

DEPARTMENT OF COMMERCE

BUREAU OF STANDARDS

George K. Burgess, Director

**ANNUAL REPORT OF DIRECTOR
OF THE BUREAU OF STANDARDS
FOR FISCAL YEAR ENDED JUNE 30, 1926**

MISCELLANEOUS PUBLICATIONS, BUREAU OF STANDARDS, No. 75

ANNUAL REPORT
OF THE
DIRECTOR OF THE BUREAU OF STANDARDS
TO THE
SECRETARY OF COMMERCE

FOR THE
FISCAL YEAR ENDED JUNE 30, 1926

(Miscellaneous Publication No. 75)

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CONTENTS

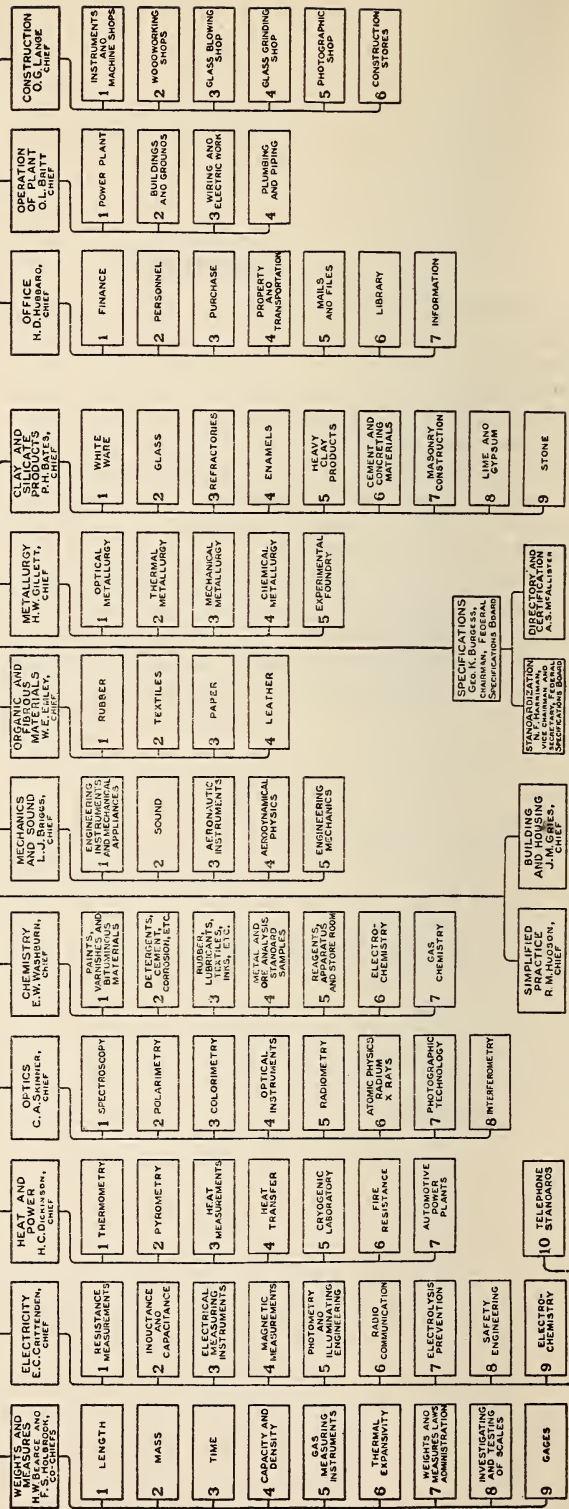
	Page
General activities.....	1
Salaries.....	5
Equipment.....	10
General expenses.....	10
Improvement and care of grounds.....	11
Testing structural materials.....	11
Testing machines.....	15
Investigation of fire-resisting properties.....	17
Investigation of public utility standards.....	17
Testing miscellaneous materials.....	19
Radio research.....	19
Color standardization.....	20
Investigation of clay products.....	20
Standardizing mechanical appliances.....	22
Investigation of optical glass.....	23
Investigation of textiles.....	24
Sugar standardization.....	25
Gauge standardization.....	26
Investigation of mine scales and cars.....	27
Metallurgical research.....	27
High-temperature investigations.....	29
Sound investigation.....	29
Industrial research.....	29
Cooperation with industry.....	34
Testing railroad-track and other scales.....	35
Standardization of equipment.....	36
Standard materials.....	40
Investigation of radioactive substances.....	41
Investigation of automotive engines.....	41
Transferred funds.....	42
General recommendations.....	43

BUREAU OF STANDARDS
CHART OF ORGANIZATION
JUNE 30, 1926

DIRECTOR'S OFFICE
DIRECTOR -- - GEORGE K. BURGESS
ASSISTANT DIRECTOR -- - F. C. BROWN

SCIENTIFIC AND TECHNICAL

OFFICE, OPRT'N AND CONST'N



SPECIFICATIONS
FOR FEDERAL
SPECIFICATIONS BOARD

STANDARDIZATION
AND PRACTICE
FOR FEDERAL
SPECIFICATIONS BOARD

DIRECTORY AND
CERTIFICATION
FOR FEDERAL
SPECIFICATIONS BOARD

BUILDING AND
HOUSING
PRACTICE
FOR FEDERAL
SPECIFICATIONS BOARD

BUREAU OF STANDARDS

DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS,
Washington, July 1, 1926.

HON. HERBERT HOOVER,
Secretary of Commerce.

DEAR MR. SECRETARY: I submit herewith the following brief report upon the work of the Bureau of Standards during the fiscal year ended June 30, 1926. The various outstanding accomplishments are grouped according to the subjects for which Congress had made specific appropriations. This is by no means a complete report of all work accomplished, but the examples cited have been chosen to give a reasonably accurate idea of the field covered in each case.

GENERAL ACTIVITIES

Organization.—For the first time in many years the bureau now has a complete administrative and scientific roster. Some important changes in the divisional organization were carried out and will make for greater efficiency through a more logical grouping of the work. The sections devoted to rubber, textiles, paper, and leather have been formed into the division of organic and fibrous materials, while the new ceramics division includes work on clay products, glass, enamels, cement, lime, gypsum, and stone, including the sections to be transferred from the Bureau of Mines on July 1.

Contacts with industry.—Contacts with industry are maintained on the one hand by means of advisory committees and on the other hand by research associates. There are approximately 80 of these advisory committees composed of technical representatives from the various industries interested in the bureau's work. The research associates are stationed at the bureau by industry, usually through trade associations, and during the past year there were 62 of these associates representing 36 industries, working on fundamental problems of immediate industrial concern. The results of this cooperative work are published by the bureau and thus made available to all. This arrangement continues to work very satisfactorily and has the advantage of making possible more prompt solution of these problems than would otherwise be the case under the limitations of the bureau's own staff. The bureau's equipment has also been used more effectively than would otherwise be the case. It is estimated that this work represents an outlay at the bureau of some \$500,000.

The bureau's staff is also represented on many technical committees of the engineering societies. This is very advantageous in keeping the bureau in close touch with programs of research, and

much of the bureau's work is planned with the advice of such national committees.

Visiting committee.—This committee, established by law "to visit the bureau at least once a year, and report to the Secretary of Commerce upon the efficiency of its scientific work and the condition of its equipment," met at the bureau twice during the past year and has given particular attention to the financial needs of the bureau to meet the ever-increasing demands from the public and Government for testing and research, as embraced in two reports to the Secretary of Commerce. The present personnel of the committee is: Ambrose Swasey, Dr. S. W. Stratton, Gano Dunn, Dr. William F. Durand, Dr. W. R. Whitney.

International relations.—The bureau has taken part in three important international conferences held in this country, the first dealing with the international standardization of screw threads, preceded by an Anglo-American conference; the second on electro-technical standardization; and the third looking to the formulation of an international body concerned with standardization projects in general. In all three fields definite advances were made.

A first Pan American standardization conference was held in Lima, Peru, and a second will be held in this country in 1927. Progress in all these fields will undoubtedly be slow, but we may expect eventually great industrial and commercial benefits to accrue as it becomes possible to facilitate and systematize the nomenclature and specifications for the commodities that enter into international trade.

Informal conferences have also been held with foreign standardizing laboratories on questions relating to length, sugar, thermometric, photometric, electrical, and X-ray standards.

A sum of 15,000 francs was awarded to the Bureau of Standards by the Institut International du Froid in recognition of the work of the laboratory in the determination of the thermal properties of ammonia. This sum is being administered by the National Research Council and is being utilized for the preparation of tables of the thermal properties of methane, based on experimental results which were obtained by the Bureau of Standards in 1917 and 1918.

Weights and measures conference.—The Nineteenth National Conference on Weights and Measures was held in May and was unusually successful, there being 27 States represented. Important progress was made in preparing model legislation on weights and measures subjects for the use of the several States and municipalities.

State utility commission engineers conference.—The third technical conference of State utility commission engineers was attended by representatives of 14 State utility commissions and 2 Provinces of Canada. Many technical problems relating to the work of these commissions were discussed.

New ceramics committee.—There was formed a new advisory committee on ceramics, which met several times at the bureau to help lay out the program of work for the newly organized division of ceramics, into which is being correlated the work of the Columbus station transferred from the Bureau of Mines as of July 1, 1926.

American engineering standards committee.—The bureau has continued actively its cooperation with the American engineering stand-

ards committee, is sponsor for 13 standardization projects, and is represented on 69 committees having for their object the formulation of "American standards."

