some attention during the past year and it will be continued during the coming year. It seems that this particular property of steel is profoundly affected by the size of grain—much more so than any other mechanical property.

Microphotographic Work.

In the study of the structure of metals by means of the microscope, permanent records are made by means of photographs. During the past year 2,118 micrographs were taken for this purpose. Of these, 409 related to materials submitted for examination, and 1,709 were taken in connection with the various research problems in progress in the division of metallurgy.

Investigations Continued and Proposed.

The study of the corrosion of various types of "noncorrodible" steels will be continued during the coming year.

The investigation of the crystallinity of wrought iron as revealed by the "nick-bend" test will also receive some further attention.

In connection with the general study of the "enameling properties" of cast iron, it is expected that considerable microscopic study will be necessary, particularly in connection with the blistering of enamels when applied to certain grades of cast iron.

Further investigation of the relation between the grain size of steel and the shock-resisting and other mechanical properties has been planned.

THERMAL METALLURGY.

Thermal Analysis.

New chronograph for thermal analysis.—The new recording chronograph for the inverse rate method of thermal analysis has been placed in satisfactory operation, and it has been possible to carry out routine and research work with equal or greater accuracy and a time saving of 30 to 60 per cent. A report covering the construction and application of this apparatus has been completed.

Magnetic method of determining critical ranges in ferrous alloys.—Additional work has been done with magnetic methods for determining critical ranges in steels with varying degrees of success.

While no results of special interest can be reported, there are indications that even the simple apparatus now available will be of value as an addition to present thermal equipment for determining transformations in special steels.

Mechanical Properties of Steels at High Temperatures.

Tensile tests.—Following the completion of the two reports referred to in 1921 tests were made of quite a number of commercial carbon and alloy steels and metals of special composition throughout the range 20 to 550° C. Among the most important of these are the following:

(*a*) Normalized carbon steels containing 0.2, 0.4, and 0.6 per cent carbon.
(*b*) Quenched and also quenched and tempered carbon steels.
(*c*) One and one-quarter per cent manganese steel (used for ordnance)—normalized.
(*d*) Cobalt steel (5 per cent Co, 0.60 C)—normalized.
(*e*) Normalized and also quenched and tempered chromium-molybdenum steel.
(*f*) Stainless steel, heat treated in various ways (three series).
(*g*) Chromium vanadium steel (3 per cent Cr. 0.20 per cent V, 0.5 per cent C)—air cooled.
(*h*) Normalized tungsten finishing tool steels (two series).
(*i*) Twenty-eight per cent nickel steel.
(*j*) Special chromium steels containing 3, 5, and 10 per cent chromium.

A "stiffening" (that is, increased strength with decreased dutility) at high temperatures between about 350–550° C. is produced by the addition of such elements as chromium and tungsten, while nickel in small proportions (3 per cent) has little or no effect on the tensile properties, and large amounts (28 per cent) produce a very soft and weak metal. Tests of a series of uranium steels are also now in progress.

While it is desired to accumulate test data for commercial steels, one of the principal functions of this work is to determine effects of various alloying elements in order that special alloys of high strength in various temperature ranges may be produced. The reports covering various phases of this work have been prepared.

Compression tests.—At the request of a manufacturer of forging equipment a special apparatus for compression tests at high temperatures was constructed, and to date one series of tests up to 700° C. has been completed. This work will be extended, and it is hoped to obtain data up to 1,000° C. for a number of the most commonly used "forging steels."

Effect of Heat Treatment on Properties of Structural Steels.

Tests of some of the newer alloy steels, referred to in the 1921 report, have been continued. Two reports were completed. One of these deals with the heat treatment of 1 per cent carbon (spring) steel, while the other considers carbon-molybdenum and chromium-molybdenum steels.

In this latter report an extended discussion is given of effects of various heat treatments on the tensile and impact properties, hardness and microstructure of two molybdenum steels. Particular attention is paid to comparison of oil and water hardening for production of definite strengths and certain peculiarities in behavior, considered to be the result of a molybdenum change, are described.

Surrounding Atmosphere in Heat Treatment and Gases in Steels.

The program of 1921 was modified and extended and some interesting results obtained for steels treated in hydrogen, nitrogen, etc. In studying the variations in mechanical properties between electric-furnace and open-hearth silico-manganese spring steels when subjected to the same heat treatments it was found that the proportion of nitrogen in the electric steel, which in the rolled bars was about twice that in the open-hearth heats, was also dependent upon the heat treatment. This work is being continued to include more observations on the relation of nitrogen to heat treatment.

High-Speed Tool Steels.

Quite a large number of lathe-cutting tests of various high-speed tool steels were made in cooperation with the Navy Department and a report is now in preparation. The work may be described as a critical examination of the severe breakdown test more or less generally used of late for high-speed tool steels and also a comparison of the performance of modern types under varying conditions of service. Examination of fracture, secondary hardness determinations, power input, fracture tests, and miscrostructure are additional factors considered.

Dimensional Changes in Hardening Steels.

As a result of reports of difficulties encountered by a number of firms in the control of dimensional changes, while hardening steel for tools and dies, some work was undertaken to determine the magnitude of these changes resulting from variations in rate of heating, time at hardening temperature, temperature and rate of cooling. Relatively small changes in any of these factors may produce large differences in the dimensional changes found in the hardened steel. In some cases dimensional changes only are obtained while in others volume changes as well are observed. Sufficient work has already been carried out to show the complexity of the problem and the difficulty of reproducing results. The question is, however, of great practical interest and importance and the work will be continued.

Proposed New Investigations.

It is planned to continue work on high-speed tool steels, the control of dimensional changes in hardening and high-temperature investigation relating to special alloys. In addition it is hoped to be able to begin work on several of the following investigations: (*a*) Temperature variation in large masses during quenching, (*b*) artificial seasoning of cast irons, (*c*) stress corrosion tests of boiler plate at high temperatures, (*d*) effect of heat treatment on certain nonferrous light alloys, and (*e*) study of quenching media.

MECHANICAL METALLURGY.

Titanium Treated and Untreated Rails.

The experimental work of this investigation, mentioned in last year's report, has been completed. Sections of rails from several heats of steel with and without titanium treatment were taken from

A-rails and a survey made of the chemical homogeneity, soundness, and uniformity of mechanical properties. The results have been compiled and will be reported as a Technologic Paper.

Corrosion of Iron-Silicon Alloys.

The experimental work of this investigation has been completed and reports submitted to the manufacturers who cooperated by furnishing material.

Effect of Rolling Conditions on the Properties of a Medium Carbon Steel.

The additional work on this report has been completed and the results have been compiled, which it is anticipiated will be issued soon as a Technologic Paper.

Equilibria of Tin-Rich Ternary Alloys.

This work, mentioned in last year's report, has been continued. One point of considerable interest is the detection of a preliminary lowering of the melting point of tin by the addition of 0.3 per cent antimony. All previous investigators have reported an immediate rise in melting point with the addition of antimony which was admittedly contrary to theory. This point is being investigated further.

Wear Testing.

There is a continued call from the industries for information on the wearing qualities and resistance to abrasion of steels and nonferrous alloys. Apparatus for studying the wearing qualities of metals has been obtained and work is actively in progress. The first phase of the work will be a study to determine if any relation exists between hardness and resistance to wear. Particular attention will also at first be given to steels suitable for gauges.

Invar Tape and Shapes.

The United States Coast and Geodetic Survey has use for and need of invar surveyor's shapes because of its low thermal coefficient of expansion. Since the war the Coast and Geodetic Survey has been unable, except with great difficulty, to obtain invar tape or shapes, either in the United States or abroad. The bureau is, therefore, making a general study of the manufacture, mechanical working of invar, and its thermal characteristics, in order to make possible the obtaining of invar products of known and guaranteed minimum thermal expansivity.

Properties of Large Crystals.

A method has been devised for obtaining very large crystals of pure lead and possibly other pure metals. The method also provides a means of studying the solidification of pure metals under unusual conditions. Briefly, the method consists of drawing a large stalactite of metal out of a molten bath. A study of these large crystals and the processes of solidification it is hoped will help to interpret the physical and mechanical properties of cast metals, as well as prove of great academic value.

Foreign Travel and Exchange of Research Personnel.

During the past year a member of the staff visited the principal metallurgical laboratories of France, Switzerland, Germany, and England, and also many large metallurgical establishments. A member of the staff also worked for over two months in the metallurgical department of the National Physical Laboratory of Great Britain, inaugurating an exchange of results between the metallurgical departments of the British and American national research laboratories.

Miscellaneous.

Apart from the major investigations which have been mentioned, this section is interested in several other problems such as a study of the causes of shrinkage of electrotype plates, the testing and development of aluminum solders, the preparation of pure alloys for standards of spectroanalysis, the determination of the melting point of nonferrous alloys.

The rolling mill, forging, and wire drawing equipment has been used a great deal in rolling, forging, or drawing special alloys and shapes for use in connection with research work within the bureau and also for other laboratories and in special work for other Government departments.

Metal Specifications.

This section has been particularly active during the past year in assisting in the formulation of metal specifications. This is best evidenced by the number of specification committees of the Government and national societies on which members of its staff are serving.

CHEMICAL METALLURGY.

Gases in Metals.

The appreciation of the practical importance of gases in metals and their probable relation to many of the hitherto inexplicable differences in quality and service of metals and alloys of supposedly identical composition has grown rapidly during the past year. Both in this country and abroad this phase of metallurgy has come to be regarded as of prime importance. Both the ferrous and nonferrous metallurgical industries are cooperating with the bureau to the fullest extent in all phases of this investigation.

Method for Total Gases in Metals.

The principles of the vacuum fusion method for the determination of gases in metals were outlined in last year's report. Three modifications of the method of fusing the metal samples in the high-frequency induction furnaces have been tested: (1) Melting the metal sample with a gas-free alloy, which lowers the melting point of the original metal and may at the same time throw carbon out of its solution in the metal, (2) melting the metal sample in a refractory oxide crucible by direct induction in the metal itself and (3) melting the sample in a graphite crucible. The second method is satisfactory in the case of carbon-free metals. However, with metals containing carbon there is in most cases an appreciable reduction of the oxide of the crucible, a reduction sometimes so great as to completely decarburize the metal sample, and as a consequence there are obtained results for carbon monoxide and oxygen which are valueless. Satisfactory results for total gas on carbon-free metals by the second method are duplicated by the first method—for example, melting electrolytic iron with an alloy of antimony tin. The antimony tin alloy procedure (originally developed by Sorens) when used with steels or cast irons has the advantage that carbon is thrown out of solution when the metals fuse. In this latter condition the carbon is much less reactive toward crucible refractories than when in solution in the iron or steel. Tests are now being carried out with the third method of melting, viz, in a graphite crucible, in the attempt to develop the procedure as a method for determining oxygen in carbon-bearing metals such as steel, pig iron, and cast iron.

Two forms of Nitrogen in Steel.

During the examination of samples of open-hearth and electric-furnace silico-manganese spring steels for gases it was found that the amount of nitrogen as determined by the Allen or acid-solution method was very noticeably increased after certain heat treatments of the electric furnace steel. No similar change in nitrogen took place in the open-hearth steel after identical heat treatments. Similar increases in nitrogen were found in a plain carbon steel from a section of an autoclave, and also in a series of small electrolytic iron ingots. The only form of nitrogen determined in iron and steel by the Allen method is combined nitrogen, probably existing as nitride of iron, or such minor constituents as manganese, aluminum, or titanium. It is probable that the increase in combined nitrogen with heat treatment observed in these classes of material was the result of the conversion of uncombined nitrogen to nitride nitrogen, and that nitrogen in two forms was present in the samples in which the increase took place. It is believed that such behavior of nitrogen in steel has not previously been reported.

Direct Method for Nitrogen.

This method has been reported previously as applicable to the determination of nitrogen in mixtures with oxygen and hydrogen. During the past year tests of the accuracy of the method for nitrogen-carbon-dioxide mixtures were completed. It is possible to determine 93 per cent of the nitrogen present in mixtures of air and carbon dioxide with the carbon dioxide as high as 75 per cent. With less carbon dioxide present the recovery of nitrogen is still higher. In the absence of carbon dioxide 98 to 99 per cent recovery of nitrogen is obtained. This method of analysis was developed for use in the absorption of nitrogen evolved from metals fused in vacuum.

The Decarburization of Ferrochromium by Hydrogen.

The recent development of "stainless" or "rustless" iron, containing chromium in about the same proportions as stainless steel, but with the carbon content in the neighborhood of, or less than, 0.1 per cent, has emphasized the need of low-carbon ferrochromium. The bureau has carried out preliminary experiments to determine the feasibility of a proposed method for the decarburization of commercial grades of ferrochromium by means of hydrogen. It was found that moist hydrogen at 1,000° C. reduced the carbon content of ferrochromium but also oxidized the ferro-alloy somewhat. Dry hydrogen reduced the carbon very slowly, if at all, at 900° C.; at 1,100° C. the reduction was appreciable; at temperatures close to the melting point of 8 per cent ferrochromium the reduction in carbon was still greater and was much more rapid at a temperature slightly above than at one slightly below the melting point. The most rapid reduction in carbon was obtained by bubbling hydrogen through molten ferrochromium at somewhat above 1,500° C. At a higher temperature and in the presence of silica the loss in carbon was partly due to the reduction of silica to silicon.

The preliminary tests made indicated that while the decarburization of high-carbon ferrochromium by means of hydrogen takes place to some extent at temperatures below the melting point of the alloy, the most promising condition for refining high-carbon ferrochromium by this method is probably blowing the molten alloy in a converter with a blast of hydrogen.

The Effect of Carbon and Manganese on the Mechanical Properties of Iron.

A paper in press describes the preparation and mechanical properties of a series of very pure vacuum-fused alloys of electrolytic iron, carbon, and manganese, whose compositions were chosen so as to bring out the specific effects on pure iron of additions of carbon and of manganese separately and of carbon and manganese together in varying relative proportions. The maximum amount each of carbon and manganese was about 1.5 per cent.

Carbon increased the ultimate strength of the iron at an average rate of 1,000 pounds per square inch for each 0.01 per cent carbon, up to a content of about 0.85 to 1 per cent, the rate increasing with the increase in manganese. The proportionate increase in Brinell hardness was about the same as that for ultimate strength. The proportional limits were less affected by carbon than were the ultimate strengths. Elongation and reduction of area were rapidly reduced as the carbon increased.

Manganese, in the absence of carbon, had very little effect on the mechanical properties of iron. With the addition of carbon its effect was increased proportionately with the carbon content, raising the ultimate strength from 90 to 250 pounds per square inch for each 0.01 per cent manganese. Brinell hardness was increased in about the same manner. The proportional limit was increased more by manganese than was the ultimate strength. The effect of manganese on ductility was negligible.

Invar (36 Per Cent Nickel-Iron Alloys).

Several departments of the Government have been interested in obtaining small amounts and special shapes of the nickel-iron alloy known as invar. This alloy has a very low coefficient of thermal expansion. The better grades of this material have in the past been obtained from European sources. During the past year several ingots of this alloy have been made in a high-frequency induction furnace, some ingots containing carbon and manganese in proportions found in commercial invar, and others free from both carbon and manganese. It was found possible easily to prepare this alloy of a quality suitable for precision-instrument material free from carbon and manganese and it has been cast in chill molds and successfully forged. The coefficient of thermal expansion of the alloy as forged varied from 0.8×10^{-6} to 1.1×10^{-6} for the range 20 to 100° C. One sample as forged had a coefficient of 0.4×10^{-6} for the range 20 to 60° C. Sand castings of invar gave, after annealing, a coefficient of expansion of 1.2×10^{-6} between 20 and 100° C.

Platinum and Platinum-Metal Alloys.

A considerable amount of work has been done on the melting and working of palladium, platinum, and rhodium of very high purity. These metals are fused by direct induction in the high-frequency induction furnace in special refractories—usually thorium oxide. The purest platinum in the possession of the bureau and now used as the standard in the thermoelectric test for the quality of thermoelement platinum was prepared in the course of this work. This sample is 55 microvolts negative to (more pure than) the best sample of Haraeus thermoelement platinum in the bureau's possession at the beginning of the present investigation. Palladium of higher purity than the bureau's previous standard has been melted and drawn to wire by the same procedure. A number of platinum-metal alloys have been prepared for standards for chemical and spectroscopic methods of analysis. Platinum and platinum-rhodium wire has been prepared and furnished to various divisions of the bureau and to other research laboratories for precision thermocouples and resistance thermometers.

It is hoped that it will be possible to undertake the preparation and investigation of the properties of a number of platinum and platinum-metal alloys with particular reference to improving the quality of platinum laboratory ware.

