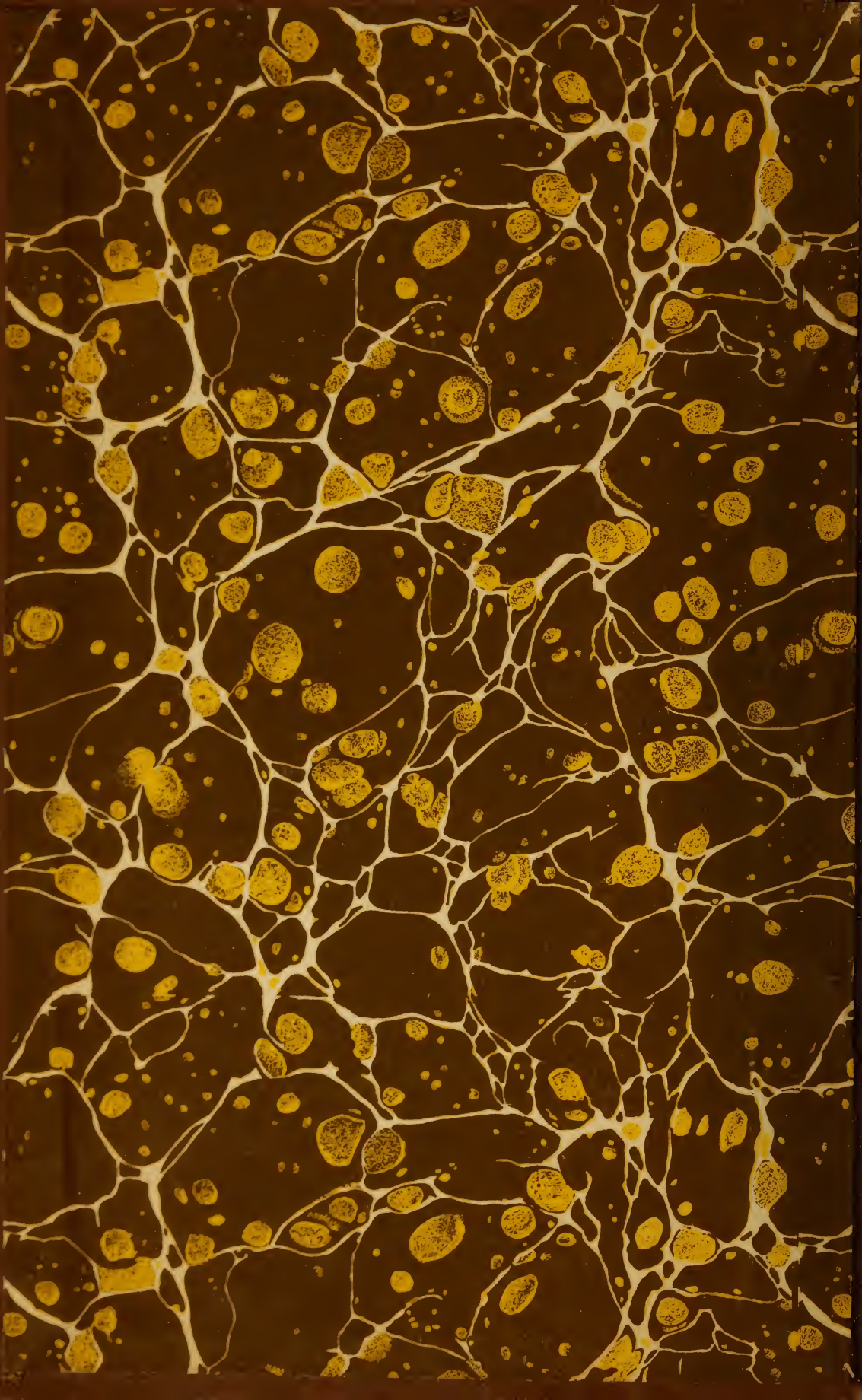
# MISCELLANEOUS PUBLICATIONS
OF THE
# BUREAU OF STANDARDS

NOS. 91-102



UNITED STATES DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS

# ANNUAL REPORT OF DIRECTOR OF THE BUREAU OF STANDARDS

## TO THE SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1929

MISCELLANEOUS PUBLICATION No. 102

U. S. DEPARTMENT OF COMMERCE
R. P. LAMONT, Secretary
BUREAU OF STANDARDS
GEORGE K. BURGESS, Director

Miscellaneous Publication No. 102

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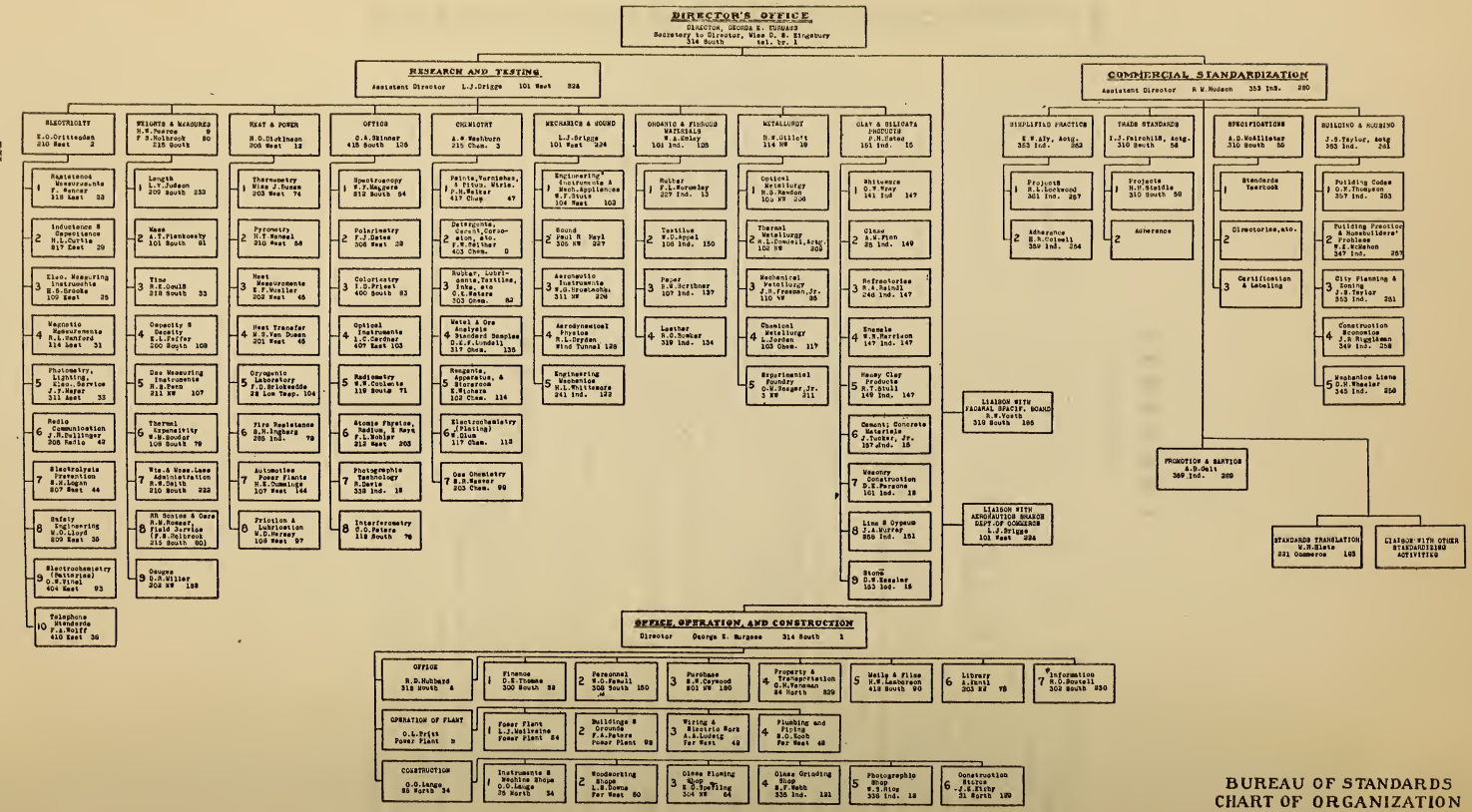


BUREAU OF STANDARDS
CHART OF ORGANIZATION

REVISED TO- May 25, 1929

# BUREAU OF STANDARDS

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
*Washington, July 1, 1929.*

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, 1929. The various outstanding accomplishments are grouped according to the subjects for which the Congress had made specific appropriations.

## GENERAL ACTIVITIES

*Organization.*—In May the divisions of simplified practice and building and housing were moved from rented quarters of the Department of Commerce to the Industrial Building of the Bureau of Standards, thus bringing together all the commercial standardization group. The closer cooperation now possible between all the divisions of the bureau and particularly between those engaged in research and testing and in commercial standardization should prove of great benefit to all concerned. As shown in the accompanying chart, the commercial standardization group has been organized in four principal divisions: Simplified practice, trade standards, specifications, and building and housing.

*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 98 of these associates stationed at the bureau, representing 48 industries and associations.

*Personnel matters.*—As of July 1, 1929, the following will be promoted to division chiefs: E. W. Ely of simplified practice, A. S. McAllister of specifications, I. J. Fairchild of trade standards, and H. S. Rawdon of metallurgy. Mr. Rawdon succeeds Dr. H. W. Gillett, who accepted the directorship of the Battelle Memorial Foundation, Columbus, Ohio. The regular staff at the close of the fiscal year numbered 965 employees. In addition, there were 98 employees assigned to the bureau under the research-associate plan and 9 miscellaneous assignments, including guests and details from other branches of the Government, making a grand total of 1,072 persons.

The turnover was 21.5 per cent. There were 369 promotions and the average salary ($2,413) increased by $170. The status of the personnel shows an increase of 83 employees as compared with last year.

The contributions of members of the bureau's staff to scientific and technical progress have received public recognition in several cases. The James Turner Morehead medal of the International Acetylene Association was awarded to H. L. Whittemore for his contributions to the art of welding; the Willard Gibbs medal of the American Chemical Society to C. S. Hudson, for his work on carbohydrates; the medal of the Annual Assay Commission to W. F. Meggers for his assistance in regulating the weight of coinage; and the John A. Penton prize of the American Foundrymen's Association to H. T. Wensel and W. F. Roeser for their method of measuring the temperature of molten cast iron. I. G. Priest is serving as president of the Optical Society of America.

*Visiting committee.*—This committee has retained its active interest in the bureau's problems, holding two formal meetings at the bureau this past year, and making important recommendations to the Secretary of Commerce on the bureau's needs and policies, particularly in reference to the more adequate financial support of research, approval of a building program, and indorsement of the bureau's patent policies. Members of the committee have 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 International Advisory Committee on Electricity met in Paris, November 20–23, 1928, and adopted resolutions proposing the establishment of an international system of electrical units based on the fundamenal centimeter-gram-second system. The report of this committee was submitted to the International Committee of Weights and Measures in February, 1929, and it is understood the conclusions were ratified by the international committee at its meeting in June.

The establishment of the proposed new basis for the units will require a large amount of experimental work in the various national laboratories and a large number of comparisons between them. Standard resistance coils and standard cells have been exchanged between the bureau and the national laboratories of Japan and Union of Socialistic Soviet Republics and a standard condenser has been measured both at the bureau and at the National Physical Laboratory of Great Britain. Other exchanges are in progress, including lamps and thermocouple wire.

At a special meeting, called by the International Electrotechnical Commission, in Paris on November 16, 1928, preliminary agreement was reached on a maximum value for conductivity of aluminum wire. Arrangements were also made to collect information which might serve as the basis for establishing a standard average value for this property.

In connection with the seventh plenary session of the International Commission on Illumination at Saranac Inn, New York, September, 1928, a conference was held with representatives of the national laboratories of France, Germany, and Great Britain looking toward the removal of discrepancies between the practical candlepower standards of those countries. Provisional agreement was reached on a basic method for calibrating high-efficiency lamps. Through an interchange of lamps and colored filters progress is being made on the experimental work necessary to carry out this agreement.

Two members of the bureau's staff attended the meeting of the International Union of Scientific Radio Telegraphy at Brussels in September, 1928. The bureau will be represented at the first meeting of the International Technical Consulting Committee on Radio Communication to be held at The Hague in September, 1929. Six special committees have been appointed by the Interdepartment Radio Advisory Committee acting under the auspices of the State Department. Members of the bureau's staff have been designated as chairmen of three of these committees.

At an international convention in Stockholm in 1928, at which the bureau was represented, agreement was reached on the value of the unit of X-ray dosage and its method of measurement. International action is also being taken on standard methods of protecting X-ray workers, a member of the bureau's staff serving as chairman of our national committee on this subject.

Because of urgent requests from many sources, the bureau has taken the preliminary steps to determine the advisability of attempting to reconvene the International Sugar Commission, which has lapsed since 1914. Scientific, technical, and standardization matters of the highest importance to the sugar and carbohydrate industries of the United States and other countries require consideration and could be handled in a satisfactory manner by this commission.

Two representatives of the bureau will attend an informal conference on the physical properties of steam to be held early in July in London under the auspices of the British Electrical and Allied Industries Research Association. The work in progress at the bureau in cooperation with the American Society of Mechanical Engineers will be discussed.

The international standards for grading wool set up by agreement between England and the United States have been adopted by several other countries. At the biennial meeting last spring of the International Commission on Standard Grades for American Cotton the bureau was represented on invitation from the Department of Agriculture, which acts as the official custodian of the cotton standards. These have been adopted by Belgium, England, France, Germany, Holland, Italy, and Spain.

It seems probable that international agreement will soon be reached on the standard temperature of 20° C. (68° F.) for shop gage blocks (end standards of length) as proposed by the bureau at the International Conference on Weights and Measures in 1927.

A paper on precision measurement of length has been prepared for presentation at the World Engineering Congress, Tokyo, Japan, in November, 1929. The paper treats precision length measurements from the standpoint of engineering and industry, with special applications to interchangeable manufacture and automatic gaging.

*Weights and measures conference.*—The National Conference on Weights and Measures, the principal agency through which the bureau cooperates with the State and local governments on matters of weights and measures administration, held its twenty-second annual meeting at the bureau June 4 to 7. The conference adopted in final form a code of specifications and tolerances for grease-measuring devices, and some amendments were also made to codes formerly adopted relative to liquid-measuring devices, liquid capacity measures, and milk bottles. It was decided to consider at next year's

meeting codes for automatic indicating scales and person-weighing scales.

*Conference of State utility commission engineers.*—The seventh annual conference of State utility commission engineers was held at the bureau on May 31 and June 1, and was attended by delegates from 25 States, the District of Columbia, and two Provinces of Canada. The subjects discussed included uniform types of rates and rate schedules, charges for fire protection, street-lighting rates, the rise and fall of prepayment gas meters, rural-line construction and cost, rural electrification, electric power generation, overhead wiring and radio antennas, electric-service rules, long-distance transmission of manufactured gas, branch line and switching transportation, and State regulation of common-carrier motor busses.

*American Standards Association.*—This body has been reorganized, and the Director of the Bureau of Standards chosen as a member of the new board of directors. The bureau is sponsor for 13 standardization projects and is represented on 71 committees having for their object the formulation of American standards.

*National Screw Thread Commission.*—The activities of the commission were confined largely to revision and publication of its 1928 (third) report, Miscellaneous Publication No. 89. This is considerably enlarged over former editions and contains much new and revised material. The basis thread data for the coarse and fine thread series and for the classification of screw thread fits remain unchanged, while the sections on special threads, threading tools, gages, and methods of gaging have been extensively revised.

*American Gage Design Committee.*—The work of the American Gage Design Committee was completed, and a report covering the design of blanks for plain and threaded plug and ring limit gages is now in the hands of the printer. This report represents the combined efforts of manufacturers and users of limit gages. The recommendations of the committee have been approved as a commercial standard and are already widely accepted by industry, even before the report is printed. The general acceptance of the recommendations of the committee will result in substantial economies in the production of limit gages.

*Federal Specifications Board.*—The board has just promulgated its six hundred and twenty-third purchase specification. These specifications are being used more and more by State and municipal governments, institutional bodies, and by industry. A large part of the research and experimental work necessary in connection with the formulation of 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 $339,923 for the support of 32 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.*—The Bureau of Standards Journal of Research has completed its first year and has been well received. The subscription list now numbers 5,620. The number of research papers published in the Journal was 76. Including the Journal, reprints, and all other papers in the regular series of the bureau, the total number of publi-

cations released during the year was 168. The monthly Technical News Bulletin has been mailed as heretofore. About 170 papers have been published in outside technical journals. There have also been released to the press 178 short accounts of interesting achievements, together with numerous photographs illustrating the bureau's work. The third annual number of the Standards Yearbook was published. Beginning on July 15, 1929, the Commercial Standards Monthly (previously issued in multigraphed form) will be enlarged and issued as a printed magazine available on a subscription basis, thus making available information on the progress of current standardization activities.

*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. The total number of tests was 173,512, representing a fee value of $544,402.