Federal specifications board.—This board, under the general supervision of the Chief Coordinator, has continued to function actively during the year and has issued in that period 114 specifications, making the total number of master specifications now in force 414, which are mandatory on all Government establishments. These purchase specifications of the Federal Government are being used more and more by local governmental and institutional bodies and by industry. There is a great deal of experimental research work being done for the Federal Specifications Board, most of which is carried out at the Bureau of Standards.

National screw thread commission.—The life of this commission has been extended indefinitely by act of Congress approved by the President April 16, 1926, which action puts the commission in a position to plan its work on a constructive, long-time basis. This is of particular advantage on account of the complexity of many of its problems, some of which take several years to mature.

During the year the commission was particularly active on matters of interest to the oil industry, the tap and die industry, electrical industry, specifications and tolerances for Acme threads, and for wrench-tight studs, bolts, and nuts; and threads for cutting and welding torches.

The commission has also cooperated with manufacturers and users of die heads and chasers used in connection with the production of threaded products and with the division of simplified practice. This cooperative effort has resulted in the elimination of many threads of special diameters and pitches and in the adoption and use of the screw-thread standards approved by the commission.

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 \$173,250 for the support of 40 projects, representing work for 15 Government establishments. In addition, the bureau does a great deal of consulting and specification work for the other departments.

Publicity.—In addition to its regular scientific and technologic publications describing the work of the bureau there is issued a monthly Technical News Bulletin, giving brief references to progress in current work, and in addition there are published many papers by the staff in outside technical journals. There are also released to the press numerous short accounts of interesting achievements, together with many photographs illustrating the bureau's work. These have been well received all over the country.

Tests completed.—The tests completed during the year numbered 179,849, involving 659,858 determinations and having a fee value of \$675,046.18. An itemized statement of tests completed is given in the table following.

Number of test items, determinations, and fee value for tests completed during the fiscal year ended June 30, 1926

Kind of instrument or material, class of test, or nature of service rendered	For public			For Government departments and State institutions (not Bureau of Standards)		
	Number of test items	Number of determinations	Fee value	Number of test items	Number of determinations	Fee value
Electrical standards, instruments, and materials.....	816	921	\$6,059.10	687	850	\$5,510.90
Electric batteries.....	-----	-----	-----	1,546	2,601	7,675.00
Electric lamps and lighting equipment ¹	173	197	518.00	2,894	2,919	13,184.00
Length measuring devices.....	192	701	721.65	148	1,242	1,223.75
Gauges and gauge steels.....	876	3,900	929.50	101	338	88.00
Miscellaneous dimensional determinations	2,928	12,632	2,377.60	303	1,325	524.90
Weights and balances.....	4,259	7,954	1,807.40	1,451	2,767	578.10
Scales.....	1	10	25.00	1,256	37,341	55,899.50
Timepieces.....	298	4,415	491.50	107	1,294	403.00
Volumetric apparatus.....	8,267	15,810	5,375.85	1,994	3,437	1,044.10
Hydrometers.....	958	2,874	1,430.25	500	1,500	551.00
Density determinations, etc.....	14	27	27.00	31	31	31.00
Laboratory thermometers.....	2,199	12,750	4,257.55	595	2,367	790.10
Clinical thermometers.....	34,382	137,528	2,775.84	26,235	104,940	1,706.84
Pyrometers.....	185	3,112	1,429.70	46	786	456.10
Insulating materials.....	29	66	250.00	-----	-----	-----
Fire-resisting materials.....	-----	-----	-----	102	363	6,115.00
Fuels and lubricants.....	15	53	444.00	1,689	7,426	12,060.50
Viscometers, calorimeters, etc.....	140	575	459.15	43	113	633.00
Optical instruments and materials.....	293	542	2,671.30	888	981	645.00
Carbohydrates.....	7	91	70.50	1,943	2,939	3,069.50
Radioactive materials.....	1,046	1,097	6,045.50	16	16	70.00
Engineering instruments and appliances.....	78	78	714.00	1,027	1,078	7,338.00
Aeronautic instruments.....	10	14	29.00	408	1,038	1,858.50
Aerodynamic tests of models.....	1	1	15.00	51	144	875.00
Physical properties of engineering materials.....	33	57	207.50	2,666	5,926	10,254.35
Sound producing and measuring instruments.....	7	7	14.00	63	64	845.00
Acoustic properties of structures.....	-----	-----	-----	6	6	300.00
Making of special castings.....	-----	-----	-----	640	640	1,056.50
Fusible boiler plugs.....	-----	-----	-----	332	332	830.00
Metallographic examinations.....	-----	-----	-----	560	837	2,912.50
Miscellaneous metallurgical tests.....	-----	-----	-----	279	1,887	2,315.00
Pottery and chinaware.....	8	11	8.00	361	1,475	5,415.00
Glass.....	-----	-----	-----	9	11	55.00
Refractories and heavy clay products.....	2	3	5.00	38	134	546.00
Cement, concreting materials, lime, etc.....	30	56	257.50	6,783	11,519	45,729.00
Stone and sand-lime brick.....	-----	-----	-----	21	31	156.00
Miscellaneous ceramic materials.....	-----	-----	-----	608	916	4,846.70
Rubber.....	7	35	102.00	1,445	11,860	22,717.00
Textiles.....	-----	-----	-----	5,758	15,883	27,036.00
Paper.....	107	190	350.50	1,630	4,547	6,833.00
Leather.....	10	30	39.00	252	1,246	1,876.00
Paint, varnish, and bituminous materials.....	-----	-----	-----	1,385	12,006	26,140.50
Chemical analysis of metals.....	8	40	120.00	568	2,564	8,718.00
Chemical tests of miscellaneous materials.....	10	12	150.00	909	3,951	9,947.00
Distribution of standard samples.....	5,259	-----	11,255.00	556	-----	974.25
Total ²	62,648	205,789	52,032.89	68,930	253,671	301,833.59

¹ In addition, the bureau inspected 1,459,201 incandescent lamps at various factories for other branches of the Government, the fee value for which would amount to \$3,792.42.

² In addition, in connection with its own work of research and standardization, the bureau tested 36,406 items, involving 166,866 determinations, the fee value for which would amount to \$254,988.09, making a grand total for testing work of 179,849 items, 659,858 determinations, and a fee value of \$675,046.18.

Number of test items, determinations, and fee value for tests completed during the fiscal year ended June 30, 1926—Continued

Kind of instrument or material, class of test, or nature of service rendered	For Bureau of Standards			Total		
	Number of test items	Number of determinations	Fee value	Number of test items	Number of determinations	Fee value
Electrical standards, instruments, and materials.....	273	275	\$901.35	1,776	2,046	\$12,471.35
Electric batteries.....				1,546	2,601	7,675.00
Electric lamps and lighting equipment 1.....	950	950	2,924.50	4,017	4,066	16,626.50
Length measuring devices.....	2	33	12.70	342	1,976	1,958.10
Gauges and gauge steels.....	2,596	6,853	1,441.25	3,573	11,091	2,458.75
Miscellaneous dimensional determinations.....	287	1,987	2,048.30	3,518	15,944	4,950.80
Weights and balances.....	552	1,287	454.00	6,262	12,008	2,839.50
Scales.....	6	74	73.00	1,263	37,425	55,997.50
Timepieces.....	21	401	61.00	426	6,110	955.50
Volumetric apparatus.....	465	748	603.30	10,726	19,995	7,023.25
Hydrometers.....	13	39	19.50	1,471	4,413	2,000.75
Density determinations, etc.....	783	783	783.00	828	841	841.00
Laboratory thermometers.....	266	1,132	293.10	3,060	16,249	5,340.75
Clinical thermometers.....				60,617	242,468	4,482.68
Pyrometers.....	108	908	625.61	339	4,806	2,511.41
Insulating materials.....				29	66	250.00
Fire-resisting materials.....	10	36	165.00	112	399	6,280.00
Fuels and lubricants.....	149	452	1,206.00	1,853	7,931	13,710.50
Viscometers, calorimeters, etc.....	136	213	583.00	319	901	1,675.15
Optical instruments and materials.....	643	1,736	4,626.00	1,824	3,259	7,942.30
Carbohydrates.....	20	147	584.00	1,970	3,177	3,724.00
Radioactive materials.....				1,062	1,113	6,715.50
Engineering instruments and appliances.....	93	94	291.00	1,198	1,250	8,343.00
Aeronautic instruments.....	16	79	225.50	434	1,131	2,113.00
Aerodynamic tests of models.....				52	145	890.00
Physical properties of engineering materials.....	95	281	1,090.75	2,794	6,264	11,552.60
Sound producing and measuring instruments.....	16	16	84.00	86	87	943.00
Acoustic properties of structures.....				6	6	300.00
Making of special castings.....	540	540	1,991.00	1,180	1,180	3,047.50
Fusible boiler plugs.....				332	332	830.00
Metallographic examinations.....	39	55	266.00	599	892	3,178.50
Miscellaneous metallurgical tests.....	442	1,191	4,382.00	721	3,078	6,697.00
Pottery and chinaware.....	17	21	167.50	386	1,507	5,590.50
Glass.....	41	59	205.00	50	70	260.00
Refractories and heavy clay products.....	134	1,119	2,407.00	174	1,256	2,958.00
Cement, concreting materials, lime, etc.....	902	1,866	4,718.75	7,715	13,441	50,705.25
Stone and sand-lime brick.....	17	23	320.00	38	54	476.00
Miscellaneous ceramic materials.....	251	390	1,095.50	859	1,306	5,942.20
Rubber.....	548	3,154	12,380.50	2,000	15,049	35,199.50
Textiles.....	316	1,255	5,768.00	6,074	17,138	32,804.00
Paper.....	25	75	125.00	1,762	4,812	7,308.50
Leather.....	10	56	127.00	272	1,332	2,042.00
Paint, varnish and bituminous materials.....	118	976	1,839.00	1,503	12,982	27,979.50
Chemical analysis of metals.....	613	2,737	7,830.50	1,189	5,341	16,668.50
Chemical tests of miscellaneous materials.....	352	1,491	3,473.00	1,271	5,454	13,570.00
Distribution of standard samples.....				5,815		12,229.25
Total 2.....	11,865	33,532	66,191.61	143,443	492,992	420,058.09

¹ In addition, the bureau inspected 1,459,201 incandescent lamps at various factories for other branches of the Government, the fee value for which would amount to \$3,792.42.

