DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
George K. Burgess, Director

ANNUAL REPORT OF DIRECTOR OF THE BUREAU OF STANDARDS FOR FISCAL YEAR ENDED JUNE 30, 1928

MISCELLANEOUS PUBLICATIONS, BUREAU OF STANDARDS, No. 88

ANNUAL REPORT

OF THE

DIRECTOR OF THE BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1928

(Miscellaneous Publication No. 88)

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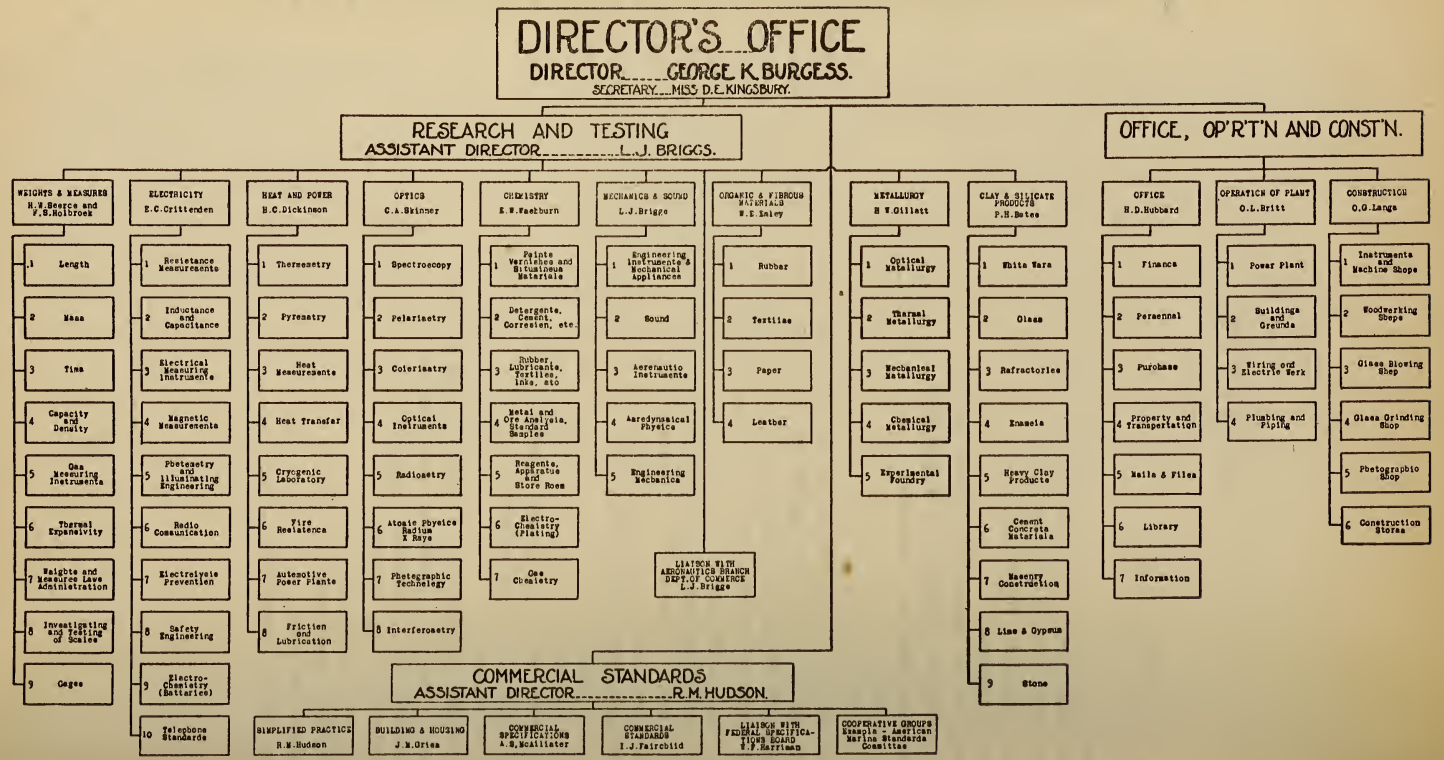
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BUREAU OF STANDARDS

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
Washington, July 2, 1928.

The honorable the SECRETARY OF COMMERCE.

DEAR MR. SECRETARY: I submit herewith a brief report upon the work of the Bureau of Standards during the fiscal year ended June 30, 1928. The various outstanding accomplishments are grouped according to the subjects for which the Congress had made specific appropriations.

GENERAL ACTIVITIES

Organization.—An important change in the administrative organization of the bureau, resulting in increased efficiency through a better grouping of the work, was carried out last September. Under the new arrangement the bureau's activities are divided into two main groups, each under the immediate supervision of an assistant director. The first group comprises all those activities having to do with scientific research and testing, the development, construction, custody, and maintenance of reference and working standards, and their intercomparison, improvement, and application in science, engineering, industry, and commerce. The second group includes the supervision, direction, formulation, and coordination of commercial standards, with particular reference to the needs of industry, including the activities of the division of simplified practice, commercial standards group, and part of the work of the division of building and housing relating to codes and standards. In addition, the correlation of the work of the Federal Specifications Board with commercial practice, and liaison duties with other branches of the Department of Commerce and with other departments in questions relating to commercial standards, are included in the work of this group. The assistant director, in charge of research and testing, has continued to act as liaison officer on matters of aeronautics with other branches of the Government.

Cooperation.—Most of the bureau's work is made effective through voluntary cooperation of the State and municipal governments, scientific and professional societies, trade associations, manufacturers, and individuals who accept the findings of the bureau and incorporate them into a State law, a municipal ordinance, a dimensional standard, or a standard of quality, performance, or practice. The extent of these relationships is shown by the fact that at the present time the bureau is cooperating with over 200 scientific, technical, and industrial organizations.

One of the most effective ways in which the bureau cooperates with American industries is through its research associate plan, referred to in past annual reports. At the close of the fiscal year there were 82 of these associates stationed at the bureau, representing 46 industries and associations.

Personnel matters.—The regular staff at the close of the fiscal year numbered 859 employees. In addition, there were 81 employees assigned to the bureau under the research associate plan and 49 miscellaneous assignments, including guests and details from other branches of the Government, making a grand total of 989 persons.

The turnover was 23.3 per cent. There were 469 promotions and the average salary ($2,243) increased by $33. The status of the personnel shows an increase of 65 employees as compared with last year.

Visiting committee.—This committee has retained its active interest in the bureau's problems and has been of great assistance in many important matters of policy. Thus, four members of the committee appeared before the House Committee on Rivers and Harbors in support of the bill to establish a national hydraulic laboratory at the bureau. The committee has held two formal meetings at the bureau and made important recommendations to the Secretary of Commerce on the bureau's needs. Members of the committee have also visited the bureau frequently. The present personnel of the committee is S. W. Stratton, Gano Dunn, William F. Durand, W. R. Whitney, and John R. Freeman.

International relations.—The usual close cooperation between the national standardizing laboratories of other countries and the Bureau of Standards has been maintained. Negotiations have been carried on for the improvement of standards on which electrical, thermometric, photometric, and radio measurements depend. Members of the staff attended meetings of the International Congress for Testing Materials, International Chemical Union, International Photometric Congress, the International Electrotechnical Commission, and the International Radiotelegraphic Congress.

The Seventh International Conference on Weights and Measures was held in Paris during portions of September and October, 1927. In many respects the conference was the most important that has been held since the first meeting in 1875. Thirty-one nations were represented, the delegates from the United States being the former and present directors of this bureau. Action was taken on several matters of fundamental importance—such as the establishment of an international temperature scale, the definition of the meter in terms of light waves, and the proper basis for the international electrical units.

The actions of the conference will go far to insure uniformity everywhere in all quantities involving length, electrical, and temperature measurements, and a uniform basis for the calibration and certification of instruments used in such work.

The proposition of the United States to define the length of the international meter in terms of the wave length of the red radiation from the cadmium lamp was adopted. The value decided upon was that of Fabry and Perot—1 meter=1,553,164.13 waves under certain definitely stated standard conditions. This decision is of great im-

portance, because so many precise measurements of science and industry are now made in terms of light waves, and will be particularly valuable for setting up and intercomparing gauge blocks and other subdivisions of the meter and yard.

In order to insure the best solution of the question concerning the basis of the electrical units, a special technical commission of 10 members, representing the several national laboratories and others, was appointed. The Bureau of Standards is actively at work on its part of the program. A similar committee was set up to define the standard temperature for industrial calibration of gauge blocks.

Weights and measures conference.—The Twenty-first National Conference on Weights and Measures was held on May 22 to 25, inclusive. The attendance (258) was the largest on record, both as to number of delegates and guests and as to States represented. Delegates were present from 28 States and the District of Columbia.

Special studies had been made at the bureau on the drainage of gasoline-measuring devices, grease-measuring devices, lubricating-oil bottles, and on the transmission drive for taximeters, and reports on these studies were presented to the conference. Through representation on the conference committee on specifications and tolerances, the bureau assisted in the development of new and amended codes of regulations for commercial devices which were adopted by the conference, principally affecting gasoline-measuring devices, grease-measuring devices, and lubricating-oil bottles. The conference also accepted the bureau's conclusions on the transmission drive for taximeters, and, by resolution, approved this method of drive. The relation of business to the weights and measures official was presented in several papers.

Conference of State utility commission engineers.—The sixth annual conference of State utility commission engineers was held at the bureau on May 31 and June 1 and was attended by 24 engineers from 12 States, the District of Columbia, and two Provinces of Canada. The subjects discussed included depreciation in connection with appraisals, effect of reduced cost of steam generation on the development and potential value of water powers, a full-price clause in rates for domestic and commercial gas service, inducement form of rate for residential use of gas and electricity, development of rural service in California, gas service problems in connection with the revision of the bureau's circular on standards for gas service, accidents and approved protective devices at grade crossings of railroads and highways, and a discussion of the fourth edition of the National Electrical Safety Code.

American Engineering Standards Committee.—Cooperation has been continued with the American Engineering Standards Committee. The bureau is sponsor for 12 standardization projects and is represented on 71 committees having for their object the formulation of "American standards."

National Screw Thread Commission.—Seven meetings of the commission have been held during the year. They have been attended by many representatives of industry. The commission has ready for final approval and publication a new report which is a revision and extension of its 1924 report. The major items completed during the year were the establishing of increased maximum minor diameters

of nuts in the range of sizes below 1⅛ inches; improving the pitch diameter tolerances for threads of special diameters, pitches, and lengths of engagement; the development of revised specifications for threading tools, including tap dimensions and tolerances, and tap-drill sizes; the development of a 12-pitch thread series for applications where special threads are required; and the development of standard sizes of blanks for plain cylindrical and threaded plug and ring gauges. The last item is the work of the American Gauge Design Committee, comprising manufacturers and users of gauges, to which the commission has lent its support.

The commission has continued its cooperation with the standardization committee of the American Petroleum Institute in the standardization of rotary drilling taper joints, pumping equipment, and gauges.

American Gauge Design Committee.—The bureau has participated in the activities of the American Gauge Design Committee in drawing up dimensional specifications of blanks for plain and threaded plug and ring gauges over the complete size range up to 4½ inches.

Federal Specifications Board.—The board has been in existence for nearly seven years and has just promulgated its 578th purchase specification. These specifications are being used more and more by State and municipal governments, institutional bodies, and by industry. Much of the research and experimental work necessary in connection with the formulation of the Federal Specifications Board specifications is done by this bureau.

Relations to Government departments.—The bureau is authorized to receive funds for specific research projects from other departments, and in pursuance of this policy in the past year the bureau has received $275,000 for the support of 30 projects representing work for 7 Government establishments. In addition, the bureau does a great deal of consulting, specification, and testing work for various branches of the Government.

Publicity.—In addition to its regular official publications, of which 134 were issued during 1928, the monthly Technical News Bulletin has been mailed as heretofore. More than 217 papers have been published in outside technical journals. There have also been released to the press over 200 short accounts of interesting achievements, together with many photographs illustrating the bureau's work. These news items serve as nontechnical progress reports on the activities of the bureau to the taxpayers of the country. There was also issued the second annual number of the Standards Yearbook, giving a summary of standardization activities in the United States and abroad for the past year.

Testing.—The testing work for the public and Government departments continues to be a heavy drain on the resources of the bureau. The following table gives a summary of the testing activities. The work often merges with the investigational and research fields and requires in addition a considerable outlay for upkeep of reference and laboratory standards. A new item of particular interest which appears in the table for the first time is the testing of airplane engines. Forty-one determinations were made on four commercial engines submitted through the aeronautics branch of the Department of Commerce.

Numbers of test items, determinations, and fee value for tests completed during the fiscal year ended June 30, 1928

Kind of instrument or material, class of test, or nature of service rendered	Number of test items for—			Total number of test items	Number of determinations	Fee value
	Public	Government departments and State institutions	Bureau of Standards			
Electrical standards, instruments, and materials	1,270	500	435	2,205	3,754	$19,644.65
Electric batteries	143	2,522	-------	2,665	5,608	19,173.50
Electric lamps and lighting equipment	392	2,443	793	[1] 3,628	3,714	[2] 19,665.97
Length-measuring devices	188	281	-------	469	2,544	2,624.50
Gauges and gauge steels	1,345	107	1,055	2,507	11,837	2,267.00
Miscellaneous dimensional determinations	2,262	425	106	2,793	12,277	5,826.85
Weights and balances	3,872	1,869	764	6,505	14,066	6,065.90
Scales	8	865	81	954	25,254	39,040.50
Timepieces	268	5	27	300	3,683	702.00
Volumetric apparatus	7,578	4,748	716	13,042	26,543	9,894.10
Hydrometers	364	201	1	566	1,739	825.15
Density determinations, etc	13	38	240	291	535	844.00
Laboratory thermometers	2,526	783	621	3,930	17,860	8,158.75
Clinical thermometers	22,470	20,976	-------	43,446	173,808	4,078.40
Pyrometers, calorimeters, etc	263	54	181	498	6,168	6,609.50
Insulating materials	109	35	11	155	137	870.00
Fire-resisting materials	25	61	-------	86	278	872.20
Fuels and lubricants	246	1,720	100	2,066	12,570	20,357.50
Automotive equipment, etc	-------	221	-------	221	340	2,607.00
Airplane engines	-------	4	-------	4	41	6,050.00
Optical instruments and materials	404	249	174	827	1,208	4,311.90
Carbohydrates	2	1,734	-------	1,736	2,634	2,717.00
Radioactive materials	659	11	-------	670	670	3,668.50
Engineering instruments and appliances	83	1,034	47	1,164	1,283	12,745.50
Aeronautic instruments	17	638	39	694	2,955	7,995.50
Aerodynamic tests of models	10	4	1	15	23	225.00
Physical properties of engineering materials	110	2,927	38	3,075	6,125	17,958.95
Sound producing and measuring instruments	18	33	15	66	67	678.50
Making of special castings	-------	34	226	260	929	1,777.50
Fusible boiler plugs	-------	359	-------	359	718	717.00
Metallographic examinations	-------	282	85	367	647	2,897.00
Miscellaneous metallurgical tests	-------	231	400	631	1,105	2,917.00
Pottery and chinaware	-------	144	10	154	569	1,115.00
Glass	-------	60	42	102	161	352.00
Refractories and heavy clay products	2	201	76	279	1,175	2,641.00
Cement, concreting materials, lime, etc	33	11,913	247	12,193	50,841	98,910.00
Stone and sand-lime brick	-------	34	50	84	395	1,147.00
Miscellaneous ceramic materials	-------	1,348	109	1,457	4,406	8,075.00
Rubber	-------	1,496	200	1,696	11,192	19,564.50
Textiles	7	6,842	456	7,305	17,904	34,178.50
Paper	22	1,791	262	2,075	6,460	18,879.00
Leather	25	292	3	320	1,386	2,049.00
Paint, varnish, and bituminous materials	-------	1,438	87	1,525	11,330	16,051.00
Chemical analysis of metals	3	302	343	648	2,862	5,376.50
Chemical tests of miscellaneous materials	23	1,110	95	1,228	4,788	6,874.50
Distribution of standard samples	6,372	577	3	6,952	-------	15,117.00
Total	51,132	72,942	8,139	132,213	[3] 454,589	[3] 465,116.82

[1] In addition the bureau inspected 1,319,456 incandescent lamps at various factories for other branches of the Government.