*Numbers of test items, determinations, and fee value for tests completed during the fiscal year ended June 30, 1929*

| 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 | 934 | 694 | 425 | 2,053 | 3,109 | $17,756.10 |
| Electric batteries | | 3,668 | | 3,668 | 7,686 | 21,725.00 |
| Electric lamps and lighting equipment | 318 | 3,329 | 448 | 4,095 | 4,226 | [1] 21,668.48 |
| Length-measuring devices | 237 | 197 | 2 | 436 | 3,125 | 2,312.50 |
| Gages and gage steels | 1,735 | 68 | 492 | 2,295 | 11,096 | 2,255.00 |
| Miscellaneous dimensional determinations | 2,050 | 820 | 108 | 2,978 | 14,711 | 6,433.65 |
| Weights and balances | 5,762 | 1,419 | 1,136 | 8,317 | 18,443 | 7,626.50 |
| Scales | 4 | 907 | 2 | 913 | 26,274 | 44,020.00 |
| Timepieces | 296 | 39 | 33 | 368 | 4,728 | 876.00 |
| Volumetric apparatus | 11,323 | 3,779 | 493 | 15,595 | 29,861 | 11,221.70 |
| Hydrometers | 876 | 146 | 3 | 1,025 | 2,980 | 1,470.25 |
| Density determinations, etc | 3 | 51 | 406 | 460 | 645 | 1,001.00 |
| Laboratory thermometers | 2,492 | 1,111 | 563 | 4,166 | 17,422 | 9,285.10 |
| Clinical thermometers | 36,333 | 40,599 | | 76,932 | 307,736 | 9,006.95 |
| Pyrometers, calorimeters, etc | 176 | 58 | 101 | 335 | 4,805 | 3,762.50 |
| Insulating materials | 80 | 23 | 46 | 149 | 149 | 1,125.00 |
| Fire-resisting materials | 3 | 26 | 12 | 41 | 100 | 2,572.10 |
| Fuels and lubricants | 287 | 1,489 | 93 | 1,869 | 10,086 | 17,561.50 |
| Automotive equipment, etc | 9 | 144 | | 153 | 270 | 2,176.00 |
| Airplane engines | | 26 | | 26 | 144 | 32,525.00 |
| Optical instruments and materials | 1,205 | 934 | 144 | 2,283 | 3,394 | 5,142.50 |
| Carbohydrates | 31 | 1,873 | | 1,904 | 2,839 | 3,247.50 |
| Radioactive materials | 1,052 | 13 | | 1,065 | 1,065 | 5,490.00 |
| Engineering instruments and appliances | 85 | 1,008 | 134 | 1,227 | 1,310 | 13,373.00 |
| Aeronautic instruments | 27 | 578 | 38 | 643 | 3,149 | 8,821.00 |
| Aerodynamic tests of models | 20 | 1 | | 21 | 74 | 580.00 |
| Physical properties of engineering materials | 63 | 2,123 | 60 | 2,246 | 4,400 | 15,068.00 |
| Sound producing and measuring instruments | 18 | 32 | 1 | 51 | 60 | 812.50 |
| Making of special castings | | 47 | 217 | 264 | 834 | 1,676.75 |
| Fusible boiler plugs | | 251 | | 251 | 502 | 627.50 |
| Metallographic examinations | | 646 | 106 | 752 | 3,345 | 6,067.00 |
| Miscellaneous metallurgical tests | | 441 | 657 | 1,098 | 2,685 | 9,370.50 |
| Pottery and chinaware | 4 | 196 | 10 | 210 | 811 | 1,514.00 |
| Glass | | 57 | 39 | 96 | 158 | 430.00 |
| Refractories and heavy clay products | | 367 | 48 | 415 | 1,204 | 4,003.00 |
| Cement, concreting materials, lime, etc | 22 | 11,566 | 207 | 11,795 | 45,491 | [2] 110,717.00 |

[1] Includes fee value of $3,687.48 for inspecting 1,401,054 incandescent lamps at various factories for other branches of the Government.

[2] Includes fee value of $23,821 for sampling and shipping 1,044,093 barrels of cement.

*Number of test items, determinations, and fee value for tests completed during the fiscal year ended June 30, 1929*—Continued

| 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 | | | |
| Stone and sand-lime brick | ------- | 72 | 60 | 132 | 420 | $2,052.50 |
| Miscellaneous ceramic materials | 26 | 1,279 | 55 | 1,360 | 7,082 | 13,128.50 |
| Rubber | 7 | 1,477 | 58 | 1,542 | 9,417 | 18,431.00 |
| Textiles | 44 | 6,036 | 499 | 6,579 | 17,102 | 35,097.00 |
| Paper | 26 | 1,714 | 443 | 2,183 | 6,342 | 18,374.00 |
| Leather | 82 | 291 | 2 | 375 | 1,351 | 2,378.00 |
| Paint, varnish, and bituminous materials | ------- | 1,535 | 17 | 1,552 | 12,327 | 22,351.00 |
| Chemical analysis of metals | 1 | 388 | 238 | 627 | 2,408 | 4,677.50 |
| Chemical tests of miscellaneous materials | ------- | 1,427 | 110 | 1,537 | 5,154 | 8,231.75 |
| Distribution of standard samples | 6,812 | 618 | ------- | 7,430 | --------- | 16,360.50 |
| Total | 72,443 | 93,563 | 7,506 | 173,512 | [3] 600,520 | [3] 544,402.33 |

[3] Of these totals 229,249 determinations were for the public, fee value $75,153.75; 348,510 determinations were for the Government department and State institutions, fee value $427,628.38; 22,761 determinations were for the bureau, fee value $41,620.20. 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, is not included in these totals.

## SALARIES ($648,146)

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.

*Ratio of the absolute to the international ampere.*—In order to measure the absolute value of a current, the Rosa-Dorsey-Miller current balance has been redesigned and reconstructed. A special observing room has been prepared so that the observer need not enter the weighing room, new piers have been constructed in the weighing room, and an entirely new set-up has been made for measuring the ratio of the radii of the coils used in the balance. In order to measure the current in international amperes, new standard resistors have been constructed which are capable of carrying relatively large currents, and the method of measuring the potential drop over these resistors has been improved.

*Ratio of the absolute to the international henry.*—The inductance of certain coils is being determined in both absolute and international henries. One coil has been completed and measured. This is wound on a porcelain form and maintained at a constant temperature. Two sets of mechanical measurements have been completed and four sets of electrical measurements. The mean value of the result is: 1 international henry = 1.00053 absolute henry, with an error of not more than two or three in the last significant figure.

*Magnetic testing and research.*—Particular attention has been given to the standardization of magnetic-testing methods and apparatus and the preparation of suitable standard test specimens. The work has included not only testing with fields of ordinary intensity but also of very high and very low intensity.

Cooperative investigations on the relationship between magnetic properties and torsion characteristics and impact tests, respectively, were undertaken.

*Electrical resistance standards.*—A new type of electrical resistance standard of much greater constancy than those in general use has been developed. The greater constancy is obtained by annealing the resistance material, manganin, after being formed to final shape, at a temperature of about 600° C. in carbon monoxide at a greatly reduced pressure and effectually sealing the containing case.

*Standards of electromotive force.*—A new standard cell bath arranged for temperature control at any point between 18° and 35° C. has been put in operation, and measurements made to determine how well standard cells, new and old, follow the accepted international temperature formula. Significant deviations have been found. International comparisons have been made on cells received from Japan and the Union of Socialistic Soviet Republics. Cells from the bureau have been sent to Great Britain, Germany, and Union of Socialistic Soviet Republics. Thirty-four new standard cells have been constructed at the bureau, including both acid and neutral types of saturated cells. Comparisons of these with the bureau's standard group showed that the new cells agree with the present standard to about one one-hundred-thousandth of a volt. The bureau's standard for voltage is made available for public use through the medium of portable cells which are being received for certification in rapidly increasing numbers.

*Standards of candlepower.*—An international photometric comparison of four blue glass filters is in progress. These glasses have already been measured at the Physikalisch-Technische Reichsanstalt and at the National Physical Laboratory. When the measurements are completed at this bureau the glasses will be forwarded to the Laboratoire Central d'Electricité.

*The Waidner-Burgess absolute standard of light.*—This standard has been realized by the use of a hollow inclosure of fused thoria in a bath of molten platinum contained in a crucible of fused thoria. This provides a convenient standard of reference, and the measurements so far made indicate a satisfactory constancy and reproducibility. A preliminary value, based on 36 freezes is 58.9 candles per square centimeter. By observing with an optical pyrometer as well as with the photometer, data on the melting point of platinum are being obtained.

*International temperature scale.*—Six standard thermocouples, two from the National Physical Laboratory, two from the Physikalisch-Technische Reichsanstalt, and two from this bureau, were calibrated and have been sent to the National Physical Laboratory. Three calibrated standard resistance thermometers have been sent to the National Physical Laboratory for the first part of an intercomparison of resistance thermometers from the national laboratories.

*Exchange of standard viscosity samples with the Physikalisch-Technische Reichsanstalt.*—The absolute viscosities of four samples of oil, received from the Physikalisch-Technische Reichsanstalt, were determined by the bureau. The average deviation from the mean values of the two laboratories was 0.5 per cent for the two lighter oils, and 1.1 per cent for the two more viscous oils.

*Constant of gravitation.*—The observational work on this project has been completed. Data for 16 values of this constant have been obtained, 11 of which have been computed. The mean result of these 11 values is $6.668 \times 10^{-8}$ in c. g. s. units.

*Absolute determination of gravity at Washington.*—A detailed study has been made of previous absolute determinations, especially that made at Potsdam. As a result of this study a tentative design for apparatus has been drawn up and construction work started.

*Definition of the yard and the inch in terms of light waves.*—There has been much correspondence and discussion relative to the question of defining the yard and the inch in terms of light waves. An alternative definition of the meter as the equivalent of 1,553,164.13 wave lengths of the red radiation from cadmium, under standard conditions, has already been agreed to by the International Conference on Weights and Measures, and this relation is widely accepted.

If, in addition, the yard should be accepted as equal to 0.9144 meter, or the inch as 25.4 millimeters, exactly, the present lack of agreement as to the exact relation between the units of length of the two systems of measurement would be overcome. If, at the same time, there might be international agreement that industrial measures of length should have their nominal dimensions correct at a temperature of 68° F. (20° C.), the problems of international interchangeability of parts would be completely and satisfactorily solved. Such a solution is regarded by this bureau as of very great and increasing importance.

*Renewed search for a source of homogeneous radiation.*—Preliminary to his comparison, in 1893, of the wave length of the red radiation of cadmium with the length of the international meter, Professor Michelson made an exhaustive search for the most satisfactory source of light. The intervening 40 years have brought forth no serious competitor of the cadmium red line. The International Congress stressed the desirability of renewing the search. In light of modern spectroscopic knowledge, the effectiveness of which lies in the extensive classifications covering nearly all the chemical elements, the spectroscopist is enabled to select for more intensive study those lines which from their classification are theoretically favorable.

To this end, the bureau has been engaged in measuring and classifying the arc and spark spectra of krypton and xenon, members of the rare gas group which, on the whole, possess very narrow lines. At low temperatures (liquid air) the lines of xenon theoretically should give visible interference fringes with path differences of 50 to 100 cm. The proposed line $\lambda$5649A, of krypton, proves to be unsatisfactory as a standard because it lacks intensity and is subject to reversal. Certain lines of krypton and xenon appear favorable as auxiliary standards, perhaps, but none compare favorably with cadmium red.

*Interferometer equipment for ruling line scales.*—Gratifying progress has been made toward completing the equipment for ruling 40-inch (or 1 meter) scales by interference methods. In a preliminary trial, without thermostatic control, a meter scale with lines at 10 cm. intervals was ruled in 50 minutes and found, on calibration, to be correct within the errors of observation.

In final operation, the ruling machine will be under strict temperature control and the auxiliary end gages calibrated in terms of the red radiation of cadmium. Search is being made for a scale material

having proper thermal expansion, stable in dimensions, noncorrosive, capable of receiving a satisfactory polish, and of homogeneous structure permitting the ruling of perfect lines. A special chromium steel has been obtained which bids fair to fulfill these requirements.

*Intercomparison of line standards.*—Each of the four platinum-iridium meter bars of the bureau was compared with all of the others and with invar meter bar No. 39. Meter No. 39 was also calibrated to decimeters and each of the bureau's four decimeter bars was compared with two decimeter intervals of meter No. 39. Each decimeter bar was also calibrated to centimeters, the first centimeter to millimeters, and a subdivided millimeter on each bar was calibrated to tenth-millimeters. As a result of this very complete intercomparison the bureau now has a much more accurate knowledge of both the relative and absolute lengths of its various precise length standards than was previously the case, and certain apparent discrepancies have been explained and eliminated.

*Intercomparison of United States and Canadian line standards.*—An intercomparison of length standards of this country and those of Canada was carried out, comparison being made at Ottawa and at Washington. The Canadian bars have since been recompared at the International Bureau at Sevres, France, and at the National Physical Laboratory at Teddington, England. These comparisons have confirmed the results obtained at Ottawa and Washington, As a result there is now a very satisfactory tie-up between the various national standards of the United States and Canada and those of the International Bureau.

*Graduation and calibration of precision circles.*—The construction of theodolites and transits suitable for first-order work, such as that of the United States Coast and Geodetic Survey, requires the graduation and calibration of circles of very high accuracy. The apparatus necessary for this work is already available at the bureau, but previous to the last year little use had been made of it. The apparatus has been put in condition for use, and trial circles have been graduated and calibrated. The results so far obtained indicate that the required accuracy can be obtained.

*Seconds signals by use of the photo-electric cell.*—The obtaining of accurate time signals from the Riefler clock using a photo-electric cell as a transmitting medium has been accomplished, and signals constant to about 0.0001 second are now available for distribution to the bureau's laboratories.

*Design of new pendulum.*—In continuation of the research on seconds signals, the bureau proposes to construct a pendulum which will give accurate seconds signals by means of a photo-electric cell and to cause the cell at the same time to close a circuit which will give an impulse to the pendulum and maintain its motion. Results so far are encouraging.

*Specifications for electric time systems, fire alarms, etc.*—The chief of the time section has served as secretary of the technical committee on Government master specifications for manual fire-alarm systems, electric and pneumatic clock systems, and watchman's time-clock systems. Specifications on manual fire-alarm systems and electric-clock systems have been prepared and are in the hands of the Federal Specifications Board. Specifications for watchman's time-clock systems will be ready shortly.

The chief of the time section has also served as a member of the certification committee and of the examining board of the Horological Institute of America. There are now certified watch repair men in every State, in Hawaii, Canada, and England. A total of 913 junior watchmaker's certificates and 360 certified watchmaker's certificates have been granted to date.

*Glass volumetric apparatus.*—Over 15,000 pieces of glass volumetric apparatus were submitted for test. Of this number 98 per cent was found eligible for test, while of that tested 93 per cent passed the test for accuracy. This is an improvement over previous years and is especially gratifying since a large part of the apparatus submitted is now made in the United States.

*Fundamental constants and properties of pure metals and their alloys.*—Work on the properties of very pure nickel, thorium, and rhodium is well advanced. That on pure zinc and cadmium will be incorporated in a circular now being prepared on those metals. The effect of cold working on the hardness of pure copper and other metals has been studied, and a report is nearly ready for publication. An attempt is being made to find out more about the nature of the $A_1$ point in pure iron by means of the beta ray spectroscope. Plans are being laid for a comprehensive study of pure iron; what has been taken as "pure" iron in the past is now known to have had appreciable contamination from oxygen.

*Development of metallographic test methods.*—An automatic polishing machine, designed and built at the bureau, has worked out very successfully, giving, even with inexperienced operators, a better quality of polish on specimens for microscopic examination than can be gotten by hand save by the most tedious and painstaking effort. With the personal equation of polishing eliminated by this machine, the way is open for the study of methods and materials used in polishing.

*Platinum metals.*—Special attention has been given to methods for the accurate determination of the individual metals. Satisfactory procedures for the determination of iridium and ruthenium were developed, and some progress was made on the determination of osmium.

An improvement was made in the method for the purification of rhodium with respect to the elimination of minute amounts of iridium. The development of a method for the preparation of very pure iridium was resumed after several months' interruption.

Several lots of pure platinum and pure rhodium were prepared for the study of physical and mechanical properties of the metals.

*Analytical reagent chemicals.*—Forty-eight individual methods for the determination of impurities in reagent chemicals were investigated and in many cases modified or replaced by better methods. As in past years this work formed a material part of the preparation of specifications for reagent chemicals by a committee of the American Chemical Society.

*Accelerated weathering tests.*—Additional work has been done with accelerated tests to simulate weather decay of organic protective coatings. Most materials can be tested with a simple cycle of light and rain, and data on a variety of coatings are being accumulated. A simpler apparatus for determining the point of breakdown of an organic protective coating on metal has been constructed.

*Tinting strength of pigments.*—The tinting strength of white and black pigments is the brightening or darkening strength, respectively; but with chromatic pigments tinting strength is a 2-factor property. New names for three different factors involved in tinting are suggested; namely, chromatic, darkening, and brightening strength. A method for treating these properties photometrically or spectrophotometrically and of indicating their relative magnitude by numerical indices is suggested.

*Preparation of pure rubber hydrocarbons.*—Some crystalline compounds have been obtained and some pure rubber gels of high transparency have been prepared.

*Molding composition for airplane propellers.*—At the request of the Navy Department a molding composition has been developed for the construction of airplane propellers for use in wind-tunnel tests.

*Apparatus and methods for the fractionation of petroleum into its constituent hydrocarbons.*—In cooperation with the American Petroleum Institute, new types of apparatus of increased efficiency have been developed for the fractionation of petroleum for the purpose of finding the amounts and nature of the constituent hydrocarbons.

*Bulkley consistometer.*—A new consistometer has been developed which embodies both speed and wide range of applicability. It has been found particularly useful in obtaining information on both the unworked and worked (or broken down) consistency of oils when in a plastic condition at low temperatures.

*Thin film lubrication.*—It has been shown that the apparent clogging of capillaries 0.3 mm. in diameter by continuous flow of an oil, which in the literature on the subject has been attributed to formation of a rigid film, is really due to impurities in the oil. Work on finer capillaries is in progress.

*Rerefining of used lubricating oils.*—Both automobile and airplane engine oils have been successfully rerefined at the bureau. A commercially successful method not only saves the oil but solves the problem of disposing of what would otherwise be a waste product.

*Low-temperature investigations.*—To make better provision for the low-temperature investigations of the bureau, a new liquefier of larger capacity was built, a new hydrogen compressor was purchased, and cryostats for temperatures down to that of liquid air were designed and are being constructed.

*Gas thermometry.*—Apparatus is being designed and constructed for use in determining the mean coefficient of expansion between 0° and 100° C. of the thermometric gases, to provide new data for calculating the interval between the ice point and the absolute zero. The designs include a thermometer with no unheated space, and very sensitive pressure measuring apparatus, so that measurements may be made at low pressures.

*Properties of carbon dioxide.*—Some additional experiments on vapor pressure were made, and equations and tables for vapor pressure of both solid and liquid have been calculated. Apparatus for determining the pressure-volume-temperature relations has been constructed.