² In addition, in connection with its own work of research and standardization, the bureau tested 36,406 items, involving 166,866 determinations, the fee value for which would amount to \$254,988.00, making a grand total for testing work of 179,849 items, 659,858 determinations, and a fee value of \$675,046.18.

SALARIES (\$516,760)

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.

Constant of gravitation.—The Newtonian constant of gravitation is one of the fundamentally important constants of nature like the speed of light and Planck's constant of action. It occurs in the formula giving the gravitative attraction of any two bodies for each other and is independent of the nature of the attracting bodies. On this later point Einstein based his theory of gravitation.

The accepted value of this constant is $6.66 \text{ by } 10^{-8} \text{ cm.}^3/\text{gm. sec.}^2$ and is based upon the independent work of Boys and of Braun some 30 years ago. It is felt that laboratory technique has advanced sufficiently in this time to make it worth while to attempt the re-determination of this constant with the end in view of obtaining one more significant figure. This work has been in progress for the past 3 years and is now within sight of completion. A tentative figure of $6.653 \text{ by } 10^{-8}$ has been obtained, subject to possible slight modification as additional results are computed.

Basic electrical standards and units.—During the past year definite progress has been made toward checking the bureau's electrical working standards by reference to the original basic standards, and also toward the establishment of units more precisely in accord with the fundamental definitions. Such work has to be reliable to at least 1 part in 100,000, and requires the choice and special training of a staff suitable for the work. During the year a new set of standard cells has been made the standard for voltage measurement; comparisons of such cells have been made with Great Britain, Canada, Japan, and Russia; details of methods for the accurate determination of the true values for the units of resistance and inductance have been worked out, and comparisons of standards of candlepower of different kinds have been made with the laboratories of Great Britain, France, and Germany.

Magnetic testing methods.—Work on magnetic testing methods has included the revision of Circular 17 on methods of making magnetic measurements; a critical analysis of current methods of testing sheet steel for electrical uses (leading to revision of the standard specifications for such tests); continuation of work on relation between magnetic and mechanical properties of materials, with several publications; besides important contributions to the general principles of magnetism, particularly the relation between magnetization curves and the degree of homogeneity of the material.

Commercial applications of measurements.—Other electrical projects have included measurements and collection of data on commercial aluminum as an electrical conductor, leading to the establishment of a tentative international standard value of conductivity for this material; periodic checks on the efficiency ratings assigned to their product by the larger lamp factories; and improvements in labor-saving methods of testing lamps described in a publication now ready for the press.

Elastic hysteresis research.—Elastic hysteresis may be defined in its restricted sense as the residual deformation of a spring, diaphragm, or any other pressure element at the end of a cycle of loading during which the load is increased to a given value and then decreased to the original value. Knowledge of the hysteresis characteristics of the various spring and diaphragm metals in relation to their other elastic constants is of importance in the design of instruments of

improved performance. Owing to the difficulty of measurement, little trustworthy information is available. It seems established that the elastic hysteresis can not be entirely eliminated due to the presence of purely statical hysteresis, but research may indicate better materials and ways of using them. Attention has been given during the past year to the development of a satisfactory method of evaluating statical hysteresis, as measured statically, if the hereditary hysteresis is negligible. Accordingly, it now seems possible to determine the statical hysteresis of the various metals under various conditions of loading by constructing tuning forks and measuring the damping. Simple bars are also under investigation.

Study of spectra of the chemical elements.—In cooperation with the National Education Board, the bureau has continued its investigations on arc, spark, and higher order spectral systems, and six publications describing the results have been issued. The quantum theory of spectroscopy—which considers the atoms of the elements as planetary systems, with each electron planet confined to certain selected orbits and radiating according to a simple frequency law as it drops from a higher energy orbit to a lower—has been a powerful aid in coordinating the numerous individual spectral lines of the chemical elements into consistent systems. These systems in turn are used for determining the theoretical constitution of the different atoms and their chemical relationships.

Improvements in aerial mapping.—Surveying by aerial photography is a war-time activity of supreme importance. Peace-time surveying by the same method, for the purpose of mapping areas and contours of watershed, woodland, etc., has become an important commercial activity. One of the greatest difficulties to overcome is the distortion which the very best photographic lenses introduce, especially the lenses used for enlarging the original photograph. The bureau has succeeded in practically eliminating this distortion without introducing other harmful aberrations, by inserting at the proper place in the camera a plate of glass of proper thickness. This device reduces flying time to about one-half that necessary before.

Eye protective blue glass.—The use of goggles or glasses for protecting the eyes of workmen engaged in electric or acetylene torch welding and cutting, reduction furnace work and the like, is mandatory. The need for protection against excessive radiant heat and the intense visible radiation has long been recognized, but in more recent years the invisible ultra-violet has been revealed as the most harmful of all. The glass used for protecting against the latter is usually brown, which does not afford metallurgical furnace workers satisfactory contrast between the melt and the furnace walls, hence they are likely to remove the glasses at critical times. The bureau has developed a blue glass which affords the proper contrast and at the same time cuts out the ultra-violet radiation.

Properties of ammonia.—Analysis of the results obtained on properties of ammonia showed that values of properties not directly determined but derivable from the results are in excellent agreement with the best direct determinations made elsewhere.

Low temperature plant.—The carbon dioxide refrigerating plant and the liquid-air plant furnished special low-temperature facilities to the other laboratories of the bureau.

Liquid hydrogen and other facilities, including assistance by the staff, were furnished to Prof. C. C. Bidwell, of Cornell University, for a research on thermal conductivities and specific heats of lithium, sodium, and lead at low temperatures.

Viscometry.—During the year the necessary equipment has been provided to furnish standard viscosity samples for calibrating viscometers, and to make the tests for determining viscosity and jelly strength of glue, as adopted by the National Association of Glue Manufacturers.

Tests of the "apparent viscosity" of airplane motor oils at 32° F. have been made in connection with a research on airplane engine lubrication undertaken for the United States Navy.

Testing of thermometers.—The number of clinical thermometers tested (60,617) greatly exceeds that for any previous year. A special appropriation made this possible. A revision of the test methods will reduce the time required to complete tests. Unfortunately it has not been possible to keep up to date in the testing of other thermometers, since the staff and facilities available are inadequate to meet the demands of manufacturers. The delay in certifying thermometers has caused severe financial loss to some makers.

Testing of pyrometers.—The testing of pyrometers has been kept practically up to date, but only by taking time which should be placed upon the maintenance of the bureau's high-temperature standards and the improvement of test methods.

Radio apparatus.—The bureau is constantly asked to test radio apparatus for manufacturers and users. Its staff and funds available do not permit it to carry out general testing in this field. As a matter of fact, for several years it has been necessary to refuse all tests except those of fundamental reference standards of manufacturers.

Development of improved methods of chemical analysis.—The properties of numerous materials such as paints, varnishes, bituminous and other kinds of protective coatings, detergents, rubber, refractory materials, wrought iron, and aluminum alloys have been studied with the object of developing improved methods of testing and particularly to assist in the preparation of specifications. Better analytical methods have been developed for aluminum, silicon, columbium, tantalum, uranium, and various other elements, and a special method was perfected for the detection of small amounts of aluminum in nonferrous alloys, the results of which work will save thousands of dollars annually to manufacturers. Purification and analysis of the platinum metals and their alloys have likewise been carried out. A method has been perfected for the preparation of pure rhodium wire, and improvements have been made in methods for accurate assaying of gold-filled metal for the analysis of dental gold alloys. An examination has been made of reagent chemicals and a critical study carried out in cooperation with the American Chemical Society on methods of testing and in the preparation of specifications for these materials. Determinations have been made of the chemical constituents of petroleum products, and automatic apparatus has been designed for analyzing respired air in connection with medical research and diagnosis.

Metallurgical tests for the Government.—Many duralumin specimens from the *Shenandoah* and *Los Angeles* have been tested for the

Navy in regard to embrittlement by corrosion. Fusible plugs for the Steamboat Inspection Service, invar tapes for the Coast and Geodetic Survey, bearing metals for the Fleet Corporation, and a variety of materials for other departments have been tested.

The experimental foundry has made iron, brass, aluminum, and special alloy castings for the bureau's shops and the Coast and Geodetic Survey. Melting and working platinum for the bureau's use has been continued.

Weights and measures.—The usual activities in connection with research, testing, and maintenance of equipment used in length, mass, time, capacity, and density measurements and in testing gas-measuring instruments have been continued. This work is of fundamental importance in carrying the national standards of weights and measures into science, industry, commerce, and everyday life. This is done through the testing of various types of length measuring devices, weights, balances, watches, chronometers, glass volumetric apparatus, hydrometers, gas meters, and meter-testing equipment, together with the necessary researches related thereto.