[2] Includes fee value of $3,484.27 for lamps inspected at factories.

[3] Of these totals 161,951 determinations were for the public, fee value $67,584.32; 267,666 determinations were for the Government department and State institutions, fee value $351,268.50; 24,972 determinations were for the bureau, fee value $46,264. The number of test items and determinations necessary in connection with the bureau's own work of research and standardization, with the resulting fee values, are not included in these totals.

SALARIES ($572,060)

This fund provides for personal services of administration and operation; the establishment, upkeep, and comparison of standards; the development of methods of test, as well as most of the testing; and for the determination of fundamental constants of importance in physics, chemistry, engineering, and technology not otherwise provided for.

Basic electrical units and standards.—The director of the bureau has been appointed as one of 10 members of an International Advisory Committee on Weights and Measures in coordinating more closely the systems of electrical units used in different countries. An American advisory committee has been formed and has unanimously recommended that the electrical standards of the future should be based upon the absolute system of units, with the understanding that the necessary researches shall be carried out at the national laboratories of the leading countries. The bureau's program of research in this field has therefore been accelerated as much as possible. Preliminary results have been obtained in a redetermination of the absolute value of the ampere by means of the Kelvin-type current balance, and work has been begun on a second type of balance, as well as on a redetermination of the ampere by the silver voltameter. A determination of the ratio of the international to the absolute unit of inductance (the henry) has been practically completed and gives the result that one international henry equals 1.0005 absolute units. This agrees almost exactly with absolute measurements of the ohm made in the national laboratories of Great Britain and Germany.

Standards of candlepower.—The bureau participated in a meeting of the International Commission on Illumination in Bellagio, Italy. Arrangements were made for international exchange and measurements on blue glasses designed to place secondary candlepower standards on a definite basis. In the measurement of the newer types of electric lamps large color differences are experienced, and agreement on secondary standards is very desirable.

Magnetic testing and research.—Adequate standards and methods should be available for the standardization of magnetic permeameters. An investigation of testing methods is in progress and suitable standards are being prepared. Testing methods for use with alternating currents and very weak fields are also being studied, since a satisfactory method of this type is needed for testing radio transformers, choke coils, and the like. Apparatus was constructed and set up for studying the thermomagnetic properties of materials to assist in the study of the constitution and properties of ferromagnetic materials. The effect of repeated stresses on magnetic properties has been investigated and a paper issued on the choice and utilization of permanent-magnet steels.

Development of seismometer.—A more complete theory of seismometers employing electromagnetic and optical magnification and electromagnetic damping has been developed and an experimental instrument constructed. The results indicate that it is superior to the best seismometers now obtainable for observations on distant earth disturbances.

Constant of gravitation.—Data for five additional values of this constant have been obtained to supplement the five values obtained last year. The computation of these results will require several months. Apparatus has been designed and constructed and is now being erected for the purpose of obtaining still another significant figure in the value of this constant.

Testing standards of mass.—Since all values on weights certified depend on the values of the high-precision laboratory standards of the bureau, the validity of these latter values is a matter of extreme

importance. The two principal sets of these standards were recalibrated, in terms of certain platinum-iridium standards, the values of which were determined by direct comparison with the national standard some time ago. The accuracy of this work has all been between one part in a million and one part in one hundred million, depending upon the size of the weight involved. Values obtained by comparisons conducted incident to the routine testing of weights had indicated the probability of changes in the values of several of these weights and the approximate size of these changes. The new values confirm this hypothesis. The changes were of the order of a few parts in ten million. While such changes as these are too small to have resulted in any error in corrections reported by the bureau on weights submitted for test, the new values are of very great importance, since not only do they place the work of the bureau upon a more stable foundation, but they also reduce the number of standards and the number of observations which must be used in order to assure values of a predetermined precision.

Orifice-meter investigation.—Cooperation with the natural gas department of the American Gas Association has been continued. The effects on orifice-meter indications of fittings close to the orifice have now been determined. Tests on the effect of widely varying rates of flow upon the discharge coefficient were studied, and the results obtained were very satisfactory. During the winter apparatus was designed and built for use in orifice tests under very high pressures. Work has already been started on the program for the present season, which includes appropriate tests to determine effects of (1) actual pipe size, (2) high line pressures, and (3) flange design.

Electric clocks.—Two types of mantel clock designed to operate on the regular household electric current were given a service test extending over several months. One of these is essentially a frequency meter, the hands being driven by a small synchronous motor running in phase with a 60-cycle alternating-current generator. In the second type of clock the electrical energy is used only to wind the mainspring, the clock mechanism then being driven by the spring in the usual way.

Ruling of line standards by the use of light waves.—Five years ago 6-inch line scales, divided into intervals of 1 inch, and with one of these intervals subdivided into fortieths, and free from errors greater than one one-hundred thousandth of an inch, were ruled by using light waves as the standard for stepping off the distances. The machine has been improved and perfected, so that now line scales 4 inches or 10 centimeters in length, or any subdivision of these lengths, can be ruled with an error not greater than two one-millionths of an inch, on any interval.

A larger machine is nearly completed. Its six ways (5 feet long) upon which the carriages slide have been made straight and parallel within one one-hundred thousandth of an inch. With this machine it is planned to make scales 1 meter or 40 inches in length with errors not greater than three one-millionths of an inch.

Tests of astronomical objectives.—The modified Hartmann test for the measurement of the aberrations of axial image points has been extended to permit its application to points off the axis. This method of test is particularly important, in that it yields results similar to those obtained with the lens interferometer and permits the results

to be obtained without the use of any optically worked surfaces additional to those of the component under test. Moreover, the results are readily interpreted in terms of the wave theory instead of in terms of geometric optics.

Refractometry of high precision.—Particular attention has been given to the minimum deviation refractometry of optical glass, including not only geometrical requirements but also the control of those conditions, such as temperature, pressure, and humidity, which affect the velocity of light either in the glass itself or in the reference medium.

Effect of solarization on window glass for transmitting ultra-violet rays of sunlight.—Solarization by exposure to the ultra-violet radiation emitted by artificial sources and by the sun decreases the transmission of most of these glasses of those ultra-violet rays of short wave lengths which are generally recognized by the medical profession as having a therapeutic value. Glasses which transmit 45 to 60 per cent of these rays, when new, transmit only 20 to 35 per cent after complete solarization. Glass substitutes, consisting of a cellulose product upon a wire mesh, may lose almost entirely their transmitting power of these ultra-violet rays after exposure to the weather.

Transparency of fabrics to ultra-violet radiation.—Fabrics made of cotton, linen, silk, wool, and rayon, especially when dyed, have a relatively low transmission of the violet rays; hence, to obtain beneficial therapeutic results an open-weave fabric should be worn.

Accelerated weathering tests.—Considerable progress was made on accelerated tests to simulate weather decay and on quantitative methods of determining the time of breakdown of organic protective coatings. Equipment has been designed and constructed which simulates the effects of sunlight, rain, and temperature changes. Small panels coated with paint, varnish, or other material can be placed in this apparatus and their relative endurance determined in a few days instead of months, as would be the case in ordinary weathering tests.

Density of creosote oils.—An investigation of the density and thermal expansion of creosote oils was carried out at the request of a joint committee representing the American Wood Preservers Association, the American Society for Testing Materials, and the American Railway Association. The necessary information has been secured, and tables are now in preparation for use by the wood-preserving industries.

Density of gasoline.—An investigation of the density and thermal expansion of "cracked" gasolines and blended motor fuels has been carried out in cooperation with the American Petroleum Institute. The results of this work will serve as an important supplement to the work previously done on petroleum oils at the bureau.

Plastic flow of lubricants and paints.—A new characteristic constant of plastic materials has been discovered in addition to two such constants previously used. These three constants are independent of the dimensions of the testing apparatus itself, at least over the customary range of conditions employed in such testing, and therefore constitute a definite step of progress toward a rational basis for measuring and specifying the consistency of lubricants, paints, and other plastic substances.

Reclamation of used lubricating oils.—At the request of the Chief Coordinator it has been shown that waste oil as obtained from Government departments or public filling stations can be readily refined so as to meet the Government specifications for new oil.

Properties of petroleum oils.—A review of available data showed that most of the thermal properties of petroleum oils could be predicted from a knowledge of the density of the oil at one temperature.

Gas analysis apparatus.—Several improvements have been made in volumetric gas analysis apparatus, including convenient means for maintaining an atmosphere of nitrogen in the distributing train, better means of controlling flow, and improvements in absorption pipettes.

Characteristics of flames.—The characteristics of flames of various gases and the relation of these characteristics to the useful applications of the gases are being investigated. Several of the properties of flames of hydrogen, acetylene, propane, carbon monoxide, and carburetted water gas have been measured. Several new phenomena were observed, the most interesting of which was the formation of polyhedral flames on burners of circular cross section.

Material for filling etched lines in thermometers.—A mixture of water glass and an organic pigment was found to make a durable color, which remains in place under most of the conditions to which thermometers are subjected in use.

Intercomparison of thermoelectric temperature scales.—Two standard thermocouples from the Bureau of Standards were calibrated at the British and German national laboratories. The results indicate that the scales of the three laboratories in the range 660° to 1,063° C. are in agreement to about 0.5° C. Further intercomparisons are expected to show closer agreement than this preliminary one.

Platinum resistance thermometry.—Platinum resistance thermometers have been calibrated from −190° to +660° C. according to the procedure specified for the International Temperature Scale for interchange with the other national laboratories.

Low-temperature investigations.—Experimental work was completed on the following investigations: Activation of cholesterol at liquid oxygen temperature, freezing points of the benzene-toluene system, absorption spectra at low temperatures of some of the aromatic hydrocarbons, absorption spectra of liquid oxygen, nitrogen, and hydrogen. Hydrogen of a purity better than 99.98 per cent has been supplied by the cryogenic laboratory in response to several requests.

Platinum metals.—Particular attention has been given to the elimination of the last traces of iridium from pure rhodium and to the development of a complete procedure for the preparation of very pure iridium. Results of all work thus far done on the purification of the six platinum metals were used as the basis of a publication on this subject. An investigation of methods for the accurate determination of each of the six metals was begun. Procedures for the determination of platinum and rhodium may be regarded as satisfactorily worked out, with work on iridium, osmium, and ruthenium in progress. The first phase of an extended investigation of the hydrolysis of platinum metal chlorides was completed. Rhodium

was the first element studied. The chemical work on the search for two new elements (atomic numbers 43 and 75) in crude osmiridium was completed. Further work on this project depends on X-ray spectrographic analysis.

Analytical reagent chemicals.—The critical study of methods for the determination of small amounts of impurities in reagent chemicals was continued. Approximately 50 individual methods were investigated and in many cases modified or replaced by more suitable methods. This work formed a material part of the preparation of the specifications for about 24 chemicals which were issued by the American Chemical Society.

Fundamental constants and properties of pure metals and their alloys.—Publication has been made on the metallographic properties of ferrite and on the density of pure iron and carbon steels after various treatments. Progress has been made in determination of various fundamental properties of very pure nickel, thorium, zinc, and cadmium. The development of strain lines when pure iron or low carbon steel is stressed to its yield point has been studied. Attempts are being made to secure a better understanding of the nature of the A2 point in iron by means of the beta ray spectroscope. The effect of excessive cold rolling on the hardness of copper and other metals is being further examined.

Development of metallographic test methods.—The use of X rays in testing and study of metals along both spectrographic and radiographic lines has been continued, with special attention to the use of the densitometer and to Laue spectrographs of wrought metals. Work has been in progress on methods of preparation of specimens for metallographic examination, using the microtome for soft metals and an automatic polishing apparatus designed and built at the bureau for harder ones.

Construction of apparatus for laboratory and other purposes.—Instruments and apparatus have been constructed by the instrument, machine, woodworking, and glass-blowing shops, and test specimens and standard samples have been prepared. Mention may be made of some of the more important apparatus constructed during the fiscal year: Carpet wear test machine, two fatigue test immersion machines, whirling test machine for varnish and paint tests, apparatus for testing the opacity of papers, constant temperature standard cell bath, two Wilson expansion apparatuses, fabric thickness measuring instrument, low voltage potentiometer, centrifuge for chemical thermometer testing, contact accelerometer, two ionization chambers, and two colorimeters.

EQUIPMENT ($88,000)

New equipment in constant temperature room.—The special basement room for precision length comparators, the circular dividing engine, and the circle testing apparatus was completed and the equipment installed. The apparatus is now used in regular testing work and in special investigations. The longitudinal length comparator has been found to be capable of making comparisons of length standards of the highest order, and it is being used in a very complete program of calibration of the bureau's length standards.

Renewal of mercury supply.—Thirteen flasks of virgin mercury, containing 75 pounds each, were purchased for general use of the bureau.

Jordan refining engine.—A No. 2 size Jordan refining engine with noncorrosive fittings was purchased for the experimental paper mill.

Sugar crystallizer.—A special crystallizer was purchased as part of the equipment of the new semicommercial sugar refinery, in which experimental work on levulose will be conducted.

Miscellaneous repairs and alterations.—This work included, in addition to the minor repairs to the buildings, such interior alterations as were necessary to accommodate the various laboratories. Extensive repairs were made to the roofs of the main buildings, and a new elevator is being installed in the South Building. The Far West Building, which was damaged by fire early in the year, has been completely restored.

GENERAL EXPENSES ($69,855)

Upkeep of mechanical plant.—The usual maintenance work, such as replacement of piping, steam traps, valves, packing of joints, etc., has been carried on. Repairs and replacements have been kept to the minimum in anticipation of the early completion of the new power plant.

Electrical construction and repair.—The work included the usual maintenance of equipment and installation of new apparatus made necessary by the fitting out of several additional laboratories.