*Molecular weights in the vapor state.*—The range over which molecular weights can be determined in the vapor state has been extended by the development of a method combining vapor pressure and evaporation experiments. This makes possible the determination of molecular weights at temperatures at which the total pressure may be only a fraction of a millimeter of mercury.

*Orifice-meter investigations.*—Cooperative orifice-meter tests sponsored by the gas measurement committee, natural gas department of the American Gas Association, with the cooperation of the Bureau of Standards and Bureau of Mines, have included tests on the effects of orifice-meter flange design; a study of the discharge coefficient of orifices in 4-inch lines for comparison with those previously obtained for an 8-inch line; and three series of tests for studying the effects of high-line pressures.

The results of the tests with different flange forms were fairly consistent, but because of the unexpectedly large effect shown, the validity of the tests was questioned by some of the companies interested. Further tests on the subject are to be made.

*Density of creosote oils.*—An investigation of the density and thermal expansion of creosote oils was carried out at the request of the American Wood Preservers Association, the American Society for Testing Materials, and the American Railway Engineering Association in order that the volume of creosote oils at various temperatures might be accurately calculated. The work is being continued to include coal-tar creosote oil.

*Development of new apparatus for testing dilution pipettes.*—A large increase in the number of dilution pipettes submitted for test made it necessary to develop a more rapid method of test than that formerly in use. The new method has already proven highly satisfactory in both speed and accuracy.

*Physical properties of baked products.*—Last September the United States Manufacturers of Cream of Tartar (Inc.) placed a research associate at the bureau for the purpose of investigating the physical properties of baked products. Attention has thus far been given largely to a study of volume, because of the wide use of this property in evaluating flour, baking powder, and other ingredients of baked products. A detailed study has been made of the various methods used in the determination of volume, and many of the sources of uncertainty in previous measurements have been discovered and eliminated. The work is being continued and other properties, such as color and texture, will be studied.

*Temperature of drying rolls.*—The bureau was requested by the United States District Court of New York to determine the temperature of milk drying rolls, under conditions of use, as the temperature was an issue in patent litigation. A satisfactory method of making such measurements was found and applied.

*Construction of instruments and apparatus and preparation of test specimens.*—The construction division took care of the requirements for instruments and apparatus, including glass apparatus of various designs, and woodwork required in the upkeep of buildings. Test specimens and standard steel and alloy samples were also prepared. Some of the apparatus built may be mentioned: Three vibration galvanometers, stroboscope, amplifier set, six resistance frames, double spectrometer, optical head for coincidence type thread gage, two quadrant resolution instruments, autographic thermal expansion furnace, eight resistance standards, two diffuse illumination color comparators, and a large amount of special radio apparatus.

### EQUIPMENT ($88,000)

*Upkeep of mechanical plant.*—The usual maintenance work, such as the replacement of piping, fittings, valves, etc., has been carried on. A number of changes have been made in piping layouts to facilitate connection to the new power plant.

*Electrical construction and repair.*—The usual maintenance work on the electrical installations has been carried on and a great number of new electrical installations incident to laboratory expansion have been made.

*Plumbing and pipe work.*—In addition to the maintenance work on existing pipe systems, new extensions to steam, water, gas, air, and vacuum lines were made incident to the installation of new laboratory equipment. A new water main has been installed to supplement the water supply.

*Spectrograph.*—A quartz spectrograph, giving a spectrum from 2100 A to 8000 A, about 200 mm. long, was purchased for use in the spectroscopic section.

*Timepieces.*—A Shortt mean-time astronomical clock with slave clock, and a weight-driven printing chronograph with an error not exceeding one 1/100 second, were ordered for the mechanics and sound division.

*Testing machines.*—One hydraulic compression testing machine with a capacity of 300,000 pounds and an Amsler rope-testing machine were ordered for use in the testing of structural materials.

*Machine tools.*—Purchases for the bureau's instrument and machine shops included three plain precision bench lathes, one motor-driven shaper, and one universal milling machine, the last for use in the Chicago master-scale depot.

*Miscellaneous machinery.*—Purchases of other machinery included three vacuum condensate return pumps, one 100-kw. frequency changer set for use with high-frequency furnace, one air-conditioning unit for the cement section, and one 4-stage belt-driven hydrogen compressor for the low-temperature laboratory.

### GENERAL EXPENSES ($69,855)

*Heat, light, and power.*—Coal for heating and electricity for lighting and power purposes have been purchased as necessary.

*Miscellaneous supplies.*—Office and janitorial supplies, gasoline, and lubricating oil have been provided as usual.

*Library books.*—The number of volumes accessioned was 1,639 (the same as last year) and 201 were canceled, making the total number of accessioned volumes 33,871. Scientific and technical periodicals received number 1,056.

*Travel.*—Provision was made for travel on general bureau business, not connected with any specific problem. Travel of the members of the bureau's visiting committee was also provided for.

### IMPROVEMENT AND CARE OF GROUNDS ($14,431)

*Improvement of grounds.*—Good progress has been made in improvement of the grounds by grading and sodding, the planting of trees and shrubs, extension of sidewalks, construction of road curbing, etc.

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## TESTING STRUCTURAL MATERIALS ($267,058)

*Plumbing codes.*—A revised edition of the report of the subcommittee on plumbing codes of the building code committee was published. These recommendations have been utilized in laws or regulations of seven States and more than 100 cities.

*Building codes.*—The building code committee practically completed its report on fire-resistive construction, and started to revise and consolidate the seven reports issued since 1923.

*City planning and zoning.*—Surveys of zoning ordinances and city planning activities throughout the country were made and issued. A standard city planning enabling act was published, and the standard State zoning enabling act has now been used in the laws of 34 States.

*Construction economics.*—A review of construction from 1919 to 1928 was written for the committee on recent economic changes of the President's Conference on Unemployment. The article on Construction for the Commerce Yearbook, and numerous other reports on building activity, building costs, and building materials, were prepared. Retail prices for building materials in 55 cities have been issued monthly.

*Home financing.*—Present Home Financing Methods, a pamphlet for prospective home builders and groups interested in improving existing financing facilities, was printed.

*Survey of small house construction.*—Data on the design, choice of materials, structural details, and general conditions relating to the construction and sale of small houses were obtained through a field survey in 31 cities.

*Cooperation with other agencies on building and housing problems.*—Cooperation was continued with Federal and State agencies and with thousands of local governments and private organizations concerned with building and housing. City planning and zoning, building codes, and home-ownership problems were taken up jointly with bodies such as Better Homes in America with its 5,700 local committees and organizations representing architects, engineers, business, civic, and other groups.

*Arlington Memorial Bridge.*—In conjunction with the Arlington Memorial Bridge Commission, measurements of temperature, during and subsequent to the hardening of the concrete; deformations of the arch barrel due to changes in loading and temperature; rotations of the piers; and effectiveness of the expansion joints are being made in one of the reinforced concrete arch spans of this bridge. Both the elastic and inelastic deformations are being determined and the measurements are planned to furnish a check on the reliability of the results of model tests.

*Durability of concrete aggregates.*—Apparently there is no relation between strength of concrete and amount of disintegration. In several cases concrete made from aggregates which have been submitted to the sodium-sulphate and sodium-chloride treatments showed at 15 months no gain in strength or a loss of strength compared to the 3-month tests. In the boil and dry and untreated aggregates there was in every case an increase in strength.

*Diatomaceous earth.*—Fourteen samples of diatomaceous earth submitted by different producers were included in an investigation to study differences in these materials when used as admixtures in

concrete. All were found to act in much the same manner, requiring more water to give the same flow as concrete without admixtures. The strength was in some cases slightly lowered.

*Durability of bond between mortar and brick.*—Cooperating with the American Face Brick Association, an investigation of the durability of the bond between mortar and brick has been started. This work includes tests to determine the effects of absorption and rate of absorption of the brick, moisture content of brick when bonded, and initial curing conditions on the durability of the bond after a few months exposure to dry, saturated, or outdoor storage, or to 50 cycles of freezing and thawing.

*Clay brick and brick masonry.*—In cooperation with the Common Brick Manufacturers' Association, the effects on wall strengths of such factors as the physical properties of the brick, composition and properties of the mortar, and the workmanship have been determined for a wide range of the commercially important types of construction and materials. In addition, the strength and absorptive properties of brick from a number of sources have been determined to obtain data useful in the development of specifications for brick.

*Cast stone.*—Samples of cast stone from all parts of the United States show a considerable range in properties. The number of cycles of freezing and thawing that the specimens underwent before any signs of disintegration varied from 15 to over 500.

*Slate.*—Approximately 2,800 tests on about 60 samples of slate from quarries in Maine, Vermont, New York, Pennsylvania, Maryland, Georgia, Tennessee, and Arkansas gave the following values:

| | Highest | Lowest | Average |
|---|---|---|---|
| Absorption by weight (per cent) | 1.63 | 0.1 | 0.27 |
| True specific gravity | 2.90 | 2.77 | 2.78 |
| Bulk specific gravity | 2.87 | 2.74 | 2.76 |
| Modulus of rupture | 16,160 | 3,380 | 9,340 |
| Modulus of elasticity | 18,400,000 | 7,400,000 | 13,400,000 |
| Maximum deflection for 3/16 inch thickness, 15.5-inch span (inch) | 0.240 | 0.081 | 0.145 |
| Abrasive hardness | 15.2 | 6.2 | 8.3 |

Frost-action tests on 23 samples of slate are in progress, some of which have undergone nearly 4,000 freezings, These tests indicate that slate has a high resistance to frost action.

*Lime.*—The compilation of data on the composition, fineness, and available lime content of chemical quicklimes was completed. Progress has been made in the development of an improved method for determining the soundness of lime. The present standard method requires at least three days for a test while the improved method takes from four to five hours. A continuous sedimentation method for determining the fineness of lime is being tried and appears to be capable of giving the desired results.

*Sand-lime brick.*—Absorption, transverse strength, compressive strength flat, and compressive strength on edge of representative samples of sand-lime bricks from 27 manufacturers have been determined. Some of the brick from each lot have been reserved for a more thorough study of the absorption characteristics, after which accelerated weathering tests will be made.

*Gypsum fiber concrete.*—This material, mixed in the proportions used in practice, may be expected to have an ultimate compressive strength of from 450 to 1,300 pounds per square inch.

*Lime and gypsum.*—Results indicate that the modified Vicat apparatus is superior to the Southard viscosimeter, the present standard instrument for testing consistency of calcined gypsum. Committee C–11 of the American Society for Testing Materials has adopted the modified Vicat apparatus as their standard.

Tests indicate that Keene's cement to be of good quality should have a tensile strength of over 450 pounds per square inch. The time of set of the majority of the cements tested was between one and four hours.

*Elastic pointing materials.*—The exposure of 60 proprietary materials to the weather for nearly two years in the joints of coping stone has indicated a large percentage of failures. Discolorations of the limestone near the joints due to oil penetration were found to disappear after a few months and hence this feature could not be considered especially objectionable. The most common failure of the materials is due to shrinkage cracks. A few of the very plastic grades flowed from vertical joints, while others became hard and inelastic after a period of weathering.

*Waterproofing compounds.*—Considerable difference has been found in the effectiveness of commercial dampproofing and waterproofing compounds. After seven days' curing, concrete test specimens are subjected to a 20 pounds per square inch water pressure. The permeability as measured by the amount of water passing through the specimen is determined at all ages up to one year.

*Stone preservatives.*—A special study has been initiated to determine the value of stone preservatives in preventing decay under various conditions. Several instances of decay of stone in important buildings have forcefully shown the need for more information in this field, since some of the building stones which have heretofore been considered to be reasonably permanent have reached advanced stages of decay within 60 years.

*Abrasive hardness.*—Further improvements have been made on the abrasion-testing apparatus, and data have been obtained on marble, limestone, sandstone, granite, and slate, as follows:

| | Ha values | | |
|---|---|---|---|
| | Highest | Lowest | Average |
| Marble (142 tests) | 34.5 | 7.5 | 17.0 |
| Serpentine (14 tests) | 97.6 | 12.9 | 42.3 |
| Limestone (149 tests) | 24.9 | 1.0 | 9.8 |
| Sandstone (12 tests) | 10.8 | 2.5 | 6.7 |
| Granite (30 tests) | 75.1 | 37.0 | 56.3 |
| Slate (94 tests) | 15.2 | 5.8 | 8.1 |

The Ha figures given above were determined by abrading the various materials under uniform conditions with No. 60 artificial corundum and expressing the result as a reciprocal of the volume abraded in a given time.

*Chemical testing and methods of analysis.*—Approximately 2,000 samples of structural materials were tested for various branches of the Government. Analyses of Portland cement, cast irons, steels, alloy steels, ferro-alloys, brasses, bronzes, bearing metals, boiler plugs, Monel metal, and light aluminum alloys were made to aid in the

development of specifications, to insure proper delivery of materials, to detect causes of failure in service, and to determine the composition of materials used in metallurgical research. Nickel and chromium plated plumbing fixtures and hardware were examined, and some time was also spent in developing improved and more rapid test methods.

*Cement reference laboratory.*—In cooperation with the committee on cement of the American Society for Testing Materials there has been established a laboratory to deal with the various difficulties encountered in the testing of cement in the 300 cement laboratories of the country. Instruction will be given to employees of cement laboratories throughout the country in proper methods of testing, equipment used in testing will be calibrated, and new test methods will be studied. A staff has been assembled and the laboratory is now ready for operation.

*Branch laboratories and inspection of cement.*—The branch laboratories maintained at Northampton, Pa., for inspection and testing of cement; Denver, Colo., for testing of cement and concreting materials; and San Francisco, Calif., for testing cement and miscellaneous materials; together with the cement-testing laboratory in Washington, have rendered a much-needed service to Government purchasing agencies. One million two hundred and ninety thousand five hundred and forty-two barrels of cement were sampled and 1,073,590 barrels were shipped.

## TESTING MACHINES ($41,003)

*Calibration of testing machines.*—Specifications have been issued covering the manufacture and use of proving rings, of which 17, with capacities up to 100,000 pounds, have been tested. Proving rings which failed to meet the specifications have been studied to determine the cause of their unsatisfactory performance. Experience has shown that proving rings are superior to any other device on the market for calibrating testing machines.

*Bridge towers.*—At the request of the Port of New York Authority the bureau has undertaken a series of strength tests on models of the tower column sections used in the Hudson River suspension bridge. Four columns, 24 feet in length, with a section area of about 160 square inches, have been tested to destruction. Two were made from ordinary structural steel and two from silicon structural steel. The former failed at loads of about five and one-half million pounds and the latter at about eight and three-fourths million pounds. The column strengths and coupon test specimen values were found to agree very well. There was no indication of detail or secondary failure.

*Fatigue of Alclad.*—In cooperation with the Aluminum Co. of America the fatigue resistance of over 120 specimens of corroded and uncorroded Alclad and comparable duralumin sheets is being determined. Some of the specimens have been subjected to over 100,000,000 cycles of stress. The results indicate that the corroded Alclad specimens have approximately the same life as the uncorroded specimens and that the fatigue limit of the corroded duralumin specimens is slightly less than for uncorroded specimens.

*Methods of locking screw threads.*—An investigation of methods of locking screw threads is being actively prosecuted in cooperation with the Dardelet Threadlock Corporation and other manufacturers. Machines are now being built to apply repeated loads to either the

bolt or nut somewhat as they are applied in service. The stresses in the bolt will be measured by means of optical instruments. All manufacturers of thread-locking devices have been requested to cooperate.

*Dome of the New National Museum.*—To insure the safety of a jacking operation during repairs to the dome of the New National Museum the bureau laid out 96 gage lines on the steelwork which were measured with strain gages morning and evening during the 40 days required for the work. The total number of readings was about 4,000. It is believed that the stresses in the steelwork were determined with an error not greater than 500 pounds per square inch.

*Copper roofing.*—Tests in cooperation with the Copper and Brass Research Association show that the maximum load which can be continuously supported by a soldered seam without eventual failure is about one-quarter of the breaking load found by the usual tensile test. Data have been obtained which will provide the basis for formulas for computing the sizes of gutters required on buildings. An investigation of a form of localized corrosion affecting open-valley flashings has been completed. An inexpensive change in the method of laying the flashing is suggested as a means for eliminating corrosion difficulties.

### INVESTIGATION OF FIRE-RESISTING PROPERTIES ($30,213)

*Fire resistance of hollow load-bearing wall tile.*—The main series of tests in cooperation with the Hollow Building Tile Association consisted of 167 fire-endurance tests and 4 fire and water tests of typical wall constructions, 71 of which were made with walls between 10 and 11 feet high and 8 to 16 feet wide. This was preceded by two preliminary series to determine the effects of fire on individual tile units, the effects of changes in design of unit, and in the constituents and preparation of the clay.

The results are summarized as fire-resistance periods, which are determined by the time the walls sustained load under fire exposure and prevented the average temperature rise on the unexposed side from exceeding 139° C. (250° F.), or the maximum rise at any point where temperature measurements are taken from exceeding 180.6° C. (325° F.). Freedom from cracks or openings large enough to transmit flame or ignite combustible materials is also required both in fire-endurance tests and fire and water tests.

The final grouping of test results is in three classes, determined by the design of the tile. Fire-resistance periods are given for 8, 12, and 16 inch walls in each class, the values varying with the thickness and design from 1¾ to 11 hours for unplastered walls and from 4 to 15 hours for walls plastered on both sides. Periods for walls assumed to have combustible members projecting into them 4 inches from the unexposed side ranged from 1 hour with 8-inch unplastered walls to 10 hours with 16-inch plastered walls built of tile of the designs giving the highest results.

*Severity of building fires.*—A burning-out test was conducted in a fire-resistive building containing kerosene in open pans to an amount giving approximately the same Btu content as was present in the furniture and paper in a previous similar test with office occupancy. Although, on account of its higher fuel value, the weight of kerosene introduced was less than one-half of that of the wood and paper for

the companion test, the equivalent duration of the resulting fire was the same within 10 minutes. The results indicate possibility of gaging the fire hazard of occupancies in terms of the severity of the standard furnace test by means of the amount and fuel value of combustibles present per unit of floor area or room volume.