Construction of apparatus for laboratory and other purposes.—The construction division, consisting of the combined instrument and machine shops, woodworking, pattern, and glass-blowing shops, took care of all requirements for instruments and apparatus needed by scientific and technical divisions of the bureau, preparing all metals and other samples submitted for tests, also the standard steel and alloy samples for the chemical division, besides furnishing mechanical service to the laboratories wherever needed.

In the past a number of the mechanics have been assigned to some of the divisions to attend to their special requirements for mechanical service. This arrangement was discontinued on January 1, 1926. All mechanics are now members of the construction force, and better service has been obtained through this change.

A heavy demand was made upon the shops in the construction of apparatus and models for the Sesquicentennial Exposition.

Some of the instruments and apparatus constructed during the year may be mentioned:

Optical set-up for double galvanometer system, magnetic testing apparatus, 4 photometric sector disks of high precision, lens mounting for galvanometer mirror projection system, gauge for barrel measurements, calorimeter, 1 A. C. shunt 0.0005 ohm 1,000 amperes, 6 strain gauges, paint and varnish testing apparatus, 10 deflection measuring instruments, 24 laboratory telescopes, one 5-point rotary mercury switch, densitometer for measuring the density of photographic films, 6 optical aberration models, model of tire-endurance testing machine, model of tire dynamometer, electroplating demonstrating apparatus, pencil testing machine, and 11 fixed air condensers.

Besides the usual construction work for the plant and repair and upkeep of buildings and office equipment, the wood shop constructed a number of wooden models and cases for exhibition purposes, also all the woodwork required in setting up the absolute electrometer, a humidity chamber for the paper and textile sections, woodwork for the new X-ray chamber, cabinets for dry-cell tests, and exposure racks for balloon fabrics. A number of pieces of glass apparatus

were made in the glass-blowing shop. On account of the high grade of work performed by this shop frequent requests have been received from other Government departments for difficult pieces of glass work which could not be obtained elsewhere. A number of aircraft instruments, designed by the aeronautic-instruments section, have been built in the instrument shop.

General administrative and office work.—During the year 158 new publications were issued, making 1,290 publications as the total published work. A complete descriptive catalog (271 pages) was issued comprising all published matter from the establishment of the bureau (1901) to June 30, 1925. A complete subject index permits instant reference to all published research. An annual supplement keeps the list and index current. A popular illustrated description of the bureau was issued as Circular 1 and placed on sale to meet a continuing demand.

More than 400,000 communications were handled in the mail room, routed, filed, and where necessary carefully recorded.

EQUIPMENT (\$70,000)

General equipment for laboratories.—The usual purchases of apparatus and supplies have been made, in order to keep the bureau's laboratories in up-to-date and efficient condition. Among the special apparatus purchased may be mentioned a large electromagnet, X-ray tube and transformer, air-conditioning equipment, and some small refrigerating equipment.

Longitudinal comparator.—A longitudinal comparator has been ordered. This is fundamental equipment which has long been needed for high precision comparisons of length standards, such as yard and meter bars. The equipment ordered will be at least the equal of any that has ever been built, and will make possible a distinct advance in this field of the bureau's work.

Circular dividing engine.—A new precision circular dividing engine was purchased and is now installed in the length section. This machine has long been needed and will permit the bureau to rule special scale and other measuring instruments for its own use and for other Government laboratories, as well as to check commercial instruments.

Refrigerating plant for watch testing.—New refrigerating equipment of small size for the watch-testing cabinets has been installed. The new apparatus has eliminated the use of ice and makes possible a much more convenient and accurate temperature control.

GENERAL EXPENSES (\$43,500)

Upkeep of mechanical plant.—Necessary repairs have been made to all steam, electrical, and mechanical equipment during the past year. A new water-service pump, a new vacuum pump, and a motor-driven centrifugal pump for brine service have been installed. The installation of these units was made necessary because of increased demands for such services and to replace worn-out units. A central refrigerating plant for the industrial building is being installed and will eliminate the necessity for the purchase of any additional refrig-

erating units for this building and will replace smaller units now installed which will be available for use in buildings where central refrigeration is not practicable at this time.

Electrical construction and repair work.—Necessary electrical repairs have been made to motors, generators, switchboards, transformers, electrical furnaces, and other miscellaneous laboratory equipment. Wiring of new installations of equipment has included a thermocouple system for the panel furnace, X-ray machine, high-frequency furnace, sugar-laboratory motors, gas-plant motors, and new trunk lines for the colorimetry laboratory.

Plumbing and steamfitting.—The necessary maintenance work on fixtures and piping for supplying water, gas, air, vacuum, steam, and refrigeration has been performed and numerous pieces of small equipment have been installed. The larger installations included piping for the gas plant and the sugar laboratory.

Miscellaneous repairs and alterations.—Numerous foundations were constructed and necessary alterations made for the installation of laboratory equipment. The settings of two of the boilers in the north building and one in the kiln building were relined and the brickwork of all boilers has been repaired.

Travel.—Necessary travel for the purpose of consulting with experts at meetings of scientific and technical societies, travel of members of the bureau's visiting committee, and travel in foreign countries in connection with cooperative work of the bureau and other national standardizing institutions is provided for by this fund.

Library books.—During 1926 there were purchased and obtained by exchange for the bureau's technical library 686 volumes of new periodicals and serials, 362 old periodicals and serials, 251 new books and continuations, and 224 old books, a total of 1,523 accessions. Practically all books and old periodicals were purchased, while of the new periodicals about one-half were obtained on an exchange basis.

Contingent expenses.—Part of the contingent expenses of the bureau and of the Department of Commerce as a whole have been provided for under this fund.

IMPROVEMENT AND CARE OF GROUNDS (\$11,000)

New roads, grading, etc.—The new entrance road has been completed and the east section of the bureau's site has been improved through grading, seeding, and the planting of trees and shrubbery. The work incident to the care of lawns, shrubs, flowers, and drain systems has also been performed.

TESTING STRUCTURAL MATERIALS (\$230,000)

Building codes.—The building code committee, which consists of nationally known professional experts, completed and published its report on Recommended Practice for Arrangement of Building Codes. A report on Recommended Building Code Requirements for Unit Working Stresses in Building Materials was also completed. At least six States have used substantial portions of the plumbing code recommendations in their laws. An incomplete survey shows

that some 50 municipalities distributed throughout the country have used recommendations of the committee in their newly revised building codes.

City planning and zoning.—In the field of city planning and zoning a report was published on zoning progress, containing an authoritative discussion of the constitutionality of zoning by Edward M. Bassett, one of the members of the advisory committee, together with a list of the 436 municipalities that have adopted zoning ordinances and references to State enabling acts authorizing cities to zone.

A preliminary edition of *A City Planning Primer* dealing with the usefulness of city planning in facilitating traffic, encouraging more careful utilization of expenditures for street and public works, and developing home sites at low cost, was published in mimeographed form. References to State acts permitting cities to create planning commissions and control the layout of new streets were obtained and made public.

A permissive standard State city planning enabling act to provide for city and regional planning, the creation, organization, and powers of planning commissions, regulation of subdivision of land, and the acquisition of the right to keep planned streets free from buildings was drafted.

Standard State Mechanics' Lien Act Committee.—The voluntary committee referred to in last year's report, the Standard State Mechanics' Lien Act Committee, completed its preliminary tentative draft which will be sent out for comments and criticisms shortly after the close of the fiscal year.

Better homes.—Substantial aid was given to Better Homes in America (Inc.), an organization which works closely with other Government departments and numerous national bodies in the preparation of pamphlets, in obtaining cooperation from various agencies, and in other ways.

Statistical work.—Statistical work included obtaining monthly prices for 24 building-material items as paid by contractors in about 50 cities. These prices were issued regularly and republished by a number of trade papers. The figures so obtained are used in compiling index numbers of the price of materials for small frame and brick houses. Current statistics on building activity; building costs; and production, consumption, and stocks on hand of the principal building materials were printed monthly in the *Survey of Current Business* and in *Commerce Reports*.

Seasonal operation in the construction industries.—The work of the bureau, in cooperation with the committee representing national organizations and with local groups, has borne very definite results. The winter months of the years 1924-25 show a distinctly greater volume of construction, as indicated by employment of labor and purchase of materials by representative contractors, with a corresponding leveling off of the peak that usually occurred during the late summer. Publication of such findings in chart form created wide and favorable comment.

Vitreous china plumbing fixtures.—Cooperation between the bureau and the manufacturers of vitreous china plumbing fixtures has resulted in the standardization of their product or procedure as

regards types, sizes, nomenclature, and grading rules. The recommendations will be submitted for the regular procedure of the division of simplified practice.

Properties of soldered joints.—Work on the properties of soldered joints under prolonged stress and on the effect of phosphorus in wrought iron was completed and published.

Holding power of wood screws.—The results of tests of the holding power of over 10,000 wood screws inserted in the side and end grain of seven different kinds of wood ranging in density from yellow poplar to white oak were summarized in a technologic paper published during the year.

Proportioning and grading of concrete aggregates.—The proportioning and grading of aggregates for concrete were extensively studied during the year, and the work is not yet completed. The variables considered were three different cements, the gradation of the coarse aggregate, and the ratio of the fine to the coarse aggregate when the latter was deficient in certain sizes. In addition to these variables, aggregates from three different sources were used: Gravel, crushed stone, and crushed slag. It appears safe to follow in concrete design the criterion that the sand should be at least one-third of the total aggregate and that the gradation of the coarse aggregate should be such that the percentage passing any one sieve and retained on the next smaller should be not less than one-third that retained on the former and passing the next larger.