Plumbing and pipe work.—In addition to the usual maintenance work on existing installations, new extensions to steam, water, air, vacuum, gas, and drainage systems were made incidental to the fitting out of several new laboratories. A very extensive piping lay-out is being installed in the new semicommercial sugar refinery where the work on levulose recovery will be conducted.

Library books.—The number of volumes accessioned this year was 1,639, and 16 were canceled, making the total number of accessioned volumes 32,433; 968 scientific and technical periodicals are received by the bureau's library.

Travel.—Provision was made for necessary travel to consult with experts at meetings of scientific and technical societies, travel of members of the bureau's visiting committee, and travel in foreign countries on cooperative work of the bureau with other national standardizing institutions.

Contingent expenses.—Part of the contingent expenses of the bureau and of the Department of Commerce, as a whole, have also been provided for.

IMPROVEMENT AND CARE OF GROUNDS ($13,000)

Improvement of grounds.—Good progress has been made in the improvement of the ground in front of the bureau by grading, sodding, and the planting of trees and shrubs. Work has been started on the improvement, by filling, of the land lying between the Industrial Building and Connecticut Avenue.

TESTING STRUCTURAL MATERIALS ($240,000)

Building codes.—The advisory building-code committee sent out the first tentative draft of its report on fire-resistive construction for comments and suggestions. The subcommittee on plumbing codes prepared a new edition of its 1924 report. The committee's recommendations have been used in code revisions in at least 120 municipalities and in uniform codes prepared by several regional bodies of building officials.

City planning and zoning.—A City Planning Primer and A Standard State City Planning Enabling Act, both by the advisory committee on city planning and zoning, were printed. Several other bulletins on city planning and zoning were issued.

Standard State mechanics' lien act committee.—This voluntary committee circulated a second tentative draft of its proposed standard State mechanics' lien act for comments and suggestions.

Statistical work.—Monthly retail prices for 24 building material items in 55 cities have been obtained, issued, and republished in trade papers and furnish the basis for price indexes of materials for small frame and brick houses. Current statistics on building activity, building costs, and production, consumption, and stocks on hand of principal building materials were printed in the monthly Survey of Current Business and its advance releases, and the annual article on construction was prepared for the Commerce Yearbook.

Cooperation with Government and private agencies on building and housing problems.—Cooperation was continued with Federal, State, and local governmental agencies and with private organizations concerned in building and housing. Several drafts of building codes were reviewed for local groups, and problems relating to city planning and zoning, building costs, and home ownership were taken up jointly with such groups as Better Homes in America, with its 5,000 local committees, the American Construction Council, the American Civic Association, and bodies representing architects, engineers, and business and other groups connected with construction. A voluntary delegation will represent the Department of Commerce at the International Housing and Town Planning Congress to be held in Paris shortly after the close of the fiscal year.

Strength of large concrete cylinders.—Over 500 test cylinders from 2 to 36 inches in diameter, containing large sizes of crushed stone as the large aggregate and screenings from crushing the stone as the fine aggregate, were tested in compression at the approximate age of 3 months.

One group of cylinders, including specimens of every size, was made in the proportion of 1 part cement to 2.7 parts of aggregate, all aggregate having been smaller than the ⅜-inch sieve. In this group the 36-inch cylinders developed an average compressive strength of 2,550; the 12, 18, and 24 inch specimens approximately 3,000; the 6 and 8 inch specimens 4,100; and the 2 and 3 inch specimens approximately 5,100 pounds per square inch.

In the other groups of cylinders the 36-inch cylinders contained aggregate of maximum size varying from 2½ to 10 inches, proportions being approximately 1:3:3, 1:3:4, and 1:3:4.6. Before filling the 8-inch molds all aggregate above 2½ inches was removed from

the concrete, for the 6-inch molds all above 1½ inches, and for the 2 and 3 inch molds all above ⅜ inch. The strength of the 36-inch diameter cylinders varied from 1,500 to 3,100 pounds per square inch, compared with the minimum and maximum average strengths of 2,260 and 4,400 for the 8-inch and 3,130 and 4,700 for the 6-inch cylinders. There was a general tendency for the smaller specimens to give higher strengths.

Stevenson Creek Dam.—The tests of this experimental arch dam were carried out by the Bureau of Standards under the auspices of Engineering Foundation and a special committee. These were the first tests ever made on a full-sized structure of this type, and many difficult problems had to be overcome. The electric strain gauge, developed by the bureau, was particularly useful in providing a means for recording stresses in inaccessible locations within the concrete. The past year has been devoted to working up the mass of data obtained, and a report has been published. Data are given on the temperatures in the concrete and on the strains, stresses, and deflections in the dam. The results have been compared with those obtained through calculation, using current methods of design, and with values obtained from small models. Engineers can now proceed with much greater assurance in the design of these structures.

Stone preservatives.—Results of tests lasting seven years indicate that the paraffin type of preservative has deteriorated very little during this period while all other types in the series practically lost their effectiveness in less than three years.

Abrasive hardness.—Abrasive hardness tests have been completed on 50 marbles, 20 slates, 23 limestones, 6 sandstones, and a few miscellaneous materials. A comparison of the average results for marble, slate, and limestone show that marble is the most resistant to wear. Slate is somewhat more resistant than the limestones in common use, but several limestones are available which are as resistant as the marbles.

Slate investigation.—About 2,000 tests have been made on slate samples, mainly from Pennsylvania, which include determinations for absorption, true specific gravity, apparent specific gravity, modulus of rupture, and elasticity. Test values, so far obtained, are as follows:

	Highest	Lowest	Average
Absorption by weight (per cent)	0.35	0.15	0.25
True specific gravity	2.80	2.77	2.79
Apparent specific gravity	2.78	2.76	2.77
Modulus of rupture	10,000	6,000	8,000
Modulus of elasticity	14,500,000	11,000,000	12,000,000

Sulphuric acid tests were made by immersing flexural test specimens for 480 hours in a 1 per cent solution. The effects were determined by weight loss, change of strength, elasticity, and general appearance. Blistering, fading, and loss of weight were noted in practically all tests, but the strength and elasticity of the materials were little affected. Evidently the acid action on these slates was confined to about 1 millimeter depth.

Sound-absorbing plaster.—A sound-absorbing plaster for correcting acoustical defects of auditoriums, offices, etc., has been developed. The plaster consists of a graded porous aggregate, held together by a cementitious material, with which is contained a substance for the production of gas during hardening, which further increases the porosity. A number of aggregates, such as pumice, volcanic tufa, burnt diatomaceous earth, ground coral rock, etc., have been found staisfactory.

Adhesion of plaster to hollow clay tile.—The strength of the bond between plaster and tile has been determined. Gypsum plaster, cement, and cement-lime stucco were tested on three grades of hollow clay tile with five types of surface. In all cases where glazed tile was used the plaster or stucco dropped off under its own weight. With the other types of tile the adhesion varied from 5.4 to 17.8 pounds per square inch. As plaster and stucco are rarely subjected to stresses aside from their own weight (about 0.04 pound per square inch), it is evident that an ample factor of safety exists on all hollow clay tile except those with glazed surface. Plaster should not be applied to such tile.

Properties of chemical limes.—The fineness and available lime content of 17 chemical quicklimes were determined. The fineness varied from 46.0 to 96.1 per cent through a No. 200 sieve. The available lime content varied from 37.9 to 97.1 per cent. The results, together with the chemical analyses, form a basis for the preparation of specifications for chemical limes and indicate the necessity of considering these factors in the purchase of lime for chemical uses.

Cast iron for enameling purposes.—Evidence has been secured that the blistering of enameled cast-iron ware can be reduced by sand blasting the castings sufficiently to remove the surface skin.

Chemical testing and methods of analysis.—Approximately 1,000 samples of structural materials were analyzed for various branches of the Government. The materials tested included cast irons, steels, alloy steels, ferro-alloys, brasses, bronzes, bearing metals, boiler plugs, Monel metal, and light aluminum alloys. The analyses were made for such varied purposes as the development of specifications, the insuring of proper delivery of materials, the detection of causes of failure in service, and the determination of the composition of structural materials used in metallurgical research at the bureau. Some time was also spent in developing improved and more rapid test methods.

Branch laboratories and the inspection of cement materials.—The bureau maintains three branch laboratories. The Northampton (Pa.) laboratory is used exclusively for the inspection and testing of cement, and being advantageously situated in the Lehigh Valley cement-producing district supervises the major portion of the Government purchases for tested cement in the East. The Denver laboratory tests cement in the territory west of the Mississippi River and is engaged in the study of available concrete aggregates used by the Reclamation Service. The San Francisco laboratory tests cement and miscellaneous materials purchased by the Government on the western coast.

There is a growing demand for increased services from these laboratories in the territories which they serve. The Government

now buys more and more of its supplies on the basis of specifications, and adequate testing facilities must be provided to meet these needs. The branch laboratories should be placed in a position to render this important service.

TESTING MACHINES ($38,000)

Tuckerman optical strain gauge.—New instruments have been designed and built which embody the experience of the past five years and which give a constant calibration factor of 1, eliminating much laborious computation and expediting testing. This has required optical and mechanical work of the highest precision. Six gauges of the new design with autocollimator and accessories have been forwarded to the Department of the Interior, Bureau of Reclamation, Denver, Colo., where they will be used in measuring the strains in a concrete model of the Stevenson Creek test dam.

Calibration of testing machines.—The 100,000-pound dead weight machine has been in regular use calibrating proving rings, Amsler boxes, and other transfer devices for the calibration of testing machines. Proving rings up to 100,000-pound capacity have been constructed and thoroughly tested for constancy in service. This experience has led to modifications in the design which make them more convenient to use.

Compressive strength of brickwork.—As the result of cooperative work with the Common Brick Manufacturers Association there is available for the first time comprehensive information on the factors which determine the strength of a brick wall, including the properties of the brick composition and properties of the mortar, type of construction, and workmanship.

Rail joints.—The investigation of rail joints in cooperation with the American Electric Railway Association and the American Bureau of Welding has been continued, resulting in modifications in practice which give increased life to the joints.

Welded steel structures.—Tests have been made of a considerable number of welded structural details in cooperation with steel fabricators to determine the safety of proposed types of construction. These included girders, columns, shelf angles, and other joint details, many requiring the use of the 10,000,000-pound testing machine. The bureau is cooperating with the American Bureau of Welding in planning a systematic research of this important subject.

Miscellaneous.—Other investigations have covered the adequacy of locking devices for screw threads, an important subject from the point of view of safety, and assistance in working up the data resulting from an investigation of gas flow through orifice meters.

INVESTIGATION OF FIRE-RESISTING PROPERTIES ($28,100)

Fire intensity and duration.—Fire tests with light commercial and record storage occupancies were completed, the tests made during the year being of record storage with metal shelving.

Tests with metal furniture indicated decided decrease in spread of fire from small and large origins and in the resultant severity of the fire as compared with wood furniture. Metal shelving, particularly that of the backed and partitioned type, also restricted the

spread of fire, although the decrease in the severity of fires completely consuming the combustible contents of the room was less marked.

These tests were made in 1-story fire-resistive buildings, and the results are applicable where the main building members have sufficient fire resistance to withstand a complete burning out of combustible contents and trim without collapse. Results are expressed as an equivalent of so many hours of exposure to the standard furnace test. For buildings with combustible or nonfire resistive interior construction the equivalent severity of the fire is less determinate, although of interest from the standpoint of exposure to neighboring buildings, to party and fire walls, and to insulated containers such as safes and vaults located within the building. A test was made with two such buildings that were otherwise due to be razed, in which considerable information was obtained on the severity of the exposure before the interior construction collapsed, the effect on the structural integrity of insulated safes of falling while hot from various heights or receiving impacts from falling masonry walls, and the intensity and duration of the temperature of the hot débris that fully or partly covered the containers after the buildings collapsed.

Fire loss statistics and fire prevention.—A paper on the seasonal variation in the fire loss and one on fire resistance in dwelling construction were published. Two papers were published that gave results of tests made to gauge the fire hazard of discarded cigarettes, cigars, and matches, and suggested modifications in their makeup that indicated possibility of decrease in hazard. Tests were made to determine the autogeneous ignition points of petroleum, nitrocellulose, and acetate cellulose products and the fire retardant effect of paint and other mineral coatings on wood. Fire tests were also made of a number of combustible and incombustible wall boards.

INVESTIGATION OF PUBLIC UTILITY STANDARDS ($100,000)

Measurement of high voltages and large currents.—The large electrometer for the absolute measurement of high voltages up to 250,000 volts has been nearly finished. The study of the corona voltmeter was completed. The wave form of the high voltage was obtained directly by an electrostatic method. A new equipment has been designed and partly constructed for testing current transformers up to 12,000 amperes. Air-cooled manganin shunts will be used up to 500 amperes; oil-cooled shunts for 1,000, 2,000, and 2,500 amperes; and a two-stage current transformer for higher ranges up to 12,000 amperes.

Electrolysis and soil corrosion.—Two field investigations of corrosion of pipe lines have resulted in considerable valuable data on the processes of corrosion of steel and cast-iron pipe lines. The Cast Iron Pipe Research Association has appointed a research associate to assist in the study of cast iron. Special tests of soil conditions have been started in 18 locations.

Code for Electricity Meter.—A new edition of the Code for Electricity Meters has been issued under the joint sponsorship of the National Electric Light Association, the Association of Edison Illuminating Companies, and the bureau.

National Electrical Safety Code and related projects.—The new (fourth) edition of the National Electrical Safety Code was approved as an American Standard by the American Engineering Standards Committee and has been issued in complete form as Handbook No. 3 (revised). A comprehensive volume of discussion and explanation of this code has been prepared and is in press. A large amount of work has been done on the 1928 revision of the National Electrical Code of the National Fire Protection Association and on final drafts of the proposed lightning-protection code for which the bureau is sponsor jointly with the American Institute of Electrical Engineers.

Telephone surveys and other cooperative work.—Progress of the local Federal building program necessitated detail studies of the initial and ultimate telephone requirements and planning for the most economical method of meeting them, as directed by the Chief Coordinator. The enactment of legislation authorizing joint-service switchboards outside of Washington has brought with it added survey work promising material economies. A standard telephone service contract form for use outside the District of Columbia is under negotiation. Much work has been devoted to cooperation with the Department of Justice in defense of an important patent suit against the United States. The Court of Claims decided another suit, in which the bureau cooperated, in favor of the Government.

Standards for gas service.—Cooperation has been given to two State commissions and to several cities in the study and discussion of the technical phases of proposed readjustments of standards for gas service. A study is being made of the design of domestic gas burners in relation to the conditions of gas supply with especial reference to the composition of the latter. The bureau has cooperated with the government of the District of Columbia in the preparation of a new code of rules for gas fitting in the District.

TESTING MISCELLANEOUS MATERIALS ($44,000)

Variety of materials tested.—A great variety of chemical and physical tests was made for Government departments on paints, varnishes, roofing and waterproofing materials, rubber goods, packings, inks, typewriter ribbons, carbon paper, textiles, boiler water and compounds, and detergents. A large number of miscellaneous materials were tested to determine their fire hazard in order to furnish data to guide the Steamboat Inspection Service in making rulings on the transportation of commodities on passenger vessels.