Special Alloys and Castings.

The bureau's equipment in the line of electric vacuum and high-frequency induction furnaces enables it to make a great variety of special metals, alloys, and castings. Among those made during the past year may be mentioned vacuum-fused electrolytic iron wire and sheets, "stainless" steel and "rustless" iron castings and forgings, manganese-steel castings, carbon-free iron-tungsten alloys, fused tungsten carbide, vacuum-fused cobalt, and cobalt-iron castings.

Proposed New Work.

It is proposed to lay special emphasis during the coming year on the study of the relation of gases in metals to variations in commercial practice in melting, refining, and working; to differences in quality or service of metals of apparently identical composition apart from contained gases. The continuation of the work on platinum metals in the direction mentioned above, viz, the development of better alloys for platinum laboratory ware, should also receive particular attention. Studies of equilibria in systems involving metals and gases at high temperatures, and the specific heats and thermal conductivities of metals and metallurgical refractories at high temperatures are proposed new lines of investigation.

EXPERIMENTAL FOUNDRY.

Production of Castings.

The foundry has continued to serve the bureau and certain other Government departments in the production of castings, mainly for instrument parts and in connection with research material. The past year there were made 1,881 castings from 15 kinds of metal. It is planned to install a cupola during the coming year for the more convenient production of cast-iron castings.

Molding-Sand Tests and Investigations.

Various samples of molding sand have been tested for State surveys, producers, and foundries. The research work on molding sands has been largely carried out in cooperation with a joint committee representing the industry. A new type of permeability apparatus has been developed and is under investigation. The research work relating to standard tests of fineness and cohesiveness has been practically completed. A muller is being installed for the preparation of synthetic sands.

PROBLEMS OF MILITARY INTEREST.

Erosion of Special Machine-Gun-Barrel Steels.

Twenty alloy steels which were recommended by members of the bureau, War Department, and sources outside of the Government departments, for service as machine-gun-barrel steels were prepared for metallurgical and service tests.

The bureau has been engaged in obtaining physical data upon these steels pertinent to the erosion problem. One of the arsenals of the War Department has been active in the manufacture and service testing of the barrels. The testing of the final lot of barrels is now in progress. The project has progressed through 80 per cent of its course and should be completed during the coming year.

During the year the bureau has replaced six of the special alloys when the supply for the experimental work had given out. Reports have been distributed on (*a*) the degree of fiberization and segregation in the special steels, (*b*) the thermal expansion and contraction of the special steels, and (*c*) the attempted electrodeposition of erosion-resisting coatings.

In connection with the work above an investigation has been begun of the possibility of impregnating a steel surface with a refractory element suitable for resisting corrosion.

Development of Light Armor Plate.

In conjunction with the War Department the bureau has undertaken the problem of developing light armor plate and of preparing specifications expressing in physical terms those properties of armor plate which are at present expressed in ballistic terms.

The first portion of the work allotted to the bureau, namely, the preparation by a special process of a series of plates, has been completed and the plates shipped to one of the proving grounds for ballistic tests. Other work in connection with this problem has been outlined but held pending the results of the firing tests.

Reports have been submitted on (*a*) the change in properties with heat treatment of two typical compositions of armor plate, (*b*) effectiveness of different commercial carburizers upon armor-plate steel, (*c*) effectiveness of different cleaning methods, (*d*) rate of carbon penetration, and (*e*) efficiency of various coatings for selective carburization.

Work on the correlation of ballistic properties with physical properties has been outlined with the purpose in view of determining the properties necessary in a successful plate. The drawing up of specifications which recommend the manufacturing procedure and demand certain physical properties is expected to remove the mystery connected with the ballistic requirements, which provoked antagonism among manufacturers.

Corrosion of Metals by Ammonia and Its Constituent Gases.

In cooperation with the bureau, the Fixed Nitrogen Research Laboratory has been engaged in an investigation of materials suitable for use in the nitrogen-fixation apparatus. A special high-pressure, high-temperature corrosion unit has been built at their laboratory and put into operation.

A series of 50 steels and nonferrous alloys have been exposed to the action of the gases and their mechanical properties and structure before and after test studied.

The initial program is roughly 50 per cent completed. The development of satisfactory materials for the fixation work is expected to follow.

During the year a compilation of all data in connection with 30 of the alloys has been made. A report on the occurrence of nitrides and oxides in boiler-tube steel and a report on the mechanical properties of a series of chrome-vanadium steels have been published. Reports which have been submitted on other phases of the work will be revised for publication.

Investigations associated with the principal problem are under way, namely, (*a*) the deterioration of tubing in ammonia at high temperatures, (*b*) the corrosion of iron under stress in ammonia gas, (*c*) strength of certain steels at the operating temperatures, and (*d*) the structure and properties of metallic-base catalysts.

Miscellaneous Investigations.

A number of minor problems and special tests associated with the work above have been undertaken and reported upon to the individuals concerned.

RESEARCH ASSOCIATES.

The same research associates as last year, representing mettallurgical industries, have continued their work in the metallurgical division. The following is an account of their accomplishments:

Iron in Brass.

The research on the effect of small percentages of iron on the magnetic properties of cast red brass has been completed. It was found that no simple relationship existed either in the cast or annealed condition between the iron content and the magnetic properties of the brass. Heat treatment of the alloy produced marked changes in the magnetic effects. Less than 0.14 per cent iron went into solid solution in the brass (82 copper, 15 zinc, 3 tin).

Sherardizing.

The sherardizing process was investigated further. The factor of the fineness of the zinc dust employed was given the chief consideration. The results showed that the rate of deposition is materially affected by the state of subdivision of the dust, but the amount and distribution of zinc oxide present is so intimately bound up with this variable that more study will have to be given the problem before more definite conclusions can be drawn.

Embrittlement of Malleable Iron by Galvanizing.

During the year an investigation was started to study the embrittlement of malleable iron in galvanizing. It has been found in practice that malleable iron that was not abnormally brittle as it came from the malleableizing oven frequently became so on coating with zinc by dipping in the molten metal. The work to date has shown that the embrittlement is probably entirely due to the heat treatment the iron receives The fact that the metal becomes coated with zinc has little effect on the shock resistance of the metal, but the circumstance that the iron becomes heated to about 450° C. on being immersed in the molten zinc, followed by rapid cooling, is the real cause of the embrittlement. Some malleable iron does not seriously deteriorate under these conditions. There seems to be a rough proportionality between the silicon content (0.5 to 0.9 per cent) and the embrittlement produced. That silicon is probably not the sole cause of this harmful effect is shown by the fact that commercially pure iron to which varying amounts of silicon up to 1 per cent had been added was not seriously influenced by the heat treatment. On varying the temperature from which samples of malleable iron were rapidly cooled it was found that up to 450° C. the resulting metal was increasingly brittle. At somewhat higher temperatures, however, the resistance returned and even increased over that of the untreated iron, so that at about 600° C. the metal became one and one-half times as resistant to shock as it was before treatment. Unfortunately the brittle range coincides with that used in hot-dip galvanizing. There appear so far to be two ways to overcome this embrittlement. One is to anneal the galvanized pieces at a low temperature (160° C.) for four hours or more. The second is to heat the malleable iron to a temperature above the brittle range (say 625° C.) and quench. This metal can then be galvanized without serious loss of resistance. Further data as to the cause of the embrittlement are now being secured.

Deoxidation of Iron and Steel.

During the past year considerable improvement has been made in the technique of laboratory work on deoxidation. Improved methods of making the magnesia crucibles used in the work have been of great help. These are now made by tamping the moistened magnesia into a paper mailing case of suitable size, using a wood mandrel for the core. The crucibles are then baked in an oven and burned in lots of 12 or 14 in a large gas furnace at about 1,500° C. Such crucibles are very satisfactory for use in the induction furnace.

Most of the laboratory deoxidation tests are now carried out in the induction furnace, since it has been found during the previous experiments that the atmosphere of an Arsem vacuum furnace causes reduction of iron oxide whether a deoxidizer is present or not; moreover a melt made in an Arsem furnace gives a sound ingot with or without a deoxidizer. This is due to the fact that the gases causing unsoundness are removed by the vacuum, and no deoxidizer is needed for such purpose when melts are made in vacuo.

When carrying out the melts in the induction furnace it has been found that a very considerable amount of oxidation occurs by action of the air on the molten ingot iron, and this is being further investigated. It is believed that some of this oxidation is due to the porosity of the crucible which allows air to enter and oxidizes the metal. This matter has been investigated by making melts under hydrogen and nitrogen in such crucibles. Although the air is thus excluded quite completely from the surface of the melt, there is nevertheless some oxidation, and this must be due to the porosity of the crucible. It is expected that this difficulty in the preparation of a standard material for testing deoxidizers will be eliminated by melting in a vacuum, then introducing enough air to give a definite oxide content in the metal, then adding the deoxidizer and pouring or allowing to solidify in the crucible. As soon as this latter part of the work is completed a paper is to be prepared giving the details of a method which has been developed for testing the iron-oxide removing power of various deoxidizers.

Considerable progress has been made in the endeavor to correlate laboratory deoxidation experiments with those on a larger scale. From the parallel sets of experiments which have been conducted thus far it is evident that the proportion of deoxidizer needed to accomplish a given result increases progressively in the order: Laboratory experiment, large ingot experiment, small ladle experiment, and large ladle experiment. The causes for this variation are now being investigated; they seem to lie partly in the reaction of the deoxidizer with the slag, in the mechanical difficulties, and in the variation of the gas content of the metal in the different pieces. It is hoped to follow some of this work by gas analyses of the various products in order to get more information on the fundamental laws involved.

Hot Shortness of Ingot Iron.

The various ingots made to test the effect of different elements on the hot forging properties of iron have been assembled and completely analyzed. A few more ingots are to be prepared to check the results already obtained and the results will then be published in a paper giving experiments and conclusions on the effect of oxygen, sulphur, manganese, and copper on the red shortness of low-carbon iron.

The Trent Process.

In order to test the products made by the Trent process of direct reduction of iron ores, several experiments were carried out in which the various factors of the process such as the fuel and ore used, various temperatures, time of reaction, etc., were varied. This gave corresponding variations in the products made by this process.

Although this work has not been completed it has been found that there is an optimum temperature range for each ore and each reducing material. If the temperature is carried too high there is considerable slagging of the reduced iron with impurities in the ore. If the temperature is too low the reduction to metallic iron is not complete. In all cases it has been found exceedingly important to protect the reduced material from oxidation while it is cooling to ordinary temperatures. If this precaution is not taken the air or the products of combustion of a fuel-fired furnace will completely oxidize the reduced iron. It was found in these experiments that a gaseous reducing agent is much more convenient and effective in general than a solid one.

In carrying out the magnetic separation phase of the Trent method it was found that not less than 90 per cent of the magnetic material was recovered and oftentimes as high as 95 per cent. Here again it was found desirable to control the reaction temperatures very closely.

Some examinations have been made of "amalgam," using dyes to color the oil and water used in making this product. The formation of the product under the microscope has also been observed. From such examinations it has been concluded that the "amalgam" consists essentially of oil-coated particles in clusters with water on the outside and in the inner spaces of the clusters. There also seems to be a certain amount of water in the interior of the oil-coated particles. During the process of formation of the "amalgam" it can be seen under the microscope that the water in the interior of the oil-coated particles tends to migrate out of the interior but probably not all of it gets out when equilibrium is reached.

Effect of Cold Rolling on Some Mechanical Properties of Monel Metal Sheet.

Tensile and hardness tests were made on a number of monel metal sheets with various amounts of cold-rolling, followed by annealing at various temperatures. The following conclusions could be drawn from these tests:

1. Cold rolling up to about 80 per cent reduction in thickness increases the hardness of monel metal. With greater cold rolling this material gives lower hardness values both for Brinell and scleroscope.
2. A temperature of 800° C. is required to thoroughly anneal Monel metal which has been cold rolled to about 80 per cent reduction in thickness.
3. Monel metal cold rolled above 85 per cent reduction in thickness is not thoroughly annealed at 900° C.
4. Increased cold rolling up to about 60 per cent reduction in thickness increases the tensile strength and decreases the elongation
5. Cold rolling beyond 20 per cent reduction in thickness followed by annealing at 700° C. or above produces a decrease in both tensile strength and elongation.

Equilibria of Nickel-Nickel Oxide.

Nickle oxide has been shown to be practically insoluble in solid nickel. It forms a eutectic mixture containing 0.47 per cent oxygen, corresponding to 2.2 per cent NiO. The melting point of this eutectic is 1,438° C. The melting point of nickel oxide in air has been found to be 1,660° C. It remains to be proved that the composition of the oxide in nickel is NiO and that this is stable up to its melting point, 1,660° C.

Stress Corrosion Test on Monel Metal.

Several specimens of monel metal stressed in tension above their yield point have been alternately exposed to air and immersed in water from the city water supply of Washington. These specimens have been under stress for eight months and have shown no indication of failure.

A specimen of monel metal was stressed in tension above its yield point and remained immersed in aqua ammonia for two months without showing any signs of local corrosion or season cracking. The ultimate strength and elongation of this specimen was not affected by this treatment.

The Effect of Impurities on the Malleability of Nickel.

It has been shown that nickel containing carbon, nickel oxide, hydrogen, or carbon monoxide and only traces of sulphur is malleable. Nickel containing a very small amount of sulphur, 0.01 per cent or more, will crack on forging, either hot or cold. The addition of magnesium to nickel containing sulphur renders it malleable.

The bureau is unable to identify the sulphur constituent in nickel which contains as low as 0.01 per cent sulphur. The addition of manganese does not change its appearance, while the addition of magnesium does. The sulphur constituent of nickel to which magnesium has been added has not been identified.

The effect of sulphur in nickel will be determined with conditions resembling commercial practice.

TESTS.

Fusible Boiler Plugs.

There were tested during the year 446 fusible boiler plugs, 440 being tested for the Steamboat Inspection Service, 2 for the Panama Canal, 1 for United States Lighthouse Service, Detroit, Mich., 1 for United States Engineering Office, St. Louis, Mo., and 2 for the Walworth Manufacturing Co. Of these 142 were rejected, 27 on account of copper content being more than 0.3 per cent, 26 on account of the lead content being more than 0.1 per cent, 26 on account of the copper content being more than 0.3 per cent and the lead content being more than 0.1 per cent, 3 on account of the iron content being more than 0.1 per cent, 1 on account of the zinc content being more than 0.1 per cent, 32 on account of the total impurity content being more than 0.3 per cent; 15 on account of the tin fillings being loose, 9 on account of the casings not being bronze, 2 on account of failures in mechanical specifications, and 1 on account of the melting point of tin filling being less than 230° C. Seven plugs were reported as having loose fillings. One plug tested was taken from the boiler which exploded on the steamer *Omer D. Conger*. Tests showed that the copper content at the small end of the bore was greater than at the large end, the chemical analysis giving copper content at small end 2.68 per cent, while at large end 0.18 per cent.

Tests Involving the Microscopy of Metals.

The following cases are given as typical of examinations of this kind which the division has been asked to make during the past year. Tests of this kind are largely investigational in character. They are of great variety and each requires individual treatment.

Steel from Knickerbocker Theater.

Of more than simply technical interest was the examination of samples of steel from the trusses of the Knickerbocker Theater. The steel did not differ materially from the usual grade of structural steel. There were no structural features found which would lead to its being regarded as defective.

Failed Parts, Subject to Stress.

The following are examples of *failed parts* subjected to *high repeated stress:*

A drive shaft from a Government Quartermaster Corps truck broke, causing an accident involving the death of a soldier. It was found that most probably the primary cause of the failure was the result of mechanical causes rather than in the inherent character of the metals used. However, the fracture occurred in the weld between the hollow shafting and the solid end, showing that this was a weak point. It was found that the tubing was of low carbon steel and seemed to be unsuitable for a part subject to high stress.

Two somewhat similar failures from a 4-wheel-drive truck were also examined.

Forged-steel anchor bolts varying widely in composition and mechanical properties but all of which showed fractures of the fatigue type all failed in the same relative position in the bolt. This indicated strongly that the fault did not lie in the material of the bolts but in the mechanical design.

A broken crank shaft from a 10-ton ammonia refrigeration machine was found to be of a chemical composition often used for such parts. Microscopic examination showed, however, that the material was porous and had received insufficient forging. There was also evidence that surface defects had been filled in with fused iron, probably by a fusion welding process. The internal discontinuities reduced the ductility very materially, so that the metal offered relatively low resistance to fatigue stresses, and the fracture once started by the surface defect easily progressed through the unsound metal.

Duralumin Forms.