*Moving of large wall furnace.*—As provided for by a special appropriation of $22,000, the structural framing of the large wall furnace and shelter has been moved to a new location and reerected with reinforced concrete inclosing walls and roof. The new furnace is designed to obtain good temperature uniformity over the wall area exposed, and a fire control that will enable the furnace exposure to be duplicated in successive tests and conform with prescribed standards.

## INVESTIGATION OF PUBLIC UTILITY STANDARDS ($107,297)

*Electrical codes.*—A new edition of Handbook 4, discussion of the National Electrical Safety Code, was issued, and a pictorial edition of this code is in preparation. Assistance was given State commissions in Nevada and Wisconsin in preparing State codes. A 1929 edition of the electrical code combining accident-prevention and fire-prevention rules was prepared, and cooperation was rendered in the preparation of a standard code for the use of electricity in metal mining. The bureau assisted in the revision of the National Electrical Code of the National Board of Fire Underwriters for a 1929 edition.

*Protection against lightning.*—Miscellaneous Publication No. 92, Code for Protection Against Lightning, was issued. Data collected by the Western Actuarial Bureau were analyzed. Assistance was given in the preparation of the report on protection against lightning of the National Fire Protection Association.

*Code for electricity meters.*—The new edition of the Code for Electricity Meters, issued under a joint sponsorship of the National Electric Light Association, the Association of Edison Illuminating Companies, and the bureau, has been submitted to the United States national committee of the International Electrotechnical Commission as a proposed basis for an international specification for alternating-current watt-hour meters.

*Surveys of Government telephone service.*—Methods of meeting the telephone service requirements of activities both in Washington and in the field have been studied. Recommendations were made for a consolidated Treasury system in Washington on completion of the Internal Revenue Building and concerning consolidated service in nine Federal buildings in other cities.

*Soil-corrosion investigation.*—Approximately 1,000 samples of pipe materials were removed from the soil-corrosion test locations and examined. The results confirm those previously published. An extensive investigation of protective coatings for pipe lines is under way.

*Measurement of high voltages and large currents.*—The optical parts for the large high-voltage electrometer were completed. The guard condenser was assembled and studies of its potential distribution were made. The original beam-arrestment mechanism was discarded and a much more accurate mechanism was designed and constructed. Oil-cooled shunts for 1,000, 2,000, and 2,500 amperes were finished,

with the necessary oil-cooling equipment, and a standard current transformer for currents up to 12,000 amperes was nearly finished. A cathode-ray oscillograph for use in studying the properties of liquid dielectrics was completed.

*Fractional distillation of gases.*—Study of methods for the analytical separation of natural gases by fractional distillation, including the definition and determination of the gasoline in the gas, was completed.

*Specific gravity and density balances for gas.*—An improved balance was constructed employing a type of suspension not previously used in this field. A balance has also been designed for the direct determination of the density of gases.

*Oven linings.*—The corrosion of the majority of available commercial oven linings under service conditions has been determined.

*Miscellaneous gas appliances.*—The efficiency of storage water heaters has been measured, methods of rating them worked out, and satisfactory performance standards recommended. A study was made of the floor temperatures under radiant heaters with reference to standard tests for safety in connection with such heaters.

*Burners for propane and butane.*—Successful laboratory burners for these "bottled" gases were constructed and are now being used as models by apparatus companies.

### TESTING MISCELLANEOUS MATERIALS ($47,125)

*Variety of materials tested.*—A great variety of chemical and physical tests were made for Government departments on paints, varnishes, roofing and waterproofing materials, rubber goods, packings, inks, typewriter ribbons, carbon paper, textiles, boiler waters and compounds, detergents, chemicals, gold alloys, etc. Miscellaneous materials were tested to determine their fire hazard to guide the Steamboat Inspection Service in making rulings on the transportation of commodities on passenger vessels.

### RADIO RESEARCH ($55,772)

*Standards of radio-frequency.*—The accuracy of the bureau's frequency standard was considerably improved by means of piezo-oscillators, in which special attention was paid to temperature control and quartz plate mountings. The error in constancy of these piezo-oscillators is less than 5 parts per 1,000,000. Intercomparisons between the bureau's standards and those of two other laboratories in the United States showed agreement to 1 part per 100,000. The transmitters used for sending out scheduled signals of standard frequency were reconstructed in order to permit closer frequency setting and control, with resulting marked improvement in the accuracy of the transmissions.

*Study of piezo-electricity.*—A theoretical and experimental study of the operation of the quartz plate in a piezooscillator was made. The modes of vibration of a quartz plate were studied by observing the glow discharge surrounding the plate when operating in helium at a low pressure. Special methods of driving the quartz plate in a piezooscillator were developed and studied.

*Improvements in testing station frequency standards.*—The accuracy of testing piezooscillators used by broadcasting stations was in-

creased about ten times by using a method which gives a calibration directly in terms of a standard piezooscillator. The temperature of the room used for testing is maintained constant at all times.

*Radio wave phenomena.*—The vagaries of radio wave transmission were studied by means of field intensity measurements, fading records, and wave direction determination. Measurements were made at the bureau, at field stations, and in a traveling laboratory. Rapid variations in the intensity of received signals were found to be partly due to continual changes in the plane of polarization of the waves which arrive by way of various paths and combine at the receiving station. Apparatus was developed to isolate the various factors involved and to make possible a study of each one independently. Measurements were made on the apparent height of the Kennelly-Heaviside layer by measuring the time difference between the arrival of the ground wave and the upper-air wave.

*Radio wave propagation.*—Continuous signal intensity records from long-wave stations in various parts of the world are furnishing information as to annual, seasonal, and diurnal variations in signal strength and as to the properties of the Kennelly-Heaviside layer which causes fading of signals, errors in direction finding, and other variations in radio propagation.

*Correlation of radio with other natural phenomena.*—When averaged over long periods, daylight signal intensity appears to vary directly while daylight static varies inversely with solar activity and the disturbances in terrestrial magnetism. Correlations with weather are very marked in the case of static and less marked in the case of signal strength.

*Assistance to Federal Radio Commission.*—Technical assistance, including preparation of data, was given the Federal Radio Commission. At the request of the commission the services of the chief of the radio section were made available for a period of four months, during which he served as chief engineer and organized the engineering division of the commission.

## COLOR STANDARDIZATION ($10,950)

*Fixing upon a standard "white."*—The spectrum colors, such as red and green, are specified by their wave length, but white must be fixed by agreement. Various suggestions are as yet open to selection: "White" shall be defined as the color (*a*) which a sufficient number of observers, having normal color vision, select by preference; or (*b*) of the sun's radiation (outside the atmosphere); or (*c*) of a completely overcast sky; or (*d*) of an equal energy spectrum; or (*e*) of a "black" body when the ratio of its luminosity to its total radiation is a maximum, about 0.14.

Of these, (*b*), (*c*), and (*e*) have been the subject of intensive study which, it is believed, will soon culminate in a generally acceptable specification for white.

*Spectrophotometric measurements fundamental to the photometry of practical light sources.*—Color differences between various light sources in common use entail a direct comparison of intensities. Calibrated optical filters for equalizing the color have proved effective.

From a recent interlaboratory comparison in this country of several such filters it was concluded that: (1) Consistent values may be obtained by the spectrophotometric method in the measure-

ment of the intensities of deeply colored light; and (2) such values agree more or less satisfactorily with the averages obtained by the so-called flicker and equality-of-brightness methods of photometry.

Blue filters are now being evaluated by the national laboratories of England, France, Germany, and the United States, by means of which the relative efficiencies of vacuum and gas-filled lamps may be expressed on a common basis in all four countries.

*Lovibond glasses.*—The calibration of 65 of the "35-yellow" Lovibond glasses, used in the color grading of edible oils, which has been conducted in cooperation with the American Oil Chemists' Society, was completed and a publication issued. The effect of temperature changes on the readings with red and yellow glasses was also determined and was found to be small. More than 1,000 red glasses have been calibrated in terms of the bureau's standards and reported to the owners. The results of these calibrations are now being collated and prepared for publication.

### INVESTIGATION OF CLAY PRODUCTS ($49,370)

*Investigations on architectural terra cotta.*—In cooperation with the National Terra Cotta Society the resistance of terra cotta to weathering was determined. Factory tests are being developed to assist terra-cotta plants in inspecting their ware before it leaves the factory.

The best method of setting terra-cotta ashlar on buildings was studied. Filled terra-cotta facing adds considerably to the strength of walls and apparently justifies reckoning filled terra cotta as a portion of the thickness of walls.

In brick-backed construction, if mortars are improperly used, the expansion of the brick masonry tends to pull apart the terra-cotta ashlar and thus open the terra-cotta joints. This expansion is capable of producing a considerable pressure on the terra-cotta facing unless expansion joints are provided.

*Refractory bricks and clays.*—Test data obtained on 27 fire clays and 14 brands of fire-clay bricks indicate that the temperature of firing of these materials has a decided influence on their physical properties, which in turn affect the life of the refractory when subjected to thermal shock. Preliminary recommendations have been made as to desirable properties for saggers to increase their life.

*Resistance to abrasion of metals, suitable for dies, to the flow of plastic clay.*—A marked difference has been found in the wearing qualities of different metals. For example, it was found that for the same length of clay column extruded the losses by abrasion of carbon-chrome steel and cast iron (both widely used in the industry) were as 1 to 12.

*Investigation of hollow-ware dies.*—Density of the clay column is affected more by slight changes in the ratio of water to dry clay—that is, from 1 to 2 per cent—than by a change of 25 per cent in die length or 50 per cent change in die taper. Die lubrication plays an unimportant part in reducing the power consumption, but materially improves the column by preventing torn corners and developing smoother surfaces generally. The most efficient hollow-ware dies for medium plastic clays are those having tapers less than 6° and a total length of not over 3 inches or less than 2 inches and cores not over 1½ inches or less than 1 inch in length.

*Application of light-colored vitreous first coats to sheet iron and steel.*—The following procedure for applying a light-colored vitreous enamel directly to sheet iron or steel was developed:

The metal is first prepared for enameling in the usual manner. It is then dipped in a 4 per cent solution of cobalt nitrate at about 95° C. and allowed to remain until hot. Upon withdrawal, the hot metal quickly dries, after which it is placed in a furnace at about 300° C. for five minutes, when the cobalt nitrate apparently decomposes and the metal simultaneously acquires a coating of its own oxide and of cobalt oxide. Both of these oxides when at the surface promote adhesiveness, and it appears that practically any enamel composition which is satisfactory in other respects will adhere well when the iron is prepared in this way.

*Cast iron for enameling purposes.*—The gas which causes blisters in an enamel when applied to some iron castings appears to be principally $CO_2$, with some CO admixed. This evolution of gas may occur without damage at certain stages of the enameling process, but from a blistering iron continues through the critical stage of the enameling during which the relatively thick finish coat of enamel is fused and too viscous to permit free escape of the gas. The evolution of gas during the critical period appears to be caused by the breakdown of combined carbon and its recombination with oxygen, and is controlled by the amount and condition of the combined carbon present in the surface of the casting to which the enamel is applied. Experiments have shown that it is possible to modify the nature of this surface layer so as greatly to reduce blistering through the addition of certain elements to the iron, notably silicon, which diminishes the proportion of combined carbon.

*Use of feldspar in white ware.*—Ten similar vitreous white-ware bodies, maturing at cone 14, were prepared and their properties determined. The kind of feldspar used and the calcination of different components appear to have very little effect on the physical properties, except in cases where the feldspar evidently lost its fluxing power in calcination.

*Crazing of semiporcelain dinnerware.*—Thermal expansion was measured on pieces of plates as received and on pieces of the same plates after they had been treated in the autoclave. The first expansion of each piece after it had been given the autoclave treatment was lower than its expansion before, thus showing that the ware had absorbed some water during treatment. There was also a material increase in weight. Specimens with a high water absorption, with two exceptions, crazed during the autoclave treatment.

*Improved apparatus for testing chinaware.*—A modified pedulum apparatus, using one 5-ounce hammer, for testing the resistance of chinaware to impact and chipping has been designed and built to obviate difficulties encountered in the use of the apparatus specified in United States Government Master Specification for Vitrified Chinaware, No. 243a.

*Columbus laboratory.*—At the Columbus branch there were secured during the year data showing the elasticity and thermal dilation of about 110 white-ware glazes. This work was undertaken to secure factors which might enable one to calculate these physical properties from the composition of the glazes. The 17 representative English china clays are being studied for use in the white-ware industry.

The data will be compared with representative china clays of domestic origin. The cooperation with the American Society of Mechanical Engineers on the study of power-house refractories was continued with satisfactory results. Studies of a special white-ware body in which fluxes are being introduced indicate the possibility of lowering maturing temperatures for certain types of white ware. The study of 26 representative alluvial and glacial clays and shales to determine the characteristics which indicate their usability was well advanced.

### STANDARDIZING MECHANICAL APPLIANCES ($29,677)

*Testing of engineering instruments.*—The volume of work in the calibration of water current meters and other engineering instruments has increased by 40 per cent in the past fiscal year and by over 100 per cent in the past three years.

*Fire-extinguishing appliances.*—The testing and investigation of fire-protection appliances for the Steamboat Inspection Service has been extended to include certain types of complete extinguishing systems for ships, as distinguished from portable apparatus. Construction and performance specifications were drawn up for portable extinguishers of the foam type.

*Performance specification for numbering machines.*—The experimental study of the durability of numbering machines, resulting in the formulation of a performance specification for machines of the lever type for the use of the Federal Specifications Board, has been extended at the request of the Post Office Department to develop performance specifications for other types of numbering machines.

*Automatic postal machines.*—The bureau has cooperated with the Post Office Department in studying the possible extension of the use of time and labor saving automatic postal machinery.

*Elevator safety interlocks.*—Additional commercial examples of interlocks have been tested. The data are made available, as a basis for their approval for use on installations in their respective jurisdictions, to certain regulatory bodies, as, for example, the Government departments, State governments, and casualty insurance companies.

*Accelerometer testing equipment.*—Equipment for testing accelerometers has been designed and constructed. This consists of a rotating disk with provision for photographing the dial of an instrument under test when a reading is desired.

### INVESTIGATION OF OPTICAL GLASS ($27,420)

*Production of optical glass.*—Thirty-nine pots of six different kinds of optical glass, borosilicate crown, barium flint, medium flint, dense flint, light barium crown, and ordinary crown, were made to determine melting procedure which will consistently yield glass of good quality.

Blanks numbering 25,910 and weighing approximately 3,500 pounds were molded and annealed, the majority being used by the Navy Department.

*Physical properties of glass as affected by thermal treatment (including annealing).*—Additional values for the increases in refractivity and density per degree centigrade decrease in the effective annealing temperature, and a slight revision of some of the values previously reported have resulted from new data. Some of the more reliable tentative values are:

| Type of glass | Increase in refractivity and density per degree centigrade decrease in effective annealing temperature | | Range of effective annealing temperature for which values were determined (° C.) |
|---|---|---|---|
| | Refractivity | Density | |
| Medium flint | 0.000024 | 0.00016 | 350–460 |
| Dense flint | .000036 | .00027 | 360–440 |
| Borosilicate crown | .000048 | .00028 | 470–540 |
| Ordinary crown | .000032 | .00017 | 500–570 |
| Light barium crown | .000047 | .00033 | 500–570 |

*Viscosity of glass.*—It has been found that the viscosity-temperature relations of light barium crown and borosilicate crown glasses can be expressed by the equation:

$$\text{Log. } \mu = C - \frac{A}{B}\sqrt{b^2 - (1{,}400 - T^2)}$$

in which $\mu$ = viscosity, $T$ = temperature (° C.), and $A$, $B$, and $C$ are constants having the following values for the two types of glasses: Borosilicate crown, $A = 8.53$, $B = 700$, $C = 10.53$, and light barium crown, $A = 8.22$, $B = 600$, $C = 10.18$.

*Relations between chemical composition, density, and index of refraction of glasses.*—A series of glasses was made by melting mixtures of pure silica and soda ash in a specially designed platinum resistance furnace. The composition of these glasses varied from approximately 50 per cent silica, 50 per cent soda to 80 per cent silica, 20 per cent soda.

The density of these glasses can be quite accurately computed from the expression:

$$D = 0.3293\ (P_a - 30)^{0.4486} + 0.01873\ (P_b)^{1.0802}$$

in which $P_a$ and $P_b$ are the percentages of silica and soda, respectively.

The work on index of refraction necessitated a modification of the method of measurement because some of these glasses are too hygroscopic to permit grinding and polishing in the ordinary way.

## INVESTIGATION OF TEXTILES, ETC. ($54,144)

*Method for testing yarns.*—An improved multiple strand method for testing yarns has been devised, in which 100 or more lengths arranged parallel to one another under the same tension may be broken simultaneously, thus giving average results for a considerable amount of material. Auxiliary equipment has been built which permits testing with the yarns wet with any liquid and at any temperature, thus simulating conditions existing during the process of manufacture, laundering, or cleaning.

*Wool meter.*—A simple portable instrument for grading raw wool has been devised. Results obtained with it agree to better than 2 microns with laborious, time-consuming, microscopical measurements.

*Properties of parachute fabrics.*—A study of the properties of silk parachute fabrics, for the National Advisory Committee for Aeronautics, shows that parachute silk of American manufacture is equal to or better than imported cloth. Specifications for parachute fabric have been prepared.

*Laundry "winter damage."*—A type of laundry damage, prevalent in the New England States in the wintertime, known as winter damage, was investigated at the request of the Laundry Owners' National Association. It was found that a slight modification of the laundry procedure will materially decrease this damage.

*Dyes.*—The fading of dyed textiles in sunlight transmitted by various glasses showed that the ultra-violet in sunlight which is not transmitted by window glass has relatively little fading action on most fabrics. The fastness to washing of dyed fabrics was studied, and a machine for making laboratory tests was built in cooperation with the American Association of Textile Chemists and Colorists which has adopted it as a standard for the association. The spectral reflection of dyeings was studied with reference to the dyeing process.