RADIO RESEARCH ($49,800)

Standard of radio frequency.—By use of piezooscillators with temperature control a very satisfactory intercomparison was made of the national frequency standards of England, France, Germany, Italy, and this country. Comparisons were also made with Canada and Japan. Transmissions of standard frequency signals were improved by basing them directly on a piezo standard. The accuracy of the standards in terms of the unit of time was increased through the use of a specially developed method involving a synchronous motor and harmonic amplifier.

Radio wave phenomena.—Irregularities of radio reception have been found to be in part due to the fact that the waves sometimes follow a multiplicity of paths in going from the transmitting to the receiving station because of varying ionization and other conditions of the atmosphere. Conditions at the transmitting station have little effect on the wave behavior. Fading occurs at much shorter distances than commonly supposed, being appreciable as close as 8 miles to a broadcasting station. Direction shifts studied in connection with a radiobeacon are due to the horizontal component of the downcoming waves. An antenna for airplanes free from the action of this horizontal component has been developed.

International radio conference.—A world-wide conference on radio communication was held in Washington in October and November, 1927. Four members of the bureau's staff served as technical advisers, one of them doing some preliminary work in Europe before the conference. Seventy-nine nations signed the resulting treaty. The conference was very satisfactory from the viewpoint of the United States. This was the first radio convention to which this country has been signatory without reservations.

Assistance to Federal Radio Commission.—Two members of the radio section spent a large amount of time, particularly during the latter half of the fiscal year, in assisting the Federal Radio Commission. Technical reports were prepared for presentation at various hearings, and fundamental plans were developed for the allocation of station frequencies, both in the broadcast and high frequency ranges. Advice was also given on the overcoming of sources of radio interference. The adoption of frequency standards for use in broadcasting stations resulted in a great increase in the testing of these standards by the bureau.

COLOR STANDARDIZATION ($10,000)

Standardization of Lovibond glasses.—In cooperation with the American Oil Chemists' Society, the bureau has proceeded with the standardization of the American Oil Chemists' " Lovibond glasses "—colored glasses used in various combinations for grading edible oils. In about one year the major part of this society's estimated 2,000 glasses will have been standardized in terms of the bureau's reference standards. The present rate of progress represents the consummation of several years of preliminary work in which much research has been carried on in developing equipment and methods; testing their adequacy, accuracy, and practicability; and, finally, establishing a series of standardized Lovibond glasses at the bureau, sufficient in accuracy and number to serve for calibrating the glasses used in the oil chemists' laboratories. After completing the program with the oil chemists it is planned to set up other reference standards for similar work in other colors and color ranges for those industries which have been pressing the bureau for a practicable solution of their problems. In this connection it is important to state that the manufacturer of Lovibond glasses has undertaken to cooperate in this standardization work of the bureau by furnishing the American trade with glasses conforming to the bureau's series of standards.

INVESTIGATION OF CLAY PRODUCTS ($47,000)

Columbus laboratory.—The work under this fund is conducted partly in Washington and partly at the bureau's branch laboratory at Ohio State University, Columbus, Ohio. In particular, work on heavy clay products is carried on at Columbus.

Workability of clays.—The first part of the investigation of the auger extrusion machine using clays and shales with different combinations of augers, spacers, and dies has been completed. Although the maximum production of clay column per unit of power was obtained by combining a single wing auger with a 6-inch spacer and a 6-inch die, defects in the clay column would appear from time to time. These were overcome by increasing the length of the spacer to 8 inches, resulting in only a slight increase in power consumption. Based on output of medium plastic clay per unit of power, the relative efficiencies of the single, double, and triple wing augers are proportionate to 100, 60.57, and 60.53, respectively. Based on output per unit time, the efficiencies are proportionate to 49.3, 90.1, and 95.1, respectively.

Preliminary tests on steam, water, and air lubrication showed that steam lubrication increased the dry die output per unit of power by 25 per cent. Water increased it by 20.6 and compressed air by 8.3 per cent.

Ceramic colors and their use in vitreous enamels.—Numerous stains have been produced and used in various enamel compositions. To obtain uniformity of texture of the colored enamels and to insure accuracy of duplication in preparing successive batches of a given stain, it was found desirable to (*a*) accurately duplicate the time and temperature of calcination and in some cases furnace atmosphere, (*b*) wash the stains free from soluble matter after calcination, (*c*) grind and pass them through a fine screen before use, and (*d*) keep the enamel composition constant. Several of the stains were produced on a relatively large scale and tested commercially under plant conditions. These gave excellent results.

Eliminating blisters on enameled cast-iron ware.—Blisters on enameled cast-iron ware may be traced either to faulty enamels and process of application or to the castings themselves. Some factors which must be considered are variations in enameling practice; differences in the tendency of different castings to produce blisters when enameled under identical conditions; different blistering tendencies of different heats of the same pig iron even when melted in the same electric furnace; an enameling test which includes a variety of firing conditions is necessary to bring out clearly the differences in the tendency of different sets of castings to produce blisters; baking treatment of the enamel-coated castings at 500° C., before firing, in a majority of cases appreciably reduced blistering tendencies; the most prolific source of blisters from iron used in this investigation is confined to a very thin surface layer. The removal of this layer by mechanical or a suitable chemical means causes a tremendous improvement.

Use of feldspar in white ware.—The true specific gravities of 19 raw and partly fused feldspars have been determined. The specific

gravity of practically pure albite was found to be 2.622 and that of microcline 2.563. The specific gravities of partly fused feldspars decreased as the firing temperatures increased to cone 8 (1,225° C.). Above this temperature the specific gravities were nearly constant, indicating that nearly all of the crystalline feldspar was changed to glass. The expansions of partly fused feldspars were determined by the interferometer method and found to be low when fired below cone 8 and above cone 10. The greatest expansion was noted for feldspars with the largest free silica content. A petrographic examination of partly fused feldspar showed no unmelted feldspar when fired to cone 14, and the indices of refraction of the glasses formed varied from 1.486 to 1.490. The fired volume shrinkage, porosity, mechanical strength, and elasticity of white-ware bodies apparently were not influenced by the kind of feldspar used. The thermal expansion of bodies was affected more by the amount of free silica than by the alkali content of the feldspar. Quenching tests did not indicate the relative merits of the feldspars regarding "glaze fit."

STANDARDIZING MECHANICAL APPLIANCES ($27,800)

Elevator research.—The investigation of undercar safeties and buffers has continued in cooperation with the American Engineering Standards Committee. Continuous velocity records of the test car are obtained by means of a homopolar generator and an oscillograph. Accelerations derived from this record are similar to those obtained with the accelerometer. Independent time-travel records are also secured. A large number of buffer measurements have been made, showing in some instances high acceleration peaks.

Elevator safety interlocks.—The work of formulating reliability performance tests for elevator interlocking devices has been extended to include performance tests of numerous commercial interlocks for regulatory bodies. The results of these tests are used as a basis of approval by several of the Government departments, the District of Columbia, several State and municipal governments, and a large group of casualty and insurance companies.

Standard vibration board.—A vibration board for testing aircraft instruments has been designed, operating on the cam instead of the eccentric weight principle, by means of which the period and amplitude are independently variable. Two boards have been constructed—one for this bureau and the other for the naval aircraft factory.

Performance specifications for numbering machines.—An experimental investigation was made of the useful life of commercial makes of lever numbering machines and a performance specification formulated for the use of the Federal Specifications Board. The tests showed a very wide disparity in the durability of different makes of machines.

Testing of engineering instruments, etc.—The volume of testing of engineering instruments and mechanical appliances, including water-current meters and fire extinguishers, has increased about 20 per cent during the year.

INVESTIGATION OF OPTICAL GLASS ($20,520)

Production of optical glass.—Five kinds of glass were made in 24 pots, a total of approximately 27,000 pounds, from which 31,851 lens and prism blanks were molded and annealed. The major portion of these blanks were used by the Navy Department.

Large glass disk.—The large glass disk which was successfully cast on May 7, 1927, was slowly cooled and reached room temperature on January 21, 1928. The strain in the glass is uniformly distributed and of a magnitude comparable with that in the finest annealed optical glass. The disk is of satisfactory quality for the purpose intended; that is, the mirror of a large reflecting telescope. It is 69.5 inches in diameter by 10.5 inches thick, and weighs approximately 3,800 pounds.

Viscosity of glass.—Further studies of the rotary viscometer necessitated an investigation of the effect of depth of immersion of the cylinder which rotates in the glass and the distance between the end of the cylinder and the crucible containing the glass. By rotating a cylinder 1.82 cm. in diameter in a cylinder 5.78 cm. in diameter it was found that for viscosities ranging from 700 to 30,000 poises the "end effect" (k) is practically independent of the depth of immersion and that (k) varies with end clearance (D) between the cylinders according to the equation:

$$k=\frac{6.3}{(D+2.426)^{0.8}}$$

Physical properties of glass as affected by thermal treatment (including annealing).—Glass must be annealed or heat treated at very definite and uniform temperatures if its optical properties are to be accurately controlled. As an example, it has been found that the index of refraction and density of a lead glass increase 0.000024 and 0.00014, respectively, per degree centrigrade decrease in effective annealing temperature; similarly the changes for a light barium crown are 0.000048 and 0.00034.

INVESTIGATION OF TEXTILES, ETC. ($40,700)

Wearing qualities of textiles—(Carpet wear test).—Apparatus was designed and built to simulate the wear of a carpet in service. It consists, essentially, of two abrading wheels, 12 inches in diameter, with leather-covered faces 2 inches wide, one fast and one loose on a common shaft. A circular carpet specimen (15 inches in diameter) is tacked to a heavy pivoted disk which is caused to bear against the abrading wheels. The wheel which is fast on the shaft is driven by the motor and causes the disk carrying the carpet to revolve. The second wheel is driven by contact with the carpet and turns against a brake. Thus, a horizontal strain is put on the sample and this, together with vertical pressure and the inherent slippage caused by the rotation of the disk, produces the wear. A vacuum cleaner picks up the abraded material.

A study of aeronautical fabric weaves.—The Navy Department has requested the bureau to study aeronautical fabrics from two standpoints—increase of tear resistance and reduction in weight without

impairing strength. In the case of balloon gas cell and airship cloth it is also important to produce a surface which will require less covering material and so reduce the weight of the finished fabric. Most aeronautical fabrics are plain woven materials, and the effect of the weave structure properties is being studied. Forty-four samples of fabrics have been woven in the experimental cotton mill. These include varieties of each of the following classes of weaves: Plain, twill, basket, satin, and mock leno. A leno attachment is being installed so as to include this class. These fabrics were woven under a tension held as constant as practicable, with 90 ends and 90 picks per inch of 60's yarn. The fabrics have been tested for breaking strength, stretch, tear, weight, thread count, crimp, and yarn size.

Tensile properties of rubber at high and low temperatures.—The properties of six soft-rubber compounds at temperatures ranging from −70° to +147° C. were determined. Temperature has a very pronounced influence on the tensile properties. At very low temperatures rubber becomes rigid with an increased tensile strength, while at very high temperatures it possesses practically no tensile strength.

Properties of leather.—In cooperation with the committee on properties of leather of the American Leather Chemist's Association, a preliminary investigation was made to show the effects of the chrome and vegetable tannages on the strength of steer hide, sheep, and calf leathers. The results showed that the vegetable-tanned leathers were generally stronger than the chrome leathers and also showed less stretch. Computed results of actual service tests of durability of retanned sole leathers showed that the thoroughly retanned or combination tanned sole leathers wore from 25 to 35 per cent longer than ordinary vegetable leathers per unit of thickness, while lightly retanned leathers wore from 75 to 100 per cent longer than the vegetable leathers.

Paper-quality standards.—At the request of the National Lumber Manufacturers Association a cooperative study of sheathing papers for development of a standard specification was undertaken and a preliminary report issued. A suggested Federal specification for fiber wall board was drawn up. Work on the permanence of paper included studies of rag newsprint paper for permanent library issues, rag bond paper for insurance policies, photostat paper for copying original records, and purified wood fibers.

Paper currency.—The United States currency paper originated by the bureau is now in commercial production. Work on improving the resistance of the surfaces of the currency to wear was continued. The use of cellulose acetate as a sizing agent for this purpose was given particular attention. Considerable additional work was done on recovery of paper pulp from the redeemed currency.

Standardization of paper-testing methods.—Cooperation with the Technical Association of the Pulp and Paper Industry in development of its official paper-testing methods was continued. Five additional methods were completed. The association publication—Paper Testing Methods—was thoroughly revised and brought up to date. Results of bureau investigations on methods for determining folding endurance, bursting strength, tearing resistance, tensile strength, and copper number were published.

SUGAR STANDARDIZATION ($48,160)

Sugar and the tariff.—More than 3,000,000 tons of dutiable sugar and approximately 270,000,000 gallons of molasses enter the United States annually from foreign countries. The scientific supervision of the collection of the duty imposed by the tariff act, about $140,000,000 annually, is one of the functions of the bureau. Even the highest attainable accuracy science can devise does not meet the requirements for this work because of the magnitude of the revenue involved in individual cargoes. New equipment is continually being designed, studied, and standardized by the bureau. Immediate shipment of standardized apparatus is imperative, and increased facilities have been provided for the storage of supplies of this character. A new short-length polariscope tube for use with liquids of high rotation and small volumes of solutions has been designed and studied and a supply obtained and distributed to the customs laboratories. In cooperation with the manufacturers, improvements have been developed and incorporated in the design of a standard sugar balance. The analytical methods used in the various customs laboratories must give reproducible and identical results over a wide range of climatic conditions. Further studies of the methods involved have been continued with the main purpose of increasing the precision and appraisal of these products. The methods of determining the densities of molasses and sirups have been under investigation and a standard table of weights per gallon has been developed.

Commercial production of levulose.—Progress in the development of an economical commercial-scale process for the production of hard refined levulose has been satisfactory. The bureau expects ultimately to have an experimental plant that can perform the whole of the projected technique of levulose manufacture. During the year activity was concentrated on building only those parts of the plant which are indispensable to the main line of work. Installation of about 75 per cent of the process pipe work, equipment, and machinery for the immediate limited program has been completed. To control the manufacturing process for levulose, a system of analysis has been elaborated which meets the requirements of speed and reliability.

Structure of the sugars.—It is now evident that the simple sugars (dextrose, levulose, etc.) exist in several molecular forms possessing various ring structures, and that the compound sugars (sucrose, lactose, etc.), the starches, and the celluloses are formed by the union of the simple sugars of certain ring types. Knowledge of the structural chemistry of the sugars is in rapid development due to this idea of ring types and to the isolation of new derivatives of the sugars possessing new ring structures predicted by theory.