Impact strength of reinforced concrete.—In cooperation with the Bureau of Mines a chamber has been designed and is in course of construction by means of which it is proposed to determine impact strength of reinforced concrete. This information is needed in the design of concrete stoppings for mines.

Stevenson Creek experimental dam.—Another extended investigation of concrete originating during the year is in connection with the testing of the Stevenson Creek Dam in California. This is a dam of the arch type, designed entirely for testing purposes. The testing of the dam has been placed in charge of the bureau. So far only a minor amount of testing has been done, the time having been spent in the construction and in the placing of instruments.

Inspection of cement.—The inspection work in connection with cement and concrete for Government purposes and use has been in about the same amount as in previous years. Approximately 800,000 barrels of cement have been shipped under bureau supervision for Government purposes. The close of the fiscal year, however, showed a marked increase in requests for service from different departments, due apparently to an increased building campaign in those departments which the bureau serves. In connection with the routine testing of cement further steps have been taken to obtain better correlation of methods and results obtained in the different laboratories of the bureau, and in the future monthly samples will be exchanged between the laboratories. The routine testing of sieves for the general public and the distribution of cement of standard fineness increased slightly during the year. One hundred and ten No. 200 sieves were tested and 404 standard samples of cement were distributed.

Hardening of cement.—The hardening of cement has been followed both by an examination of the solutions resulting when water, chlorides, and sulphates act on cement and also by means of an adiabatic calorimeter. It has been found that the aluminate reacts with the chlorides and sulphates to form definite compounds, and that the aluminate present in Portland cement reacts with water to form one and possibly two compounds. The study of the reaction of the silicates is more complex, and definite information is not available. The calorimeter has not proven as satisfactory as anticipated in the study of the heat of reaction of the compounds, or cement with water or solutions, due to the fact that the reaction extends over several days, but it has been found that it will distinguish between different cements and the effect of SO_3 in retarding the rate of setting of different cements.

Durability of glass tank block.—A thorough study of commercial glass tank blocks was made in small tanks constructed at the bureau in which about 400 pounds of glass were melted per day for 30 days. It was found that the physical structure of the block is the dominating factor controlling its life in service irrespective of chemical composition. The block should be homogeneous, the pores small, and, if possible, either closed or nonconnected. Corundum and mullite resist solution better than the other possible solid phases, and hence if block of these could be obtained of the proper structure, a most satisfactory product would be obtained.

Waterproofed gypsum products.—There is much demand for waterproofed gypsum products for exterior use, consequently this problem has been attacked from three angles, first, waterproofing the set product; second, precipitating on the surface a soluble compound; third, by the addition of an integral waterproofing compound. A very large number of each of these methods has been tried. Up to date the one which seems to promise the most success is the use of a small amount of blood albumin glue added to the mixing water. Some specimens which have been treated with a solution of barium hydroxide also give some promise, but to a lesser degree.

Sand for gypsum plaster.—Considerable time was spent in determining what should be the characteristics of sand that would give the best results in gypsum plasters, so very much used for interior plastering. As was expected the finer sands proved to have greater tensile and compressive strengths and gave the most workable mixes. As 25 per cent of calcined gypsum for use in mortars may be replaced by other products, use of lime, asbestos, talc, and clays was studied. In general, these all improved the workability of the plaster mixes, but on the other hand decreased their strength and required more water to bring the mixes to the desired consistency.

Miscellaneous lime and gypsum problems.—Other problems studied during the year were the use of hydrated lime in Portland cement mortars, limes for the chemical industry, strength of bond between mortar and sand-lime brick, the acoustics of wall plasters, electrical calcination of gypsum, rate of drying of wall plasters, and the effect of impurities in limestones and in gypsum on the properties of the lime and calcined gypsum produced from them.

Physical properties of limestones.—The physical properties of the characteristic limestones of the country have been determined. It

was found that the compressive strengths varied from 2,000 to 24,000 pounds per square inch, modulus of rupture from 500 to 2,500 pounds, and shearing strength from 800 to 4,400 pounds, and the modulus of elasticity ranges from 2,000,000 to 11,000,000 pounds. The weathering of these stones has also been followed by freezing tests and by the crystallization of salts in the pores. The data, however, are not yet completed. Waterproofing tests have also been carried out, and it was found that one of the most satisfactory of these was one both readily available and very cheap, namely, the application of a solution of paraffin in light solvents from mineral oils.

Molding sands.—Improved apparatus has been developed for determining the compressibility, permeability, and refractoriness of molding sands. Cooperative work has been conducted with the American Foundrymen's Association and the Washington Navy Yard on sand testing and sand control.

Specifications.—The following specifications have been prepared during the year in cooperation with representatives of other Government departments: Seamless brass pipe, seamless brass tubing, cast-iron soil pipe, lapwelded charcoal iron boiler tubes, malleable iron or steel unions, padlocks, plumbing fixtures. These specifications have been submitted to the Federal Specifications Board for promulgation as mandatory Government standards.

Branch laboratories.—To take care of the many requests from governmental agencies for the testing of structural materials the Bureau of Standards maintains three branch laboratories which are located at Northampton, Pa., Denver, Colo., and San Francisco, Calif.

The work of the Northampton laboratory is exclusively cement testing and as it is situated in the Lehigh Valley cement-producing district, it supervises the major portion of Government orders for Bureau of Standards tested cement. The Denver laboratory cares for the cement testing of the territory west of the Mississippi River and east of the Rocky Mountains. Besides its cement-testing work many studies are made of the suitability of local aggregates for use in concrete structures for the Reclamation Service. The San Francisco laboratory cares for the cement testing on the west coast which includes many shipments to the Hawaiian Islands and also cares for many tests of miscellaneous materials used in construction work.

At the present time with the large amount of work undertaken by the Government in various parts of the country, these branch laboratories are caring for a volume of work which prohibits further demands unless the personnel and equipment can be increased. With the demand of purchasing agents that materials meet the requirements of the specifications of the Federal Specification Board this commodity testing work will continue to increase.

A careful survey of the needs of the several districts should be made and provision by added personnel and equipment made in order adequately to care for this important part of the bureau's work.

TESTING MACHINES (\$38,000)

Strength of brickwork.—Special attention is being given at present to the measurement of the strength of brickwork under com-

pression. Test walls are built and aged, and then subjected to a slowly increasing load in the testing machine until they fail. The machine used in this work has a capacity of 10,000,000 pounds in compression, and is the largest testing machine in the world. The walls under test are 6 feet long by 9 feet high, corresponding approximately in height to the distance from one floor to the next and in length to the distance between adjacent windows. The program is being carried out in cooperation with the Common Brick Manufacturers Association and includes four grades of brick, three mortars, and two grades of workmanship, as well as several novel methods of constructing walls, such as the Ideal brick wall. It is probable that about 200 walls will be built, aged, and tested before the investigation is completed. The results of these tests are greatly needed by engineers, architects, and city officials who are responsible for safe construction.

Welded rails.—Another investigation of importance relates to the strength of welded rails for street railways. In this work the American Bureau of Welding, the American Electric Railway Association, and a large number of traction companies in different parts of this country have cooperated whole-heartedly.

Tensile tests of welded joints have been made in the large Emery testing machine (capacity 1,150,000 pounds in tension, 2,300,000 pounds in compression). A large number of joints have also been subjected to repeated impact until they failed, using a machine designed for the purpose which simulated service conditions. The metallurgical and electrical divisions of the bureau have cooperated extensively in portions of the work which lay in their fields.

Calibration of testing machines.—There is a very great need for accurate and inexpensive methods of measuring the load applied to test specimens by testing machines.

A portable proving ring has been developed at the bureau for testing Brinell machines, the maximum load being 3,000 kilograms. These rings are simple and accurate and are now being supplied commercially by a reliable manufacturer. Each ring is calibrated by the bureau under dead weights and a certificate furnished the purchaser.

Proving rings for higher loads are being developed and it is expected that apparatus for calibrating testing machines having a capacity of 1,000,000 pounds will soon be available. This work can not be completed until dead-weight machines for loads of, say, 200,000 pounds are available in our laboratories.

Investigation of strength of steel columns.—The results of tests of 69 steel columns, having H-shaped sections and of 5 different types of construction, have been prepared for publication. This work was conducted in cooperation with the American Bridge Co. and the Bethlehem Steel Co. These firms supplied more than 130 tons of steel for this purpose. The finished columns were tested to destruction in the 10,000,000-pound testing machine. Over 1,000 test specimens were cut from the columns and subjected to chemical analyses and physical tests to determine as accurately as possible the properties of the steel from which the columns were made.

This work indicates that differences in the physical properties of the material entering into the columns produce greater variations in strength than all the differences in type of construction.

Lines of stress in fabricated columns.—A poster illustrating and describing the method used by the bureau to render visible the lines of stress in steel columns under compression has been issued. The method was first used in the investigation of special fabricated steel columns for the Delaware River Bridge.

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

Fire tests of materials.—The program of fire tests of brick walls was completed, and 40 fire or fire and water tests of hollow-tile walls were made.

Over 300 fire tests of roofing materials were conducted. In this work, 126 decks were tested with brands, 77 for flame resistance, and 114 for spread of flame over the surface. Tests of gypsum-block partitions conducted elsewhere were summarized. Two fire tests of plaster partitions were made.