*Postage stamps.*—Cooperative work with the Bureau of Engraving and Printing on United States postage stamps was undertaken at the request of the Secretary of the Treasury, to effect any possible improvements in the manufacturing processes or in the quality of the stamps. One complete printing, gumming, and drying unit is being used for experimental purposes, and thorough laboratory tests are being made of the raw materials and the finished product.

*Paper currency.*—A publication was prepared which describes further developments in the manufacture of currency paper, including the use of various combinations of linen and cotton fibers, and the effect of variations in the cooking, bleaching, beating, and sizing operations.

*Paper quality standards.*—Chemical and physical tests, including accelerated aging tests, of representative commercial writing and book papers are being made. One of the important indications of the tests is that the processing of the fiber, irrespective of its source, is the most important factor in its rate of deterioration.

*Paper-testing methods.*—A recommended procedure for determining the bulk of paper was developed. Modifications in the design of bursting strength testers were suggested to assist in overconing some of the variables of such instruments. The cooperative work with the Technical Association of the Pulp and Paper Industry on development of official association test methods resulted in the completion of methods for gloss, opacity, and bulk.

*Miscellaneous.*—Experiments have been conducted on a humidity-recording instrument for use in paper laboratories, on methods of measuring gloss and brittleness, and on several unusual papers and paper-making fibers. The use of sawdust and waste papers has been found feasible in the manufacture of roofing felts. On the other hand, rayon, which is commonly found to some extent in paper-making rags, was found to have no paper-making value. Some investigations have been made on building board from compressed wood, flax from New Zealand, insulating board from licorice root, and a very strong paper made from mitsumata fiber, submitted by the Imperial Government Printing Bureau of Japan.

### SUGAR STANDARDIZATION ($58,227)

*Hard refined levulose production.*—The semifactory-scale plant is practically completed. The problem of washing the artichoke tubers and removing foreign material has been successfully solved, and the hydraulic press station has been improved.

About 10 tons of cleaned artichokes were worked and the juice concentrated for dilution later in the experimental operation of the plant. Further study of the 8 per cent of substance which does not convert to levulose revealed the presence of a group of new disaccharides, one of which has been recovered in crystalline form. This sugar is composed of two molecules of levulose and has been named difructose anhydride. As no system of analysis of products containing levulose is in existence, the bureau has carried forward the development of such a system to the point where it is now available for plant control.

*Color research in sugar production.*—The transparency and optical stability of sugar solutions for spectrophotometric analysis have been studied, and the methods for obtaining them have been improved and the time of preparation reduced. A method of preparing the asbestos fiber used for the filtration has been worked out so that only two hours are required for a step which formerly required several days.

*Testing of sugars.*—The testing of sugars and sugar products, as well as of polarimetric equipment used in pure research and in the industries, was continued on an augmented scale. The scientific supervision of the collection of the duty imposed by the tariff act on sugars, molasses, etc., vested in the bureau, has been continued by means of daily exchange samples of sugar and molasses. In response to industrial requests a table of weights per gallon of sugar solution at the standard temperature of 20° C. has been developed and a supplementary table of weights per gallon at different temperatures computed.

## GAGE STANDARDIZATION ($40,713)

*Measurement and certification of master gages.*—There has been a considerable increase in the number of gages submitted for test. The largest volume of work has been submitted by the petroleum oil industry which has sent master gages for well-casing threads, rotary tool joints, rotary drill pipe, line pipe, and sucker-rod gages. An increasing number of gages have also been submitted by manufacturers of machine tools and automobile accessories.

*Cooperation with standardizing bodies.*—The bureau has cooperated with the National Screw Thread Commission in carrying out researches on the strength of screw threads and in preparing and editing the 1928 report of the commission; with the American Gage Design Committee in preparing standard designs for gage blanks; with the American Petroleum Institute in fixing tolerances for master gages and products used in the production of petroleum oil; and with the Diamond Core Drilling Manufacturers Association in standardizing equipment used in diamond core drilling operations.

New and improved methods have been devised and utilized in the measurement of gages. Particular attention has been given to the setting up of standard conditions and equipment for the measurement of screw-thread gages.

*Standard method of determining pitch diameter of thread gages.*—Disputes frequently have arisen between gage maker and the purchaser and user of thread plug gages with regard to values of pitch diameter of the thread obtained by the wire method of measurement. This method is almost universally used and its intrinsic accuracy is satisfactory from a practical viewpoint. While a difference in the value for pitch diameter may be due to inaccurate wires or measuring

instruments such differences may arise from variations in the method of determining the diameter of the wires or the use of widely different or excessive contact pressures. The bureau, after consulting with some of the gage makers, has adopted definite limits for contact pressures and a standard method for determining diameter of the wires used. These standard methods together with specifications for measuring wires have been adopted by the National Screw Thread Commission.

### INVESTIGATION OF MINE SCALES AND CARS ($13,688)

*Tests of mine scales.*—The mine scale test equipment of the bureau made tests of 153 mine scales in the eastern coal fields. Fifty scales, or 32.7 per cent, were within tolerance, while 103, or 67.3 per cent, were found to be incorrect.

The general results, in comparison with results of other years, show no appreciable changes which might be interpreted to indicate consistent betterment of weighing conditions at coal mines. In sections of the eastern coal regions, since recent dissolution of previously existing labor agreements, a noticeable trend toward the system of payment by contract or by car is apparent.

### METALLURGICAL RESEARCH ($51,614)

*Foundry sands.*—In cooperation with various rubber companies and with foundries a study has been made of special rubber cements and of rubber latex as a binder for foundry core sand. Such binders give cores of high permeability which allow the use of fine sand and consequent smooth finish on the cored surfaces. The cores burn to loose sand, which is extremely easy to remove from the casting, thus greatly reducing difficulties in cleaning out the cores. Core strengths equivalent to those obtained with linseed oil core binders can be reached with the rubber-bonded cores.

*Foundry practice.*—Work in cooperation with the Steel Castings Development Bureau, and with the Bureau of Mines, on causes for low ductility in steel castings continues.

In cooperation with the American Foundrymen's Association a study has been started of methods for determining the shrinkage of metals and alloys during freezing; that is, on the propensity to give unsound castings because of internal shrinkage. Methods of determining the fluidity of metals—that is, their ability to fill a mold during casting—are likewise being investigated.

*Rail steel.*—The endurance properties of steel from rails taken from track after service have been compared with those of steel from rails from the same ingot before service. The endurance properties of steel from rails that have failed by transverse fissures have also been studied. Fissures apparently arise from tiny cracks present in the rail before service. Further work on endurance properties of failed rails and of alloy and heat-treated rails is in progress, as is work on the relation between endurance values determined by axial loading instead of in rotary bending.

Active work on the properties of rail steel at high temperatures is being continued. A large proportion of the rail steel examined has a range of brittleness at high temperatures, in which the steel is both weak and of low ductility. While it is not yet certain that cooling stresses exerted as the rail passes through this temperature range are

responsible for the "shatter cracks" that appear to be the nuclei responsible for transverse fissures, there is enough evidence that the cracks have some thermal source to justify much further work along this line.

*High-speed tool steel and the machinability of steel.*—A report on a new method of evaluating the ability of tool steels to take light cuts (finish turning), and on the effect of nickel, cobalt, arsenic, antimony, copper, tin, aluminum, titanium, or tantalum in high-speed steel, both in roughing and finishing cuts, is in press. A study of the behavior of tungsten carbide tools has been started.

*Bearing bronzes.*—The effect of zinc as impurity of copper-tin-lead bearing bronzes for automotive use has been studied in cooperation with a research associate from a manufacturer of bearings, and a paper describing the work is in press. Zinc is by no means as harmful as is often supposed. Work on the effect of nickel, antimony, and phosphorus in these bearing bronzes is in progress.

*Substitutes for platinum.*—The working of pure rhodium, and of alloys of platinum and rhodium high in rhodium has been successfully accomplished, and these alloys are showing up well in service as furnace windings. Information on the properties of alloys and on their utility as cheaper substitutes for pure platinum and other platinum alloys is nearly ready for publication. Work is in progress on the quality of various platinum alloys for laboratory crucibles.

*Corrosion of metals.*—Results of a study of laboratory corrosion test methods for zinc-coated steels have been published, and a paper on the effect of aeration in electrolytic corrosion testing is in press. Apparatus for the study of the effect of aeration in submerged corrosion testing is in operation. The study of corrosion of nonferrous screen wire cloth and corrosion of zinc-coated products when exposed to the weather has been continued in cooperation with the American Society for Testing Materials.

*Specifications.*—The usual cooperation has been given to the Federal Specifications Board and to technical societies in preparation of specifications for metals, metallic products, molding and core sands, and foundry supplies.

### HIGH-TEMPERATURE INVESTIGATION ($10,401)

*Comparison of older temperature scales.*—After the adoption of the international temperature scale a comparison was made between the thermoelectric portion of this scale and the three other thermoelectric scales which had been used by the bureau since 1912. None of the older scales differed from the international scale by more than 0.3° C. The freezing point of copper on the international scale was determined as 1083.0° C. and that of the copper-silver eutectic as 779.4° C.

*Thermoelectric properties of platinum-rhodium alloys.*—The emf against platinum of a series of these alloys with rhodium content from 1 to 100 per cent was determined over the range 0° to 1,200° C.

*Freezing point of nickel.*—The location of this point makes it a very convenient one for the calibration of the standard optical pyrometer. The temperature was found to be constant and reproductible, the average found for each of two separate lots being 1,454.9° C., which when rounded to 1,455° C. is believed not to be in error by more than 1° C.

## SOUND INVESTIGATION ($11,469)

*Acoustic properties of building materials.*—The demands upon the new reverberation chamber for measuring the sound absorption of materials used in the interior finish of auditoriums are already greater than can be promptly met. One reason for this is the development of the talking picture, which has suddenly directed attention to the acoustic quality of existing theaters which had been built with no consideration of this point. A large number of measurements have been made to develop a lime plaster that shall be a good absorber of sound. These experiments have given promising results but are not yet completed. Panels of stud and steel construction have been tested for their soundproof character. The soundproofing of airplane cabins has been studied and flight tests have been made with the cooperation of the Navy Department and of the Army Air Corps.

*Tuning fork investigation.*—The behavior of tuning forks made of materials other than steel has been studied to find some material which will produce a fork free from certain errors inherent in steel, especially the effect of amplitude of vibration upon frequency. Incidentally, it has been necessary to study somewhat extensively the effect of the character of the mounting upon the period of a tuning fork.

## INDUSTRIAL RESEARCH ($203,627)

*Properties of water and steam.*—In cooperation with the American Society of Mechanical Engineers, experiments yielding data on the heat capacity of water over the range 0° to 270° C. were completed. Observations were taken over intervals of 10° C. and values of the heat content or enthalpy of saturated water at 10° intervals have been obtained, each value being the result of nine or more complete determinations.

Representative values follow:

| Temperature, °C. | Enthalpy Mean cal/gram | Temperature, °C. | Enthalpy Mean cal/gram |
|---|---|---|---|
| 10 | 10. 03 | 150 | 150. 88 |
| 30 | 29. 99 | 200 | 203. 99 |
| 50 | 49. 94 | 250 | 259. 11 |
| 100 | 100. 00 | 270 | 282. 76 |

Experimental data on latent heat at 100°, 130°, 150°, and 200° have been obtained.

*Properties of petroleum products.*—In cooperation with the American Petroleum Institute, the correlation of existing data on important properties of these products has been completed and the experimental work is designed to furnish data now lacking. Measurements of the thermal expansion and compressibility of petroleum products over the range 0° to 300° C. and 1 to 50 atmospheres are in progress. A calorimeter for measuring specific and latent heats of petroleum products has been constructed, assembled, and tested.

*Thermal conductivity of insulating materials.*—A new apparatus for making measurements of conductivity at lower temperatures was built and used to make measurements on a number of typical insulating and building materials over the range of temperatures from −30° to +70° C. The conductivities increase with temperature at rates of 0.2 to 0.4 per cent per degree centigrade. Measurements of conductivity of loose fibrous materials showed that conductivity

increases as the packing becomes very loose. The conductivities of some of these materials, particularly asbestos fibers, are unexpectedly high. Comparison of conductivity tests by other laboratories by means of calibrated specimens showed average deviations of about 3 per cent, which is satisfactory for commercial purposes.

*Efficiency of street car reduction gears.*—Comparative tests have been made on two spur gears and one worm gear type in cooperation with the American Electric Railway Engineering Association, improved methods of testing and new equipment having been specially developed for the purpose.

*Quenching media.*—In hardening steel by quenching, in heat treatment, it is often desired to cool the steel at a rate intermediate between the rate obtained by quenching in water or aqueous solutions and by quenching in oil. The use of hot aqueous solutions, while it has some drawbacks, appears to solve the difficulty in at least some cases.

*Metal spray.*—The method of coating a metal or some material like wood or paper with another metal to produce a surface more resistant to moisture, or with other desirable properties, has drawbacks in that it is sometimes impracticable to roughen the surface which is to receive the coating so that it will adhere properly. There is a tendency for the coating to be porous. By the use of special rubber cements the adhesion can be much improved and the pores filled. Experimental specimens have been produced which have satisfactorily withstood severe corrosion or exposure tests in cooperating plants which have to combat corrosion of chemical vapors or liquids.

*Gases in metals.*—Work on the problem of determining the tiny amounts of oxygen, hydrogen, and nitrogen in iron and steel has been centered on overcoming some of the remaining difficulties in the analytical methods and a determination of their limitations. Both vacuum fusion and "residue" methods have been studied, the latter in close cooperation with the Bureau of Mines. A study of the ways in which nitrogen combines with iron has been completed.

*Heat-resisting alloys.*—Long-time tension ("flow" or "creep") tests on several alloys of industrial importance and similar tests on a series of alloys of nickel, chromium, and iron were made in cooperation with the joint committee on high temperature properties of metals of the American Society of Mechanical Engineers and the American Society for Testing Materials, as well as with a research associate from a manufacturer of alloy steels. These alloys are the foundation upon which most of the industrial alloys for service under extreme temperature conditions are built. Further work on these alloys, including a study of the effects of various other elements, is contemplated.

*Wear-resisting alloys.*—The wear resistance of chromium plating, applied under different conditions of deposition, and of the new nitrided steels has been studied, using the gage wear tester, previously developed at the bureau. A rather comprehensive study of a commercial wear tester made abroad, which uses sand as the abrasive, has not so far shown much promise in that method of testing, as it does not distinguish sharply between metals known to vary in wear resistance in actual service.

*Health hazards in chromium plating.*—In cooperation with the United States Public Health Service a study was made of the effects of chromic acid spray upon the health of the operators and the meth-

ods and degree of ventilation required to eliminate such hazards. The results showed that with reasonable precautions there is no serious hazard in this industry.

*Thermal expansion.*—The thermal expansion of magnesium and some of its alloys, as well as of tantalum, rhodium, and amber, have been determined. Determinations of the thermal expansion of chromium and fused quartz are now in progress.

*Elastic hysteresis research.*—Progress has been made in determining the source of the discrepancy in the values of the elastic hysteresis modulus when obtained by measuring the deflection of bars under load and by observing the damping of tuning forks. The measurements of damping give values twice as great as the deflection method. It has been found that the damping of a tuning fork is unchanged when the fork is mounted rigidly, suspended by strings, mounted on rubber, or mounted rigidly and unbalanced by adding weights to one prong. Attention will now be given to further experiments employing the deflection method.

*Optical heterogeneity of fused quartz.*—Various parts of a single piece of clear fused quartz, from which it was planned to make a standard of refractive index for testing refractometers, were rigorously investigated as to uniformity of refractive index throughout the mass of the sample. The variations found were not only small, but the nature of their distribution indicated that an annealing process might entirely remove them.

*Properties of flames.*—The properties of flames which affect their stability and efficiency are being studied. An investigation will soon be finished of the relative proportion of carbon monoxide and hydrogen in the gases from flames in which combustion is nearly but not quite complete.

*Heat of formation of sulphur.*—The heat of formation of sulphur dioxide, at 25° C. and atmospheric pressure, from rhombic sulphur and gaseous oxygen was found to be $+296{,}890 \pm 200$ absolute joules per mole, or dividing by the factor 4,185, this value becomes 70,940 $g\text{-}cal_{15}$.

*Heat of formation of nitric acid.*—A method and apparatus for determining directly the heat of reaction between nitric acid and hydrogen to form nitrogen and water has been perfected and measurements of this thermochemical constant are under way.

*Identifications.*—Attention has been given to the identification of typewriting, handwriting, bullets, cartridge cases, and firearms. The bureau's purpose is to establish standards which may be regarded as reasonable minimum requirements for equipment and training for carrying on this work. On numerous occasions the bureau has assisted other departments of the Federal Government in problems of identification.

*Fading of dyes.*—A spectrophotometric method has been perfected for the quantitative measurement of the degree of fading of dyed fabrics. Tentative standard methods for determining the fastness to washing of dyed fabrics have also been developed, and a machine embodying these methods has recently been placed on the market.

*Sole leather.*—Tests recently completed show that sole leathers first tanned with chromium salts and then retanned with vegetable materials wear from 25 to 75 per cent longer than the ordinary vegetable tanned sole leathers now chiefly used.

*Acid in leather.*—Leather prepared with one particular tanning material has lasted two years without appreciable deterioration, although it contained 3 per cent sulphuric acid. Leather prepared with another material showed deterioration in samples containing about 1 per cent sulphuric acid. It appears that the resistance of leather to deterioration by sulphuric acid is influenced by the vegetable material with which it is tanned. A study of the effects of relative humidity upon the deterioration of leather by sulphuric acid indicates that deterioration takes place at a greater rate with high than with low humidities.

This project is sponsored jointly by the Tanners' Council of America and the American Leather Chemists Association, and cooperation is effected through an advisory committee representing these organizations.

*Influence of temperature and humidity on the physical properties of rubber compounds.*—In cooperation with the American Chemical Society an investigation has been completed of the effect of temperature and relative humidity upon the physical properties of rubber as exemplified by the stress-strain relation and the resistance to abrasion. The effect of relative humidity and temperature upon the resistance to abrasion is of interest to the industry, for it concerns the seasonal tire wear as well as the standardization of the laboratory procedure in determining this property.