These shapes were to be used in the construction of an all-metal seaplane. They showed a number of surface markings designated as crude spots, scale blisters, oxide spots, hard spots, etc. Since they occurred usually at the sharp bend of the specimens, it appeared that they were the result of preëxisting defects which were made prominent by the shaping of the specimens.

Welded Sheet Aluminum.

Two grades were submitted; one was claimed to have welded satisfactorily, the other showed cracks adjacent to the welds. It was found that the satisfactory material was a much purer metal and also that it had been rather severely cold rolled, so that its tensile strength was greater. The immediate cause of the cracks was undoubtedly the high local stresses resulting from the high shrinkage of aluminum upon cooling from the welding temperatures. It is still an open question whether to attribute the superior welding properties of the satisfactory sheet to the ability of this material to withstand such stresses because of its higher yield point and tensile strength or to the absence in this metal of the network of the constituent resulting from impurities (iron and silicon). Further investigation is needed on this point.

Corroded Copper Tubing.

This tubing was from a heating and cooling coil of a milk pasteurizer. Iced brine is used as a cooling agent and this, together with the action of the steam upon the heating, had badly pitted the tube and completely perforated it in places. The copper was found to be of high quality, so that the trouble could not be attributed to any defect in the metal but rather to the conditions under which it was used.

Brass Condenser Tubing.

A large number of new and used brass condenser tubes were tested, the new ones in accordance with the specifications of the United States Shipping Board. These require a grain-size determination and mercurous-nitrate solution test among others. Many of the old corroded tubes that were examined consisted of the two-constituent, alpha-beta brass which corroded much more easily than the one-constituent, alpha brass, particularly if the latter contains 1 per cent tin called for in the present specifications.

Special Rolled Steel.

This material, submitted by the inventor, was prepared by pressing machine turnings into briquets, heating and rolling to shape. The metal is not melted. This process is claimed to have a decided commercial value. The amount of oxide was found to be greatly in excess of what is ordinarily found even in low-grade steels. This would limit the material to those uses for which the cheaper and lower grades of steel are generally employed.

Cooperative Tests.

A large number of microstructural examinations were made in connection with the following investigations of the bureau which are described elsewhere: Study of magnetic properties of the microconstituents of hardened and tempered carbon steel, Schoop spray process for coating metals, enameling of sheet steel, deoxidation of monel metal, special deoxidizers for steel, effect of mechanical working on properties of steel, and study of iron-carbon-manganese alloys.

Effect of Hot Gases Upon Steel.

The examination of a steel used in the construction of an autoclave used in the Haber process for nitrogen fixation showed that the metal underwent very decided changes in composition and properties in contact with the hot gases (principally the hydrogen). The carbon was removed to a large extent and the metal developed very pronounced "blisters." An alloy steel of the chrome-vanadium type was recommended in place of the simple carbon steel previously used.

Chart of Tests.

There is attached a chart giving a summary of the tests carried out in the division during the past year, the estimated value of which is $12,662.

TESTS COMPLETED DURING FISCAL YEAR 1922.

	Heat treatment and thermal analysis.		Metallographic (including physical, chemical, and corrosion tests).				Fusible plugs.	Castings.		Total.
	Irons and steels.	Nonferrous metals.	Irons and steels.	Aluminum alloys.	Brass and bronze.	Miscellaneous.		Ferrous.	Nonferrous.	
For the Government:										
Agriculture Department			1							1
Bureau of Standards	2,056	67	14						1,592	3,729
Navy Department			9	9	3					21
Panama Canal			4							4
Steamboat Inspection Service							446			446
War Department	18		7							25
Treasury Department			1		2	1				4
U. S. Shipping Board			1		48	4				53
Bureau of Lighthouses					3					3
Foreign and Domestic Commerce			1							1
Government Printing Office			1							1
Coast and Geodetic Survey								289		289
General Supply Committee			27							27
Total	2,074	67	66	9	56	5	446	289	1,592	4,604
For the public	1,512	5	43	13	4	26				1,603
Grand total	3,586	72	109	22	60	31	446	289	1,592	6,207

PUBLICATIONS.

Publications Issued During the Year.

Publications by members of the metallurgical staff appearing during the year are as follows:

The manufacture and properties of steel plates containing zirconium and other elements (G. K. Burgess and R. W. Woodward), Tech. Paper 207.

Thermal stresses in chilled iron car wheels (G. K. Burgess and R. W. Woodward), Tech. Paper 209.

Tests of centrifugally cast steel (G. K. Burgess), Tech. Paper 192.

The Government laboratory and industrial research (G. K. Burgess), Trans. Am. Soc. for Steel Treating, 1, p. 91, and Scientific Monthly; December, 1921.

Effect of sulphur on rivet steel (G. K. Burgess and C. L. Warwick), Preliminary report of the joint committee on phosphorus and sulphur in steel, Proc. Am. Soc. for Test. Mat., 22; 1922.

The structure and related properties of metals (H. S. Rawdon), Circular 113.

Metallographic testing (revised edition) (H. S. Rawdon), Circular 42.

Chemical and mechanical properties of arc-fused steel (H. S. Rawdon), Proc. Am. Welding Soc., Vol. III.

The microscopic study of the structure of metals (H. S. Rawdon), Am. Machinist, 55, p. 659.

Fusion welding—a new use for castings (H. S. Rawdon). (Contribution to discussion of fusion welding.) Year Book, Am. Iron and Steel Inst., pp. 340–348; 1921.

Metallographic factors in carburization. Discussion of "Effect of quality of steel on case carburizing results" (H. S. Rawdon), Trans. Am. Inst. of Min. and Met. Engineers; 1922.

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Brittleness developed in pure lead by stress and corrosion (H. S. Rawdon, A. I. Krynitsky, and J. F. T. Berliner), Chem. and Met. Eng., 26, p. 109; 1922.

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Tensile properties of some structural alloy steels at high temperatures (H. J. French), Tech. Paper 205. Trans. Am. Soc. for Steel Treating, Vol. II, p. 409; 1922.

The effect of heat treatment on the mechanical properties of a carbon-molybdenum and a chromium-molybdenum steel (H J. French), Trans. Am. Soc. for Steel Treating. Vol. II, p. 769; June, 1922.

The elements of heat treatment of steel (H. J. French), Amercian Machinist, 55, pp. 907, 960.

Experiments on the artificial seasoning of gage steels (H. J. French), Chem. and Met. Eng., 25, p. 155; 1921.

Discussion of paper by R. S. MacPherran on Steels at high temperatures (H. J. French), Proc. Am. Soc. for Test. Mate., 21, p. 861; 1921.

The effect of heat treatment upon the properties of one per cent carbon steels (H. J. French and G. W. Johnson), Tech. Paper 206. Trans. Am. Soc. for Steel Treating, Vol. II, p. 467; 1922.

Discussion of paper by MacQuaid and Ehn on "Effect of quality of steel on case carburizing results" (H. J. French and L. Jordan), Trans. Am. Inst. Min. and Met. Engineers; 1922.

Strength and elasticity of boiler plate at high temperatures (H. J. French), Chem. and Met. Eng., 26, p. 1207; 1922.

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Mechanical properties of metals and alloys (R. W. Woodward), American Machinist 55, p. 596.

Note on the properties of antimonial lead (J. S. Hromatko and L. Gurevich), Chem. and Met. Eng., 25, p. 62; 1921.

Nitrides and oxides in boiler tube steels (J. S. Vanick and A. E. White), Trans. Am. Soc. for Steel Treating, Vol. II, p. 323; 1922.

Some mechanical properties of hot-rolled Monel metal (P. D. Merica and R. G. Waltenberg), Proc. Am. Soc. for Test. Mate., 21, p. 922; 1921.

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Graphitization of white cast-iron below the A_1 transformation (S. Epstein), contribution to the discussion of "Malleableizing of white cast iron," Trans. Am. Inst. of Min. and Met. Engineers; February, 1922.

Contribution to discussion of "Experiments with sherardizing" (L. H. Marshall), Trans. Am. Inst. of Min. and Met. Engineers; February, 1922.

The Coprecipitation of vanadic acid with ammonium phosphomolybdate (J. R. Cain and J. C. Hostetter), Jour. Am. Chem. Soc., 43, pp. 2552–2562; 1921.

Publications in Press.

Comparison of titanium treated and untreated steel rails (G. K. Burgess and Willard Quick).

Thermal stresses in steel wheels (G. K. Burgess and Willard Quick).

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Some observations on the corrosion of various types of chromium steels (H. S. Rawdon and A. I. Krynitsky), Chem. and Met. Eng.

Deterioration of alloys by internal oxidation. Contribution to discussion of "The effect of impurities on the oxidation and swelling of zinc-aluminum alloys" (H. S. Rawdon), June (1922) meeting, Institute of Metals, Am. Inst. of Min. and Met. Engineers.

Some metallographic features of aluminum-bronze. Contribution to discussion of "Occurrence of blue constituent in high-strength manganese bronze" (H. S. Rawdon), June (1922) meeting, Institute of Metals, Am. Inst. of Min. and Met. Engineers.

Effect of grain-size in low-carbon steel on the results of impact tests. Contribution to discussion of "Effect of sulphur in rivet steel" (H. S. Rawdon), June (1922) meeting, Am. Soc. for Test. Mate.

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The decomposition of martensite into troostite in alloy steels (H. Scott), forging and heat treatment.

On precision altimeter design (J. R. Freeman and J. B. Peterson), Report No. 126 of National Advisory Committee for Aeronautics; 1922.

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The decarburization of ferrochromium by hydrogen (L. Jordan and F. E. Swindells).

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CERAMICS.

The work in connection with ceramics deals with standards of quality, methods of test, and specifications for ceramic materials and products; the study of problems relating to the preparation and utilization of ceramic materials and to the manufacture of ceramic products; the elimination of waste by supplying definite guides to purchasers, governmental and private, and by obtaining and disseminating to manufacturers scientific information of assistance in the improvement of products and in increasing the efficiency of methods. The products embraced in this work include building materials, such as brick, hollow tile, wall tile, and architectural terra cotta; drainage materials, such as sewer pipe and draintile; paving materials, such as paving brick and floor tiles; refractory materials required for the lining of metallurgical and other furnaces; pottery and porcelains, including dishes, sanitary ware, electrical porcelain, and chemical porcelain; glass products, including window glass, glass containers, and optical glass; and products made by the enameling of sheet iron or sheet steel, cast iron, and other metals.

GENERAL.

The assistance which the bureau can render to both the consumer and producer of ceramic products has never been more appreciated than during the past year. This has been shown both in the demands which these interests have made on the bureau for technical help, and the amount of time which representatives of individual corporations or of organizations have spent in conferences with representatives of the division. Two striking examples of this are in the cooperative work under way dealing with refractories and white ware (tableware).

In the former case a strong demand was made both by the public and certain Government departments for a more discriminating set of specifications for refractories for various uses. A rather too marked attitude of indifference on the part of both the consuming and producing interests and a lack of interest in and appreciation of the problems of each other was quickly removed at the first joint conference of all concerned. A very comprehensive investigative outline was prepared which is now being carried out by the bureau with the hearty cooperation of all interested.

The National Government and the various State and large municipal governments are larger consumers of tableware than is generally appreciated. That they should have presented to the bureau the need of specifications for the purchase of this ware should not be surprising. They have been accustomed to make purchases on the sole requirement of equality to a certain brand or make or that the ware should be "fully vitrified." This latter request, while fully justified, on account of the need of a nonabsorptive dish in the various municipal or other Government hospitals and institutions, does not in itself secure the end in view. Simple as the term may seem, it does not serve to define the amount of absorption desired or allowable. Also this is but one of the properties which such a product should have; equal important are the resistance to breaking, or chipping, or crazing, or cutlery making. These features have been considered of but secondary importance by the manufacturer when compared with the general appearance and the cost of production of the ware as affected by different raw materials or procedures in manufacture. When the importance of these factors was recognized at conferences, a very broad investigation was outlined, in the carrying out of which a representative of the bureau visited all the plants making "vitrified" tableware and prepared special test pieces at all but two plants. These specimens will later be tested at the bureau.

Preliminary work done at the bureau on finished ware has shown that on the average domestic ware of this type is superior in these points to imported ware.

Such problems as the above, dealing with the properties of finished ware, immediately bring to the attention of the manufacturer the question of the quality and effect of the raw materials on their products. With the example before them of the methods of investigating the finished product used by the bureau and having seen the equipment available for such lines of work, they have brought many of their individual manufacturing problems and difficulties to the bureau for solution.

The two examples cited above are both typical of the work which is being done for the other branches of ceramics, as: The enameled ware industry; the glass industry (particularly glass containers and sheet glass); hollow tile, architectural terra cotta, and heavy clay products industries.

CLAY PRODUCTS.

Development of Methods of Tests and Specifications for Vitrified China and Semiporcelain Tableware.

Several departments of the Government which are large purchasers of tableware, as well as large private purchasers, have felt the need of adequate tests to enable them to distinguish between different makes of chinaware which, while similar in appearance, differed widely in cost, the claim being made that the higher priced wares were superior in qualities essential to satisfactory service. In order to satisfy the needs of these purchasers and at the same time place the purchase of chinaware on a basis more satisfactory to those manufacturers who are producing, or preparing to produce, goods of high quality, the bureau has undertaken the development of tests for the most essential qualities. These are: Freedom from tendency to craze, resistance to acids and alkalies, nonabsorbent quality of body, and resistance to mechanical injury. As the result of a large amount of experimental work, methods of test, applicable particularly to hotel china, have been developed for absorption, resistance to breakage, to chipping and crazing. A series of chemical tests demonstrated the fact that none of the hotel china now on the market in this country is affected by such acids and alkalies as are likely to be encountered in actual service, and consequently no method for chemical test has been adopted. Attempts to develop a satisfactory test for ability to withstand the abrasion of table cutlery and other wear incident to washing and handling have not been successful, and this test will require further work as it is important.

The tests so far adopted have been applied to 35 brands of ware, part of which were of foreign make. American manufacturers cooperated heartily in the work by supplying samples for test. The results of these tests, which have been published, show that American-made hotel china is superior to the best imported brands in several respects, particularly in resistance to breakage and chipping and to sudden temperature changes.

The United States Potters Association and the American Vitrified China Manufacturers Association are cooperating with the bureau in the work of preparing specifications to be based on the information obtained and to be obtained by additional studies that have been outlined.

Physical Properties of Hotel China Bodies.

This is one of the additional studies referred to above in connection with the work on specifications. One of the factors which complicate the situation and on which it is necessary to obtain definite, quantitative information is the effect of the differences in heat treatment secured in different parts of the commercial pottery kiln on wares of different body compositions. Test pieces have now been made up in 11 of the American factories producing vitrified china, and these are being fired in different portions of the kilns; in order that these pieces might all be made up in the same way and be fully comparable a representative of the bureau visited the various factories and personally prepared the test pieces. They will be shipped to the bureau, where a systematic comparison of their properties will be made and the results made available to the manufacturers cooperating in the work.

Effect of Thickness of Plates on Resistance to Impact.

This is another problem which has arisen in connection with the work on specifications and which has been taken up in cooperation with the manufacturers. Producers are making plates of various types in several different thicknesses and sending them to the bureau to be tested for resistance to breakage by impact. It is hoped that it will be possible from the data obtained in this study to establish relations between thickness of plates and resistance to impact and to determine approximately what thicknesses are most advantageous, particularly in plates.

Properties of Foreign and Domestic Ball Clays.

The question of ball clays is one which has given potters and other manufacturers of white ceramic products a great deal of trouble. This is due to the fact that ball clays from different sources vary to an important extent in their essential properties and that there has been no complete information as to the properties of the various clays. In changing from one clay to another, the potter was likely, in securing proper working properties in his body, to encounter bad firing qualities and to suffer such losses as tended to discourage all changes that could be avoided. This has had the effect of retarding the adoption of the American ball clays and at the present time the English clays are used in much greater quantities by American manufacturers than are the domestic materials, although large deposits of the latter are available.

A comprehensive investigation of all the American and English clays in use in the manufacture of china, earthenware, electrical porcelain, sanitary ware, and floor and wall tile has been completed and is now ready for publication. Among the properties studied were water of plasticity and drying shrinkage relations, strength in the plastic condition, strength when dried, viscosity of slips of the clays, oxidation behavior, volume and porosity changes in firing over a wide range of temperatures, and color in a standard body.

It has been found that while the English clays have a greater strength in the dried state, and a more desirable behavior in firing, the American clays contain less coarse mineral matter and carbonaceous material, and fire in general to a better color. The data obtained in this work will serve as a guide to the manufacturer in making changes in the ball-clay content of his ware and will thus facilitate the greater use of domestic clays than heretofore.