GAUGE STANDARDIZATION ($38,320)

Certification of master gauges.—Until rather recently the principal work of the gauge section was to act as referee in disputes between manufacturers and purchasers of gauges as to the acceptability of gauges in question. During the past two years, however, there has been an increasing tendency on the part of certain industries to require that all master gauges be submitted to the bureau for test and

certification. This has been particularly marked in the petroleum industry, which is carrying through an active standardization program under the leadership of the American Petroleum Institute. All master gauges for interchangeable parts of oil-well equipment made to A. P. I. specifications, such as well casing, drill pipe, pump rods, and drilling tools, have been submitted to and certified by the bureau. A similar tendency has recently developed among manufacturers of automobile accessories. The section is also called upon to an increasing extent to determine dimensions of parts of scientific apparatus.

Development of new equipment.—Apparatus for determining the lead or pitch of ring thread gauges in sizes for which no suitable equipment was previously available has been designed and built. This apparatus permits determination of lead of straight or taper ring thread gauges of 1½ inches and larger to an accuracy of 0.00002 inch. Three projection lanterns incorporating the latest improvements were built. One of these is for use in the gauge-testing laboratory and the other two are for the Ordinance Department of the War Department. An interferometer of foreign make was rebuilt to overcome the tendency to vibrate and become unreliable in its indications as a result of unavoidable vibrations of the building in which it was used. The reliability and usefulness of the instrument were much improved by the changes made.

INVESTIGATION OF MINE SCALES AND CARS ($12,800)

Test of mine and tipple scales.—One hundred and sixty-two mine scales in four States were tested. The percentage of accuracy by States varied from 18.5 to 40 per cent. The average accuracy of all the scales included was about 32 per cent. This figure is somewhat lower than last year, but is subject to considerable fluctuation from year to year due to the fact that the figure for a single year is not, and can not be, with present facilities, representative of the coal regions as a whole. General experience over a period of years demonstrates a gradual improvement in accuracy. Especially it is demonstrated that there is not so great a percentage of scales favoring the operators as was formerly the case.

METALLURGICAL RESEARCH ($48,140)

Bearing bronzes.—The tensile and impact properties, resistance to repeated pounding and to wear of a series of railroad bearing bronzes at various temperatures up to or above the operating temperature of the bearings, have been determined. Both chill and sand cast bearings were studied, in cooperation with a research associate from a manufacturer of bearings. There would appear to be no justification for the wide variety of bearing metal compositions now specified by many railroads for the same class of service. Much wider ranges of composition could be allowed without appreciably altering the performance of the bearings and with a consequent saving in manufacturing costs. The specifications of the American Society for Testing Materials for railroad bearing bronzes seem, on the basis of the properties studied in the tests, to be well framed, and their use appears advisable. Work on automotive bearing bronzes is now in progress in cooperation with a research associate.

Rail steel.—Results of endurance tests on new rail steel show a considerable variation in the endurance properties of steels meeting railroad specifications. Work is under way on the endurance properties of the same steels on specimens taken from rails removed from service on account of wear. Endurance tests have been in progress on steel from alloy steel rails and heat-treated steel rails. The study of endurance testing by rotary bending and by axial loading has been continued, especially for its bearing on rail endurance. Much work has been done on the properties of rail steel at high temperatures, since this may have a bearing on the problem of rail failure from transverse fissures. Marked differences in high temperature properties have been found. This work is in cooperation with the American Railway Engineering Association, Manufacturer's Rail Steel Committee, American Society of Civil Engineers' Committee on Stresses in Track, the Sperry Development Co., and various railroads in this country and Canada.

Aluminum alloys.—A 400-page circular dealing in comprehensive fashion with the properties of alloys of aluminum, of magnesium, of silicon, and of beryllium has been issued.

Corrosion of metals.—A report on testing methods for appraising the corrosion resistance of nonferrous metals has been published, and one on methods applicable to zinc-coated materials is in press. Apparatus has been made ready for study of the effect of aeration in corrosion and corrosion testing. Cooperative work with the American Society for Testing Materials in the study of the corrosion of nonferrous screen wire cloth continues. In cooperation with a research associate from the American Petroleum Institute, a field survey of corrosion problems and remedies in the oil industry has been begun.

Foundry practice.—In cooperation with a research associate from the Steel Castings Development Bureau, work was begun on the causes for low ductility in steel castings. The Bureau of Mines has cooperated in this problem. Preliminary work was done on methods of testing the fluidity of metals; that is, their ability to fill a mold during casting.

Other metallurgical investigations.—The study of steel for carburizing has been completed and a report is in press; a report has been issued on the effect of antimony, arsenic, copper, and tin in high-speed tool steel; work has been completed on the sintering point test for molding sand and an investigation started of core binders; progress has been made in developing substitutes for platinum in laboratory work; the rate of cooling of steel in various quenching media has been studied; and the development of metal spray processes for the Army and Navy has been continued.

Metallurgical advisory committees.—The usual meetings of the ferrous and nonferrous advisory committees were held at the bureau on May 11 and 12. Progress of work was discussed and a program of research for the coming year was adopted.

HIGH-TEMPERATURE INVESTIGATION ($9,740)

Pyrometry of molten cast iron.—It was found that at a temperature of about 1,375° C. the character of the surface of molten iron undergoes a marked change. By applying suitable corrections for

this effect the optical pyrometer becomes applicable to accurate temperature measurements in the foundry.

Thermoelectric properties of pure metals.—Measurements have been made on gold, silver, nickel, iron, aluminum, and thorium. The measurements have been extended to include the change of thermoelectric power in a magnetic field.

SOUND INVESTIGATION ($10,580)

Acoustic properties of building materials.—Sound-transmission measurements were made on 26 large panels of masonry and stud construction, 12 of which were floor panels. It was found that furred-out surfaces on masonry walls give excellent sound insulation. Experiments have been made on types of construction suitable for airplane cabins. Measurements of sound absorption were made on a large number of substances commonly used in interior finish. This property is of importance in predetermining the acoustic quality of a proposed auditorium. A reverberation chamber has been constructed for the purpose of making such measurements on a much larger scale than has been possible in the past.

Tuning-fork investigation.—Tuning forks made of unusual materials, such as aluminum, magnesium, and silica, have been studied with a view to finding the material for the construction of such forks. This work is being continued.

INDUSTRIAL RESEARCH ($172,320)

Research associates.—The greater portion of the bureau's expenses in connection with the research associate plan are cared for by this fund. Forty-six industrial groups are now represented at the bureau by 82 research associates. One of the most notable cases is that of the Portland Cement Association, which maintains a corps of seven expert physicists and chemists in the clay and silicate products division. Numerous publications on the fundamental properties of Portland cement have been published by this group.

Chromium plating.—A small chromium-plating plant was designed and installed at the United States Mint in Philadelphia. It is now in successful operation. A broad investigation of the principles and practice of chromium plating and of the properties of electrolytic chromium has been initiated.

Optical screw-thread gauge for measuring internal threads.—At present there is no method for determining all the dimensions of an internal screw thread other than those which necessitate the cutting of a section from the gauge or indirect measurements made on a cast of the thread. An optical instrument has been designed which permits measurements to be made directly on the thread by a coincidence method analogous to that of the coincidence-type range finder.

Journal-bearing performance.—Tests in cooperation with the American Society of Mechanical Engineers have been completed on a series of 84 journal bearings, comprising 21 variations of length or clearance dimensions, in order to determine the effect of the length of the bearing and the closeness of fit on the friction loss. The results will provide data for rational design of journal bearings over a considerable range of speed, load, and viscosity of lubricant.

Wear-resisting alloys.—Besides further study of the wear resistance of chromium plating on plug gauges, the resistance of materials for the manufacture of shovels to wear by abrasive materials has been examined by various laboratory tests. The general subject is being studied to find out what properties are required in a metal to produce wear resistance under different conditions of use and what tests can be carried out in the laboratory so as to give an accurate prediction of wear resistance under these different conditions.

Heat-resisting alloys.—In cooperation with the joint committee on high temperature properties of metals of the American Society of Mechanical Engineers, American Society for Testing Materials, etc., and with a research associate from a manufacturer of alloy steels, work has continued on long-time tests at high temperatures under continued loading, as well as on short-time tests. A series of special heat-resisting alloys has been made up and is under test.

Gases in metals.—Results from the first intercomparison of analyses for oxygen in specimens of iron distributed to cooperating laboratories in England and Germany show good agreement. Publication was made on vacuum fusion methods for nitrogen, and one is in press on the hydrogen-antimony-tin method for oxygen. Improvements were made in the vacuum fusion method for oxygen which increase the precision and decrease the time required. Progress was made in the study of the iron-nitrogen system.

Heat of combustion of sulphur.—A method was developed for burning sulphur so as to produce only sulphur dioxide, thus making it possible to control this reaction in a calorimeter and determine the amount of heat developed.

System zinc oxide-silica.—The determination of the phase equilibrium diagram was completed. In connection with this investigation the melting point of zinc oxide was determined for the first time and found to be 1,975° C. For this purpose a furnace was designed by means of which temperatures up to 2,300° C. could for the first time be attained in an oxidizing atmosphere.

Spectrochemical analysis.—During the past year the bureau's methods for making qualitative and quantitative chemical analyses by means of the spectrograph have been greatly extended by the accurate measurement and classification of the spectra of 11 different elements. These methods of analysis, which are effectively applied where the customary methods of chemistry are inoperative, have been successfully employed during the year for determining the composition of 169 different industrial and scientific materials.

Atomic structure investigations.—Studies with a new type of electrical discharge led to the observation of continuous emission bonds in the spectra of various monatomic gases and vapors. Theory indicates that these must result from recombination of ions and electrons. This has afforded an opportunity to measure for the first time an atomic property which has been the subject of much speculation and to develop methods which will be applicable to many other problems. A preliminary report of the experiments is given in the Physical Review, February, 1928.

A study of the Zeeman pattern of the fine structure of the mercury line at 2537A represents an outstanding technical achievement of timely theoretical interest. Under the highest attainable resolving power this line is seen to be in reality fine, very close lines, and

in a magnetic field each of these splits into three. The resulting pattern is far beyond the resolving power of any instrument, so that methods were devised to single out various parts of the pattern. The results show that none of the proposed theories of fine structure apply to this case. The results were published in the Physical Review, June, 1928.

Photographic emulsions.—The experiments on introduction of colloidal particles to act as sensitivity nuclei have been extended and completed. The only mechanism consistent with the results produced by metallic nuclei is that they localize the photochemical action in the emulsion grains; this strongly indicates a similar mechanism for sensitivity nuclei produced by normal ripening. On the other hand, silver iodide nuclei only accelerate development; other effects caused by iodides may be explained in the light of these results. Preliminary results have been obtained comparing the effects of hydrogen and bromide ion concentrations on color sensitization by different types of dyes.

Storage-battery investigations.—This work has included four principal items: (1) Corrosion tests on large storage-battery plates have been continued to determine the cause of failures in plates used in cells for submarine use, and a probable cause of such failures has been found in crevice corrosion such as is known to occur in other materials. (2) The effect of temperature on the positive and negative plates of storage batteries has been determined in connection with use of batteries in airplanes. Measurements have been made at three temperatures, three concentrations of the electrolyte, three different rates of discharge for positive plates and for negative plates separately. The results have shown quite definitely why some aviation batteries have failed to give the service expected. (3) The work on lead oxides used in the manufacture of storage-battery plates has been actively in progress, including a study of the physical and chemical properties of the oxides as well as the process of preparing the paste to be used in making the plates. (4) A beginning has been made on the study of grid materials and structure.

Properties of electrical insulating materials.—Research has been confined to rubber and rubberlike materials. Especial attention has been given to the properties of pure materials. Methods have been devised for removing the natural impurities from crude rubber. Measurements of the electrical properties of the rubber hydrocarbons of rubbers from different species of plants indicate that the hydrocarbon is the same from all sources. Likewise, there is evidence that the hydrocarbons from gutta-percha and gutta-belata are identical. For all these hydrocarbons the resistivity is much higher than for the crude material and the power factor much lower.

Elastic hysteresis research.—Elastic hysteresis constants of diaphram and spring metals are being determined. Emphasis has been laid on a mathematical investigation of the deflection of tuning forks in order to be able to use the damping of tuning forks made of various metals in the evaluation of the hysteresis modulus.

Gas-burner design.—A study has been made of the details of design of gas burners for use with propane, which is being extensively distributed as a domestic fuel. A similar study is being made of butane. Optimum conditions are developed with relation to the efficiency, capacity, and safety of the burners for domestic purposes. A

brief study was made of the efficiency and safety of several commercial acetylene burners when using pure acetylene and when using mixtures of acetylene and pentane.

Thermal expansion.—Researches on the thermal expansion of beryllium and beryllium alloys, stainless iron alloys, pure nickel, magnesium, and magnesium alloys, and on sand-lime brick have been completed. Further attention has been given to types of equipment suitable for the various needs of laboratories wishing to make expansion measurements.

Thermal conductivity of insulating materials at ordinary temperatures.—A new apparatus capable of greater precision than those previously used was constructed and tested. A number of specimens of materials were calibrated for use as "conductimeters" and have been sent to various laboratories making similar measurements, in order to ascertain the agreement between the laboratories.

Radiator investigation.—Measurements of superficial area of a number of radiators have been made for one of the Government departments. To provide a rational basis for rating, a test room has been designed for measuring the performance of radiators under accurately controlled conditions.

Properties of water and steam.—Observations of the specific heat of water over the temperature range from near 0° to 250° C. have been carried out. Further observations are to be made at temperatures above 100° C. The work completed yields as a definite result that the mean calorie, defined as one one-hundredth of the change in the heat content of water at saturation pressure, between 0° and 100° C. is equivalent to 4.189 by 10^7 ergs.

Dyes.—A series of light-fading tests of dyed textiles, which was started in 1926, was brought practically to completion. An apparatus, with a Martens photometer as the basis, was constructed for quantitatively measuring the amount of fading. It can also be used for transmission measurements on dye solutions. The Department of Agriculture is interested in its use for measuring the color of meats and of citrus fruits.

Acid in leather.—Four tannages of leather were prepared in the experimental tannery using chestnut wood and quebracho wood extracts as tanning materials. From this leather 624 standard leather samples were prepared which were treated with amounts of sulphuric acid varying from 0 to 4.5 per cent. After nine months aging the four tannages of leather showed deterioration in strength in all samples containing in excess of 3, 3.5, 1.5, and 2 per cent sulphuric acid, respectively. The degrees of tannage for these four lots of leather were 48, 43, 62, and 54, respectively. The deterioration is in the order of the degree of tannage. It is of prime importance to determine the effect of the degree of tannage on the deteriorating action of the acid before drawing any conclusions as to the effects of the tanning materials themselves. Accordingly, additional leather is being prepared with the same tanning materials with much higher degrees of tannage in order to establish this point. All deterioration which took place in nine months occurred in samples having a pH value of less than 2.5.

Wear of pneumatic tire treads.—A study was made of the flexing of pneumatic tire treads and a simple method developed for demon-

strating and measuring the relative movements of different parts of the tread due to flexing. It was concluded that tread movements constitute one of the principal causes of tread wear and especially of nonuniform tread wear.