*Sponge rubber.*—A survey of the manufacture of sponge rubber has been made, using samples of sheet sponge of different types obtained from several sources. This investigation covers hardness, porosity, strength, permanent set, water absorption, buoyancy, hysteresis under compression, cushioning properties, and heat insulation.

*Abrasion tests for rubber.*—A new abrasion-test machine has been designed and built, and data on its performance are being obtained.

*Rubber floor tile.*—A report covering the properties of rubber floor tile has been prepared and discussed at conferences with manufacturers and users. Further work is planned to make available definite information regarding the physical properties desirable in rubber floor tile and the conditions of service for which it is best adapted.

*Properties of electrical insulating materials.*—This research has been largely confined to the electrical properties of compounds of sulphur with pure rubber hydrocarbon. A series of 17 compounds has been studied in which the sulphur content varied from 0 to 32 per cent in steps of 2 per cent. The dielectric constant, power factor, and resistivity of each member of the above series were measured at approximately temperatures from $-77°$ to $+102°$ C., the dielectric constant and power factor being measured at 60, 1,000, and 3,000 cycles. A comparative method for measuring the thermal conductivity of electrical insulating materials has been developed.

*Storage-battery investigation.*—Experiments to determine the effect of expanders as well as variations in the treatment of plates after pasting have been made. The causes of corrosion of positive plates in large storage batteries, such as those used in submarines, are being studied. An investigation to determine the possibility of using other material than antimony to harden the lead of the grids has been begun.

*Wind pressure on structures.*—Measurements of the wind pressure on a relatively smooth cylindrical stack 10 feet in diameter and 30

feet high in a natural wind have shown a pressure corresponding to approximately 10 pounds per square foot (projected area) at a speed of 100 miles per hour. On the brick stack of the bureau's power plant values corresponding to 15 to 17 pounds per square foot at 100 miles per hour have been noted. The wind pressure in model tests is known to increase with the height-diameter ratio and with roughness, and the same appears to be true of large structures in natural winds. For general use the bureau can not at present recommend any reduction below the commonly used figure of 20 pounds per square foot at 100 miles per hour.

*Spectrochemical analysis.*—New descriptions of the arc and spark spectra of lanthanum, chlorine, bromine, iodine, arsenic, krypton, and xenon have been prepared. These have led to the classification of nearly all the lines in the first (arc) spectrum of each and have given information as to the most sensitive lines for spectrochemical detection and quantitative estimation of small quantities, of the elements. In each, excepting arsenic, the main features of the second (spark) spectrum have been found, and the strongest spark lines classified. About 100 samples of metals, alloys, salts, and miscellaneous materials were examined by spectrographic methods. Impurities were identified in proof gold of the Bureau of the Mint and a higher standard of proof is now being maintained by the spectroscopic method of testing.

*Atomic structure investigations.*—The rate of disappearance of ions and electrons in an ionized gas by recapture of the electrons has long remained an unknown quantity in ionization problems. Attention has been centered on measurements of this probability of recombination. The intensity of the radiation resulting from the capture process is a convenient measure of the rate of recombination. The results give reliable values for the relative probabilities of capture for electrons of different speeds into various atomic levels, while a study of the converse process, ionization of atoms by light, fixes the absolute value of the probabilities.

*Photographic emulsions.*—An investigation relating the hydrogen and bromide ion concentration with the sensitivity of the emulsion shows that these control sensitivity directly, as well as through their effect on the efficiency of both nuclear and dye sensitizers. Experiments on sensitization by sulphites indicate that this is peculiarly dependent on removal of soluble bromide. The study of the effect of washing and coating pH was therefore extended to include the effect of bromide ion concentration. A study of a particular dye bath has been made to develop correct principles governing the use of two dyes.

*Research associates.*—The following table gives the names of associations and manufacturers cooperating with the bureau under the research associate plan, together with the number of associates and the problems on which they are engaged:

*Research associates at the Bureau of Standards*

| Assigned by— | Number | Specific project |
|---|---|---|
| American Association of Textile Chemists and Colorists, W. E. Hadley, secretary, care of Clark Thread Co., Newark, N. J. | 1 | Assisting in study of methods for testing fastness to light of dyed fabrics. |
| American Chemical Society, rubber section, Mills Building, Washington, D. C. | 1 | Physical testing of rubber. |
| American Dental Association, Columbus, Ohio | 3 | Study of dental materials. |
| American Electric Railway Association, care of R. H. Dalgleish, president, Capital Traction Co., Washington, D. C. | 1 | Testing of oils for use on street railways. |
| American Electroplaters Society, George Gehling, secretary-treasurer, 5001 Edmund Street, Philadelphia, Pa. | 2 | Spotting out of plated finishes. |
| American Face Brick Association, 130 North Wells Street, Chicago, Ill. | 1 | Prevention of stain on brick structures. |
| American Foundrymen's Association, Cleveland, Ohio | 1 | Liquid shrinkages in metals. |
| American Gas Association, 342 Madison Avenue, New York, N. Y. | 3 | Methods of testing gas appliances to determine their safety. |
| American Petroleum Institute, 250 Park Avenue, New York, N. Y. | 7 | Thermodynamic properties of petroleum products; corrosion in pipe lines. |
| American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York, N. Y. | 2 | Steam tables. |
| American Society for Testing Materials, 1315 Spruce Street, Philadelphia, Pa. | 3 | Cement testing. |
| Asphalt Shingle and Roofing Institute, 285 Madison Avenue, New York, N. Y. | 1 | Relative values of different fibers used in roofing felt. |
| Associated Knit Underwear Manufacturers of America (Inc.), 329 Main Street, Utica, N. Y. | 1 | Standardization and simplification of underwear sizes. |
| Atlas Lumnite Cement Co., 25 Broadway, New York, N. Y. | 3 | Properties of high alumina cement. |
| Brown Co., Berlin, N. H | 2 | Permanency of papers. |
| Bunting Brass & Bronze Co., 715–755 Spencer Street, Toledo, Ohio. | 1 | Testing of bronze. |
| Bureau of Efficiency, Washington, D. C | 1 | Durability of currency paper. |
| Cast Iron Pipe Research Association, 566 Peoples Gas Building, Chicago, Ill. | 2 | Study of cause of soil corrosion of cast-iron pipe. |
| Celite Co., Los Angeles, Calif | 2 | Investigation of workability of concrete. |
| Celotex Co., 645 North Michigan Boulevard, Chicago, Ill. | 1 | Heat transmission of materials. |
| Cerro de Pasco Copper Corporation, 44 Wall Street, New York, N. Y. | 1 | Development of new uses for metallic bismuth. |
| Committee on Glass, E. C. Sullivan, chairman, Corning Glass Works, Corning, N. Y. | 1 | Research in physical properties of glass. |
| Common Brick Manufacturers Association of America, 2121 Guarantee Title Building, Cleveland, Ohio. | 1 | Sound measurements and compression tests of brick walls. |
| Copper and Brass Research Association, 25 Broadway, New York, N. Y. | 1 | Investigation of safe loading of corrugated copper roofing, etc. |
| Cotton Textile Institute (Inc.), 320 Broadway, New York, N. Y. | 3 | Study of specific uses for cotton materials. |
| Dardelet Thread Lock Corporation, 120 Broadway, New York, N. Y. | 6 | Investigation of Dardelet lock thread. |
| Department of Scientific and Industrial Research, London, England. | 1 | Research in Portland cement. |
| Elevator Safety Code Committee, subcommittee on research, approval, and interpretation, American Standards Association (formerly American Engineering Standards Committee), 29 West Thirty-ninth Street, New York, N. Y. | 3 | Elevator safety equipment; development of methods and instruments; construction, maintenance, operation, etc. |
| Engineering Foundation, 29 West Thirty-ninth Street, New York, N. Y. | 1 | Preparation of bibliography on wire rope. |
| Hugh L. Cooper Co., 101 Park Avenue, New York, N. Y. | 1 | Clays in concrete mixtures. |
| Indiana Limestone Co., Bedford, Ind | 1 | Properties of Indiana limestone; waterproofing, discoloring, etc. |
| International Association of Electrotypers of America, George C. Stock, field secretary, Leader Building, Cleveland, Ohio. | 1 | Nickel electrotyping. |
| International Education Board, 61 Broadway, New York, N. Y. | 1 | Spectroscopic research. |
| Marine Underwriters Committee, 82 Beaver Street, New York, N. Y. | 1 | Investigation of spontaneous combustion in jute fibers, etc. |
| Metalloid Co., 53 West Jackson Boulevard, Chicago, Ill. | 1 | Study of composition and absorptive properties of metalloid and similar clarifying agents. |
| Midvale Co., Nicetown, Philadelphia, Pa | 1 | High-temperature testing of metals. |
| National Association of Glue Manufacturers, J. R. Powell, consulting secretary, Armour Glue Works, 1355 West Thirty-first Street, Chicago, Ill. | 1 | Glue for use in paper sizing. |
| National Association of Hosiery & Underwear Manufacturers, 334 Fourth Avenue, New York City. | 2 | Development of methods of measuring hosiery; standardization of twist with respect to dye application. |
| National Lead Co., 105 York Street, Brooklyn, N. Y | 1 | Research in pigments. |

*Research associates at the Bureau of Standards*—Continued

| Assigned by— | Number | Specific project |
|---|---|---|
| National Research Council, Washington, D. C. | 8 | Testing materials; structure of the alkali atoms; insulating liquids. |
| National Terra Cotta Society, 19 West Forty-fourth Street, New York, N. Y. | 3 | Investigation of architectural terra cotta. |
| Phillips Petroleum Co., Bartlesville, Okla. | 1 | Design of burners for propane gas. |
| Portland Cement Association, 33 West Grand Avenue, Chicago, Ill. | 7 | Constitution and hardening of Portland cement. |
| Society of Automotive Engineers, (Inc.), 29 West Thirty-ninth Street, New York, N. Y. | 4 | Vapor lock; cooperative fuel research. |
| Steel Castings Development Bureau, 500 Stock Exchange Building, Philadelphia, Pa. | 1 | Research in steel castings. |
| Steel & Tubes (Inc.), Cleveland, Ohio | 3 | Tension and compression tests of steel tubing. |
| United States Manufacturers of Cream of Tartar (Inc.), 39 West Thirty-eighth Street, New York, N. Y. | 1 | Physical and chemical characteristics of baked products. |
| Welded Steel Tubes (Inc.), 224 East One hundred and thirty-first Street, Cleveland, Ohio. | 1 | Preparation of reports on tubes. |

## TESTING RAILROAD-TRACK AND OTHER SCALES ($49,085)

*Railroad-track scales.*—A total of 726 tests of railroad-track scales in 23 States was made. Of this number 434 were owned by railroads, 288 by industries, 4 by the Federal Government, and 1 by a municipality. Fifty-four scales were adjusted to improve their weighing accuracy, and faulty mechanical conditions in 12 scales were corrected by bureau inspectors.

*Track-scale test results.*—Of the scales tested 71.8 per cent were correct within the prescribed tolerance. The average error for all scales tested was 0.20 per cent of the applied test loads. Both of the figures establish new records for accuracy. Corresponding figures for the preceding year were 70 and 0.23 per cent, respectively.

The comparative standing of the eastern, southern, and western districts with regard to the proportion of correct scales is represented by the respective values 68.2, 65.4, and 75 per cent.

*Master-track scale tests.*—Fifteen of the 19 master-track scales in use throughout the United States were tested. With the exception of two scales which had undergone overhauling or modification since the last preceding test, all proved to be accurate within the "maintenance tolerance" which allows maximum weighing errors of approximately 0.02 per cent of the test load values.

*Track scales for weighing grain.*—Ninety-seven of the scales tested this year were in grain weighing service and therefore subject to a special tolerance fixed by the Interstate Commerce Commission. Forty-three scales or 44.3 per cent were within the tolerance. The average weighing error for all scales was 0.15 per cent. Repeated tests of grain weighing track scales show that the majority of this equipment is not adapted for service under the special tolerance requirement and that frequent repair and adjustment of the equipment do not compensate for deficiencies of design or construction.

*Test car calibrations in the field.*—Twenty-seven track-scale test cars were weighed by substituting them against the standard weights of the field units. This service is extended at remote points where transportation of a test car to a master scale would be impractical or where the test car wheel base exceeds the rail length of the conventional master scale. Recently, several cars of long wheel base

type have been modified to allow ready conversion to a short wheel base.

*Bureau master scale and test car depot.*—New load-bearing blocks of improved design were made and installed in the longitudinal extension levers of the master scale at Clearing. With the exception of more or less slight functional variations, the performance of the scale has since been satisfactory.

Forty-four track-scale test cars received at the depot this year were weighed and adjusted to standard weight value. A seal designating formal certification of the car as a test weight was affixed to each car designed and built according to approved standards.

*Research and investigation.*—A cooperative activity with the National Scale Men's Association resulted in a set of specifications formally approved by that association for the repair of heavy capacity scales.

*Cooperation with States in weights and measures matters.*—Formal conferences of State and local weights and measures officials have been attended in Indiana, Maine, Massachusetts Michigan, Minnesota, New Jersey, New York, Ohio, Pennsylvania, Texas, and Virginia. Incident to these meetings, conferences have been held with officials in Alabama, Delaware, Georgia, and Tennessee.

*Cooperation with other Government departments.*—Numerous consultations have been held with representatives of other Federal departments and of the District of Columbia on questions of weighing scales, measures, etc., and a considerable amount of equipment has been examined or tested for the agencies mentioned.

### STANDARDIZATION OF EQUIPMENT ($192,123)

*General conferences on simplified practice.*—Sixteen general conferences were held to adopt simplified practice recommendations. The first general conference in connection with a new service of the division of simplified practice resulted in the adoption of a regional recommendation. Simplified practice recommendations have been accepted covering 98 commodities and 14 simplified practice recommendations and 1 regional recommendation are now in process of acceptance. Printed recommendations have been issued for 88 commodities.

*Number of acceptances to simplified practice recommendations.*—A total of 1,199 acceptances have been received from trade associations and other organized groups, as well as individual acceptances from 20,790 manufacturers, distributors, and users.

*Revision and reaffirmation conferences.*—Forty-one conferences were held by the members of the industries concerned, resulting in the revision of items in 10 of the simplified practice recommendations already in effect and the reaffirmation of 31 recommendations, or 75.5 per cent. This shows an increasing stability in simplified practice recommendations over last year when only 25, or 67.5 per cent of the 37 recommendations reviewed, were reaffirmed without change.

*Adherence to simplified practice recommendations.*—Field surveys showed that the average degree of adherence for 26 commodities was 85.43 per cent. This compares favorably with the figure for the previous year which was 86.86 per cent and covered 30 commodities.

*Degree of adherence obtained by actual survey*

| S. P. R. No. | Commodity | Degree of adherence | S. P. R. No. | Commodity | Degree of adherence |
|---|---|---|---|---|---|
| | | *Per cent* | | | *Per cent* |
| 1 | Vitrified paving brick | 70.10 | 48 | Shovels, spades, and scoops | 96.62 |
| 4 | Asphalt | 91.00 | 50 | Bank checks and other commercial instruments | 82.64 |
| 6 | Files and rasps | 93.14 | 51 | Die-head chasers | 100.00 |
| 7 | Face and common brick | 89.00 | 52 | Staple vitreous china plumbing fixtures | 88.77 |
| 17 | Forged tools | 93.00 | 54 | Sterling silver flatware | 94.89 |
| 20 | Steel barrels and drums | 90.83 | 60 | Packing of carriage, machine, and lag bolts | 67.14 |
| 22 | Paper | 64.78 | 61 | White glazed tile and unglazed ceramic mosaic | 86.63 |
| 26 | Steel reinforcing bars | 96.21 | 62 | Metallic cartridges | 99.00 |
| 28 | Sheet steel | 94.28 | 75 | Composition blackboard | 86.54 |
| 29 | Eaves trough and conductor pipe | 93.55 | 79 | Malleable foundry refractories | 64.31 |
| 30 | Roofing ternes | 100.00 | | Average | 85.43 |
| 31 | Loaded paper shot shells | 80.45 | | | |
| 36 | Milling cutters | 54.40 | | | |
| 41 | Insecticides and fungicides | 82.00 | | | |
| 43 | Paint and varnish brushes | 85.64 | | | |
| 46 | Tissue paper | 76.50 | | | |

*Field surveys in progress.*—Surveys of existing varieties are in progress for 20 industries.

*Benefits of simplified practice.*—Correspondence from the acceptors of simplified practice recommendations continues to bring in interesting examples of savings that are being effected. The ultimate realization of the potential benefits of simplified practice by the consumers of the country will, of course, take some time, but indications, of which the following is a sample, clearly illustrate that none of the claims made for it are beyond the realm of probability:

> On the item of shovels alone we are pleased to advise that, due to the elimination of a vast number of sizes and styles, our inventory on this line has been cut practically in two, without any complaints whatever from the consuming trade. This proved of such benefit to us that after the inventory was straightened out and the old sizes disposed of we were able, in January of this year (1929), to reduce our prices to the consuming trade ranging from $1 to $2.50 per dozen.

*Regional recommendations.*—The division of simplified practice has been developing a new service to industry, in the form of regional recommendations. Hitherto the work has been confined to projects which, from their inception, were national in scope. It has, however, become increasingly evident that there is a large field for service in programs covering only a part of the United States. Obviously, some limit must be set up beyond which the bureau can not be expected to go, and for the present it has been decided to limit this new activity to (*a*) natural products or commodities, the nature of which varies in different parts of the country, and (*b*) to programs which hold forth a definite promise of ultimately developing into national recommendations.

During the last quarter a general conference was held for the development of one such regional recommendation, covering screen sizes and terminology of high-volatile bituminous coal in the Great Lakes region.

*Commercial standards.*—This classification covers standards of grade, quality, measurement, tolerances, and other specification requirements established voluntarily by industry as a basis for marketing and certifying various commodities. In cooperation with the Bureau of Foreign and Domestic Commerce standards are translated into foreign languages as a basis for promoting foreign trade.