Comparison of Foreign and Domestic Clays as Fillers for Paper.

A large tonnage of high-grade clays is used in the United States as fillers for various grades of paper, particularly in the line of book papers. A very large part of this material is imported, due to the fact that the domestic clays that are available are not considered as satisfactory as the foreign grades. With a view to obtaining definite information as to what properties of clays determine their suitability for this purpose an investigation consisting of a combination of laboratory studies and factory experiments is being carried out. Samples of 18 foreign and 22 domestic clays were obtained and these have been tested for grit, color, and plasticity. Eight of the 40 clays were selected to be tried out in actual factory production in order to establish the relations between their physical properties and their suitability for commercial use. On these eight clays the following physical properties were determined: (1) Volume shrinkage, (2) slaking behavior, (3) transverse strength of clay in dry state, (4) ratio of pore water to shrinkage water, (5) viscosity water relations after treatment with various percentages of sodium hydroxide and alum, (6) fineness as indicated by rate of settling in water, (7) fineness as determined by elutriation, (8) specific gravity, (9) grit content, and (10) plasticity. The physical testing has been completed; the mill runs are still in progress.

In this connection, acknowledgment should be made of the hearty cooperation accorded the bureau by paper manufacturers, not only in carrying out in the mill operations which necessarily interfere with normal production, but also in contributing liberally of their time and the information at their disposal.

Clays for Coating Paper.

The situation in regard to coating clays is similar to the filler clay situation, most of the material being imported although domestic clays for the purpose are on the market. An investigation is accordingly being made for the purpose of obtaining information which will serve as a guide to paper manufacturers in the purchase of coating clays and if possible promote the more general use of the domestic clays.

The usefulness of a clay for this purpose depends on: (1) Color, (2) freedom from grit, and (3) fluidity of the clay slip when mixed with a sizing material. This last property is very necessary and different clays differ greatly in their behavior in this respect. Considerable work has been done in an attempt to connect this essential property, or tendency of clay suitable for coating paper with some readily measurable property or properties of clays. The Bingham plastometer has been used in connection with this work and some promising results have been obtained. The work is still in progress.

Plasticity of Clays.

One of the most essential properties of clays and the one which makes it possible to form a wide variety of commercial articles from them by practical methods is plasticity. While this is a property common to almost all useful clays, it is one which is difficult to define and still more difficult to measure. Because of the need for a better understanding of plasticity and of means for determining it quantitatively, so that this property may be included in practical commercial specifications for clays for specific uses and that it may be studied more intelligently in relation to other characteristics, a study is being made of various methods that have been proposed for measuring it. During the year an experimental study has been made of the results that may be obtained by the use of the Bingham plastometer. By virtue of the principles involved in the operation of this instrument it resolves the property plasticity into two components—yield value and mobility. The work with the plastic flow of clay slips has shown that these slips do not behave like plastic substances that have previously been investigated. The equation for reducing the two components, yield value and mobility, to values independent of the capillary does not apply to the flow of clay slips through capillary tubes. It has not so far been possible to formulate equations reducing these components to absolute values independent of the capillary, but by using the same capillary with different slips it is probable that approximate comparisons of the values for different clays may be made.

Cooperative Investigation of Water Smoking and Dehydration of Clays.

This work is being done in cooperation with a group of manufacturers' organizations, including the American Face Brick Association, Hollow Building Tile Association, Common Brick Manufacturers' Association of America, and National Paving Brick Manufacturers' Association. Both the water smoking and the dehydration of clays are processes which have long been recognized as marking essential stages in the burning of clay products, but definite information as to the temperature limits within which each takes place, the rates at which the water is eliminated at different temperatures, and the safe rate of heating, at different stages for different types of clay, has been meager. The rapid development in new types of kilns for the burning of heavy clay products that is now in progress and in prospect adds greatly to the present importance of such information because some of the most vital problems involved in the design and operation of continuous kilns are those connected with these stages of the burning.

The method adopted for obtaining quantitative data in this investigation has been to make up samples of the various clays to be studied in the form of 4-inch cubes and to pass these through the initial stages of burning at different rates in a special electric furnace which is so constructed that the loss in weight taking place in the specimen can be observed continuously. The furnace is equipped for testing two cubes at once. The cubes are prepared with small holes running through them at different depths, so that by means of thermocouples in tubes extending through these holes the temperatures at different points in the interior of the pieces can be determined.

The data obtained up to this time indicate that important progress can be made in the reduction of time necessary for burning and in fuel economy. One of the points that has been brought out is that with many clays the safe rate at which the material can be taken through the dehydration period depends on the rate at which the oxidation can be accomplished. Provision is being made for determining, separately, the loss of weight by dehydration and that by oxidation at different temperatures.

GLASS.

Specifications for Glass Products.

1. *Tumblers.*—The attention of the bureau was first directed to the matter of specifications for tumblers by a complaint from a manufacturer in regard to the specifications of one of the Government departments. As a result of inquiry into this matter for the manufacturer, it was learned that the department concerned would welcome an effort, on the part of the bureau, to prepare specifications for glass tumblers which would secure the character of tumbler required by the service for which it was intended and at the same time admit as many bidders as possible to competition for the business. The matter was taken up in a systematic way and simple but reliable tests by which the quality of tumblers could be determined were developed. Specifications for lime-flint glass tumblers were then written and these have been adopted by the War and Navy Departments, the Public Health Service, and the General Supply Committee. Some of the producers have also adopted the tests included in these specifications as routine factory tests. It has been reported by one of the departments of the Government that satisfactory tumblers have been secured by the use of these specifications, at a much lower price than previously.

2. *Glass tableware and containers.*—Methods of test for these products are being developed along the same general lines as those that have been adopted for tumblers. Some of these are now in use as factory control tests.

3. *Window and plate glass.*—Not only the Government departments but also architects and jobbers feel the need of specifications which will make it possible to identify the various grades of window glass and plate glass when they are delivered. The production of these wares in the United States is on a high plane, and the factory grading, done by skilled men, is generally accurate and satisfactory. However, due to the lack of suitable specifications, it is extremely difficult for the builder to tell with certainty whether he has received the grade ordered or a lower and cheaper grade. This gives opportunity for unfair practice on the part of the unscrupulous dealer, with possibilities of unnecessary expense to the purchaser and loss of business on the part of the high-class distributer. A representative advisory committee has been organized to cooperate with the bureau in undertaking to prepare specifications which will place the purchase of this line of materials on a more satisfactory basis. This committte is made up of representatives of the glass manufacturers,

the American Institute of Architects, the National Glass Distributers Association, the Wholesale Sash and Door Association, and interested Government departments. Four conferences have been held and considerable work on classification and definitions and tentative specifications has been done. It can be said with assurance that understandings already arrived at will go far toward eliminating the most serious cause of confusion and trouble in the window-glass business.

Standardization of Milk Bottles.

The lack of uniformity of State and municipal laws in regard to the marking and the capacity of milk bottles imposes a serious hardship on manufacturers on account of the large variety of sizes, shapes, and identification marks required. The additional equipment, additional stocks, and added production cost result in the end in a tax on the consumer. The bureau has undertaken to cooperate in the matter of obtaining relief from this condition. The needs of the milk-bottle manufacturers were brought to the attention of the annual Weights and Measures Conference, which was held at the Bureau of Standards in April, and resolutions favorable to the request for action made by the milk-bottle manufacturers were passed by the conference. Later a conference of bottle manufacturers, dairy supply dealers, milk dealers, and food inspectors was held and an organization for proceeding with the work of securing the standardization of laws regarding milk bottles, and of various essential details of milk bottles themselves, was effected.

Specifications for Lime for Glass Making.

A study of the requirements for lime for glass-making purposes has been made and specifications for lime for such purposes have been prepared. These have been adopted by the Interdepartmental Conference on Chemical Lime, which is made up of representatives of various interested Government departments. The specifications have been issued as Circular 11, and the demand for them has necessitated the printing of a second edition within the year.

Strength of Window Glass.

As a part of the studies preliminary to the preparation of specifications for these materials more than 5,000 samples of plate glass and window glass have been tested for transverse strength and resistance to impact in order to obtain data on the strength of a wide variety of types.

Study of Disintegration of Glass in Water.

The deterioration of glass containers which are repeatedly subjected to treatment in hot water, especially in the process of sterilization, has become a matter of importance because of the tremendous increase in the use of such articles, and a study has been made of the causes of such deterioration and of differences in the ability of containers of different compositions to resist it. A part of this work consists in the development of methods of test to determine the suitability of glass containers for various purposes. The experimental study of the relation between composition of glass and solubility in water is nearing completion, as is the development of a standard method for determining the alkaline solubility of glass.

Ampoule Glass.

In response to inquiries as to the necessary qualities of glass for use in special containers for packing vaccines and intravenous solutions a study of this problem has been made and recommendations submitted.

Glass Containers' Association Fellowship.

The above association of glass manufacturers, food packers, and associated industries now maintains a fellowship at the bureau for research on problems relating to the glass industry. The chief problem now being investigated is "the scumming of bottles," a rather important and troublesome defect which develops while the empty article is in storage and causes considerable loss. This trouble develops more extensively in humid climates, such as exist in parts of South America, and methods of prevention would be very valuable in developing South American trade. A progress report on this work has been written and circulated among the manufacturers of glass, in which is given a simple method for removing this defect from bottles by a washing process. This method, heretofore regarded as impracticable, is proving of considerable practical value.

Optical Glass.

This work consists of investigations relating to (1) the making of optical glass; (2) the molding of optical shapes, such as blanks for prisms, lenses, and optical flats; (3) the annealing of optical glass; (4) the testing of optical glass; and (5) the development and improvement of specifications for (*a*) materials from which optical glass is made, and (*b*) for finished optical glass.

Melting.—During the past year 27 experimental melts of various kinds of optical glass were made. These melts gave approximately 29,000 pounds of glass as follows:

		Pounds.
Boro-silicate crown	(N_d=1.52)	15,500
Light barium crown	(N_d=1.57)	2,300
Dense barium crown	(N_d=1.60)	1,500
Medium flint	(N_d=1.62)	6,750
Dense flint	(N_d=1.65)	3,000

Molding.—The technique of molding blanks for optical purposes has been decidedly improved. Blanks ranging in weight from a few grams to 1,500 grams are now made quite readily by the "sticking up" process, while slabs about 20 by 30 by 10 cm are easily made by melting large pieces of glass in clay boxes.

Annealing.—In nearly all cases strains affecting the optical properties of glass or inducing breakage in it can be removed by proper annealing. This is a process of heating the glass to sufficient temperature and holding it there for a certain time, after which it is cooled slowly. To outline the technique of the best annealing procedure involves the study of many of the properties of glass. Certain problems involved are being investigated by this section in cooperation with the optics and heat divisions.

The electric furnace for annealing optical glass, which was completed early this year, has given very satisfactory results. A system for the automatic control of the temperature of this furnace is being developed in order to insure satisfactory annealing in the shortest time possible; this is difficult to accomplish without such control.

Thermal Properties of Glass.

The problem of producing glass free from strain is of major importance in the commercial production of this material but the available scientific knowledge in this field has long been extremely meager. In the production of optical glass for scientific purposes the elimination of strain as far as possible is indispensable. In the temperature region where glass becomes practically rigid there is, on cooling, an excessive evolution of heat while on heating through this same region there is an abnormal absorption of heat. Through the investigation of these phenomena it has been found that rapidly cooling the glass from a high temperature appears to suppress some molecular transformation which normally takes place. Reheating the glass and annealing it appears to allow the suppressed transformation to proceed, thereby liberating heat to a degree depending on the temperature and annealing time. New data have been collected on this phase of the problem in order to determine the significance of these phenomena and their relation to the general problem of glass annealing.

Hardened Glass.

The resistance of glass to mechanical shock can be increased many times by hardening processes. These processes are practically the opposite of those followed in annealing, the object in annealing being to eliminate as far as possible all strain, while in hardening certain strains properly distributed must be introduced. Glass so hardened is very valuable in the production of protective goggles and other glass which are subjected to extreme shocks. During the year a quantity of glass has been hardened under as wide a variety of procedure as possible. The relative resistance of the various samples has been measured with the object of determining the effect of the variation in the molecular transformation due to various heat treatments. It is expected that the above procedure will lead to an improved process of hardening.

Cooperation with the Navy Department.

One of the fundamental purposes of the work on optical glass is to assure a domestic source of optical glass for scientific and military purposes. The experimental melts of glass often yield considerable quantities of first-quality glass. By special arrangement this glass is molded into optical shapes and delivered to the Navy Department for use in the construction and repair of various optical instruments used in naval service, and performance of such glass is then investigated. This arrangement gives ample opportunity to study the effect of various conditions and defects, such as strain, striæ, etc., on optical performance under actual service conditions. The information thus obtained should eventually become a satisfactory basis for definite specifications for optical glass.

During the past year this bureau has delivered to the naval optical shop glass as follows:

	Pounds.
Medium flint lens blanks	124.25
Light barium crown lens blanks	378.5
Boro-silicate crown prism blanks	1,021.5
Boro-silicate crown slabs, etc	1,122.75
Total	2,647.00

In addition to the above, the requirements for optical glass used in research work of this bureau have been supplied.

Burning Glass Pots and Stirring Rods.

A decided improvement in the quality of glass pots has been obtained by heating the pots very slowly up to 300° C. and then burning them to a temperature at which they begin to soften (about 1,425° C.), which is about 50° higher than the bureau's previous practice. It should also be noted that the pots are completely burned in pot arches instead of a preliminary burn in arches with a final burn in the melting furnace, as is ordinary practice in optical-glass plants.

The slow initial heating and the higher final burning in the pot arch produce pots that are relatively free from cracks and are more resistant to the corrosive action of melted glass.

A decided economy in gas has been effected by burning the stirring rods with the pots instead of in a separate furnace, as is ordinary practice.

Inspection.

The detection of striæ in irregular pieces of glass and molded blanks by the immersion method has been found to be greatly influenced by the intensity of the light used. Fine striæ are invisible in strong light, but become visible when the intensity is reduced.

Chemical.

A study of the relations between composition and optical properties of optical glass is in progress. The information available as to these relations is incomplete and the purpose of this work is to supplement that which has already been obtained by various investigators.

REFRACTORIES.

Specifications for Refractories.

In connection with the work of the Federal Specifications Board, a conference was held at the Bureau of Standards at which those departments of the Federal Government which are large purchasers of refractories were represented. It was brought out at this conference that different departments employ different methods in the purchase of refractories and that the matter could be placed on a better basis if specifications which would be satisfactory to all departments could be established for use in the purchase of refractories for various purposes. The action of the conference took the form of a request to the Bureau of Standards to prepare such a set of specifications.

Realizing, to some extent, the magnitude of this undertaking, the bureau brought about the formation of an advisory committee on which are represented the commercial organizations and technical societies most interested in refractories. Two conferences of this advisory committee have been held at the bureau. At the first, the entire question of tests for refractories was considered, all of the tests that have attained any recognized status being discussed. In the second conference, an attempt was made to prepare tentative specifications for fire brick for the linings of the furnaces of stoker-fired boilers. Test requirements for fire-clay brick for this purpose and for the fire cement to be used with them were written but because of a lack of assurance that they would be effective in drawing a definite line between suitable and unsuitable fire brick it has been considered necessary to carry out an extended investigation in which a systematic comparison of test results with service records of a large number of brands of fire brick should be made. One of the members of the advisory committee has undertaken to secure service records from various sources as well as samples of the brands of brick on which these reports are obtained. These records and samples are being obtained from all the important industrial districts of the United States. The samples are to be subjected not only to the tests in the new tentative specifications, but to other recognized tests for refractories, including (I) 72-hour reheating at 1,450° C., (*a*) on end without load, (*b*) supported at ends and loaded for bending; (II) quenching tests, (*a*) after reheating five hours at 1,400° C.—(1) quenching from 1,350° C., (2) quenching from 1,100° C., (3) quenching from 850° C., (*b*) after 72-hour reheating at 1,450° C.; (III) load test, (*a*) standard load test, (*b*) standard load test except maximum temperature held longer than in present test, (*c*) ball impression test; and (IV) softening-point test. It is possible that a test method may be developed which will give essential information that is not obtained by any of the present tests.

An unusual feature of this investigation is that the samples for test are being obtained from the user instead of from the producer. The advantage of testing samples taken from shipments is obvious, and the fact that a considerable number of consumers (practically all of those who have been asked to cooperate) are willing to go to the trouble and expense necessary to ship, charges prepaid, 40 bricks of each brand asked for seems to be indicative of an interest in this undertaking.