Wind pressure on structures.—Measurements have been made of the pressure distribution on a cylindrical stack 10 feet in diameter and 30 feet high in the natural wind in order to determine the wind pressure on full-scale chimneys. To supplement the measurements of pressure at one elevation, the whole structure has been supported on sylphon bellows which are filled with water and connected with pressure gauges, so that the overturning moment can be measured. The results obtained thus far show that the overturning moment corresponds within reasonable limits to that predicted from wind-tunnel measurements on a 1-foot cylinder tested at 70 miles per hour. The pressure distribution measurements in the natural wind show certain features which are not as yet entirely accounted for.

TESTING RAILROAD-TRACK AND OTHER SCALES ($47,000)

Railroad-track scales.—Three track scale testing units operated over 68 railroad systems making tests in 34 States and the District of Columbia. Seven hundred and three track scales were tested, of which 459 were owned by the carriers, 230 by industries, 4 by States or municipalities, and 10 by departments of the Federal Government. Bureau inspectors adjusted 54 scales to correct for abnormal weighing errors which were due to faulty adjustment.

Of all scales tested during the year 70 per cent were within the tolerance used by the bureau for grading weighing accuracy. The average error for all scales tested was 0.23 per cent of the applied test loads. Both these values are substantially the same as the corresponding values for the preceding year.

In the eastern district 77.4 per cent of the tested scales were within tolerance, and the average error for all was 0.16 per cent. Too great significance should not be attached to these values as indications of high grade weighing performance, since tests made within the district this year were too few to form a satisfactory basis for generalizations.

In the southern district 63.6 per cent of the scales tested were correct within tolerance, the average error for all scales being 0.30 per cent. The first figure represents an increase of 1 per cent over last year's figure. Improvement of weighing accuracy in the southern district is being retarded by inferior maintenance standards, delayed replacement of inadequate facilities, and some laxity of supervision.

Of all scales tested in the western district 74.8 per cent were within tolerance, and the average error was 0.17 per cent. Slight improvement over last year's results is indicated by these items. Only slight advances may be expected henceforth in this district where maintenance measures, replacements, and supervision are now at practicable maximums.

Master track scales.—Eighteen master track scales were calibrated during the year. Sixteen were found to be within precision weighing tolerances. One found deficient in performance has been abandoned and one found to have inherent defects in installation is being

rebuilt. A new master scale installed by the Atlantic Coast Line Railroad at Jacksonville, Fla., was placed in service during the year and now forms an added and vital link in the master scale system of the country.

Railroaod track scales in grain weighing service.—Included among the track scales tested were 54 scales used for weighing grain. Thirty-two scales, or 59.2 per cent of the tested grain scales, were within the tolerance which is twice as rigorous in its requirements as the regular track scale tolerance. Speaking generally, a large amount of obsolete equipment is still in use, and grain weighing scales are correspondingly inferior to railroad scales in accuracy and dependability.

Test car calibrations.—While operating in the field, the test units calibrated 18 test cars for industries and railroads which do not have access to master scales.

Installation of master track scale.—The construction of the master track scale and test car depot at Clearing, Ill., was begun early in the year, and the work progressed so rapidly that the master track scale was installed, and calibrations of test cars submitted by railroads and industries were started on May 1. Nine test cars have been calibrated. Some further work on the scale will be necessary before its performance is entirely satisfactory.

Cooperation with States in weights and measures matters.—Meetings under State auspices have been attended in nine States. In connection with traveling incident to these meetings, officials of 12 other States have been visited with reference to the work of existing departments of weights and measures or for consultation on the establishment of new departments.

Weights and measures publications.—Three important publications were issued—a Compilation of the Federal and State Laws Relating to Weights and Measures, a report of the Twentieth National Conference on Weights and Measures, and a Handbook on Weights and Measures Administration.

STANDARDIZATION OF EQUIPMENT ($130,000)

General conferences on simplified practice.—Twenty-four general conferences were held, an increase of 38 per cent over the previous year. Simplified practice recommendations have been accepted covering 86 commodities, an increase of 24 projects. Thirteen recommendations are now in process of acceptance, and printed recommendations have been issued for 73 commodities.

Number of acceptances to simplified practice recommendations.—A total of 883 acceptances have been received from trade associations and other organized groups, as well as individual acceptances from 9,754 manufacturers, distributors, and users.

Revision and reaffirmation conferences.—Fourteen conferences were held by the members of the industries concerned, resulting in the revision of items in 14 of the simplified practice recommendations already in effect. There were also held 26 conferences, in which the various industries reaffirmed the existing simplified practice recommendations, an increase of 9 reaffirmations over the year 1927.

Adherence to simplified practice recommendations.—Field surveys showed that the average degree of adherence for 31 commodities was

86.86 per cent. That figure compares most favorably with the one of 1926 and 1927, which was 75 per cent for 12 commodities. The data collected through the resurveys also provided a basis for further eliminations and substitutions, thereby making it possible to keep the simplified practice recommendations up to date and in line with the best current practices of the industry concerned. Individual commodities and the degree of adherence in percentage are detailed below.

Degree of adherence obtained by actual survey

S. P. R. No.	Commodity	Adherence	S. P. R. No.	Commodity	Adherence
1	Paving brick	79.80	33	Cafeteria and restaurant chinaware	80.60
4	Asphalt	91.00	35	Steel lockers	85.18
5	Hotel chinaware	80.60	38	Sand-lime brick	77.60
6	Files and rasps	93.00	39	Dining-car chinaware	80.60
8	Range boilers	97.87	40	Hospital chinaware	80.60
9	Woven-wire fencing	99.00	41	Insecticides and fungicides	97.00
13	Structural slate	85.00	42	Paper (grocers') bags	95.55
14	Roofing slate	98.00	43	Paint and varnish brushes	80.50
15	Blackboard slate	93.00	44	Box board	65.00
18	Builder's hardware	79.66	46	Tissue paper	85.00
19	Asbestos paper and asbestos millboard	76.00	49	Sidewalk, floor, and roof lights	94.28
20	Steel barrels and drums	89.04	51	Die-head chasers	80.74
28	Sheet steel for jobbers:		55	Tinware, galvanized, and japanned ware	92.00
	Sheet-steel portion	85.00	57	Wrought-iron and wrought-steel pipe, valves, and fittings	99.79
	Roofing portion	52.00			
29	Eaves trough and conductor pipe	92.00		Average	86.86
30	Terneplate	100.00			
32	Concrete building units	90.00			

Field surveys in progress.—Surveys of existing varieties are in progress for 15 industries.

Benefits of simplified practice.—Replies received regarding the advantages of simplified practice show that manufacturers, distributors, and users are deriving many material benefits. For example, one manufacturer of die-head chasers reduced inventory by $225,233.75 between December 31, 1925, and December 1, 1927, with a saving in interest of approximately $13,500 per year and an estimated saving from reduced obsolescence of $10,000 per year. In addition, the same manufacturer reduced his office pay roll $25,000 per year, half of which he attributes to simplified practice. A large retailer reduced his inventory of bed blankets 40 per cent, with a 7 per cent increase in his sales. In the building-construction field one manufacturer of concrete building units reduced the selling price of his product 25 per cent. The foregoing and similar information not only sustains the estimates made by leaders in industry that simplified practice is saving $300,000,000 per year, but indicates that the benefits are shared in large measure by the distributors and users.

Interest of domestic and foreign business men in simplified practice.—That interest in simplified practice is growing is shown by the increasing number of visitors. Two hundred and five American business men and 26 foreign callers interviewed members of the staff. That foreign interest is increasing is shown by the numerous requests for information, of which there were 6 in the first quarter and 14 in the last quarter, the total for the year being 41.

American Marine Standards Committee.—This committee is now composed of 340 member bodies, among which practically all phases

of the marine industry are represented. Technical activities are carried on by technical committees, subject committees, and special committees, comprising an aggregate personnel of about 270 members. The finished work so far accomplished consists of 80 standards, which are being published as a series of the Department of Commerce.

Commercial standards.—This classification includes establishment of standards of grade, quality, dimensional tolerances, and other specification requirements. This work is carried out in cooperation with industry along lines similar to simplified practice procedure.

Six general conferences have been held covering Stoddard solvent; clinical thermometers; chain-link fence of copper-bearing steel, galvanized after weaving; porcelain (all-clay) plumbing fixtures; steel pipe nipples; and genuine wrought-iron pipe nipples. The first three of these standards have been circulated for written acceptance, and one—clinical thermometers—has been prepared for printing. Commercial Standard No. 1, "New Billet-steel Concrete Reinforcement Bars, was canceled following withdrawal of producer support.

Requests for cooperation in the establishment of 13 additional commercial standards have been received, and 36 others are in various stages of initiation and formulation, indicating a very real demand and support for this service from industry, particularly on the part of trade associations.

Directory of laboratories.—In a revised edition of the Directory of Commercial Testing and College Research Laboratories data are given concerning the laboratories in 186 colleges, as compared with 143 in the first edition, and 271 commercial testing laboratories, with 92 branch laboratories or offices, as compared with 207 commercial laboratories in the first edition.

Specifications in various industries.—To supplement the National Directory of Commodity Specifications, there was issued, with the title "Standards and Specifications in the Wood-Using Industries," the first of a series of publications dealing with the standards and specifications in various industries. Manuscript is now being prepared for the second volume of this series, to be called "Standards and Specifications for Nonmetallic Minerals and Manufactures Thereof."

Standards Yearbook.—In the Standards Yearbook, an annual publication of which the second volume was issued during the year, are given outlines of the standardization activities and accomplishments of not only the Bureau of Standards and other agencies of the Federal Government but also of the American societies and associations and of foreign national and several international agencies of which standardization is a major or very important activity.

Cooperation with public purchasers.—In connection with the compilation of material for the National Directory of Commodity Specifications and the Standards Yearbook, and the inauguration of the so-called certification plan, the bureau has cooperated with the public purchasing officers in all of the 48 States and with all of the State highway commissions. It has established contact with more than 1,500 additional public purchasers for all of the cities throughout the country, all of the municipalities having the city-manager form of government, and many counties, public schools, hospitals, and other public institutions. To these public purchasers

have been sent copies of lists of manufactuers who have expressed their willingness to certify to compliance with United States Government master specifications, 146 of these specifications now having been covered in this way.

Facilitating the use of specifications.—The "certification plan," which was introduced to overcome the disadvantages incident to the use of specifications by purchasers not equipped to test the goods delivered, has been so extended as to include commodities covered by a total of 146 United States Government master specifications. Self-identifying quality-guaranteeing labels are now being used by manufacturers of certain staple lines of merchandise to show that they comply with the requirements and tests of certain of the specifications. The list of commercial and college laboratories equipped to make tests to determine whether delivered commodities comply with the specifications has been revised and published in a second enlarged edition.

Dry cell standardization.—Qualification tests of dry batteries are made at intervals of approximately six months. In December, 1927, approximately 1,593 batteries were collected from 21 manufacturers, while in June, 1928, 1,703 batteries were collected from 19 manufacturers. The information obtained on these tests is furnished to Government purchasing officers and also to each battery manufacturer on his own product. The revised Federal specification for dry batteries issued November 23, 1927, has since been approved by the American Engineering Standards Committee as an American Standard.

Safety standards.—A code of colors for traffic signals for which the bureau has been a sponsor was approved by the American Engineering Standards Committee November 15, 1927; but this code omits all provisions for nonluminous signs, and consequently efforts have been continued to work out a more comprehensive code on which general agreement can be obtained. A revision of the Code for Protection of Heads and Eyes of Industrial Workers is in progress, with an extension of scope to include respirators and gas masks.

Automobile headlight standards.—Tests on automobile headlamp devices to determine compliance with State requirements have been made for a few States and standard lamps and technical information supplied to State officials making such tests. The bureau has cooperated in an investigation on headlighting under the auspices of the Society of Automotive Engineers and the National Automobile Chamber of Commerce.

Radio standardization.—The bureau has cooperated with the Institute of Radio Engineers and the American Engineering Standards Committee in standardizing methods of testing radio receiving vacuum tubes and component parts. A member of the bureau was chairman of the technical committee of the former organization which formulated testing procedures for receiving sets. A member of the bureau was chairman of the vacuum tube committee of the American Engineering Standards Committee sectional committee on radio; the work of this committee led to the adoption of an American standard receiving tube base.

Lenses for the Tuckerman autocollimator.—The performance specifications of the autocollimator demand a lens having an aper-

ture ratio f/5, with the correction for spherical aberration very much better than is the usual commercial practice, and with a spacing which might be varied to permit the focal lengths to be adjusted to 250 mm. with a departure not greater than ±0.05 per cent. A special design comprising two doublets was computed. Components have been ground and polished for the assembly of nine lenses, and the performance of the first lens which has been assembled agrees, in a gratifying manner, with the expectations based on the computations.

STANDARD MATERIALS ($10,000)

Distribution of standard samples.—The standard samples of ores, metallurgical products, and pure chemicals prepared and distributed by the bureau are used to check methods of chemical analysis that control the manufacture and sale of metallurgical and agricultural products, to calibrate scientific instruments, and to further research in methods of analysis. A direct result of the use of the samples is a saving of thousands of dollars a year through improved manufacturing operations and the avoidance of costly disputes based on faulty analysis. The standard sample fund is unique in that the return to the United States Treasury in fees and accumulated stocks of saleable samples has always exceeded the appropriation. In 1927 and 1928, $14,600 was received from the sale of 6,725 samples, and approximately $25,000 worth of standard samples were added to the saleable samples on hand.

INVESTIGATION OF RADIOACTIVE SUBSTANCES AND X RAYS ($29,540)

X-ray standardization.—In connection with X-ray standardization efforts have been centered largely on installing adequate equipment for the problems to be attacked. Work in the laboratory has been limited to the problems of dosage-measurement; that is, intensity and quality of high voltage X rays such as are used for therapeutic purposes. Ionization chambers suitable for primary standards have been made and preliminary comparisons with the German and American standards have been completed. A new tube-rectified high-voltage set, including a motor generator, has been installed for precision measurements under constant conditions. Conferences with American and foreign specialists have guided this development, and in the near future we should be in a position to calibrate the dosage meters used in American hospitals in terms of a generally accepted standard and with a precision as high as the instruments or methods require.

Geiger ion counter.—The Geiger counter—a specially prepared and negatively charged point inside an oppositely charged cavity, and between which an electric discharge occurs each time an ion enters the cavity—is used to measure the number of alpha particles (positive ions shot off with great velocity) emitted by radioactive substances per unit time. The principle of action of the counter has puzzled investigators for several years. The bureau has discovered that a catalytic surface is necessary to sensitive the point in a Geiger ion counter. Experiments show a strict correlation between

the catalytic behavior of the material used as a point and its action in the counter.

Alpha ray tracks.—Some interesting results have been obtained by use of an automatic Wilson expansion chamber for photographing the tracks of alpha particles. Out of 80,000 photographs, one very close collision between an alpha particle involved in this collision shows that some other factor than mere closeness of approach is involved in determining whether or not an atomic disintegration occurs as a result of the collision.

Tests of radioactive preparations.—A total of 657 radioactive preparations were tested, from which measurements the sale price, amounting to a total of $600,000, was determined.