Fifteen general conferences were held, covering the following commodities: Surgical gauze, steel pipe nipples, wrought-iron pipe nipples, standard weight malleable iron or steel screwed unions, plain and thread plug and ring limit gage blanks, builders' template hardware, brass pipe nipples, regain of mercerized cotton yarns, domestic and industrial fuel oils, dress patterns, boys' blouses, waists, shirts, and junior shirts, men's pajamas, wall paper, diamond core-drill fittings, and hickory golf shafts.

A satisfactory majority of acceptances have been received and the success of the following projects has been announced: Stoddard solvent, staple porcelain (all clay) plumbing fixtures, steel pipe nipples, wrought-iron pipe nipples, brass pipe nipples, regain of mercerized cotton yarns, and dress patterns.

The following four commercial standards have been issued in printed form: Clinical thermometers (CS1–28), Stoddard solvent (CS3–28), staple porcelain (all-clay) plumbing fixtures (CS4–29), steel pipe nipples (CS5–29).

*Radiator investigation.*—To develop a logical basis and test for the rating of radiators used for heating purposes, a test room of average size was built, having one wall exposed to a refrigerated space, corresponding to the exterior wall of a building. In testing a radiator measurements are made of the useful heat output as well as the total heat output. The latter determines the capacity of the radiator, and the former is a measure of its effectiveness as a heater. The two factors are essentially independent, but it is hoped that they can be combined in such a way as to form a logical basis for ratings.

*Standardization of fire-control instruments for the Army.*—The Ordnance Department of the Army has adopted the plan of standardizing optical systems to govern the design of future fire-control instruments, which was proposed some years ago by a member of the bureau's staff. This will apply to all optical instruments controlled by the Ordnance Department and will result in greatly simplifying the problems of design, production, and maintenance.

*Dry-cell standardization.*—Qualification tests on dry cells collected at intervals of approximately six months have been in progress continuously.

*Specifications for storage batteries.*—Attention has been given to tests of storage batteries to obtain information necessary in preparing specifications for automotive and other types of batteries. While good progress has been made on the specifications for battery performance, the tests to determine quality of the cases are proving a serious obstacle.

*Safety codes.*—A report on dry cleaning was prepared for the National Safety Council. Sponsorship for the safety code for aeronautics was discontinued. In connection with the elevator safety code a handbook for elevator inspectors has been prepared. Members of the staff have participated actively in the work of the safety code correlating committee and in sectional committees preparing and revising safety codes for various industries. Codes for refrigeration, window washing, woodworking, factory lighting, street traffic signs, signals, and markings, and for floor openings, railings, and toeboards, were completed. Work was continued on codes for walkway surfaces, conveyors and conveying machinery, and colors of gas-mask canisters.

*Directories of laboratories.*—In a second revised edition of the Directory of Commercial Testing and College Research Laboratories data are given concerning the laboratories in 196 colleges, and 294 commercial testing laboratories, with 94 branch laboratories or offices. A directory of all Federal governmental testing laboratories has been prepared for the use of the Federal Government purchasing agents.

*Specifications in various industries.*—The second volume of the bureau's encyclopedia series, entitled "Standards and Specifications for Nonmetallic Minerals and Their Manufactures," has been prepared for printing.

*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 15,000 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.

*Facilitating the use of specifications.*—The certification plan has been so extended as to include commodities covered by a total of 248 United States Government master specifications. More than 7,500 separate requests for listing as willing to certify to compliance with the specification requirements have been received from about 2,000 manufacturers. 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.

### STANDARD MATERIALS ($10,824)

*Distribution of standard samples.*—A direct result of the use of the standard samples of ores, metallurgical products, and pure chemicals prepared and distributed by the bureau 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 salable samples has always exceeded the appropriation. In 1928 and 1929 $16,062 was received from the sale of 7,336 samples and approximately $45,000 worth of standard samples were added to the salable samples on hand.

### INVESTIGATION OF RADIOACTIVE SUBSTANCES AND X RAYS ($31,741)

*Measurement of X-ray dosage.*—A precise measurement of the intensity (power) of X rays is one of the most difficult problems associated with the study and application of this radiation. In therapeutic applications measurement of the dose administered is of prime importance, yet it was not until the 1928 international conference on X rays at Stockholm that a unit for expressing X-ray dosage and its method of measurement was agreed upon. Inasmuch as leading laboratories were then at variance in their measurements

of the same radiation by as much as 4 per cent of the magnitude involved, the bureau has been engaged in identifying the possible sources of the existing discrepancy, and has met with considerable success. The theory of the measurement remains unquestioned, but sufficient precautions do not appear to have been taken to insure that experimental conditions fulfilled the requirements of the theory.

*X-ray and radium protection.*—The (1928) International Congress on Radiology adopted proposals on X-ray and radium protection which various national committees have been formed to promulgate. A member of the bureau's staff was appointed chairman of our national committee.

*Tests of radioactive preparations.*—Upon these tests the prices of the preparations are based. During the year 1,050 preparations, ranging in radium content from 0.05 to 100 mg. and totalling 11,300 mg., were tested.

### UTILIZATION OF WASTE PRODUCTS FROM THE LAND ($53,148)

*Wall board from cornstalks.*—The bureau continued to operate the plant at Ames, Iowa, in cooperation with the Iowa State College, for the manufacture of insulating board from cornstalks. With new types of equipment recently installed wall board has been made with a thickness of ½ inch and twice as strong as any insulating board on the market. An insulating board designed for refrigerators, 2 inches thick without lamination, can also be made.

Small-scale experiments have been completed on the manufacture of pressed board from cornstalks, which is intended to be used as a substitute for lumber.

A process has been developed for the manufacture of a new material called maizolith, which is also made from cornstalks and has many characteristics of hard rubber or vulcanized fiber.

*Manufacture of xylose.*—Laboratory work on the manufacture of xylose from cottonseed hulls has been completed. The bureau has erected and is operating a semicommercial factory at the plant of the Federal Phosphorus Co., Anniston, Ala., in cooperation with the University of Alabama and the Alabama Polytechnic Institute. The factory is designed to make 100 pounds of xylose per day.

This factory started operation on March 16. It is planned to use other raw materials, such as peanut shells and corncobs, and to reduce cost and improve efficiency.

Samples of xylose are being supplied to interested individuals and concerns who are assisting in finding a market for the material. There is a possibility of it being used in the dyeing and tanning industries, for use in foodstuffs, for manufacture of chemicals, explosives, furfural, and for manufacture of alcohol to be used as solvent for lacquer, etc.

*Utilization of cornstalks.*—A field survey of the economic possibility of using cornstalks as an industrial raw material has been completed by an economist retained for the purpose. This included a study of the cost of collecting cornstalks, of the cost of manufacture of insulating board and wall board from competitive materials, and of the probable expansion of the markets of these products.

*Miscellaneous.*—Many preliminary investigations of other types of waste land products have been conducted. A study of the Texas

sunflower indicated small possibility of the industrial use of this plant at present.

Cotton burs were found to be high in potash and therefore valuable as a fertilizer.

Experiments with artichoke tops show that they can be used for the production of a strong brown paper.

Peanut shells contain a considerable quantity of xylose, and it is possible that the fiber left after the extraction of the xylose may have some value.

Complete chemical and microscopical analysis of wheat straw have been completed, the stem and the nodes being analyzed separately. Based on this information we have now started to investigate the paper-making qualities of straw.

The acid which is produced by the oxidation of xylose has certain characteristics which may make it of value in the tanning and dyeing industries. The bureau has produced this acid in the laboratory and is now investigating the optimum conditions for its manufacture.

### INVESTIGATION OF AUTOMOTIVE ENGINES ($26,833)

*Automobile engine acceleration.*—The effect of fuel characteristics and operating conditions on engine acceleration has been studied. To evaluate the influence of engine design, specified acceleration tests will be repeated by request on representative engines at the laboratories of certain automobile companies. These field tests will conclude one phase of the joint motor-fuel research started seven years ago in cooperation with the American Petroleum Institute, the National Automobile Chamber of Commerce, and the Society of Automotive Engineers.

*Phenomena of combustion.*—Using the soap bubble as a constant pressure bomb, an intensive study in cooperation with the National Advisory Committee for Aeronautics has been made of the explosive reaction with oxygen of butane and of composite fuels containing butane as one constituent. The results show that the relations already found to hold for simple gases and their mixtures hold also for complex hydrocarbon molecules. The equivalent reaction order of a composite fuel may be determined from the reaction orders of its components, and the velocity constant of the fuel may also be determined from the velocity constants of those components.

*Antiknock characteristics of fuels.*—The bureau is cooperating with representatives of the automotive and petroleum industries in an organized attempt to reach agreement upon satisfactory methods of measuring and expressing the tendency of motor fuels to knock or detonate. Specially designed detonation test engines have been distributed to the laboratories represented on the committee and each laboratory will make the same series of preliminary tests with this engine on six special fuels. The ultimate object is the general adoption of a common test engine and procedure as a tentative standard.

*Gasoline volatility.*—The final form of the correlation between the distillation curves of the American Society for Testing Materials and the complete equilibrium air-distillation data for 38 fuels, gains accuracy by taking into account the slope of the distillation curve, and appears to furnish a comprehensive answer to the problem of equilibrium volatility of hydrocarbon fuels of any degree of complexity in the temperature range covered by gasolines. This basic investiga-

tion should be supplemented by a study of the differences between volatility under equilibrium conditions and under nonequilibrium conditions such as exist in automotive engine manifolds.

*Vapor lock in airplane fuel systems.*—The investigation of vapor lock began with a study of the contribution of the various constituents of a gasoline to the total vapor pressure, when every opportunity was given for bubbles to form. Bubble formation and growth under typical flow conditions are at present being studied.

*Engine tests of lubricating oils.*—A six-cylinder bus engine has recently been set up for testing automobile engine oils under constant conditions, a reference oil being used to serve as a check on changes taking place in the engine itself. Tests thus far have been confined to the reference oil.

*Vibration of motor vehicles.*—Vertical accelerometers are used by the Bureau of Standards in estimating the comparative riding qualities of motor vehicles. They are also used by the Bureau of Public Roads in estimating the vertical impact forces which tend to wear out the road surface. A machine for calibrating such instruments has been set up at the Bureau of Standards, and the two bureaus are cooperating in the calibration of various types of vertical accelerometers.

*Automotive headlighting.*—The bureau has continued to cooperate with the Society of Automotive Engineers in the investigation of headlighting from the automobile driver's point of view. The light spread required for safe driving at various speeds over typical roads was determined photographically. A multiple-element photometer has been developed for estimating the approximate light intensity thrown in the driver's eyes when meeting another car on the road.

*Cooperative investigations in the automotive field.*—The appropriation for the automotive work is not sufficient to carry on investigations of fundamental importance in this field. However, it has been used as a nucleus for cooperative research in which other branches of the Government and industrial associations have joined. Some valuable research has thus been made possible.

### INVESTIGATION OF DENTAL MATERIALS ($5,421)

*Physical and chemical properties of dental materials.*—The investigation of the physical and chemical properties of inlay materials, amalgams, plasters, and waxes has continued, and purchase specifications have been drawn up for these materials. Assistance has been given to dental colleges, manufacturers, and dental testing laboratories in the design, selection, and installation of testing equipment for dental materials.

*Cooperative dental research.*—The dental research in cooperation with the American Dental Association, which was begun last year, has been continued and most satisfactory relations have been maintained. The $7,500 per year appropriated by the association for this work has made possible the establishment of one full-time research associateship and the part-time employment of two additional men. The progress made has been most gratifying to the bureau and, it is believed, satisfactory to the association. Defective dental materials and technics have been pointed out to the profession and to manufacturers, and improvement in the quality of certain materials is already apparent.

### POWER-PLANT EQUIPMENT ($100,000)

*Equipment.*—The boiler-room installation has been completed with the exception of two boilers which are to be moved from another location and for which a contract has been placed. Steam connections to the old plants have been completed and the new boiler plant will be in full operation beginning July, 1929.

*Cooling pond.*—Although the power-plant building proper was completed last year, one unit of the water-spray pond was completed this year. This pond will serve as a source of supply for condenser circulating water and will, when put in service, greatly conserve our water supply.

### TRANSFERRED FUNDS ($339,923)

*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:
- Lighting of airways.
- Radiobeacons.
- Testing of commercial airplane engines.

Bureau of Engraving and Printing:
- Electrodeposition problems.
- Paper currency.
- Postage stamps.

Bureau of Foreign and Domestic Commerce: Preparation of directories of specifications.

Coast and Geodetic Survey:
- Development of seismometers.
- Making of special castings.

National Advisory Committee for Aeronautics:
- Aerodynamics.
- Fatigue of duralumin.
- Light alloys for aircraft.
- Power plants.
- Steel and duralumin tubing.
- Substitutes for parachute silk.

Navy Department:
- Aircraft instruments.
- Airship girders.
- Altitude control of carburetors.
- Corrosion of metals.
- Gas-cell fabrics for airships.
- Gaseous fuels for aircraft.
- General aeronautical fabrics.
- Ignition systems for aircraft engines.
- Production of optical glass.
- Storage batteries for submarines.

War Department:
- Application of supercharger to Curtiss airplane engine.
- Bomb ballistics.
- Development of machine guns.
- Embrittlement of duralumin.
- Experimental length gages.
- Problems of friction and lubrication.
- Radio transmission.

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:

*Type testing of commercial airplane engines.*—The importance of testing new designs of commercial engines before permitting their use in licensed aircraft is shown by the fact that of 24 engines received for test 12 failed, 5 were withdrawn, and 7 were approved. The failures were due in many cases to faults which would have been evident to the manufacturer had he done more adequate preliminary testing. Three engines which failed initially were corrected and have passed a second test. Engine-testing equipment, including three complete torque stand units, has been installed at Arlington Farms. This plant takes the place of a single test stand at College Park and will permit testing on the average of one engine a week.

*Effect of spark character on ignition ability.*—A single-cylinder testing engine is being used under controlled operating conditions to ascertain whether one type of spark is superior to another in its ability to ignite the mixtures which actually occur in engines. Methods have been devised for estimating the "dryness" of the explosive charge at the end of the compression stroke and for comparing the "sphere of influence" of different sparks. The efficiency of aircraft ignition systems shielded to prevent interference with radio communication is also being studied. This work was supported jointly by the National Advisory Committee for Aeronautics and the Bureau of Aeronautics of the Navy Department.

*Prevention of embrittlement of duralumin by corrosion and of deterioration of magnesium alloys by corrosion.*—Two more technical notes on the progress of the work, which is supported by the Navy Department, War Department, and National Advisory Committee for Aeronautics, have been published by the last-named organization. Two other progress reports were published.

Exposure tests at the bureau, Hampton Roads, Va., and Coco Solo, Canal Zone, on bare and coated duralumin and magnesium or magnesium alloy specimens are in progress. A total of 2,373 exposure or control specimens remain to be tested. So far no thoroughly satisfactory protective coating has been found other than pure aluminum, which has so far been applied only to duralumin. All exposure and laboratory tests continue to show that duralumin quenched in cold water and naturally aged is greatly superior to that quenched in hot water or oil, and to that aged at elevated temperatures. The Alclad duralumin is extremely resistant to the type of corrosion that causes embrittlement. Even under repeated flexure and corrosion combined, the most severe set of conditions that can be met, the Alclad duralumin was vastly superior. Under severe corrosion and in repeated flexure at 10,000 pounds per square inch hot-water quenched duralumin broke in 5 days, cold-water quenched lasted 30 days, but became brittle in 7 days, while Alclad duralumin was unharmed after 24 days and ran 65 days without breaking. The life of the Alclad duralumin when tested at three times the stress, 31,000 pounds per square inch, was about the same as the cold-water quenched bare durlaumin at 10,000 pounds per square inch. Alclad duralumin is an outgrowth, in commercial hands, of fundamental data obtained by the bureau in this cooperative work, on the good protection afforded by an aluminum coating, and is now in wide commercial use in aircraft.

*Nickel deposition.*—A study of the colorimetric and electrometric methods of measuring the pH or acidity of nickel-plating solutions was conducted, and the corrections to be applied to colorimetric readings were determined.

*Iron deposition.*—Experiments on the electrolytic production of iron printing plates have been continued. One unit for carrying out this process is just being installed at the Bureau of Engraving and Printing.

*Gas-cell fabrics.*—Practical tests of gas cells constructed with the new gas-cell fabric developed at the bureau have shown that the rubber film in the fabric needs improvement. Considerable time has been spent in the factory where the large-scale production of this fabric has been undertaken, in order that the experience gained at the bureau might be translated into industrial practice. Some preliminary tests indicate that a new type of gas-impermeable material, quite different from the fabric referred to above, offers considerable promise. It will be further investigated.

*Aircraft in commerce—Radio.*—In cooperation with the Aeronautics Branch of the Department of Commerce a new visual type of beacon transmitter was developed, marking out any number of courses, up to 12, at any desired angles. Changes were made in the visual receiving indicator to improve its operating characteristics and to adapt it to the use of the new beacon. A method for aiding landing in fog was designed and the equipment constructed. Methods of shielding airplane engine ignition systems were studied; in cooperation with the aircraft and radio industries a shielding assembly was developed which is satisfactory from an airplane operating standpoint and also effective from a radio standpoint. Manufacturers of radio receiving sets for use on airplanes submitted preliminary designs of their sets and suggestions were made as to improvements in design. The development of a direction finder for use aboard aircraft, with visual indication, was begun. A complete installation of shielding and radio receiving equipment was made on an airplane of Pitcairn Aviation (Inc.).

*Lighting of airways.*—A series of field observations on an experimental beacon consisting of a neon lamp, an incandescent lamp with red color filter matching the neon color, and a clear incandescent lamp, was made during foggy weather. It was found that neon light has no superiority over light of the same color and intensity from incandescent lamps as regards visibility through fog, haze, rain, or clear air.

A series of tests on different methods of illuminating wind-indicator cones is in progress, and an improved reflector system for lighting the indicators has been developed.