Theater curtains.—Strength tests of asbestos theater-curtain cloth were made at high temperatures and inspections made of installations in the city of Washington.

Building safety codes.—The bureau has cooperated with the National Fire Protection Association and the American Engineering Standards Committee on building safety codes and with the latter in adoption of specifications for the conduct of standard fire tests of building constructions and materials.

Strength of materials at high temperatures.—Fifty strength tests of structural steel and cast iron were made at temperatures up to 910° C.

Insulated safes.—Six fire and impact tests and three fire-endurance tests of insulated safes were conducted for Government departments.

Fire intensity and duration.—A new structure 30 by 60 feet in area has been built for fire intensity and duration tests and filled for burning out with a record room occupancy. Two sheet-metal garages were burned out to determine the hazard to adjacent structures.

Ignition points and spontaneous ignition.—During the past year tests for ignition points or spontaneous ignition have been made on three insulating felts, one type of timing-pad holder, and four classes of rayon.

INVESTIGATION OF PUBLIC UTILITY STANDARDS (\$100,000)

Measurement of high voltages, large currents, and electric power in large blocks.—Accomplishments during 1926 include the development of improved methods of using standardized transformers so as to get reliable measurements up to 100,000 volts, design and construction of shunts for measuring alternating current up to 1,200 amperes, approximate completion of parts for an absolute electrometer to operate up to 300,000 volts, preliminary tests on the corona voltmeter to determine conditions which affect its use at these high voltages, and mathematical work which indicates that a new and more exact method for measuring power at high voltages is practicable.

Electrolysis and soil corrosion.—An extensive technologic paper on methods of electrolysis testing has been prepared, and a circular explaining the use of the earth-current meter has also been prac-

tically completed. These papers summarize the results of several years' experience in testing for electrolysis conditions; another paper summarizing the results obtained by different methods of remedying those conditions is well under way. The second installment of pipe samples in the soil-corrosion research has been dug up and returned to the bureau for examination, together with samples of the soils in which they are buried. There are some 7,000 samples in 46 locations involved in this investigation.

National Electrical Safety Code.—Two volumes of the new edition of the National Electrical Safety Code have been published, and two more are ready. The additional part which covers rules for the installation and maintenance of overhead and underground electrical supply and communication lines has also been completed. A considerable part of the year has been spent in rearranging the form of the code to comply with the wishes of the industrial interests involved and to facilitate adoption of the rules as a whole by State authorities.

Surveys of Government telephone service and defense of patent suits.—Practically the full time of the bureau's telephone group has been given to surveys of Government telephone service and defense of patent suits in accordance with requests from the Chief Coordinator. This continuing survey work returns several fold what it costs, while the patent suits involve an aggregate which may run into millions of dollars of possible savings to the Government.

General cooperation with State utility commissions and utility companies.—General cooperation with State utility commissions and utility companies has been maintained. The regular annual conference of State Commission Engineers, May 13 and 14, 1926, was attended by 26 engineers representing 14 States and 2 Canadian Provinces. The work on standards for electric service and street-lighting service has been continued, the code for electricity meters has been revised in cooperation with the National Electric Light Association and the Association of Edison Illuminating Companies. Many standardization projects in the electric utility field have been dealt with through the machinery of the American Engineering Standards Committee, the American Institute of Electrical Engineers, and the International Electrotechnical Commission. Several members of the bureau staff took an active part in the plenary session of the latter organization which was held in New York City, April 13 to 22.

Investigation of gas service and appliances.—The relation between the conditions of manufacture, distribution, and use of fuel gases and economical and satisfactory public service, including the effect of changing heating-value standards, has been studied and methods have been developed for determining the safety and efficiency of gas appliances. Several successful methods for such determinations have been perfected and a large number of domestic appliances have been tested. The results of this work have been used by the American Gas Association in the preparation of appliance specifications. The corrosive effect of gas flames on the appliances have likewise been investigated. The national gas safety code, sponsored by the bureau and the American Gas Association, has been adopted as an American standard by the American Engineering Standards Committee.

TESTING MISCELLANEOUS MATERIALS (\$44,090)

Routine chemical tests.—Many chemical and physical tests have been conducted on a great variety of materials such as paints, varnishes, roofing and waterproofing materials, boiler waters and compounds, metals, alloys, graphite, fire-extinguishing compounds, asbestos products, boiler scale, cements, antifreeze solutions, technical and photographic chemicals, soaps, polishes, rubber, packings, type-writer ribbons, carbon paper, adhesives, lubricants, textiles, rope, twine, and dyes. Most of the above materials were tested for the Government departments, the total number of samples being about 4,700. These tests serve to control the quality of Government purchases of these materials.

RADIO RESEARCH (\$44,800)

Reduction of interference.—On the general problem of reduction of radio interference the bureau's work during the year has been of importance. This work was directed largely to the holding of broadcasting and other transmitting stations exactly on their assigned frequencies. Marked progress in the actual operation of the country's radio stations in this respect has been made possible primarily through increasing the accuracy of the bureau's frequency standards and certain procedures adopted for their dissemination and application. These have included the transmission of special signals of standard frequency and the setting up of a system of standard frequency stations. The accuracy of frequency measurements generally has been raised to a higher level of precision through development by the bureau of specific applications of the piezo oscillator, a remarkable new device serving as a constant frequency standard. A form of this instrument as well as other necessary measuring instruments were designed for the use of the radio inspectors of the Department of Commerce. The results of a statistical study of the distance range and interference conditions of broadcast reception were issued.

Propagation of radio waves.—Several contributions were made to the knowledge of the vagaries of radio wave propagation. A study on a nation-wide scale of the effects of high power broadcasting was directed by the bureau. This definitely established that certain deleterious effects that had been anticipated through the use of many kilowatts of power did not exist, and also that high power does not bring with it a cure for radio fading. The fading or fluctuation of received signal intensity remains as the principal obstacle to radio development, and the bureau, with the cooperation of 20 laboratories in universities and other places, made a concerted attack on this problem. The year's work resulted in the establishment of a number of conclusions as to the nature and characteristics of fading. This study led to a better understanding of the way in which radio waves are transmitted in the space between the transmitter and receiver. In connection with this, studies of the peculiar behavior of very high frequencies or short waves was also made.

Radio-direction finder.—A number of advances were made in the technique and applications of the radio-direction finder, one of the main reliances of the future for both marine and air navigation.

Special developments extended the frequency range in which it is possible to do accurate direction finding. Direction finders of special design for several types of service were developed for the Coast Guard, the Navy, and the Signal Corps. A number of improvements of detail were made on a laboratory scale in the directive beacon system provisionally designed for use in air navigation.

COLOR STANDARDIZATION (\$9,000)

Consistent system of color standards.—The eye is capable of distinguishing about 1,000,000 different colors, no 2 of which match. To match in white light, two given colors must be alike in three attributes: Brightness, hue (dominant spectral color), and saturation (percentage of white). To match under all lights, the spectral distribution of the transmitted light, or reflected, as the case may be, must be identical in the two cases. There has been established as yet no system of color standards sufficiently precise and consistent for the demands of trade in which considerable financial loss often hinges on barely perceptible color differences, while the comparison standards used vary by a much greater amount. For several years the bureau has been working on the widely used Lovibond system of about 400 colored glasses with the object of selecting out of these as adjusted color standards the ones which are consistent with each other as regards the three attributes mentioned. During the past year the spectrophotometric measurements on these glasses have been completed and are now ready for publication. The colorimetric analysis of the same glasses, which involves a revision of the three elementary excitations of the normal eye, is to be pushed to rapid conclusion. With this second part completed the bureau will have the first existing set of color standards of a precision adequate to the demands of trade. In this standardization program the bureau has been greatly assisted by the cooperation of the Munsell Research Laboratory.

INVESTIGATION OF CLAY PRODUCTS (\$27,000)

Use of feldspars in whiteware.—In the investigation of the use of feldspars in whiteware, the following properties have been determined: Softening point, chemical composition, specific gravity, fineness, deformation range, mineral constituents as determined by the microscope, rate of vitrification, resistance of glazed ware containing the spars to impact, and resistance of glazed ware containing the spars to thermal shock. It has not been possible to find any general law connecting the spars with their properties. Further work will therefore be done considering such features as thermal expansion, rate of solution of the clays, flints, and spars, etc.

Consistency of enamel suspensions.—An apparatus has been developed by means of which it has been possible to determine the consistency and follow the changes in consistency of enamel suspensions. The apparatus has been simplified for use under plant conditions so that it will be possible for an inexperienced operator to use the equipment and foretell whether a slip will act as desired in the dipping process, also what changes in the slip will be needed to bring it to the right condition when it is not in that state.

Clay for saggars.—In the study of the determination of those properties which make a clay of value in the making of saggars the thermal dilation of a large number of clays and sagger mixtures was determined. It was definitely noted that certain clays are characterized by rapid expansion between 100° and 200° C. and there seems to be relation between this phenomenon and the durability of saggars made from such clays. It is also noted that repeated use of saggars brought about an increased expansion between these temperatures.

Drying of clay bodies.—A satisfactory method has been devised for measuring the velocity of water flow, percentage of water evaporated, percentage of shrinkage grading, and percentage of water concentration in the drying of a clay body. It was found that successful drying requires a high humidity and a temperature not over 45° C. for the first one-fourth to one-third of the total drying period; that successful drying also depends on preserving a low shrinkage grading within the dry clay body. It is also not possible to predict the behavior of a full-sized specimen in drying from the drying of smaller sections.