UTILIZATION OF WASTE PRODUCTS FROM THE LAND ($50,000)

Wall board from cornstalks.—A semicommercial factory to make wall board from cornstalks has been built at Ames, Iowa, in cooperation with Iowa State College. All of the necessary equipment was installed during the fiscal year 1927–28. After installation several months were required to get the separate machines to function properly and then to get them all synchronized. Laboratory work was necessary to correlate the composition of the sizing with the alkalinity of the Iowa water. Further experiments showed how to reduce the weight of the board to the necessary figure without sacrificing too much of the strength. Board is now being produced regularly at the rate of 6 linear feet per minute, 2 feet wide by $\frac{7}{16}$ inch thick (2 tons per 8-hour day). The board compares favorably in all properties with similar products now on the market. The weight is 639 pounds per 1,000 square feet, and the thermal conductivity is 0.39 B. t. u. per hour per square foot per inch thickness per Fahrenheit degree temperature difference.

Production of xylose.—Analyses of many agricultural wastes showed that they nearly all contain considerable quantities of xylose. Laboratory methods have been worked out for recovering this rare sugar from cottonseed hulls and peanut shells. Semicommercial equipment is now being designed. Possible markets for xylose are being investigated, with promising results.

Peanut shells in gypsum fiber concrete.—Experiments are in progress on the use of peanut shells as a substitute for hardwood planer shavings in gypsum fiber concrete. The cost of these shavings is quite high, while peanut shells can be obtained at a price only slightly above the transportation charges. The concrete so far made with peanut shells shows less strength than that made with wood chips, but this is believed to be the result of decay of the shells. Various preservative methods are now being studied. Other problems relating to cotton and wood waste utilization are being surveyed.

INVESTIGATION OF AUTOMOTIVE ENGINES ($25,000)

Gasoline volatility.—In the analysis of the data on engine starting, previously reported, it was shown that a relation existed between the distillation curve of the American Society for Testing Materials and the equilibrium distillation curve at 5 and 15 per cent evaporated.

Subsequent analysis of volatility data obtained on 25 diverse gasolines showed that similar relations hold at any percentage evaporated from 10 to 90 per cent, these relations being general and independent of the specific characteristics of the gasoline. Thus, over this range, the complete equilibrium volatility curves of interest in engine performance, covering air-vapor mixtures from 8–1 to 20–1, may be obtained readily from the customary distillation test without additional experimentation. It has also been shown that the dew point for any desired mixture of any gasoline and air may be computed from the A. S. T. M. 90 per cent point.

Economic volatility of motor fuels.—The effect of fuel volatility on engine acceleration is the aspect of this problem which is now being studied in cooperation with the American Petroleum Institute, the National Automobile Chamber of Commerce and the Society of Automotive Engineers. A new spark accelerometer, giving records of high precision, has been developed, and a description of this instrument, together with preliminary acceleration data on six fuels, will soon be published.

Antiknock characteristics of fuels.—Cooperation has continued with the automotive and petroleum industries in the effort to find some satisfactory common basis for rating antiknock motor fuels. Joint tests in which various laboratories undertook to rate the same set of fuels have shown how difficult it is at present to correlate the results obtained by different laboratories. The solution of this problem may be found in the general adoption of a common test engine and procedure, or it may require the extended study of typical methods and equipment by one or more laboratories.

Properties of oxidized oils.—The effect of the products of oxidation on the properties of motor lubricating oils has been studied to discover to what extent these effects can be predicted by a knowledge of the oxidation number. Especial attention is being paid to the corrosive nature of oxidation products.

Efficiency of spur-gear and worm-gear drives.—An investigation has been undertaken in cooperation with the American Electric Railway Association for the purpose of determining the relative efficiency of different types of reduction gearing under all conditions of load, speed, and lubrication factors which will be met in street-railway service.

Vibration of motor vehicles.—The contact accelerometer with electrolytic recorder has been used several times at the request of the Veterans' Bureau to compare the riding qualities of ambulances and to study the effect of shock absorbers on riding comfort.

Phenomena of combustion.—More than a thousand photographic records of explosions at constant pressure have demonstrated that it is possible from the velocity coefficients of carbon monoxide and methane to predict the flame velocity of any composite fuel made up of these ingredients for any mixture ratio of fuel and oxygen that will ignite. The explosive reaction of gaseous mixtures containing hydrogen is more complex and will receive further study. The effect of inert gases (nitrogen, helium, or carbon dioxide) on the carbon monoxide-oxygen reaction was found previously to depend on the thermal properties of the inert gas used. Recent experiments

using argon suggest that the important factor is the molecular heat rather than the thermal conductivity.

Automotive headlighting.—The investigation of headlighting from the automobile driver's point of view has been continued throughout the year. The effect on visibility of changes in the shape, aiming, and intensity of the headlight beams has been studied under a variety of road conditions, especially that of meeting another car.

INVESTIGATION OF DENTAL MATERIALS ($5,000)

Studies in the composition, physical properties, and manipulation of dental materials.—The work being done under this appropriation is the first comprehensive research in the field of dental materials to be undertaken and financed by the Federal Government. Information already obtained has established many of the important properties of gold alloys and accessory materials used in making dental restorations and has revealed numerous defective materials and technics. Standards have been established for the proper selection of gold-silver-platinum alloys extensively used in the dental profession. This information is welcomed and is being taken advantage of by leaders of the profession.

Cooperative dental research.—The cooperative research that has extended over the past six years, through the financial support of the Weinstein Research Laboratories, has been completed and final results are now in press. This cooperative investigation is recognized as the pioneer work in the field of dental research at the Bureau of Standards. Much valuable information was obtained which was made freely available to the public through the issuance of numerous reports as the work progressed. A similar investigation is now in progress in cooperation with the American Dental Association. This is expected to extend over a period of at least five years, and it is anticipated that equally valuable results will be obtained. The work has already been productive of much information of practical value to the dental profession and to the public.

BUILDING FOR POWER PLANT ($200,000)

The new building which will house the bureau's central power plant is completed. The brick smokestack, with a height of 185 feet above street level, is nearly finished, and in addition to serving the usual purposes of a chimney will be equipped with instruments for measuring wind pressure.

POWER-PLANT EQUIPMENT ($100,000)

Equipment.—The equipment for the boiler room of the bureau's new power plant is under contract, and parts of it are now being installed. It is expected that this portion of the plant will be ready for operation by the latter part of December of this year.

TRANSFERRED FUNDS ($275,000)

Organization and projects.—During the year funds were transferred from the following branches of the Government covering the projects listed:

Aeronautics Branch, Department of Commerce:
- Use of radio in aeronautics.
- Lighting of airways.

Bureau of Engraving and Printing:
- Development of more durable currency paper.
- Electrodeposition as applied to printing plates.

Bureau of Foreign and Domestic Commerce: Directory of commodity specifications.

National Advisory Committee for Aeronautics:
- Aerodynamic problems.
- Aeronautic power-plant investigations.
- Development of substitute for parachute silk.
- Fatigue of duralumin.
- Embrittlement of duralumin.

Navy Department:
- Gas as a fuel for automotive engines.
- Altitude control of carburetors.
- Lubrication of aircraft engines under starting conditions.
- Study of combustion by means of fuel bomb.
- Performance of storage batteries.
- Aircraft instrument development and testing.
- Investigation of parachute cloth.
- Investigation of airship fabrics.
- Corrosion of metals.
- Development of new types of airship girders.
- Study of bomb ballistics.
- Manufacture of optical glass.

Shipping Board: Miscellaneous physical, chemical, and engineering investigations.

War Department:
- General radio investigations.
- Embrittlement of duralumin.
- Lubricants for automotive engines.
- Construction of experimental gauges.
- Development of optical projection apparatus for testing gauges.
- Construction of improved extensometer.
- Development of machine guns.

Many of these projects were supported partly by bureau and partly by transferred funds. The more important of these have already been described under the appropriate bureau fund. Important investigations supported wholly by transferred funds include the following:

Aircraft beacons.—Serving as the research unit of the aeronautics branch of the Department of Commerce, the bureau conducted research on several problems involving the use of radio in aeronautics. The principal work done was a continuation of the development of the directive radiobeacon. A practical type of beacon to supply signals of the visual type was worked out, and demonstrations of its operation were given at College Park, Md. This marks out a course between airports along which airplanes can fly in fog or darkness without regard to visible landmarks. Indication that the airplane is on the course, or the extent of deviation from the course, is given by a simple indicator, visually observed, on the airplane instrument board. Incidental to this development, receiving sets of special design were developed for airplane use, and improvements were made in methods of shielding against airplane engine ignition interference. Variations in the indicated radiobeacon course at night were discovered, and means of overcoming them through use of a short pole antenna were developed. This has several advantages over the trailing wire hitherto used. A member of the bureau's staff went to

Europe to study the uses of radio in aeronautics and the progress of research in this field, and information was secured of value in the establishment of a program for future research.

Photometric measurements on various types of reflectors and lenses designed for airway and landing field lighting were made in cooperation with the Bureau of Lighthouses, airways division. An experimental beacon in which different light sources can be compared under various weather conditions was designed, and plans were made to erect it on the coast of Maine.

Type testing of commercial airplane engines.—This line of work was initiated during the past year. Engines thus far submitted for test by the aeronautics branch of the Department of Commerce have been air-cooled radial engines, and they have been tested on a torque stand, using suitably designed propellers to absorb the power and at the same time produce sufficient air blast to cool the cylinders. Equipment is also being installed in the laboratory to permit dynamometer tests of air-cooled engines. Each power plant is considered on its own merits, and there are no requirements beyond sound design, adequate materials, good workmanship, and reliable performance of the engine and its accessories.

Gas cell fabrics.—The bureau, in cooperation with the Navy Department, supervised the construction of an experimental gas cell for the naval airship *Los Angeles*. The gas-impermeable fabric used was developed by this bureau, and the seam construction was the result of the bureau's suggestions and recommendations. This cell has already been placed in the *Los Angeles*, and after a period of two months naval officers who have observed its behavior are of the opinion that it is almost as good as the best of the goldbeater's skin cells now in use. Furthermore, it is their belief that improvement in the technic and workmanship employed in the construction of the seams will yield a cell equal, if not superior, to those made with goldbeater's skin. Outdoor exposure test, under cover cloth as in an airship, on experimental panels of this type of fabric have shown that, after three and a half years, the fabric has undergone practically no change in permeability and but little deterioration in strength, thus indicating a probable life greater than that of the goldbeater's skin fabric. The new type of cell is made from materials which are available in unlimited quantities and may be built at a considerably lower cost than the old type.

Helium purity meters.—Three helium purity meters were constructed for the Air Corps, War Department.

Investigations of wind tunnel turbulence.—In cooperation with the National Advisory Committee for Aeronautics, experiments have been continued on the fundamental problem of measuring the characteristics of turbulent flow. It is now possible with somewhat elaborate apparatus to measure the mean amplitude of the time variations in air speed occurring at any point in the wind tunnel or behind objects of various shapes.

Airship girders.—This investigation has been continued along the lines outlined last year. Several girders made from duralumin sheets having a rectangular cross section have been tested in which circular openings are cut in the sheet to reduce the weight.

Strength of tubes.—The experimental work has been continued. Considerable study has been given to a method of presenting the

results so that they may be most efficiently used by aircraft designers. Apparently, a wholly satisfactory method has not been found up to the present time.

Strength of flat plates.—In cooperation with the Bureau of Aeronautics, Navy Department, the strength of flat plates under edgewise compression was determined experimentally. The specimens were duralumin, stainless steel, nickel, and Monel metal. Different widths up to 24 inches were tested. The load at which buckling of the plates began was determined as well as the ultimate load. Graphs showing the deformation of the specimens have been drawn; also graphs from which a designer can obtain the ultimate load for any plate within the range covered by this investigation.

Prevention of embrittlement of duralumin by corrosion.—Previous findings as to the value of a rapid quenching rate (cold water-quenching) and of a coating of pure aluminum as means of preventing the corrosion which causes embrittlement were substantiated by extensive exposure tests. Exposure tests have been in progress on many other types of protective coatings. A study of the increase in rate of corrosion as the result of static tensile or repeated bending stresses was begun. This work was supported by the Navy and War Departments and by the National Advisory Committee for Aeronautics. Four progress reports have been issued in the technical notes of the last named.

Miscellaneous aeronautic research.—This work has included the investigation of (1) the influence of chord and span of ailerons on rolling and pitching moments, (2) soundproofing qualities of various combinations of light materials in relation to airplane cabin construction, (3) strength of various types of welded joints of tubular members used in fuselage construction, (4) endurance tests of air-cooled aircraft engines used in commercial aviation.

Iron deposition.—Promising experiments have been made at this bureau and at the Bureau of Engraving and Printing upon the production of electrolytic printing plates by depositing iron instead of the copper and nickel now used. If this process proves practicable, it will represent a further saving in the cost of such plates.

GENERAL RECOMMENDATIONS

Fundamental research.—As stated in last year's report, a substantial increase in the salaries fund is urgently needed for extension of the work relating to standards of measurement and the determination of fundamental constants of importance to science and industry. The Congress has made provision for starting work on an international program relative to standards of length, heat, optics, and electricity. This program will require further support, and additional funds should be provided to enable the bureau more adequately to meet the serious deficiencies in our knowledge of important constants used in physics, chemistry, technology ,and engineering.

Development of commercial standards.—The simplified practice program has been an unqualified success, and a beginning has been made in applying similar methods of cooperation with industry in the field of standardization. We may look for corresponding benefits to industry if the work of the commercial standards group of the bureau receives adequate support, and I therefore recommend

additional appropriations for this work, which is fundamental to economic progress in industry.

Consolidation of funds.—The study of this subject has been continued, and it is expected that recommendations, satisfactory to the Bureau of the Budget and to the Congress, may be made, greatly simplifying the work of the accounting, auditing, and disbursing officials. It is believed the funds of the bureau may be condensed advantageously into four.

Hydraulic laboratory.—This project, of a national hydraulic laboratory at the Bureau of Standards to serve all the field services of the Government interested in water-flow problems, has been approved by the President, through the Bureau of the Budget, and a bill authorizing the expenditure of $350,000 for a building and permanent equipment, and setting up a program board of the three Secretaries of Commerce, War, and Interior, has passed the Senate, and hearings have been held before the House Committee on Rivers and Harbors. The only opposition comes from the Chief of Engineers of the Army. It is of the greatest economic importance to the country that this project be realized at an early date.

Power-plant equipment.—The estimated cost of equipping the new power plant is $300,000, of which $200,000 has been appropriated. In order that the plant may be put in full operation at the earliest possible date, the remaining $100,000 should be made available not later than June 30, 1929.

New permanent location for aircraft research.—The bureau is by law the research unit of the aeronautics branch of the department. The testing of aircraft engines and the execution of outdoor wind tunnel experiments are necessarily accompanied by noises which disturb our neighbors. This condition has been partly met by transferring certain of this work to the rented field at College Park, Md. There the bureau also carries out much of its field work on problems relating to aviation, such as radio and lighting.