*Vertical component seismometer.*—A design has been completed and construction started on a vertical component seismometer for the Coast and Geodetic Survey. This seismometer is to be equipped for electromagnetic and optical magnification and electromagnetic damping and will form a companion instrument to two horizontal component seismometers of the type previously developed in this bureau.

*Wind-tunnel turbulence.*—Measurements of the turbulence in the bureau's three wind tunnels have been completed. It has been found that the effects of turbulence afford a fairly complete explana-

tion of the discrepancies in the results obtained in different wind tunnels with the airship models circulated by the National Physical Laboratory.

*High-speed airfoil tests.*—Results of measurements of the aerodynamic characteristics of 24 airfoils at speeds up to and slightly above the speed of sound have been published by the National Advisory Committee for Aeronautics.

*Aileron investigation.*—Results of work for the Aeronautics Branch of the Department of Commerce on the effect of variation of chord and span of ailerons on rolling and yawing moments in level flight has been published by the National Advisory Committee for Aeronautics.

*Strength of aircraft tubing.*—The strength of tubing has been found to depend greatly upon the yield point of the material. As the yield point of the tubing used in this investigation was considerably higher than the specified minimum, it seems possible to raise the yield point requirements and thus use higher stresses with safety.

*Airship girders.*—Further developments have been made leading to more economical inspection testing of these girders. Comparative tests at the bureau and the Goodyear Zeppelin Corporation have been carried out in connection with the new 6,500,000 cubic-foot airship now building for the Navy.

*Aircraft instrument investigation.*—Investigations to provide a basis for the specification of performance of aircraft instruments have been carried out for the Bureau of Aeronautics on bank indicators, altimeters, tachometers, air-speed indicators, oxygen equipment, and bakelite cases.

## GENERAL RECOMMENDATIONS

There was set forth in last year's report a detailed statement of some of the more urgent needs of the Bureau of Standards for its future development, and this program has been indorsed by the visiting committee. It includes more adequate support for fundamental research relating to standards and the determination of fundamental constants of importance to science and industry, including further development of cooperative research with industry; the further extension of the commercial standards group in its program of cooperation with business; and a building program.

The building program includes a hydraulic laboratory, the authorization for which passed the Senate but was not reported out of committee in the House at the last session of Congress; the remodeling of the North Building, which has heretofore been a combination of power plant and shop building into a structure to house all the bureau's shops; the construction of a greatly needed central administration building to relieve much-needed space for laboratories in other buildings and provide suitable quarters for the commercial standards group which was recently transferred from down town, resulting in very serious congestion, and also providing for adequate space for library, auditorium, and the central administrative functions; and a building for high-voltage standardization, testing, and research, of special design to enable the bureau to carry out such operations at 1,000,000 volts. To meet the needs of the Federal Radio Commission and keep pace with requirements in the increase of accuracy of radio transmission, provision should be made for sending and receiving stations in the suburbs of Washington. There also will be required eventually

a building to house the fire-resistance work of the bureau; a new mechanical laboratory suitably designed to house heavy equipment for tests and investigation of large structures; enlargement of the dynamometer laboratory for research relating to automotive and aircraft engines; enlargement of the laboratory for low-temperature research; and provision should eventually be made for a building to take care of expanding work, particularly relating to precision measurements in the weights and measures field.

As pointed out in previous reports, increased facilities and personnel are needed at the branch laboratories of the bureau in order to handle in a more satisfactory manner work relating to testing for the various Government departments, and in particular provision should be made for testing on a more comprehensive scale Government purchases of cement and other commodities.

Provision has not yet been made for establishing at the bureau a first-aid station, not only for accidents but for supervision of workers in such fields as radium, X rays, and furnace and chemical operations. I feel strongly that provision for such a station will greatly help the morale and health conditions of the employees working in these fields.

Very truly yours,

GEORGE K. BURGESS,
*Director, Bureau of Standards.*

# APPENDIX

## GENERAL FINANCIAL STATEMENT

During the fiscal year 1929 the bureau expended and accounted for funds aggregating $2,751,798.05, including $339,923.05 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., 1929, 1928, and 1927 appropriations*

| Appropriation | Total appropriation | Disbursements | Liabilities | Balance |
|---|---|---|---|---|
| 1929 | | | | |
| Salaries | $648,146.00 | $587,844.79 | $55,668.40 | $4,632.81 |
| Equipment | [1] 88,014.11 | 65,181.28 | 22,753.45 | 79.38 |
| General expenses | [2] 71,761.60 | 53,754.78 | 17,944.73 | 62.09 |
| Improvement and care of grounds | 14,431.00 | 11,390.06 | 3,027.39 | 13.55 |
| Testing structural materials | [3] 268,653.68 | 223,373.54 | 39,736.92 | 5,543.22 |
| Testing machines | 41,003.00 | 36,066.50 | 4,205.66 | 730.84 |
| Metallurgical research | 51,614.00 | 42,761.85 | 6,369.77 | 2,482.38 |
| Investigation of optical glass | 27,420.00 | 23,229.42 | 3,837.17 | 353.41 |
| Standard materials | 10,824.00 | 9,631.48 | 1,022.90 | 169.62 |
| Investigation of textiles | 54,144.00 | 48,268.50 | 5,775.54 | 99.96 |
| Sugar standardization | [4] 61,027.00 | 50,963.54 | 10,013.91 | 49.55 |
| Gage standardization | 40,713.00 | 36,499.89 | 3,549.67 | 663.44 |
| High-temperature investigation | 10,401.00 | 7,249.99 | 2,119.16 | 1,031.85 |
| Testing railroad scales | 49,085.00 | 42,633.22 | 6,253.70 | 198.08 |
| Investigation of fire-resisting properties | 30,213.00 | 27,009.14 | 2,619.30 | 584.56 |
| Testing miscellaneous materials | 47,125.00 | 42,373.75 | 4,642.55 | 108.70 |
| Investigation of public utility standards | [5] 107,715.19 | 95,221.93 | 11,074.39 | 1,418.87 |
| Radio research | [6] 56,429.03 | 51,674.32 | 4,658.20 | 96.51 |
| Industrial research | [7] 205,679.78 | 162,648.40 | 41,349.36 | 1,682.02 |
| Sound investigation | 11,469.00 | 10,117.28 | 1,192.85 | 158.87 |
| Investigation of clay products | 49,370.00 | 43,417.92 | 3,722.57 | 2,229.51 |
| Color standardization | 10,950.00 | 10,785.52 | 144.87 | 19.61 |
| Investigation of radioactive substances and X rays | 31,741.00 | 27,850.86 | 3,786.66 | 103.48 |
| Standardizing mechanical appliances | 29,677.00 | 24,196.04 | 5,067.16 | 413.80 |
| Investigation of mine scales and cars | 13,688.00 | 8,316.66 | 5,233.52 | 137.82 |
| Standardization of equipment | [8] 192,584.51 | 164,199.58 | 23,509.98 | 4,874.95 |
| Investigation of automotive engines | 26,833.00 | 25,904.01 | 554.23 | 374.76 |
| Utilization of waste products from the land | 53,148.00 | 41,704.17 | 7,599.08 | 3,844.75 |
| Investigation of dental materials | 5,421.00 | 4,439.70 | 818.30 | 163.00 |
| Power-plant equipment | 100,000.00 | 69,180.89 | 30,670.73 | 148.38 |
| Testing structural materials, 1929–30 | 12,500.00 | 459.60 | 216.66 | 11,823.74 |
| Appropriations transferred from other departments which are available for the current year: | | | | |
| Aircraft in commerce | [9] 140,360.00 | 125,802.14 | 14,151.51 | 406.35 |
| Party expenses, Coast and Geodetic Survey, 1929 | 2,000.00 | 1,710.00 | 217.75 | 72.25 |
| Incidental expenses of Army | 10,000.00 | 8,066.24 | 1,903.89 | 29.87 |
| National Advisory Committee for aeronautics | 43,372.15 | 33,762.20 | 9,582.29 | 27.66 |
| Air Corps, Army | 11,500.00 | 7,398.40 | 4,083.13 | 18.47 |
| Signal Service of Army | 1,800.00 | 1,741.27 | 40.67 | 18.06 |
| Materials and miscellaneous expenses, Bureau of Engraving and Printing, 1929 | 15,000.00 | 12,738.11 | 2,120.54 | 141.35 |
| Aviation, Navy | 66,140.00 | 53,399.80 | 12,525.63 | 214.57 |
| Export industries, Bureau of Foreign and Domestic Commerce | 2,640.00 | 2,066.64 | 542.84 | 30.52 |
| General expenses, Coast and Geodetic Survey, 1929 | 200.00 | 200.00 | | |
| Air navigation facilities | 15,700.00 | 4,494.73 | 11,187.73 | 17.54 |
| Appropriations transferred from other departments which are available for a period of two years: | | | | |
| Gages, dies, and jigs for manufacture | 2,750.00 | 1,466.67 | 560.00 | 723.33 |
| Ordnance stores, ammunition, 1929–30 | 1,000.00 | 265.00 | 128.78 | 606.22 |
| Ordnance and ordnance stores | 12,000.00 | 8,005.00 | 617.00 | 3,378.00 |
| Safeguarding dome of rotunda, 1929–30 | 3,000.00 | 1,320.05 | | 1,679.95 |
| Automatic rifles, 1929–30 | 2,555.00 | 916.63 | 493.32 | 1,145.05 |
| Total | 2,751,798.05 | 2,311,701.49 | 387,293.86 | 52,802.70 |

See footnotes at end of table.

*Disbursements, liabilities, etc., 1929, 1928, and 1927 appropriations*—Continued

| Appropriation | Total appropriation | Disbursements | Liabilities | Balance |
|---|---|---|---|---|
| **1928** | | | | |
| Salaries | $572,060.00 | $571,685.41 | | $374.59 |
| Equipment | 88,000.00 | 86,215.35 | $1,571.15 | 213.50 |
| General expenses | [10] 71,856.36 | 70,502.33 | 154.16 | 1,199.87 |
| Improvement and care of grounds | 13,000.00 | 12,883.53 | | 116.47 |
| Testing structural materials | [11] 241,897.38 | 241,064.54 | | 832.84 |
| Testing machines | [12] 38,025.00 | 37,753.37 | | 271.63 |
| Metallurgical research | [13] 48,414.92 | 48,229.18 | | 185.74 |
| Investigation of optical glass | 20,520.00 | 20,457.48 | | 62.52 |
| Standard materials | 10,000.00 | 9,922.19 | | 77.81 |
| Investigation of textiles | 40,700.00 | 40,462.49 | | 237.51 |
| Sugar standardization | [14] 50,960.00 | 50,692.40 | | 267.60 |
| Gage standardization | 38,320.00 | 38,214.76 | | 105.24 |
| High-temperature investigation | 9,740.00 | 9,732.09 | | 7.91 |
| Testing railroad scales | 47,000.00 | 46,965.27 | | 34.73 |
| Investigation of fire-resisting properties | 28,100.00 | 27,821.02 | | 278.98 |
| Testing miscellaneous materials | 44,000.00 | 43,985.05 | | 14.95 |
| Investigation of public utility standards | [15] 100,282.46 | 100,009.23 | | 273.23 |
| Radio research | 49,800.00 | 49,669.96 | | 130.04 |
| Industrial research | [16] 175,860.00 | 175,411.69 | | 448.31 |
| Sound investigation | 10,580.00 | 10,517.65 | | 62.35 |
| Investigation of clay products | 47,000.00 | 46,579.21 | | 420.79 |
| Color standardization | 10,000.00 | 9,829.64 | | 170.36 |
| Investigation of radioactive substances and X rays | 29,540.00 | 29,212.33 | 221.00 | 106.67 |
| Standardizing mechanical applicances | 27,800.00 | 27,633.33 | | 166.67 |
| Investigation of mine scales and cars | 12,800.00 | 12,750.64 | | 49.36 |
| Standardization of equipment | [17] 130,135.50 | 130,091.49 | | 44.01 |
| Investigation of automotive engines | [18] 27,700.00 | 27,345.94 | | 354.06 |
| Utilization of waste products from the land | 50,000.00 | 49,732.27 | | 267.73 |
| Investigation of dental materials | 5,000.00 | 4,983.60 | | 16.40 |
| Power-plant equipment | 100,000.00 | 98,081.23 | 1,830.00 | 88.77 |
| Sugar standardization, 1928–29 | 25,000.00 | 23,189.19 | 1,789.23 | 21.58 |
| Standardization of equipment, 1928–29 | 15,000.00 | 13,502.30 | 1,265.73 | 231.97 |
| Radio research, 1928–29 | 30,000.00 | 18,534.79 | 11,426.40 | 38.81 |
| Salaries, 1928–29 | 35,000.00 | 32,664.76 | 2,274.97 | 60.27 |
| Color standardization | 5,000.00 | 3,480.63 | 863.74 | 655.63 |
| Furnaces and shelter, 1928–29 | 22,000.00 | 6,419.03 | 15,571.30 | 9.67 |
| Appropriations transferred from other departments which are available for the current year: | | | | |
| Aircraft in commerce | [19] 110,000.00 | 108,608.27 | 874.21 | 517.52 |
| Incidental expenses of the Army | 10,000.00 | 9,910.79 | | 89.21 |
| Compensation of employees, Bureau of Engraving and Printing | 11,000.00 | 10,913.94 | | 86.06 |
| Export industries, Bureau of Foreign and Domestic Commerce | 2,820.00 | 2,765.82 | | 54.18 |
| National Advisory Committee for Aeronautics | 34,900.00 | 34,605.16 | | 294.84 |
| Aviation, Navy | 77,500.00 | 76,727.01 | 5.00 | 767.99 |
| Air Corps, Army | 2,500.00 | 2,419.00 | | 81.00 |
| Signal Service of Army | 1,800.00 | 1,695.42 | | 104.58 |
| Air navigation facilities | 234.50 | 234.50 | | |
| Appropriations transferred from other departments which are available for a period of two years: | | | | |
| Ordnance and ordnance stores | 12,000.00 | 11,775.44 | | 224.56 |
| Ordnance stores, ammunition, 1928–29 | 1,000.00 | 896.06 | 55.00 | 48.94 |
| Air Corps, Army | 500.00 | 425.71 | | 74.29 |
| Automatic rifles, 1928–29 | 2,000.00 | 1,836.63 | | 163.37 |
| Gages, dies, and jigs for manufacture | 2,750.00 | 2,616,62 | | 133.38 |
| Total | 2,540,096.12 | 2,491,655.74 | 37,901.89 | 10,538.49 |
| **1927** | | | | |
| Salaries | 567,320.00 | 556,424.91 | | 10,895.09 |
| Equipment | 88,000.00 | 86,119.82 | | 1,880.18 |
| General expenses | [20] 71,968.31 | 70,223.49 | | 1,744.82 |
| Improvement and care of grounds | 12,000.00 | 11,811.31 | | 188.69 |
| Testing structural materials | [21] 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 | [22] 36,000.00 | 35,260.52 | | 739.48 |
| Sugar standardization | [23] 40,960.00 | 40,559.13 | | 400.87 |
| Gage standardization | 38,320.00 | 37,644.82 | | 675.18 |
| High-temperature investigation | 9,740.00 | 9,437.82 | | 302.18 |
| Testing railroad scales | 39,000.00 | 38,141.03 | | 858.97 |
| Investigation of fire-resisting properties | 28,100.00 | 26,926.37 | | 1,173.63 |
| Testing miscellaneous materials | 44,090.00 | 42,254.84 | | 1,835.16 |
| Investigation of public utility standards | 100,000.00 | 99,148.19 | | 851.81 |

See footnotes at end of table.

*Disbursements, liabilities, etc., 1929, 1928, and 1927 appropriations*—Continued

| Appropriation | Total appropriation | Disbursements | Liabilities | Balance |
|---|---|---|---|---|
| 1927—Continued | | | | |
| Radio research | $49,800.00 | $48,173.91 | | $1,626.09 |
| Industrial research | [24] 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 | 8,345.65 | | 654.35 |
| Investigation of radioactive substances | 9,540.00 | 9,281.53 | | 258.47 |
| Standardizing mechanical appliances | [25] 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 | [26] 116,000.86 | 109,734.74 | | 6,266.12 |
| Investigation of automotive engines | 25,000.00 | 24,330.60 | | 669.40 |
| Sugar standardization, 1926–27 | 25,000.00 | 24,346.62 | | 653.38 |
| Master track scale and test car depot | 50,000.00 | 49,524.59 | | 475.41 |
| Building for power plant | 200,000.00 | 194,060.88 | $930.00 | 5,009.12 |
| 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 | 1,946.45 | | 53.55 |
| Signal Service of the Army | 1,800.00 | 1,790.40 | | 9.60 |
| Aircraft in commerce | 93,809.25 | 93,518.54 | | 290.71 |
| Oil, gas, and oil-shale investigation, Bureau of Mines | [27] 5,410.00 | 5,375.00 | | 35.00 |
| Aviation, Navy | 81,900.00 | 81,494.15 | | 405.85 |
| 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 | [28] 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 two years: | | | | |
| Ordnance and ordnance stores | 13,400.00 | 13,327.38 | | 72.62 |
| Gages, dies, and jigs, for manufacture | 5,750.00 | 5,719.90 | | 30.10 |
| Air Service of the Army | 1,000.00 | 887.50 | | 112.50 |
| Total | 2,474,589.73 | 2,419,051.62 | 930.00 | 54,608.11 |

Includes reimbursements and transfers received from other departments as follows:

[1] $14.11.
[2] $1,906.60.
[3] $1,595.68.
[4] $2,800.
[5] $418.19.
[6] $657.03.
[7] $2,052.78.
[8] $461.51.
[9] $360.
[10] $2,001.36.
[11] $1,897.38.
[12] $25.
[13] $274.92.
[14] $2,800.
[15] $282.46.
[16] $3,540.
[17] $135.50.
[18] $2,700.
[19] $500 transferred back to Aeronautics Branch.
[20] $3,613.31.
[21] $3,186.12.
[22] $1,000.
[23] $2,800.
[24] $5,700.
[25] $415.
[26] $1,000.86.
[27] $1,395.
[28] This fund was reappropriated from the unincumbered balance of the 1926 appropriation.