Workability of clays.—The apparatus designed for measuring the workability of clays under conditions that prevail in plants, and to measure the efficiency of various designs of augers, dies, and spacers, has been given a thorough trial and found to meet all requirements needed for the proper determination of the fundamentals on which an auger machine should be designed. It is surprising to note that a decrease of about 2 per cent of moisture content below that of optimum plasticity caused a decrease of more than 50 per cent in workability. This illustrates the close control that will be needed in preparing the material for use in the machine.

Data on burned-clay products.—Two publications have been issued covering the obtaining of data for engineers in the use of burned-clay products. One of these covers the tests of hollow tile and concrete slabs reinforced in one direction, and the other the compressive and transverse strength of hollow-tile walls. There has also been completed a second series of tests of slabs of hollow tile and concrete, and there has been partially completed a series of tests of common brick walls. These tests all cover the use of built-up specimens of a size comparable with that used in construction, the walls being approximately 6 feet long by 10 feet high and of the several thicknesses used commercially.

German and American fire brick.—Among other investigations which have been conducted are those relating to the comparison of German and American fire brick, examination of refractories after service in boiler installations, resistance of glazes to abrasion, properties of vitrified chinaware, study of white ground coats for enameling, effect of typical enamels on colors obtained with various stains, and the blistering of enamels. The American Face Brick Association and the National Terra Cotta Society have maintained fellows studying problems in relation to their industries.

Ceramics Advisory Committee.—There was formed an advisory committee, representing the various members of the ceramic industry, to assist the bureau in formulating its investigations in this field, including the work of the Columbus, Ohio, station to be taken over July 1 from the Bureau of Mines.

STANDARDIZING MECHANICAL APPLIANCES (\$27,800)

Testing mechanical appliances.—The amount of testing carried out for other bureaus of the Government in the field of mechanical appliances and engineering instruments is constantly increasing. Current meters have been calibrated for the Reclamation Service, the Geological Survey, the Coast and Geodetic Survey, and other agencies. These meters are used in gauging the stream flow of rivers and canals, and are standardized by towing them at various known speeds through still water in a testing tank about 450 feet long. Numerous tests have been made of various types of fire extinguishers to determine their suitability as fire-fighting equipment on vessels under the jurisdiction of the Steamboat Inspection Service. For the Supervising Architect's Office tests have been made of radiator return line valves. Many aeronautic instruments, anemometers, pressure gauges, and paper testers have been calibrated for other branches of the service, and new instruments developed.

Elevator safety interlocks.—About three-fourths of the accidents to passengers on elevators can be prevented by reliable elevator interlocking safety devices. Previous work in developing methods of testing the reliability of such devices has been extended to determine the reliability of additional existing commercial devices. The results of these tests are made available to and are used as a basis of approval by several of the Government departments, the government of the District of Columbia, several municipal and State governments, and one of the largest groups of casualty and insurance companies.

Radiator air valves.—The successful operation of certain types of heating systems in common use is largely dependent upon the manner in which an air valve placed on each radiator performs its functions. At the request of the Supervising Architect of the Treasury Department an investigation was made of commercial samples which resulted in the formulation of a standard of performance for these radiator air valves and in the development of methods of testing them, which will permit their purchase on the basis of a previously determined compliance with definitely stated performance requirements.

Altitude chamber for testing instruments.—Progress has been made on the fittings and equipment of a steel chamber which will be used to reproduce in the laboratory the low temperatures and pressures experienced in airplane flight. The size and arrangements are such that the observer may be inside of the chamber during its operation, thus permitting both the test and adjustment of many instruments under conditions encountered in flight. The chamber is designed to obtain low pressures corresponding to an altitude of 40,000 feet and temperatures as low as -20°C .

Aeronautic instrument specifications.—In cooperation with the Army and Navy Air Services a general revision of the specifications for aircraft instruments has been completed. This work involved the revision and amplification of 23 specifications and included experimental work on a number of types of instruments for the purpose of establishing tolerances.

INVESTIGATION OF OPTICAL GLASS (\$20,520)

Production of optical glass.—In the course of the study of the factors which affect the quality of optical glass during melting, molding, and annealing, 36 pots of approximately 1,000 pounds each were melted. It was found that the eliminating of the seeds in the borosilicate glass can be accomplished to a major degree by the use of about 2 per cent zinc oxide in the batch. Just why the zinc acts in this manner is not known. This suggests the possibility of finding a material which will act similarly in the barium crown glasses which even at the best contain more bubbles than are allowed in other glasses. The glass produced was turned over in a certain amount to the optical shop of the Navy. Approximately 9,300 blanks were molded and annealed for this purpose.

Viscosity of glass.—Viscosity of glass is of great interest to manufacturers, because it is believed that the most advantageous temperature for melting, fining, and working of the glasses depends upon the viscosity at that temperature. A viscometer of the rotary type has been developed and calibrated with a mineral oil of naphthene base between 200 and 25,000 poises. Following calibration the instrument has been used in the determination of the viscosity of some commercial and some optical glasses in which the viscosity in poises varies from 140 to slightly over 25,000, depending upon the temperatures at which the determination was made and the composition of the glass. The study will ultimately, of course, show the effect on viscosity at different temperatures of various constituents in glasses.

Reduction of strain in glass.—Strain is a result of the temperature of glass while being molded or pressed and too rapid cooling after this process. This strain can be removed by annealing, which consists in heating glass to a certain temperature and then cooling at a definite rate. The annealing range has been determined for a number of glasses and has been found to vary, especially with the composition of the glass. The rate at which the glass may be cooled depends also upon its thickness. Glass 1 centimeter thick can be cooled at about 100° C. per hour initially, while glass 4 centimeters thick should not be cooled faster than 4° C. per hour.

Large glass disk.—During the past two years considerable work has been done on the production of a large glass disk for a reflecting telescope. It is to be made of borosilicate crown glass and when finished will be 61 inches in diameter by 11 inches thick and will weigh about 3,000 pounds. The cast pots in which the glass is melted were made at this bureau. They weigh about 2,500 pounds and will hold 5,000 pounds of glass. Results have not been satisfactory because the glass cracked during cooling, either on account of too rapid cooling or too large temperature differences in the furnace. Plans are now being perfected to pour the molten glass into a cast-iron mold which will be placed in an electrically heated furnace. This will insure better control of the cooling rate and a greater uniformity of temperature throughout the furnace, which are thought to be the chief requirements in obtaining a large disk of satisfactory quality after the glass is properly melted.

INVESTIGATION OF TEXTILES (\$26,560)

Effect of laundering upon thermal insulating value of cotton blankets.—A study has been made of the changes in thermal insulating value of cotton blankets resulting from repeated laundering. The sample materials used in the experiments were representative of most common blanket types, and the laundering process corresponded to a good commercial practice. Washing was found to cause small losses in thermal resistance (0 to 10 per cent), which were almost completely restored by the application of a suitable process for raising the nap of the laundered fabric. This result emphasizes the importance of such a restoration of the nap. Shrinkage was also observed to produce a counteracting gain in thermal resistance.

Physical tests of yarns of different twist.—A comprehensive study of the physical properties of cotton yarn is being made in order to furnish adequate data to cotton mills. The lack of fundamental knowledge on this subject is frequently a serious handicap in cotton manufacturing. Twist, for instance, is a primary factor in production costs, so it is economically desirable that a knowledge of the effect of different twist factors be available.

In the bureau's experimental cotton mill, quantities of the following cotton yarns were made: Seven sizes of yarns, each with seven twist factors, on single and double roving mill organizations for both carded and combed types. The following physical tests were made: Size, twist, angle of twist, diameter, and breaking strength, using single strand and skein methods. The data have been obtained and are being evaluated.

Improvement of wearing quality of paper currency.—Research on improving the wearing quality of United States paper currency was carried on actively in cooperation with the Bureau of Efficiency, the Treasury Department, and the manufacturers of the paper. Study of the paper-making processes in the bureau's semi-commercial mill led to commercial production of currency paper having double the former strength, with no increase in cost of production. A glue-formaldehyde surface sizing treatment for the printed bills was evolved. This appears to be of much value for making the bills resistant to surface disintegration and to soiling. It seems assured that these developments will materially increase the service life of the bills and make it possible for the Treasury Department more adequately to meet the demand for paper currency at reduced cost.

Water absorption of paper.—A publication was prepared containing the results of a critical examination, including experimental comparison, of 38 different methods proposed by various investigators for measuring the rate at which paper absorbs aqueous liquids. The need of inexpensive and simple means of testing paper under controlled humidity led to development of an air-conditioned testing cabinet which so far has given very promising results.

Use of glue in paper.—As a part of the cooperative work with the National Association of Glue Manufacturers a demonstration was given of the results obtained in the study of the use of glue

for mineral coating paper. Representatives of both the glue and the paper industries observed the technic on a semicommercial practice. Additional results in using glue for beater sizing tend to confirm in general the view that the rosin-sizing quality and the folding endurance of paper can be improved by such application.

Aging of soft rubber compounds.—An investigation of the aging properties of soft rubber compounds, which was started in January, 1925, has been continued during the past year. The work to date covers the aging of a series of rubber compounds under all conditions of storage and exposure. It was found that certain types of compounds resist the deteriorating effects of age much more than others, and the results showing striking differences in aging properties are being compiled for publication. The importance of this investigation lies in the fact that rubber goods purchased in quantity often deteriorate in storage to such an extent that they are unfit for use.