The testing is now under way and will extend over a period of several months.

Glass Pots for Use in Experimental Optical Glass Making.

Glass pots large enough to contain approximately 1,000 pounds of optical glass are made in the laboratory by the casting process developed by the bureau. While the primary purpose of this work is to supply pots to the glass plant, it affords an opportunity to do full-scale experimenting in the study of glass-pot bodies. During the year 25 pots have been made. Trial was made of the substitution of grog made from kaolin and ball clay for the pottery bisque that has ordinarily been used and of other modifications of the body composition that were made as the result of indications obtained from a small-scale investigation. The introduction of gallic acid as a deflocculating agent was tried out in 10 of these pots, this material being substituted for a part of the sodium silicate in varying proportions, from 1 part acid to 9 parts silicate, to 5 parts acid to 5 parts silicate. It was found that the use of 1 part of gallic acid to 8 parts of sodium silicate assisted materially in producing a slip of good working or flowing qualities. The pot cast from this slip attained the rigidity necessary for safe handling in an unusually short time.

Resistance of Glass Pots to Corrosion.

While important work has already been done, in this bureau and elsewhere, in the study of relations existing between body composition and resistance to the attack of corrosive glasses at high temperatures, our knowledge as to these relations is still incomplete, so that it is not possible to say with assurance what is the best silica-alumina ratio for pots for use in making, for example, dense barium crown optical glass. Since this is an important matter, not only in connection with the manufacture of optical glass but also in its bearing on the best compositions for other glass refractories, a somewhat comprehensive investigation has been undertaken in which a wide range of variations of kaolin, ball clay, flint, and feldspar is to be covered. To date 216 experimental pots of about 25 cubic inches capacity have been made and burned. These and others of other compositions are to be subjected to the action of corrosive glass at high temperatures. It is the intention to select promising compositions for trial in full-size glass pots in the optical glass plant.

TERRA COTTA.

Cooperative Investigation of Problems Relating to Architectural Terra Cotta.

This work, which is carried on in cooperation with the National Terra Cotta Society, has included during the past year extended work on the actual freezing of burned samples of terra-cotta bodies made by the different manufacturers. Small bars were first used in the freezing tests and after observing the results of these freezings pieces 4 by 4 by 1 inch were subjected to this test for comparison.

A study has been made of the types of pore systems of a series of bodies made from materials of widely different types with a view to classifying terra-cotta bodies on a basis of the nature of their pore systems and to determining relations between the type of pore system and other physical properties of the body. In the work done so far the rates of absorption of a series of synthetic bodies have been compared with the total absorption and the transverse strength.

A short laboratory study has been made of the effect of rate of cooling of terra-cotta pieces on their tendency to develop cracks or other defects after being removed from the kiln. Three-inch cubes made from bodies of five different types were cooled at widely different rates and afterwards quenched in running water to obtain indications as to the resultant states of strain. The results obtained, while interesting, can not be definitely interpreted in terms of the factory cooling of large commercial pieces of terra cotta. Future work will be in the form of an investigation to be made partly in the factories and partly in the laboratories of the bureau.

ENAMELED METALS.

Wet-Process Enamels for Cast Iron.

While enamels of this type have been applied on cast-iron kitchen utensils for many years, the literature on the subject is very limited and indefinite. There has been a great demand in the past few years for wet-process enamels for cast-iron stove parts, as dry-process enameling is not especially adapted to the many sizes and types of castings used, and repeated requests have come to the bureau from manufacturers for information on the compositions and application of this type of enamel.

The bureau has therefore conducted an extended investigation of this subject and has developed some very satisfactory compositions and has secured information on the limits of composition and technic in the preparation and application of the enamels. White and colored enamels requiring a ground coat and those used without a ground have been developed. The laboratory results have been checked in one of the large enameling plants, and several of the compositions suggested by the bureau are now being successfully used in a number of enameling plants throughout the country.

A preliminary report of this work will appear in a forthcoming number of the Journal of the American Ceramic Society, and the final report is being compiled for publication as a technologic paper.

Fish Scaling of Enamels on Sheet Iron and Steel.

The defect known as "fish scaling" is the spontaneous chipping of minute portions of the enamel from the surface of the ware. The fractures are usually in the shape of a half moon and can thus be differentiated from those caused by impact. This defect has been one of the most costly and probably the most elusive one encountered by the enameled-metal-ware industry. An extended investigation has shown that the defect is due primarily to the difference in contraction of the enamel and the metal to which it is applied, and that it can be eliminated by the development of enamels which have a coefficient of expansion more closely approximating that of steel and iron than is true of the usual commercial enamels.

It has been shown that the surface condition of the metal is an important secondary factor in the reduction of fish scaling and that mechanical treatment of the steel is effective in preventing the development of the defect. This explains the tendency of the unworked portions of an enameled vessel to fish scale, while the "spun" (curved) portions almost invariably are free from the defect.

In order to check the laboratory results on this phase of the bureau's findings, the cooperation of both sheet-steel producers and enamel-ware manufactures has been enlisted. Several tons of enameling steel which has been given two and three passes through the cold rolls have been especially prepared by one of the steel companies. This stock has been fabricated and enameled under factory conditions by several manufacturers of kitchen ware. While the general results indicate that this treatment was beneficial, further extended experimentation must be done before definite conclusions can be drawn as to the commercial value of this method of preparing enameling stock.

The question has been raised as to whether cold rolling, while eliminating the tendency to fish scale, might introduce new difficulties, such as the tendency of the enamel to flake from the steel over large areas. Tests of some of the ware manufactured from the cold-pass steel has shown, however, that the adherence of the enamel to this stock is equal to and in some cases superior to that of the same enamel applied to ware made from enameling stock prepared by the usual methods.

It is of interest to note that recent work of enamel investigators has confirmed the bureau's original conclusions in regard to the causes and control of fish scaling. A cooperative investigation of enamels for sheet steel now being conducted in this laboratory is also giving further definite information as to the direct relation between fish scaling and the relative contraction of the enamels and the steel base.

A preliminary report of this investigation has appeared in the Journal of the American Ceramic Society (vol. 4, No. 8), and the final report is now being compiled for publication as a technologic paper by this bureau.

Specifications for Enameled Kitchen Ware.

The subject of specifications for enameled kitchen ware is of importance to the departments of the Government and to private parties interested in the purchase of enameled kitchen ware as well as to the manufacturers in attaining and maintaining high standards of their product.

Through the cooperation of the Sheet Metal Ware Association the bureau has had the opportunity of testing some 20 different brands of kitchen ware, as well as some foreign ware which was obtained through jobbers and dealers. Standard tests have been developed in this investigation for the resistance to impact, to thermal shock, and to dilute acids. It was found that American ware was equal and in some cases superior to that of foreign manufacture.

Tentative specifications based on these tests have been prepared and submitted to a conference of the manufacturers' association held at this bureau and at New York, N. Y. A representative has also conferred with the technical committee of the Sheet Metal Ware Association and revised tentative specifications have received their approval and have been referred to the association for their action.

Relation of Composition and Properties of Sheet-Steel Enamels.

This investigation is being conducted in cooperation with a manufacturer of enameled kitchen ware to determine the relation of composition of the enamels to resistance to impact, to thermal shock, and to acids. While this work has only been under way a short time, some very interesting information has been obtained on the relation between the fit of the enamel to the steel base and resistance to impact and thermal shock. The relative contraction of the several coats of enamel applied to the steel also appears to be very important. The preliminary results indicate that, as the investigation proceeds, information of importance to the manufacturers of sheet steel enameled ware will be obtained.

Cooperative Investigations.

The enamel division of the American Ceramic Society is cooperating with the bureau in a study of suitable iron for enameled cast-iron ware. Samples of commercial irons will be obtained from representative plants and tested at this bureau for chemical composition, physical and enameling properties.

Similar cooperative work is being conducted with the same organization in an investigation of the warpage of sheet iron and steel in the enameling process. This organization has also cooperated in the investigation of fish scaling of enamels on sheet steel.

TESTING AND INFORMATION.

A significant indication as to the progress of the work of the division of ceramics is to be found in the increase in the scope of the testing that has been done for other Government departments and for outside parties. In previous years, a very large part of the testing has been on fire brick. During the past year the testing of refractories has continued but since methods of test have been developed for vitreous china tableware and for glass tumblers and glass containers, there have been calls for tests of dishes and glassware that show not only an interest in the differences in quality in these wares, but a need for practical test requirements covering them. It is also significant that the first calls for tests have come from the manufacturers themselves. Even before test methods have been fully developed for a given product, manufacturers have sent in samples of their standard product and also samples made up from other bodies with which they had been experimenting in order to obtain comparisons. In one case the bureau was able to determine for a manufacturer that a new body which had been developed and which was about to be adopted for quantity production made a product inferior to the one in regular use. Manufacturers of glass products have shown a constructive interest in the work. Some of the tests made indicate that glassware of very inferior quality, in point of resistance to the effects of boiling and sterilization, has been made unnecessarily simply because of the lack of practical tests by which to measure this quality. The manufacturer could have produced high quality ware without increase in cost if he had known what composition to adopt to get the best results.

Next to the manufacturers themselves, and in some cases preceding them, the Government departments using these wares have called for tests to secure information for guidance in the placing of contracts in order to determine which articles possessed the qualities necessitated by their specific conditions and to avoid the possibility of paying a premium for imaginary superiority. This applies particularly to the purchase of hotel china; tests for quality have been needed to do away with the old but somewhat persistent belief that chinaware made in Europe must necessarily be superior to that made in the United States.

Numerous samples of material have been received from individuals in various parts of the United States with requests that these samples be analyzed and tested in other ways to determine whether they are suitable for the manufacture of certain products. In some cases these parties need the services of a consulting engineer to investigate not only the material but also the property in question, but in most instances little more than a casual examination is needed to determine that the material is not of such a character that it could be marketed profitably. In such cases the bureau is able to give information which unquestionably avoids unnecessary expenditures for tests; in some instances it is apparent that materials are worthy of thorough investigation and the bureau is able to direct the interested parties to competent and reliable persons or firms who are in a position to do the work in a commercial way.

As a result of the work on specifications there has been an unusually large number of inquiries during the past year for information regarding proper test requirements for materials for various purposes. The requests for specifications for refractories have been particularly numerous, and in several cases the bureau has been asked by users of refractories for advice in regard to specifications for their use in purchasing and in testing materials delivered. Similar requests have been received from large purchasers of tableware. The bureau's own work along these lines has progressed to such an extent that in all cases information has been given which would keep those consulting the bureau from working along unpromising lines and possibly adopting undesirable specifications.

Cooperation with Technical Societies.

A number of the senior members of the staff of the division have continued to do important work as members and officers of committees of technical societies. However, the most essential committee work in which the division is taking part is that done by the committees which have been formed to assist the bureau in the work of establishing standards and specifications. The usual order is reversed and the technical societies are finding representation on the bureau's committees instead of members of the bureau's staff working on outside committees whose lines of activity are not directly controlled by the bureau. The following technical societies and commercial organizations are cooperating with the bureau in one way and another, some in investigative work on specific problems but the majority in committee work on the broader problems of standardization and establishment of specifications: American Institute of Architects, American Society for Testing Materials, American Society of Mechanical Engineers, American Ceramic Society, American Iron and Steel Institute, American Electric Light Association, National Terra Cotta Society, United States Potters Association, American Vitrified China Manufacturers Association, Hollow Building Tile Association, Refractories Manufacturers Association, American Face Brick Manufacturers Association, Common Brick Manufacturers Association of America, National Paving Brick Manufacturers Association, Wall Tile Manufacturers Association, American Stokers Association, National Glass Distributors Association, Wholesale Sash and Door Association, and Sheet Metal Ware Association.

Special acknowledgement should be made of the cooperation that is being received, in the work referred to above, by other Government departments whose representatives participate in the bureau's conferences.

Publications.

During the year the following reports of work done in the division have been published:

Technologic Paper No. 196, High fire porcelain glazes (H. H. Sortwell).
Note on the hardness of glazes (G. Blumenthal, jr.), Jour. Am. Cer. Soc., 4, No. 11, p. 896.
Earthenware bodies and glazes (H. H. Sortwell), Jour. Am. Cer. Soc., 4, No. 12, p. 990.
The properties of some ball clays (H. H. Sortwell), The Ceramist, 2, No. 1, p. 5.
Comparative tests of American and foreign tableware (H. H. Sortwell), Jour. Am. Cer. Soc., 5, No. 6, p. 276.
Plasticity of clays (F. P. Hall), Jour. Am. Cer. Soc., 5, No. 6, p. 346.
Causes and prevention of scumming (Arthur E. Williams and K. L. Ford), printed and distributed by Glass Containers' Association to manufacturers.
Specifications and standard methods of testing glass (Arthur E. Williams), The Glass Industry, March, 1922.
The disintegration of soda lime glasses in water (Arthur E. Williams) (at the printers to appear in Jour. Am. Cer. Soc., August, 1922).
Recommended specification for limestone, quicklime and hydrated lime for glass making, Circular No. 118.
Specifications for lime flint glass tumblers, Circular No. 119.
Refractories for the steel plant, (W. A. Hull), Year Book of American Iron and Steel Institute (1922), p. 470.
Causes and control of fish scaling of enamels for sheet iron and steel. (R. R. Danielson and W. H. Souder), Jour. Am. Cer. Soc., 4, No. 8, p. 620.
Production of some white enamels for copper, (R. R. Danielson and H. P. Reinecker), Jour. Am. Cer. Soc., 4, No. 10, p. 827.
Some relations of composition to solubility of enamels in acids (H. F. Staley), Jour. Am. Cer. Soc., 4, No. 9, p. 703.

BUILDING AND HOUSING.

The work of this division includes the collection and dissemination of scientific, practical, statistical, and other information tending to encourage, cheapen, and improve construction and housing. It covers investigations for use in framing local building and plumbing codes, and a study of problems connected with city zoning. Information on the prices, production, consumption, and stocks of building materials, and on building activity is collected, analyzed, and distributed. Examinations are made of some special aspects of the housing problem. The work includes studies in building practice, and cooperation with the efforts to eliminate waste which are being made by different parts of the construction industry.

GENERAL.

Scope of the Work on Building and Housing.

The construction industry is one of the largest and most important to the people of the United States, and it is a function of the division of building and housing to study the needs of the industry and their relation to the public welfare. It endeavors to see that these needs are met, partly through its own efforts, and by enlisting the aid of other branches of the Federal Government whose work can be of constructive value, and partly by presenting its conclusions to the industry itself, through the trade press, trade associations, and individuals in the industry.

The division of building and housing is the only agency of the Federal Government whose duty it is to survey the entire field of construction from the point of view of the general welfare. The work of the division, as pursued during the first year of its activities, has fallen into four general groups.

One group includes specialized investigations aiming to improve the relations between the different local governments throughout the United States and the construction industry. The work under this heading includes the formulation of recommendations for local building and plumbing codes and an analysis of city zoning regulations.

The second main group of work lies in the collection and coordination of current statistical information connected with the building industry. This includes gathering building-material prices as paid by contractors in different cities, publication of figures on building activity, building costs and building materials, and handling of inquiries in regard to statistics in these fields.

Under the third group of activities come economic and statistical studies related to the building industry and to the housing problems of the American people.

The fourth group of the division's work has been in the way of elimination of waste and service to individual home builders. Under this heading come the work on building practice, and cooperation with the Architects Small House Service Bureau, a nonprofit-making organization, in its work of preparing and distributing improved small-house plans.

General Condition in the Division.

The division of building and housing was organized under the provision of a supplemental appropriation item, which was made available July 1, 1921. Preparations for the work of the division had been made by Franklin T. Miller, who had been assistant to the Select Committee on Reconstruction and production of the Senate of the Sixty-sixth Congress, and who was therefore in close touch with current conditions in housing and the construction industry.

By July 1, 1921, the work on building codes had already been under way for several weeks, and was transferred to this division at that time. The direction of the division's activities had to be determined, and building up a staff required some time. The difficult problems before the construction industry at the time, and the acute national shortage in housing, which amounted to about 1,000,000 homes, made it a question of choosing from among the many activities suggested. The effort was made to meet the most pressing needs that promised the greatest results for the efforts expended and at the same time to cover a sufficient range of problems to keep the division in touch with the principal elements of the construction industry, for only by so doing could the division get the proper perspective and be in a position to get support to accomplish results in matters in which the cooperation of several groups was required.

In taking up the work on building and plumbing codes and on city zoning, it was felt that, while the staff of the division could do a part of the technical work, the assistance of outside authorities in the sifting and weighing of material would be invaluable, and accordingly the work of the advisory committee on building codes, which had been appointed prior to the fiscal year, was continued, and special committees were appointed on plumbing codes and zoning.