It would seem wise for the department to make permanent provision for a headquarters experimental flying field in the immediate vicinity of Washington, where work requiring the use of planes, engine testing, and other activities relating to field work in aeronautics could be carried on under more advantageous conditions.

New buildings needed.—The present small building (39½ by 39½ feet) used for high voltage testing is inadequate in size and dangerous when operating at many high voltages; 150,000 volts is the present limit, but 300,000 volts is required in some experiments. Provision should be made for replacing this structure by one adequate in size and design to meet the demands in this increasingly important field of testing and research. The nature of this work is such that a separate building is imperative. The cost would be about $100,000.

The fire-resistance work of the bureau is growing in importance and volume and requires in addition to temporary structures a building of suitable size and design to meet the needs of this important activity. I recommend that consideration be given to the authorization of a fire-resistance building to cost about $125,000.

The North Building of the bureau does not conform in architecture with the rest of the group. The roof should be made over, giving another story, and the removal from this building of the main

units of the power plant will necessitate alterations which would make available much needed laboratory and shop space. These highly desirable alterations would cost about $60,000.

Exhibits.—In view of the numerous requests which the bureau receives for exhibits of its work at meetings of scientific and technical societies, expositions, etc., it would seem advisable to provide a small sum for such purposes. Judging by the interest displayed, this is an important way of acquainting the general public with the scientific work of the Government.

Need for increased facilities at branch laboratories.—In order to care for certain of the requests from governmental agencies for the testing of structural and miscellaneous materials, the bureau maintains three branch laboratories, located at Northampton, Pa.; Denver, Colo., and San Francisco, Calif. At the present time these branch laboratories are caring for a volume of work which prohibits meeting further demands unless the personnel and equipment can be increased. With the demand of purchasing agents that materials meet the requirements of the specifications of the Federal Specifications Board, this commodity testing work will continue to increase, and it is in the interest of economy to make adequate provision for it.

Medical aid.—I again recommend that there be established at the bureau a first-aid station in care of a competent physician preferably detailed from the Public Health Service. Such a station is an imperative need because of the many accident hazards which are inseperable from some of the bureau's work. Also, there are several lines of work, including radium, X-ray and furnace operations, requiring medical oversight of the physical condition of the operating personnel.

Very truly yours,

George K. Burgess,
Director, Bureau of Standards.

APPENDIX

GENERAL FINANCIAL STATEMENT

During the fiscal year 1928 the bureau expended and accounted for funds aggregating $2,739,792.85, including $282,357.85 received by transfer and reimbursement from other departments for special researches.

The amounts and objects of each appropriation for the past fiscal year and two previous fiscal years, together with disbursements, unpaid orders outstanding, and unexpended balances for each appropriation, are shown in the following tables:

Disbursements, liabilities, etc., 1928, 1927, and 1926 appropriations

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
1928				
Salaries	$572,060.00	$528,409.90	$43,287.65	$362.45
Equipment	88,000.00	72,753.59	15,069.21	177.20
General expenses	[1] 71,198.69	57,214.03	13,893.72	90.94
Improvement and care of grounds	13,000.00	10,710.83	2,211.47	77.70
Testing structural materials	[2] 241,751.78	212,025.68	28,378.62	1,347.48
Testing machines	[3] 38,025.00	29,557.37	8,328.22	139.41
Metallurgical research	[4] 48,414.92	43,677.04	4,548.53	189.35
Investigation of optical glass	20,520.00	18,128.40	2,373.81	17.79
Standard materials	10,000.00	8,897.60	1,024.25	78.15
Investigation of textiles	40,700.00	36,771.47	3,737.89	190.64
Sugar standardization	[5] 50,960.00	45,782.34	4,974.13	203.53
Gauge standardization	38,320.00	34,876.16	3,347.60	96.24
High-temperature investigation	9,740.00	8,290.54	1,439.47	9.99
Testing railroad scales	47,000.00	42,998.09	3,688.30	313.61
Investigation of fire-resisting properties	28,100.00	25,789.53	2,051.38	259.09
Testing miscellaneous materials	44,000.00	38,974.38	5,011.49	14.13
Investigation of public utility standards	[6] 100,282.46	89,790.68	10,272.27	219.51
Radio research	49,800.00	45,311.83	4,338.64	149.53
Industrial research	[7] 175,860.00	153,902.55	21,526.04	431.41
Sound investigation	10,580.00	10,238.31	279.22	62.47
Investigation of clay products	47,000.00	41,494.40	5,384.42	121.18
Color standardization	10,000.00	8,609.10	1,245.02	145.88
Investigation of radioactive substances and X rays	29,540.00	26,193.96	3,228.74	117.30
Standardizing mechanical appliances	27,800.00	24,052.99	3,582.96	164.05
Investigation of mine scales and cars	12,800.00	10,651.94	2,089.90	58.16
Standardization of equipment	[8] 130,135.50	114,403.99	14,833.33	898.18
Investigation of automotive engines	[9] 27,700.00	24,740.85	2,639.14	320.01
Utilization of waste products from the land	50,000.00	44,122.42	5,671.06	206.52
Investigation of dental materials	5,000.00	3,528.51	1,454.75	16.74
Power-plant equipment	100,000.00	5,662.04	94,333.94	4.02
Building for power plant	200,000.00	143,501.03	41,988.31	14,510.66
Sugar standardization (1928–29)	25,000.00	5,693.44	1,638.20	17,668.36
Standardization of equipment (1928–29)	15,000.00			15,000.00
Radio research (1928–29)	30,000.00	6.71	1,037.72	28,955.57
Salaries (1928–29)	35,000.00	266.66		34,733.34
Color standardization (1928–29)	5,000.00			5,000.00
Furnaces and shelter (1928–29)	22,000.00	443.33		21,556.67
Appropriations transferred from other departments which are available for the current year:				
Aircraft in commerce	110,500.00	92,680.74	17,366.78	452.48
Incidental expenses of Army	10,000.00	9,361.62	549.18	89.20
Compensation of employees, Bureau of Engraving and Printing	11,000.00	9,992.28	921.66	86.06
Export industries, foreign and domestic commerce	2,820.00	2,765.82		54.18
Advisory committee for aeronautics	34,900.00	29,303.48	5,368.60	227.92
Aviation, Navy	77,500.00	64,354.97	12,501.02	644.01
Air Corps, Army	2,500.00	2,214.00	205.00	81.00
Signal Service of Army	1,800.00	1,261.60	418.76	119.64
Air navigation facilities	234.50	234.50		

Footnotes at end of table.

Disbursements, liabilities, etc., 1928, 1927, and 1926 appropriations—Continued

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
1928—Continued				
Appropriations transferred from other departments which are available for a period of 2 years:				
Ordnance and ordnance stores	$12,000.00	$9,604.32	$1,123.82	$1,271.86
Ordnance stores, ammunition (1928–29)	1,000.00		100.00	900.00
Air Corps, Army	500.00	425.71		74.29
Automatic rifles (1928–29)	2,000.00	1,316.63	355.00	328.37
Gauges, dies, and jigs, for manufacture	2,750.00	1,616.64	233.32	900.04
Total	2,739,792.85	2,192,604.00	398,052.54	149,136.31
1927				
Salaries	567,320.00	556,424.91		10,895.09
Equipment	88,000.00	85,825.58	394.19	1,780.23
General expenses	[10] 71,968.31	69,909.74	1,714.57	344.00
Improvement and care of grounds	12,000.00	11,811.31		188.69
Testing structural materials	[11] 233,186.12	228,209.02		4,977.10
Testing machines	38,000.00	37,380.72		619.28
Metallurgical research	43,140.00	42,700.49		439.51
Investigation of optical glass	20,520.00	19,787.24		732.76
Standard materials	10,000.00	9,880.96		119.04
Investigation of textiles	[12] 36,000.00	35,260.52		739.48
Sugar standardization	[13] 40,960.00	40,559.13		400.87
Gauge standardization	38,320.00	37,630.93		689.07
High-temperature investigation	9,740.00	9,437.82		302.18
Testing railroad scales	39,000.00	38,141.03	170.17	688.80
Investigation of fire-resisting properties	28,100.00	26,926.37	20.28	1,153.35
Testing miscellaneous materials	44,090.00	41,934.84	314.40	1,840.76
Investigation of public utility standards	100,000.00	99,148.19	155.96	695.85
Radio research	49,800.00	48,173.91		1,626.09
Industrial research	[14] 179,820.00	176,475.71		3,344.29
Sound investigation	10,580.00	10,070.01		509.99
Investigation of clay products	47,000.00	44,603.18		2,396.82
Color standardization	9,000.00	8,405.62	34.50	559.88
Investigation of radioactive substances	9,540.00	9,281.53		258.47
Standardizing mechanical appliances	[15] 28,215.00	26,763.29		1,451.71
Investigation of mine scales and cars	12,800.00	12,440.42		359.58
Standardization of equipment	[16] 116,000.86	109,734.74		6,266.12
Investigation of automotive engines	25,000.00	24,102.52	318.32	579.16
Sugar standardization (1926–27)	25,000.00	24,346.62		653.38
Master track scale and test-car depot	50,000.00	48,551.59	986.85	461.56
Building for power plant	200,000.00	143,501.03	41,988.31	14,510.66
Appropriations transferred from other departments which are available for the current year:				
Compensation of employees, Bureau of Engraving and Printing	14,000.00	13,949.76		50.24
Export industries, Department of Commerce	4,500.00	4,355.60		144.40
Advisory committee for aeronautics	34,000.00	33,835.43		164.57
Engineering, Bureau of Engineering	2,500.00	2,416.01		83.99
Automatic rifles (1927–28)	2,000.00	1,791.45		208.55
Signal Service of the Army	1,800.00	1,790.40		9.60
Aircraft in commerce	93,809.25	91,810.14	1,797.21	201.90
Oil, gas, and oil shale investigation, Bureau of Mines	[17] 5,410.00	5,375.00		35.00
Aviation, Navy	81,900.00	81,494.15	9.00	396.85
Air Service of the Army	7,425.00	7,274.16		150.84
General expenses, Coast and Geodetic Survey	400.00	352.20		47.80
Incidental expenses of the Army	11,750.00	11,489.05		260.95
Ordnance stores ammunition (1927–28)	1,000.00	983.50		16.50
Construction and repair, Bureau of Construction and Repair	1,750.00	1,743.59		6.41
Conference on oil pollution of navigable waters (1925–1927)	[18] 2,482.19	2,385.00		97.19
Field Artillery armament	5,000.00	4,533.19		466.81
Air navigation facilities	1,613.00	1,613.00		
Appropriations transferred from other departments which are available for a period of 2 years:				
Ordnance and ordnance stores	13,400.00	12,843.59	350.10	206.31
Gauges, dies, and jigs, for manufacture	5,750.00	5,719.90		30.10
Air Service of the Army	1,000.00	100.00		900.00
Total	2,474,589.73	2,363,274.09	48,253.86	63,061.78
1926				
Salaries	[19] 516,760.00	516,487.24		272.76
Equipment	70,000.00	69,251.12	48.77	700.11
General expenses	[20] 45,568.74	42,149.12	362.89	3,056.73

Footnotes at end of table.

Disbursements, liabilities, etc., 1928, 1927, and 1926 appropriations—Continued

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
1926—Continued				
Improvement and care of grounds	$11,000.00	$10,929.55		$70.45
Testing structural materials	[21] 232,175.27	230,783.79	$319.35	1,072.13
Testing machines	38,000.00	37,752.76	111.50	135.74
Metallurgical research	[22] 43,220.00	42,619.11		600.89
Investigation of optical glass	[23] 20,561.88	20,320.61		241.27
Standard materials	10,000.00	9,999.85		.15
Investigation of textiles	[24] 27,560.00	27,005.11		554.89
Sugar standardization	[25] 40,960.00	40,741.73		218.27
Gauge standardization	38,320.00	37,716.57		603.43
High-temperature investigation	9,740.00	9,685.91		54.09
Testing railroad scales	39,000.00	38,737.57	237.78	24.65
Investigation of fire-resisting properties	28,100.00	27,907.86		192.14
Testing miscellaneous materials	[26] 49,090.00	48,933.71		156.29
Investigation of public utility standards	100,000.00	99,571.46		428.54
Radio research	44,800.00	44,762.52		37.48
Industrial research	[27] 174,886.62	173,674.08		1,212.54
Sound investigation	[28] 5,655.00	5,606.52		48.48
Investigation of clay products	27,000.00	26,302.92		697.08
Color standardization	9,000.00	8,781.74		218.26
Investigation of radioactive substances	10,680.00	10,389.09		290.91
Standardizing mechanical appliances	27,800.00	27,713.10		86.90
Investigation of mine scales and cars	14,540.00	14,354.25	185.75	
Standardization of equipment	[29] 111,634.00	110,916.89		717.11
Investigation of automotive engines	[30] 30,280.00	29,945.40	69.61	264.99
Appropriations transferred from other departments which are available for the current year:				
Compensation of employees, Bureau of Engraving and Printing	6,000.00	5,970.58		29.42
Signal Service of the Army	1,800.00	1,775.82		24.18
Automatic rifles (1926–27)	2,000.00	1,970.16		29.84
Construction and repair, Bureau of Construction and Repair	5,585.25	5,487.75	95.06	2.44
General expenses, Bureau of Entomology	3,000.00	2,895.23		104.77
Advisory Committee for Aeronautics	32,600.00	32,289.36		310.64
Ordnance stores, ammunition (1925–26)	3,300.00	3,195.43		104.57
Aviation, Navy	53,610.79	53,610.79		
Export industries, Department of Commerce	4,500.00	4,336.08		163.92
Air Service of the Army	9,100.00	8,933.09		166.91
Incidental expenses of the Army	11,750.00	11,375.35		374.65
General expenses, Lighthouse Service	10,000.00	9,970.67		29.33
Engineering, Bureau of Engineering	2,424.55	2,424.55		
Appropriations transferred from other departments which are available for a period of 2 years:				
Ordnance and ordnance stores	12,000.00	12,000.00		
General expenses, Coast and Geodetic Survey	1,000.00	998.66		1.34
Gauges, dies, and jigs for manufacture	2,750.00	2,552.20		197.80
Air Service of the Army	1,000.00	960.00		40.00
Signal Service of the Army	7,500.00	7,391.34		108.66
Total	1,946,252.10	1,931,176.64	1,430.71	13,644.75

Includes reimbursements and transfers received from other departments as follows:

[1] $1,343.69.
[2] $1,751.78.
[3] $25.
[4] $274.92.
[5] $2,800.
[6] $282.46.
[7] $3,540.
[8] $135.50.
[9] $2,700.
[10] $3,613.31.
[11] $3,186.12.
[12] $1,000.
[13] $2,800.
[14] $5,700.
[15] $415.
[16] $1,000.86.
[17] $1,395.
[18] This fund was reappropriated from the unincumbered balance of the 1926 appropriation.
[19] Includes supplemental appropriation of $5,000.
[20] $2,068.74.
[21] $2,175.27.
[22] $80.
[23] $41.88.
[24] $1,000.
[25] $2,800.
[26] $5,000.
[27] $766.62.
[28] $75.
[29] $1,634.
[30] $5,280.