These committees consist of seven or eight members each, and represent the leading technical bodies interested in each field. Thus the advisory committee on building codes consists of two architects, three engineers, a building official, and the head of the section of timber mechanics of the United States Forest Products Laboratory. The zoning committee includes men designated by the National Conference on City Planning, National Municipal League, American Civic Association, National Association of Real Estate Boards, and the National Housing Association, while the members individually represent such professions as law, landscape architecture, civil engineering, and municipal engineering, and occupy important positions in such organizations as the United States Chamber of Commerce and the American Society of Landscape Architects.

TECHNICAL SERVICE FOR MUNICIPALITIES.

Building Codes.

The lack of uniformity in local building regulations, and their technical backwardness in many cities, were noted by the Select Committee on Reconstruction and Production of the Senate of the Sixty-sixth Congress, and were declared to exercise a retarding influence on construction activities and the best interest of many cities. The differences in the codes are much wider than different climatic and other conditions justify. Most of the studies that have been undertaken in connection with building codes have been made with special reference to conditions prevailing in a particular city, and at the same time, some of the most fundamental problems, and those most important from the point of view of cost of construction and health and safety have never been thoroughly investigated.

The aim of the work on building codes is not to force the adoption of uniform regulations covering all classes of construction in cities throughout the United States, where conditions vary. It is simply to provide the State and city officials charged with framing codes, and the local organizations and associations who ordinarily assist them in this work, with certain of the basic data which they require, and which have either not been available at all, or at least not in authoritative form. There are, however, certain sections which could be made uniform throughout the country with advantage to everyone.

It was felt that the provisions of codes affecting small houses were, perhaps, most in need of revision, and that, in view of the present housing shortage, a revision of these sections in the light of modern methods and the results obtained with present-day types of buildings, would be of greatest value at the present time, as directly affecting the better housing of the American people. Accordingly, an exhaustive investigation of sections of building codes relating to small houses in cities throughout the United States, was undertaken, and the views of building officials, architects, fire chiefs, engineers, experts in the use of different building materials, and of professional societies and associations connected with the building industry, and the production of building materials were obtained.

Not the least important part of the committee's work has been the systematic polling of the most expert opinion available on certain matters, which, either through lack of scientific investigation or from their very nature, must be decided according to the best judgement of experts. This condition applies to some of the most basic parts of the building code, such as sections governing minimum thickness of masonry walls, the floor loads to be provided for in small houses and other structures, and the amount of protection necessary to prevent chimneys from constituting an undue fire hazard.

About the end of April, 1922, a preliminary set of recommended provisions governing small-house construction was sent out to practically all those individuals and organizations with which the committee had been in contact, for comment and criticism. At the close of the fiscal year, these recommendations were being revised for publication in the light of the comment submitted.

Plumbing Codes.

The work on plumbing codes followed rather closely the lines outlined for work on building codes proper. The advisory subcommittee on this subject, appointed in August, 1921, likewise decided to concentrate its attention on problems connected with small-house plumbing systems. In this case, a special series of tests with actual plumbing installations, was undertaken by the bureau, and the results obtained were of great value in preparing a preliminary report which was completed just before the end of the fiscal year, and which was to be sent out for comment and criticism by several hundred interested parties throughout the country.

Zoning for Towns and Cities.

The rapid spread of zoning in American cities, and the popular interest in the measure as a possible means of eliminating great wastes, providing for the orderly development of cities, and protecting the property of home owners and other holders of real estate, caused a number of national organizations to request that the Department of Commerce make a study of the problem, and such work was initiated after a careful survey of the field.

The advisory board on zoning was organized in November, 1921, and its work so far has included a study of State acts enabling cities to zone, and of city zoning ordinances, together with a survey of the literature on the subject. A selected bibliography of zoning, containing references to the more important articles on the subject was issued in mimeograph form, and has been circulated throughout the United States to zoning commissions, city plan commissions, and others specially interested, and in response to requests received by mail from nearly every State in the Union. "A Zoning Primer," explaining the elements of zoning in popular style was issued as a department publication, and in addition to being reprinted extensively in real estate sections of newspapers and in the construction and real estate press, has been purchased in large quantity from the Government Printing Office by such organizations as the United States Chamber of Commerce and its local bodies, the American Civic Association, and local city planning commissions.

CURRENT STATISTICS.

The principal original material collected by the division is a monthly table of building material prices for 24 items, as paid by contractors in about 60 cities. It was felt that the gap in existing current statistics was greatest at this point, and the division has had the support of a number of associations in the work of collecting these prices and circulating them.

The division is also cooperating with the editor of the Survey of Current Business in obtaining figures on building activity, building costs, and the production, consumption, and stocks on hand of the principal building materials. Several pages of this Department of Commerce publication are devoted to these figures each month, and it therefore serves as an invaluable statistical guide to conditions for those in the industry, as well as for those interested in it indirectly.

Some of the more important figures, which are believed to be of greatest value as an index to conditions, are plotted in graphical form, and receive wide distribution through republication in trade papers of the construction industry and allied fields.

The division has also served as a clearing house for inquiries in regard to statistics collected by other Government departments that relate to building and building materials, and it has been possible to answer several hundred requests involving information collected elsewhere, either directly or by reference to the proper bureau.

ECONOMIC AND STATISTICAL STUDIES.

This work has included investigations of the extent and nature of the housing shortage, of the proportion of family income usually paid for rent, a study of the census figures showing home ownership, of the number of families as compared with the number of dwellings, and surveys of the facilities for financing home building.

An original report on the materials of which houses are built, by districts throughout the country, is also under way. Investigations of price movements of building materials, and the relation of apparent supply to demand, have also been made from time to time, and the results given out in addresses or statements in the press.

ELIMINATION OF WASTE AND SERVICE TO HOME BUILDERS.

Elimination of Waste.

The work outlined under "Technical Service for Municipalities" aims at the elimination of waste, but is treated separately. There are certain other activities of the division, however, which fall mainly under this heading. The need for standardization of building materials has been widely manifested, and the division is endeavoring to call the attention of the industry to the savings possible through greater simplification and elimination of dimensional varieties. This work was carried on independently by the division until the formation of the division of simplified practice, and since that time the division has cooperated with the division of simplified practice in connection with building materials.

Standards of building practice also vary widely from city to city, and an effort has been made to ascertain what could be done to promote wider use of the best methods of construction and workmanship, and in the way of obtaining some of the fundamental data which every contractor and builder should have in order to compare the efficiency of the different parts of his own organization with general standards.

Along this line, an investigation of the proportionate cost of separate building materials to the total cost of materials entering into the construction of small brick and frame houses was made, and the results set forth in a simple table. Similarly, the proportionate distribution of wage bills for small houses to the different trades was determined. The results of these two studies have been extensively published in trade papers, newspapers, and accounting journals.

Service to Individual Home Builders.

The division has been able to refer large numbers of individuals requesting information on dwelling construction to available pamphlets issued by Government bureaus. In order to assist the people in obtaining better house plans for economical and livable homes, the Architects' Small-House Service Bureau, a nonprofit-making organization fostered by public spirited architects throughout the country, has been indorsed by the department, and is working in close harmony with the division of building and housing.

At the close of the year, a "Financial Primer" for home owners was in course of preparation, and is expected to embody the results of some of the economic and statistical studies mentioned above.

COOPERATION, INFORMATION, AND PUBLICATIONS.

Cooperation with Public Bodies and Societies.

As noted above, the division has obtained the valuable cooperation of different architectural, engineering, and trade associations, and public officials, both in obtaining material for technical investigations and statistics and for distributing it generally.

An important part of the division's work has consisted in supplying local community conferences that have been endeavoring to "clean up" the building industry in different cities, with necessary statistical information and reports on what other cities have done along similar lines. Thus, the information obtained on methods of financing home builders has been frequently called for by cities in different sections of the country.

The chief of the division was executive secretary of the committee on construction industries of the President's Conference on Unemployment, which was held in Washington September 26 to October 13, 1921. The staff of the division was, as far as possible, placed at the service of this committee for the period of the conference, and has kept in touch with the committee on construction development, which, in accordance with the instructions of the conference was appointed by the Secretary of Commerce to follow up the recommendations of this committee.

The chief of the division was also a member of the Distrist housing committee, appointed by the Commissioners of the District of Columbia, and served as chairman of the subcommittee on building materials. He is also on the board of governors of the newly formed American Construction Council, and on its executive board.

Members of the staff have addressed meetings of the American Civil Association, American Construction Council, American Society of Civil Engineers, Baltimore Real Estate Board, National Association of Builders Exchanges, National Federation of Construction Industries, National Municipal League, Special Libraries Association, and the Women's City Club of Washington.

In addition to the organizations mentioned above, the division has important contacts, among others, with the American Civic Association, American Institute of Architects, including local and State chapters; American Society of Civil Engineers; Associated General Contractors; Chamber of Commerce of the United States; National Association of Builders' Exchanges; National Association of Real Estate Boards, including many local boards; and United States League of Building and Loan Associations.

The methods of distributing information have varied with the different branches of work. Charts and other material issued by the division have appeared in nearly all classes of trade papers connected with building; building materials; real estate; in the Building and Loan Association News; in the house organs of local organizations, such as chambers of commerce, real estate boards and builders exchanges; in the monthly bulletins of Federal reserve banks; in the real estate sections of newspapers; and in the proceedings of professional societies. In addition, the Survey of Current Business is widely used as a source of statistics on conditions in the building industry.

Publications.

A zoning primer (Advisory Committee on Zoning), Dept. of Com. Pub.; 1922.

The papers listed below have appeared in current publications:

Stabilization of prices of materials, etc. (John M. Gries), New York Evening Post, December 31, 1921, and syndicate of newspapers.

Housing—broad economic aspects (John M. Gries), Proc. Am. Soc. of Civ. Eng., March, 1922.

Standardization in the building industry (John M. Gries), American Contractor, March 25, 1922; The Permanent Builder, June, 1922; The Nation's Business, April, 1922; and elsewhere.

SIMPLIFIED PRACTICE.

This division is cooperating with American industries with the object of furthering a nation-wide program for the elimination of waste in commerce and industry, through the reduction in the number of sizes and types of standard products, the abandonment of useless varieties, and the concentration of the attention of manufacturers upon articles of the greatest interchangeability.

GENERAL.

The new division of simplified practice, which was organized in January, 1922, is vigorously engaged on a basis of cooperation with American business groups, in developing a nation-wide program with a view to lending the hand of the Government to the elimination of collective wastes in commerce and industry. These wastes, it is estimated, result in a loss of 30 per cent of America's energies.

The experience of this country during the war, followed by the report Waste in Industry, prepared by the Federated American Engineering Societies, proved conclusively the urgent necessity of utilizing standardization, of eliminating freak varieties, and of concentrating the processes of manufacturing and distribution upon articles of the greatest interchangeability. Accordingly, the division of simplified practice was established as one of the units in a general program for eliminating industrial and commercial wastes, for stabilizing employment, developing our foreign commerce, increasing the quantity of American products, and, in general, securing for every American citizen a higher standard of living.

The chief function of the division of simplified practice is to supplement the work heretofore carried on by other divisions of the bureau, by setting up a centralized agency to bring producers, distributors, and users of specific commodities together, and to support the recommendations of those interested when they shall mutually agree upon a certain program of simplification of benefit to the industries and the public concerned.

ELIMINATION OF USELESS SIZES.

Paving Brick.

Excellent illustrations of the opportunity for simplified practice are found in the work already done by several national industries. The National Paving Brick Manufacturers' Association called the attention of the division to the need of simplifying the number and sizes of paving bricks. They estimated that there were about 30 sizes and varieties. After a preliminary conference with the department they undertook in the name of the department an exact survey of the field, and found that instead of 30 there were 66 sizes and varieties of paving brick actually being manufactured and sold.

As a result of that survey, the department called a conference of the manufacturers, municipal engineers, various associations in the ceramic industry representing engineers, architects, and buyers, as well as the manufacturers of bricks. In a one-day meeting 30 representatives of organizations reduced the sizes and styles of paving brick by mutual consent from 66 to 11, and recommended that these sizes be adopted by their various associations and groups as recognized sizes in the paving-brick industry.

At a later conference of the standing committee appointed by the first conference, a further reduction from 11 to 7 was effected.

Metal and Wood Beds.

The metal and wood bed industry, together with the spring and mattress groups, realizing the advantages to be gained through simplification, asked the cooperation of the department in aiding their industry, and upon completion of surveys by the several associations, a general conference was called of representative manufacturers, distributors and users, and again in a single day, four sizes of beds of one standard length were adopted as recognized sizes in that particular industry. It was also agreed at the same time that the mattress and spring manufacturers should have their products conform to the sizes agreed upon by the bed industry.

The results of these conferences have been published in a Simplified Practice Recommendation of the Department of Commerce.

Preparatory Surveys of the Field.

Surveys preparatory to calling conferences for the elimination of excess varieties and sizes are now being conducted by parent associations in the following industrial fields: Warehouse commercial forms; lumber; hardware; paints and varnish; sash, door, and millwork; clay products; cigar boxes; metal lath; common brick; storage batteries; spark plugs; automobile tires; ball bearings; milk bottle openings and caps; and hollow building tile.

SIMPLIFICATION OF DIMENSIONAL SIZE AND VARIETIES.

Work Now Under Way.

Opportunities similar to those just mentioned for simplification of dimensional size and varieties exist in hundreds of lines, and although the division has only been operating for six months, contacts have been made with more than 65 industries, most prominent of which are those manufacturing farming equipment, electrical lighting fixtures, cordage, railway car wheels, stoves, machine tools, boxes and food containers, refrigerators, barrels, pianos and musical instruments, copper and brass products, structural slate, small tools, jute products, safes and vaults, tents and awnings, fabricated structural steel, metal culverts, flags, linoleum, and sheet glass.

Requests for Assistance.

Initial requests for action by this division come from all branches of the trades. In some cases programs for simplification come from groups of retailers, and others are submitted by the manufacturers. In general, these programs look to reducing the amount of capital tied up in inventories by both manufacturers and retailers, reducing the unit cost of manufacturing by making possible the introduction of mass-production methods, and the more effective use of materials, equipment, and machinery by standardization of the work going through the plant. It intensifies competition on articles of greatest interchangeability and tends to open up new opportunities for small and specialized manufacturers.

III. THE OFFICE.

The work of the office comprises supervision of the units of the administrative branch; selection, recommendation, and assignment of office personnel; planning and supervision of the bureau's clerical routine (finance, personnel, property and stores, transportation, mail and files, purchase, and information); supervision of the editorial work of the bureau; and of the technical library.

GENERAL CONDITION IN THE OFFICE.

During the year 208 changes affecting office personnel were made, including 36 resignations, 32 new appointments, leaving the net office personnel at the close of the year 141. The work of the office has increased and has proceeded in a very satisfactory manner. The simplification of procedure and concentration of work has proceeded about as far as feasible without decrease of effectiveness. An important piece of work completed during the year was the rivision of the bureau's descriptive list of publications bringing the list up to the close of the fiscal year, with a supplement which will be issued every few months to keep the main list up to date. The main list (Circular 24) will carry a comprehensive index to all published work of the bureau (1904–1922), supplying a long-felt need of the bureau and the general public.

FINANCE.

Funds.

The regular appropriations of the bureau amounted to $1,257,360. Additional items amounting to $250,000 were carried in the second deficiency act, making a total of $1,507,360 appropriated by Congress. In addition, $325,673 was transferred to the bureau during the current year from other departments for cooperative investigational work, and $3,418 was received in reimbursements, making the total funds received this year available for obligation $1,836,451. A large proportion of the money received from other departments for cooperative work was transferred under the fortifications act of May 21, 1920.

Appropriation Statements.

The following statement shows the amount and object of each appropriation provided for the bureau for the fiscal year 1922, the disbursements during the year, the amount of unpaid orders at the close of the year, and the unexpended balance remaining at the close of business June 30, 1922. The large balances remaining on most of these funds are due to the amount reserved for the budget savings.

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
Salaries	$432,360.00	$399,568.63	$21,792.99	$10,998.38
Equipment	95,000.00	59,230.26	17,797.38	17,972.36
General expenses	75,000.00	51,679.21	13,965.45	9,355.34
Grounds	10,000.00	8,317.32	1,384.92	297.76
Testing structural materials	[1] 178,035.00	142,791.44	15,871.40	19,372.16
Testing machines	30,000.00	26,155.94	1,975.01	1,869.05
Metallurgical research	40,000.00	34,341.49	3,338.67	2,319.84
Optical glass	[2] 28,000.00	20,835.77	2,943.26	4,220.97
Investigation of textiles	15,000.00	13,263.47	696.23	1,040.30
Sugar standardization	[3] 31,800.00	27,153.81	2,888.32	1,757.87
Gauge standardization	40,000.00	36,619.72	1,337.13	2,043.15
High-temperature investigation	10,000.00	8,926.88	524.87	548.25
Testing railroad scales	40,000.00	34,487.86	2,600.49	2,911.65
Investigation of fire-resisting properties	25,000 00	17,737.06	5,534.17	1,728.77
Testing miscellaneous materials	30,000.00	26,003.95	2,416.45	1,579.60
Investigation of public utility standards	70,000.00	63,902.28	5,453.69	644.03
Radio research	30,000.00	25,615.85	2,569.77	1,814.38
Investigation of public utility standards 1921–22	15,000.00	14,795.07	....	204.93
Industrial research	[4] 437,757.00	177,303.45	59,383.32	201,070.23
Sound investigation	5,000.00	4,641.48	187.83	170.69
Clay products	25,000.00	21,757.46	1,674.92	1,567.62
Color standardization	10,000.00	7,484.50	1,777.99	737.51
Standardizing mechanical appliances	15,000.00	10,716.73	3,215.79	1,067.48
Investigation of mine scales and cars	15,000.00	12,878.20	1,142.52	979.28
Standardization of equipment	100,000.00	71,504.18	17,494.68	11,001.14
Appropriation transferred from other departments:				
Gauge standardization, War transfer	3,000.00	2,324.56	484.38	191.06
Total	1,805,952.00	1,320,036.57	188,451.63	297,463.80

[1] Includes reimbursement of $3,035 received from other departments.
[2] Includes transfer of $3,000, which is available for the incurring of obligations for the fiscal year 1923 and 1924, received from the Navy Department.
[3] Includes reimbursement of $1,800 received from other departments.
[4] Includes transfer of $286,173.66, a large portion of which is available for the incurring of obligations for the fiscal year 1923 and 1924, and reimbursement of $1,583.34 received from other departments.

The following statement shows the condition of the appropriations for the two preceding fiscal years at the close of business June 30, 1922:

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
FISCAL YEAR 1920.				
Salaries	$486,760.00	$462,361.53	....	$24,398.47
Equipment	[1] 108,033.00	103,852.84	$3,248.92	931.24
General expenses	95,000.00	80,926.80	3,639.13	10,434.07
Grounds	7,500.00	7,397.95	....	102.05
Testing structural materials	[2] 150,817.86	148,284.80	321.17	2,211.89
Testing machines	[3] 35,263.49	34,614.09	12.21	637.19
Metallurgical research	[4] 30,154.00	29,677.69	144.25	332.06
Investigation of optical glass	[5] 63,761.12	62,961.72	.50	798.90
Standard materials	5,000.00	4,818.75	....	181.25
Investigation of textiles	15,000.00	14,840.44	....	159.56
Sugar standardization	[6] 21,800.00	21,056.34	....	743.66
Gauge standardization	[7] 56,276.90	55,823.27	146.28	307.35
High-temperature investigation	10,000.00	9,930.92	....	69.08
Testing railroad scales	[8] 43,841.06	42,854.84	29.81	956.41
Investigation of fire-resisting properties	25,000.00	24,320.04	32.52	647.44
Investigation of railway materials	15,000.00	14,649.36	....	350.64
Testing miscellaneous materials	30,000.00	29,858.18	....	141.82
Investigation of public utility standards	[9] 114,159.82	113,548.37	39.45	572.00
Radio research	[10] 31,555.94	31,382.76	1.70	171.48
Industrial research, 1919–20	[11] 71,899.23	71,485.79	25.30	388.14

[1] Includes reimbursement of $33 received from other departments.
[2] Includes reimbursement of $25,817.86 received from other departments.
[3] Includes reimbursement of $5,263.49 received from other departments.
[4] Includes reimbursement of $5,154 received from other departments.
[5] Includes reimbursement of $13,761.12 received from other departments.
[6] Includes reimbursement of $1,800 received from other departments.
[7] Includes reimbursement of $16,276.90 received from other departments.
[8] Includes reimbursement of $3,841.06 received from other departments.
[9] Includes reimbursement of $29,159.82 received from other departments.
[10] Includes reimbursement of $1,555.94 received from other departments.
[11] Includes reimbursement of $21,899.23 received from other departments.

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
FISCAL YEAR 1920—continued.				
Industrial research, 1920	[12] $291,775.05	$287,408.54	$602.37	$3,764.14
Sound investigation	[13] 7,237.04	7,129.24	....	107.80
Investigation of clay products	20,000.00	19,817.60	....	182.40
Color standardization	10,000.00	9,937.25	....	62.75
Determining physical constants	5,000.00	4,996.00	....	4.00
Standardizing mechanical appliances	[14] 50,820.26	50,066.31	216.69	537.26
Investigation of mine scales and cars	[15] 15,179.73	15,059.22	11.99	108.52
Industrial safety standards	25,000.00	24,468.67	13.65	517.68
Testing Government materials	[16] 100,300.66	98,885.71	6.00	1,408.95
Standardization of equipment	[17] 52,292.00	34,447.03	151.09	17,693.88
Platinum and rare metals	15,000.00	14,982.23	....	17.77
Retaining wall	20,000.00	17,674.27	....	2,325.73
Equipping laboratory, 1919-20	100,000.00	98,018.26	1,086.94	894.80
Total	2,129,427.16	2,047,536.81	9,729.97	72,160.38
FISCAL YEAR 1921.				
Salaries	432,360.00	421,133.68	....	11,226.32
Equipment	[18] 95,330.00	89,813.72	1,551.56	3,964.72
General expenses	75,000.00	69,423.26	3,586.85	1,989.89
Grounds	10,000.00	9,933.51	....	66.49
Testing structural materials	125,000.00	124,321.28	149.31	529.41
Testing structural materials (interior civil)	2,250.00	1,882.64	....	367.36
Testing machines	30,000.00	29,900.74	....	99.26
Metallurgical research	[19] 25,163.59	25,018.57	....	145.02
Optical glass	[20] 31,000.00	27,467.44	2,902.03	630.53
Additional land	47,272.00	47,272.00	....	....
Investigation of textiles	[21] 15,680.00	15,569.38	....	110.62
Sugar standardization	[22] 31,800.00	31,660.85	....	139.15
Gauge standardization	[23] 46,183.54	44,709.00	42.56	1,431.98
High-temperature investigation	10,000.00	9,965.62	....	34.38
Testing railroad scales	40,000.00	39,655.31	13.76	330.93
Investigation of fire-resisting properties	25,000.00	24,495.43	....	504.57
Investigation of railway materials	15,000.00	14,751.88	4.90	243.22
Testing miscellaneous materials	30,000.00	29,918.33	....	81.67
Investigation of public utility standards	[24] 85,272.86	85,045.08	33.84	193.94
Radio research	[25] 30,096.00	29,711.79	201.42	182.79
Industrial research	[26] 837,856.88	658,556.01	30,093.11	149,207.76
Sound investigation	[27] 7,000.00	6,914.52	51.12	34.36
Investigation of clay products	25,000.00	24,519.71	65.83	414.46
Color standardization	10,000.00	9,778.69	.72	220.59
Standardizing mechanical appliances	[28] 35,000.00	34,089.28	531.93	378.79
Investigation of mine scales and cars	15,000.00	11,847.94	22.93	3,129.13
Standardization of equipment	15,000.00	9,675.50	....	5,324.50
Appropriations transferred from other departments: [29]				
Air Service, Army, War transfer	450.00	297.83	14.07	138.10
Armament and fortification, War transfer	3,250.00	2,669.01	162.75	418.24
Manufacture of arms, War transfer	1,625.00	1,332.91	127.10	164.99
Ordnance stores ammunition, War transfer	1,500.00	1,349.24	23.00	127.76
Experiments, Ordnance, Navy transfer	5,000.00	4,147.38	333.35	519.27
Aviation, Navy transfer	50,000.00	29,577.90	5,443.39	14,978.71
Total	2,209,089.87	1,966,405.43	45,355.53	197,328.91

[12] Includes reimbursement of $41,775.05 received from other departments.
[13] Includes reimbursement of $2,237.04 received from other departments.
[14] Includes reimbursement of $35,820.26 received from other departments.
[15] Includes reimbursement of $179.73 received from other departments.
[16] Includes reimbursement of $300.66 received from other departments.
[17] Includes reimbursement of $2,292 received from other departments.
[18] Includes reimbursement of $330 received from other departments.
[19] Includes reimbursement of $163.59 received from other departments.
[20] Includes transfer of $6,000, which is available for the incurring of obligations for the fiscal years 1922 and 1923, received from other departments.
[21] Includes reimbursement of $680 received from other departments.
[22] Includes reimbursement of $1,800 received from other departments.
[23] Includes transfer of $2,420 and reimbursement of $3,763.54 received from other departments.
[24] Includes reimbursement of $272.86 received from other departments.
[25] Includes reimbursement of $96 received from other departments.
[26] Includes transfer of $773,877, a large portion of which is available for the incurring of obligations for the fiscal years 1922 and 1923, and reimbursement of $13,979.88 received from other departments.
[27] Includes transfer of $2,000 received from other departments.
[28] Includes transfer of $20,000 received from other departments.
[29] These funds were transferred under the fortifications act dated May 21, 1920, and are available for the fiscal years 1921, 1922, and 1923.

PERSONNEL.

Bureau Staff.

The staff averaged 342 statutory employees and 546 other employees engaged in connection with researches and investigations specially authorized by Congress. The average total staff for the year was 888 regularly appointed employees. There were also engaged 40 experts on part-time basis, their services being rendered for short periods at intervals during the year. The slight increase is caused by new lines of work authorized by Congress, which includes the division of building and housing and the work of simplified practice, as well as the standardization of specifications, for which the Director of the Budget established the Federal Specifications Board with the Director of the Bureau of Standards as ex-officio chairman.

Changes in Staff.

There were 1,461 personnel changes during the year—262 separations, 317 entrances, 341 promotions, and 541 miscellaneous changes of status. The total turnover—30 per cent for the entire staff—was 35 per cent for the scientific staff; clerical staff, 26 per cent; construction force, 10 per cent; and operating staff, 30 per cent. A summary by divisions shows the staff and average salary for the year.

AVERAGE NUMBER OF EMPLOYEES AND APPROXIMATE SALARIES BY CLASSES.

Division.	Employees.	Salaries.	Average salary per employee.
Scientific staff	555	$1,008,831	$1,818
Office staff	141	175,028	1,241
Construction force	128	182,995	1,430
Mechanical plant	64	52,317	817
Total	888	1,419,171	1,598

Sources of Personnel.

Employment conditions affecting the bureau are becoming normal with respect to workers not highly specialized. For higher specialized technical grades eligibles are scarce and not easy to locate. To fill low salaried statutory positions is still a problem, since experienced workers are unwilling to enter at such salaries. It is a pleasure to acknowledge cordial, effective cooperation by the Civil Service Commission and its staff in recruiting candidates for the scientific staff.

Leave of Absence.

The employees on the average took 32.4 days of leave (compared with a possible maximum of 60 days), divided 27.3 days annual and 6.1 days sick leave.

Deaths.

During the past fiscal year the bureau has lost nine employees by death, including two division chiefs and one section chief. The losses include Mr. L. A. Fischer, chief of the weights and measures division since the establishment of the bureau; Dr. C. W. Waidner, chief of the division of temperature and heat for 20 years; and Mr. S. S. Voorhees, chief since 1910 of the section devoted to the investigation and analysis of cement and bituminous materials. Their invaluable services in developing specialized branches of the bureau's work will be an enduring memorial to their memory, although the loss of their experience and wise counsel will not easily be replaced.

Special Activities.

The personnel section maintains the accident records of the staff as required in administering the employees' compensation act; cooperates with the emergency and first-aid volunteer staff distributed throughout the bureau; maintains rooming lists to aid employees in securing accommodations; keeps records of applicants and of those who have resigned, including their reasons for leaving the service; and maintains a visible index and directory of all employees.

The complexity and wide range of specialization of the bureau's work involves a very large number of grades and specialties in technical and other personnel. There are, for example, approximately 126 grades and specialties in the scientific work, 27 in office work, 27 in construction, and 13 in the mechanical plant or operating force, making a total of approximately 193 grades and classifications in which it may be necessary to call upon the Civil Service Commission for eligibles. In the development of such registers the bureau cooperates with the Civil Service Commission by publicity and by direct appeal through the sources of well-trained scientific personnel.

PURCHASE.

Procurement of Equipment and Materials.

The purchase section has placed during the year a total of 6,633 orders, involving the issuance of more than 15,000 proposals to prospective bidders for furnishing the industrial, scientific, and technical equipment and materials required in the bureau's work. This work included the preparation of all contracts for large purchases and enterprises. An efficient follow-up system for securing prompt delivery was maintained, and a dependable system of accessible records kept for all orders, bids, travel reports, vouchers, and supply sources pertinent to the bureau's work.

The total orders placed included 4,735 orders for industrial, scientific, and technical equipment and materials; 500 exigency orders covering emergency purchases; 73 orders for miscellaneous office supplies, secured through the division of supplies; and 350 orders for printing, including forms, results of scientific researches and tests, and other documents, secured through the division of publications. Orders were also placed by this section for 975 travel authorizations applying to the bureau's work.

More than 5,800 vouchers were received by this section and given all necessary attention up to the time they are ready for final approval for payment.

Scientific Catalogue Library.

For the efficient selection and procurement of the latest types of scientific apparatus and grades of technical materials, this section maintains an up-to-date library of 10,000 scientific and industrial catalogues, exclusive of price lists and circulars, for the direct use of the scientific staff. The chief of the section confers with the laboratory men in locating sources of such special supplies and equipment. The section has an effective system for the prompt procurement of the late issues of such technical supply literature—catalogues, descriptive ciruclars, and price lists.

PROPERTY, STORES, AND TRANSPORTATION.

Stores.

During the year special storerooms for the supply of chemicals and mechanical stores were placed under the general supervision of the head of this section, and approximately $72,000 worth of scientific and other supplies were received, checked, and shelved; and supplies to the value of $65,000 were dispensed through the technical storerooms of the several laboratories.

Property.

More than 8,000 pieces of apparatus, tools, and other equipment were received, inspected, and stamped with the bureau's inventory numbers, and the necessary accountability records were prepared and filed.

Shipping.

The bureau's freight and express shipments—20 tons per week—included much delicate and valuable apparatus, calling for unusual care in unpacking, inspection, and distribution. Approximately seven shipments of apparatus and materials per day were returned to the owners after being tested by the bureau.

Transportation.

An effective schedule of transportation service by motor trucks has been maintained: (1) By mail truck between the Department of Commerce, the post office, and the bureau; and also (2) by heavy trucks between the bureau, the express offices, and freight depots, and Government buildings. All hauling has been done with the bureau's own trucks, and freight has been moved promptly from the depots, avoiding storage fees. Freight movements have at times been as high as 20 to 25 tons per day. The bureau has also saved to the department considerable amounts of hauling by using the bureau trucks for the purpose. With the cooperation of the automotive section of the bureau, the truck mileage has been increased 15 per cent per gallon of gasoline and 30 per cent per quart of lubricating oil.

MAIL AND FILES.

Communications.

A daily average of more than 800 pieces of first-class official mail are handled by the mail and files section. About one-half of this mail requires special card indexing. An effective system provides both writer and subject indexes. Telegraphic communication during the year included the receipt of 1,600 and the dispatch of 1,070 telegrams. The first-class official mail handled during the year aggregated 263,345 pieces.

Schedules.

The mail and files section operates efficiently on strict time schedule, each essential step in the complete handling of incoming and outgoing mail being graphically controlled. Simple graphic schedules are maintained showing the daily magnitude of the several classes of mail received and sent and the actual time schedule of sorting, indexing, and distributing operations.

Availability and Use of Files.

The importance of the contents of the technical correspondence made it especially desirable to adopt a subject filing system for letters. Sections of the file may therefore be drawn by the experts promptly owing to the efficient classification adopted by the section. The section is now enabled to locate any correspondence received by the bureau since its establishment in 1901, since adequate accountability records for withdrawals are filed in place of the withdrawn correspondence.

Standard Correspondence Practice.

The mail and files section, on the basis of regulations, special orders, and authoritative sources of data concerning good correspondence practice, maintains, under the immediate direction of the chief of the administrative branch, a "standard office practice" for the entire clerical staff of the bureau. A series of office notes supplements this practice by adding later orders and regulations and by pointing out items calling for special care as ascertained from the daily inspection of the mail by this section. The system has resulted in uniformity and standard quality in the bureau's outgoing correspondence, including letters, reports, certificates, and other material.

General Services.

The mails and files section maintains a complete system of collection and delivery of intrabureau communications covering all sections of the bureau and extending to about 20 separate buildings. This section also acknowledges and refers mail addressed to the bureau in error. The communication service of this section includes the messenger, telephone, telegraph, and elevator services.

LIBRARY.

Accessions of Technical Literature.

During the year 2,089 books were accessioned in the scientific library of the bureau, making the net total at the close of the year 23,350 volumes. The library receives currently 578 scientific and technical periodicals, more than half of them by exchange. Of the total number, 230 are American journals, 135 British and other journals printed in English, 64 in French, 110 in German, and 39 in 9 other languages.

Relations with Other Libraries.

The bureau maintains cordial exchange relations with the various technical libraries in Washington and elsewhere, including, especially, the Library of Congress. Books are loaned to such libraries and their facilities are in turn extended to the bureau. By mutual understanding this arrangement results in economy, since rare and expensive books and sets of journals can be obtained by the respective libraries most concerned and be made available for occasional use to all other libraries.

Subject Analysis of Periodicals.

The technical journals are the important means by which the specialist obtains promptly the new knowledge in his field. Such literature is, therefore, of the utmost importance to the work of a research bureau such as the Bureau of Standards. So far as is known, the technical periodical literature, even of one specialty, is not available at any single library. The limited funds available permit the selection of only those found most helpful. Of the 578 periodicals currently received, the bureau takes 18 periodicals in the field of scientific and technical bibliography and abstracts; 61 journals on general science; 15 in physics, and 38 additional journals very closely related to physics; 60 journals in general engineering, and 59 in special fields of engineering; 48 journals in metallurgy; 70 journals in electricity, telephony, and wireless; 51 in chemistry and chemical technology; 11 in illumination and radiology; 9 in architecture and building; and the remainder in miscellaneous or general technical subjects.

Library Expenditures.

During the year 1921–22, $3,627.24 was spent for books and periodicals as compared with $4,176.37 for the preceding year, and $5,954.17 for the fiscal year 1920. The working value of up-to-date technical literature is particularly large in a research institution such as this bureau.

General Services.

The librarian, who is technically trained in physics and mathematics, as well as library science, aids the staff in locating and collating sources of special and recent scientific literature, aids in technical translation and bibliography, and maintains a close contact with dealers in this country and abroad in order to complete important sets and secure rare works which are out of print. The bureau's library is, as a result, peculiarly well equipped in physics and related subjects.

INFORMATION.

Scope of the Information Work.

The information section collates and disseminates technical information, and arranges for the distribution of bureau publications and the issuance of reports covering tests of materials. The work is probably the most important means which the bureau possesses of rendering the results of its researches available to the public.

Special Reports.

Several special reports and articles of a more or less popular character describing various phases of the bureau's work were prepared during the year. In addition, a number of articles written by persons outside the bureau were sent to the information section for correction, the amount of this work being considerably greater than has been the case heretofore.

A new series of mimeographed pamphlets, known as letter circulars, each one dealing with some special subject, was started early in the year. These circulars are made up of topical lists of publications and timely statements on technical topics of particular interest. Where the importance of the subject warrants, such material will later be included in regular printed publications of the bureau.

The Technical News Bulletin has been issued regularly each month, as heretofore, for the prompt announcement of the bureau's researches and new publications to industrial experts, laboratories, and technical libraraies, to facilitate the prompt application of the bureau's research results in the industries.

Directing Inquiries.

This section routes incoming inquiries by mail and telephone to members of the staff best qualified to answer the questions. General inquiries concerning the functions of the bureau are answered directly by this section. Many letters are received each week from newspaper information bureaus and the routing of these communications forms part of the work of the section.

Announcements of New Publications.

The announcement of new publications is now handled very effectively in several ways: (*a*) Announcements in the monthly list issued by the Superintendent of Documents, of which a large edition is circulated; (*b*) announcements in the monthly list of Department of Commerce publications; (*c*) announcements in Commerce Reports, the weekly publication of the Bureau of Foreign and Domestic Commerce; (*d*) technical abstracts of all new publications distributed to the technical press; (*e*) announcements in the monthly issues of the bureau's Technical News Bulletin; (*f*) publication of title and abstract in the descriptive list printed in the Supplement to Circular 24, and later in the circular itself; (*g*) an advance copy of each new publication is sent with a personal letter to the editor of selected technical journals directly concerned with the subject treated; and (*h*) in addition to the above, copies of bureau publications are sent by the Superintendent of Documents by provision of law to selected (several hundred) libraries throughout the country, known as Government depository libraries, which undertake to keep the publications available for consultation by the public.

Publications Issued During the Year.

During the fiscal year just closed the bureau has issued 67 new publications and 23 reprints—a total of 90 publications. The new publications comprise 25 scientific papers, giving the results of scientific researches; 22 technologic papers, giving results of new investigations in the field of engineering and the special technologies; 16 circulars, containing important compiled technical information in the bureau's field useful to the industries, and especially to scientific and technical laboratories; and 4 miscellaneous publications.

Tests.

The bureau's work includes, among other things, a large amount of testing of standards, weights and measures, measuring instruments, and materials. Incident thereto much of the testing involves primary investigation of the scientific principles underlying such tests, the study of existing methods, and the development of new standard tests of determinate precision. A reasonable fee is charged for each test, except when made for the National or for State Governments. The tests completed during the year, together with their value, are summarized in the following table:

NUMBER AND VALUE OF TESTS COMPLETED,[1] FISCAL YEAR ENDED JUNE 30, 1922.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length:						
Tapes	199	$499.45	83	$181.65	282	$681.10
Other length tests	395	1,060.20	1,490	1,461.60	1,885	2,521.80
Mass:						
Weights	1,079	504.80	2,231	997.80	3,310	1,502.60
Scales and balances	1,088	50,325.50	3	12.50	1,091	50,338.00
Capacity	4,235	1,702.55	8,954	5,230.75	13,189	6,933.30
Hydrometry	306	429.50	281	418.85	587	848.35
Time	15,488	10,833.50	38	61.00	15,526	10,894.50
Electrical tests	1,096	4,352.80	690	3,136.00	1,786	7,488.80
Photometry [2]	2,575	10,226.00	403	887.00	2,978	11,113.00
Radioactivity	57	124.80	2,216	18,455.80	2,273	18,580.60
Temperature:						
Clinical thermometers	5,785	474.44	8,652	768.05	14,437	1,242.49
Other thermometers and miscellaneous	1,552	1,691.91	1,421	3,802.68	2,973	5,494.59
Optical tests:						
Sugar polarimetry	1,628	1,628.00	26	91.00	1,654	1,719.00
Other optical tests	2,200	1,223.00	200	1,096.50	2,400	2,319.50
Chemical analyses:						
Structural meterials	778	7,780.00	....	....	778	7,780.00
Other materials	7,598	118,667.00	7	70.00	7,605	118,737.00
Standard samples	584	1,126.15	2,905	5,808.37	3,489	6,934.52
Mechanical instruments and appliances	400	1,950.00	61	377.50	461	2,327.50
Aeronautical instrument tests	81	2,098.00	10	78.50	91	2,176.50
Physical tests of materials:						
Cement	4,076	32,086.00	10	27.00	4,086	32,113.00
Other structural materials	927	2,017.00	89	269.00	1,016	2,286.00
Miscellaneous materials, including paper, textiles, rubber, leather, etc	9,351	44,774.25	551	1,946.50	9,902	46,720.75
Metallurgical tests	564	2,617.50	9	141.25	573	2,758.75
Miscellaneous	62	1,014.00	134	475.40	196	1,489.40
Total	62,104	299,206.35	30,464	45,794.70	92,568	345,001.05

[1] The tests reported in this table include only the tests for which all technical procedure was entirely completed during the year 1921–22.

[2] In addition the bureau inspected 1,646,692 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to $4,297.78.

IV. ENGINEERING AND CONSTRUCTION.

This division operates and maintains the power, heating, and refrigerating plants, installs and repairs electrical and plumbing equipment, and cares for buildings and grounds.

GENERAL.

Aims and Recommendations.

The division has with great difficulty met the most urgent requirements for power, heating, and lighting, made necessary repairs and installations of new equipment, and furnished the best service possible in meeting all special requirements. This has on many occasions entailed work on holidays, Sundays, and after hours, to make repairs, change overs, and new connections which could not be made during office hours without serious interruption of service. A special effort has been made and economies effected in the use of electricity, water, and gas, not only in the plant but throughout the bureau.

The need for a new centralized power plant of greater capacity is becoming more pressing as additional and heavier power-consuming equipment is being installed in the laboratories. A larger maintenance force is also needed. The pressure of work frequently necessitates the delay of needed repairs, sometimes causing operating wastes or greater repair expense due to the delay.

OPERATION AND MAINTENANCE OF MECHANICAL PLANT.

The mechanical plant comprises heating, ventilating, air conditioning, and refrigerating equipment; electric generating, converting, and transforming equipment, and storage batteries; water; air; vacuum; steam; and gas service.

The plant has been improved during the year by the installation of an automatic combustion control-system and a venturi feed-water registering and recording meter. These have made possible a closer check on boiler operation, which has resulted in material savings. A new feed-water pump was added and a new and larger vacuum pump installed to replace worn-out equipment. The absorption refrigerating plant was thoroughly overhauled and several new sets of coils installed.

The electric-power service during the past year has been better than before from the standpoint of continuity of service owing to the addition of an emergency power feeder, from which the bureau is supplied when service is interrupted over the regular line. However, the direct-current service is continually becoming more inadequate to carry the new loads, totaling several hundred horsepower, which have been added during the past fiscal year. A frequency changer of 500 kilowatts capacity was installed during the year, which provides an ample supply of 3-phase 60-cycle power.

CONSTRUCTION AND REPAIR.

Electrical.

The installation, extension, and repair of all wiring, switchboards, motors, and electrical equipment for the various laboratories, as well as for the mechanical plant, are performed by this section. In addition to necessary repairs to present equipment the section erected a heavy power feed line to supply a 200-horsepower motor for the new wind tunnel, installed permanent wiring to supply new service or replace temporary wiring in the ceramics laboratory, rubber laboratory, leather laboratory, the optical shop, the annex machine shop, the dynamometer building, the sound chamber, and made numerous other small installations of switchboards, motors, ovens, and other electrical apparatus. Watt-hour meters were installed to meter the power used by all of the heavier power consumers.

Plumbing.

This section installs, maintains, and repairs all plumbing fixtures and all pipe lines and steam traps used in connection with the heating systems, and for the distribution to the laboratories of water, air, gas, vacuum, steam, and refrigerating service. In addition to the necessary maintenance and repair work in connection with the above, the section has taken an active part in the investigation of plumbing fixtures which has been in progress during the past six months at the bureau. Plumbing service was extended to the sound chamber and the large compressor supplying the kiln building furnaces was taken out of the industrial building to make room for the Emery testing machine. This, with another compressor to provide for emergency service, was installed in the kiln building; the absorption refrigerating plant was overhauled; and a large number of smaller installations of apparatus, and supplying or altering of service, were taken care of by this section.

Miscellaneous.

The most important work under this section during the past year includes the construction of the sound chamber, laying of a new roof on the northwest building, removal of a wireless mast with massive concrete base, construction of cinder concrete roadway between the north and south buildings, building of an incenerator, pouring reinforced concrete foundations for the Olsen and Emery testing machines, and numerous smaller installations of motors and other apparatus. Necessary internal and external painting was done, leaky roofs were repaired, cornices and gutters broken by the heavy snows were repaired.

BUILDINGS AND GROUNDS.

Janitors and Laborers.

The work of this section is largely of a routine nature in cleaning the buildings, including offices and laboratories, disposing of rubbish and keeping sanitary conditions throughout. This section is also called upon for moving heavy equipment about the bureau or assisting in the handling of such equipment from the freight stations to the bureau. The janitor service is entirely inadequate and should be increased immediately.

Watchmen.

The duties of the watchmen consist in making inspections of the buildings to prevent fire, theft, and damage by weather to the property of the bureau. They also report to the superintendent's office all matters pertaining to this division which need attention such as locks out of order, broken windows, leaking valves and faucets, burned-out lamps, waste of water, gas, or power. They also shut off or start apparatus at specified times as requested by members of the scientific staff. Watchmen's clocks make a record of their movements.

Grounds.

Some progress has been made in the improvement of the appearance of the grounds. Grading was done north and east of the south building, south and west of the chemistry building, around the sound chamber, and the industrial and kiln buildings. Drainage was improved around several buildings and a material decrease in trouble from heavy rains effected.

V. GENERAL RECOMMENDATIONS.

Salaries.

The question of salaries of the scientific employees in the Government service has been so much before the public of late that it might be considered unnecessary to refer to it again. However, this problem is of such extreme importance in the case of the Bureau of Standards and is so closely connected with its satisfactory functioning that I feel compelled once more to call attention to the very unsatisfactory conditions which exist.

At the time my last annual report was prepared, most of the industries in this country were passing through a period of extreme depression. At such times the salaries which can be offered by private corporations are naturally far less attractive than during periods of commercial activity. Nevertheless, the bureau lost many members of its scientific staff, who felt obliged to accept the higher pay which they could obtain in private employ, although by so doing they realized that they were lessening their opportunities for research work. As a matter of fact, it is this devotion to their work which has enabled the bureau to keep its staff in a reasonably efficient condition; without this loyalty the labor turnover in the more important positions would be excessive.

During the coming fiscal year, with industrial conditions improving everywhere, Government scientific institutions will be under a greater handicap than ever before, and it will become increasingly difficult to render efficient service. The staff of a scientific laboratory can not be picked up "overnight" to carry a peak load. New employees in scientific positions, no matter how willing they may be, are an actual drag on the work of the more experienced members of the staff until they become familiar with the particular problems in hand. The loss of one man from a laboratory may set back an entire investigation much more effectively than the destruction of all that laboratory's equipment.

There should be no need for such financial sacrifice on the part of scientific men in the Government service. We can and ought to pay them salaries commensurate with the importance of the work and more nearly on a plane with what they can earn in the industries and in educational institutions.

It is, therefore, again earnestly recommended that steps be taken to remedy this situation. Such action will be found in the end to be a paying investment for the entire country.

Power Plant.

The need of a new power plant for the Bureau of Standards has been pointed out in previous annual reports. Entirely aside from the more reliable service which would be rendered by a plant specially designed to meet the needs of a research institution, the matter is of particular importance at the present time owing to the greatly increased economy which would result from centralization of the bureau's heating and power-producing equipment. The tendency in all lines of work is toward centralization of equipment, and it is well known that nowhere does this result in greater economy than in the operation of a power plant.

The bureau's original plant, designed for two buildings, and now supplemented by two separate boiler plants for heating purposes and numerous pieces of electrical equipment for changing the electric power bought from the commercial company into energy suitable for the needs of the laboratories, forms a glaring example of decentralization with the unavoidable accompaniment of high labor charges and low fuel economy. Owing to the small capacity of the electric generating equipment of the bureau's plant, it has been found necessary for some years to purchase a large part of the current from the local power company. Such a source of supply is necessarily much less reliable than a plant specially designed for the needs of a research institution.

It is believed that the expenditure necessary to build a modern central power plant capable of caring for all the probable future needs of the bureau would be saved in a short time through increased economy in fuel and operation and greater reliability in the service rendered.

Care of Buildings.

The same conditions as regards the number of janitors, laborers, and watchmen necessary to properly care for the buildings and grounds, as mentioned in my report of last year, still apply. The bureau is made up of a large number of separate buildings, each of which contains a great deal of valuable apparatus and in which some processes must necessarily be carried on day and night. Watchmen with more than ordinary intelligence are therefore absolutely necessary. To curtail services of this character is questionable economy, and may result in accident and loss of equipment. The force at present provided is too small and should be increased immediately.

Buildings and Grounds.

It is again recommended that provision be made by Congress for the purchase of the land between the present boundary of the bureau's property and Connecticut Avenue on the east. This tract is needed to round out the site, and as it will without doubt be purchased eventually it would be better to secure it now before it it is built upon.

Considerable progress has been made in grading and clearing up the grounds and in the construction of some permanent road, but a more adequate fund is needed to properly finish up this work and to keep the bureau's grounds in proper condition.

Respectfully,

S. W. Stratton,
Director.

To Hon. Herbert Hoover,
Secretary of Commerce.

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