Guayule rubber.—In cooperation with the Continental Mexican Rubber Co., a study is being made of the properties of guayule rubber. By improved processes in the extraction of this material from the shrub, an attempt is being made to obtain a better quality of product than has been produced from this source. The use of guayule in place of Hevea rubber would prove of great economic value to the United States, as the shrub from which it is secured can be successfully grown in southwestern United States, California, and in Mexico.

SUGAR STANDARDIZATION (\$63,160)

Production of crystalline levulose.—The first plant for the production of crystalline levulose has been assembled at the bureau. It is made up of borrowed and purchased pieces of equipment, the capacities of which do not match, but nevertheless it has been found possible to produce the new sugar with this plant. The important fundamental problem in this development is the determination of an economically sound method of extraction of the levulose from the raw material. Experiments on the diffusion method of extraction used in the beet-sugar industry have been carried to a point where it has been definitely determined that the results are complete and economically sound. A scientific paper on the preparation of levulose was issued during the year.

New sugars discovered.—A method for transforming certain sugars into new ones has been discovered, which represents a distinct advance in the creation of new carbohydrates. The method employs the action of aluminum chloride upon the acetates of the reducing sugars; and by it the well-known sugars, lactose and cellobiose, have been changed to new sugars of the type known as disaccharides. The names neolactose and celtrobiose have been given to these new sugars. The change of structure resulting from applying this reaction is of a novel type, and the method gives promise of wide applicability in the production of new sugars from old ones and of rare sugars from the more common ones.

Discovery of gentiobiose in dextrose (corn sugar) molasses.—Two important contributions have been made to the bureau's newly created dextrose (corn sugar) industry, one economic in character,

and one of considerable scientific importance. The hydrol, or molasses, from the dextrose industry is a very complex product of unknown composition. Knowledge of similar products has long been sought. In cooperation with the Corn Products Refining Co., the bureau has cracked this hydrol for the first time and taken therefrom a rare sugar, gentiobiose, present in considerable quantities. The work led also to the discovery by the bureau that Prof. Emil Fischer's classical isomaltose, a compound of great importance in organic developments, is none other than gentiobiose. This discovery promises to reopen the whole subject of the synthesis of the sugars.

Imported sugar and molasses.—Approximately \$140,000,000 per year in revenue is derived by the Government from the customs duty on imported sugar and molasses. The supervision of the testing methods at the customs' laboratories is one of the important functions of the bureau. The tariff act of 1922 provided for the collection of duty on imported molasses on the basis of total sugars. This required the bureau to develop precise methods for testing molasses. These were worked out, and during the past year have proved to be very satisfactory.

GAUGE STANDARDIZATION (\$38,320)

Testing of gauges for manufacturers.—Practically all quantity production of machines and machine parts is dependent upon the use of limit gauges, and the degree of interchangeability obtained in the product is a measure of the adequacy of the gauging system employed.

An idea of the importance of limit gauges in interchangeable manufacture can best be gained from a few representative examples. The production and inspection of the Springfield Army rifle requires the use of 1,263 gauges; a machine gun about 2,200 gauges; and one make of automobile about 15,000 gauges. The Ordnance Department of the War Department has under its charge in the various arsenals more than 500,000 gauges, the replacement value of which is about \$30,000,000.

Obviously the Bureau of Standards or any other single organization could not hope to test all or even a large proportion of the limit gauges in use in the manufacturing industries of the country. Fortunately this is not necessary, since each manufacturer can, through the use of certified standards, be largely responsible for the accuracy of his own gauges and product. It is desirable, however, for all manufacturers and users of gauges to have access to the same ultimate standards. This means is provided by the gauge section of the Bureau of Standards.

In addition to the ordinary testing and research carried on under this fund, two projects deserve special mention—work on gauges for use in the petroleum oil industry and researches on screw threads carried on in cooperation with the National Screw Thread Commission.

New equipment purchased for gauge standardization.—A Zeiss interference comparator designed primarily for use in the measurement of length, planeness, and parallelism of gauge blocks was purchased during the year. This instrument is similar to the Fabry and Perot

interferometer and is useful in checking measurements made by the interference method ordinarily employed at the bureau. It is especially useful in the comparison of relatively long blocks, blocks of poor reflecting surfaces, and blocks differing in length from the standard by more than five bands.

A second interference comparator of the modified Michelson type has also been ordered. This instrument will be used primarily for checking the bureau's master precision gauge blocks. By its use both the absolute length of blocks and the difference in length of blocks of different nominal sizes can be determined.

Cooperation with Federal Specifications Board.—A member of the bureau's staff has served as chairman of the gauge committee of the Federal Specifications Board. Preliminary surveys have been made of existing specifications, and in cooperation with the National Screw Thread Commission it is believed that uniformity will soon be brought about.

INVESTIGATION OF MINE SCALES AND CARS (\$14,540)

Mine-scale tests.—Bureau mine-scale testing equipment operating in Pennsylvania, Maryland, and West Virginia, tested 233 scales used for fixing the amount of wages due miners.

Of this number 117, or 50.2 per cent, were found to be correct within the tolerance adopted by the bureau for scales in service of that character.

The figure of 50.2 indicating the percentage of correct scales is somewhat lower than the corresponding figure for the preceding year, when 56.5 per cent of the scales passed the prescribed tolerance. This circumstance, however, does not represent a general retrogression in weighing conditions in the coal fields, since the districts covered in the two successive years are different. It is the bureau's policy to investigate different coal-mining districts in succeeding years in order that all may have the benefit of the inspectional service and in order that information as to progress may be had for all important coal-producing sections of the country.

In general, it is evident that progress is being made toward securing a greater degree of accuracy in weighing throughout the various coal-mining fields. For example, of 54 scales tested in West Virginia fields during 1919, 15 scales, or 27.8 per cent, were found to be within the bureau's tolerance.

METALLURGICAL RESEARCH (\$43,140)

Properties of steel.—A thorough investigation has been made of the cutting properties of high-speed tools and a publication was issued on the effect of various alloying elements. A comprehensive report on the machineability of carbon and alloy steels is nearly ready for publication.

Dimensional changes with time and the wear resistance of gauge steels have been studied, special apparatus having been constructed for the last-named work. Two publications have been made on this project, which is carried on in cooperation with the Gauge Steel Committee.

The presence of aluminum has been found to be concomitant with the "abnormality" of carburizing steel, and the effect of dissolved gases in the quenching media in favoring the formation of soft spots has been noted. The Bureau of Mines has cooperated with the bureau on this project and many manufacturers and users have likewise assisted.

Corrosion of metals.—Cooperative work with the Bureau of Mines on tarnish resistant silver alloys and with the American Society for Testing Materials on screen-wire cloth has been practically completed and the latter has been reported on. Very extensive work on methods of nonferrous corrosion testing for the American Society for Testing Materials has been completed and reported. Work for the same society on accelerated corrosion testing of zinc-coated materials has been begun. The electrolytic method of testing is also being studied.

Much work has been done for the Navy, the Army, and the National Advisory Committee for Aeronautics upon the problem of the embrittlement of duralumin by corrosion. Accelerated methods for testing have been developed and various coatings have been studied, some of which appear so satisfactory as to greatly strengthen confidence in duralumin as a material of construction in aircraft.

Resistance to wear of car bearings and soundness of railway rails.—In cooperation with a guest worker from a manufacturing company the resistance to wear of bronze railway bearings has been studied. Metallographic work has been done on welded rails for the Welded Rail Committee, and plans laid for work on the relation between ingot soundness, rail failures, and transverse fissures.

Methods of testing metals and studies of their properties.—Projects were completed and information published on methods of testing the flow in steel at high temperatures, on quenching media, and on determination of hardness by the scratch method. Progress was made in the study of precision methods for crystal analysis by the X-ray spectrometer and of methods for wear testing.

The study of the properties of pure zinc was completed and published, and those on pure nickel, pure iron, and pure thorium are in progress. Work on the recrystallization temperatures of electrolytic iron and open-hearth steel strips was completed and prepared for publication. Work on the density of carbon and alloy steels is still in progress.

Meetings of metallurgical advisory committees.—The annual meetings of the advisory committees to the Bureau of Standards on ferrous and nonferrous metallurgy were held at the bureau on May 5 and 6. The total attendance numbered 76 at the first meeting and 66 at the second. The committees agreed that the major projects in hand at the bureau should be continued and that new projects should be taken up only as the present ones are completed, except in cases where the necessary support can be furnished through the establishment of research associateships.

Information on metallurgy.—A dozen papers on projects previously finished experimentally were completed and published. Five letter circulars were issued. Current metallurgical literature was reviewed and indexed for use in replying to the many inquiries received from the public; revision of the circular on aluminum is under way.

HIGH-TEMPERATURE INVESTIGATIONS (\$9,740)

Standardization of pyrometric cones.—The thermal characteristics of the pyrometric cones most widely used in this country were determined and standard tests for refractories developed. A committee of representative ceramists cooperated with the bureau in this work. The results will improve the facility of control of ceramic kilns, thus decreasing the losses of badly fired ware.

Optical pyrometry.—The methods and computations in optical pyrometry have been thoroughly revised, which will simplify all high-temperature measurements in the pyrometry laboratory of the bureau and improve the measurements in industrial laboratories which depend upon the Bureau of Standards.

SOUND INVESTIGATION (\$5,580)

Acoustic properties of building materials.—Investigations of the acoustic properties of building materials have been continued with the cooperation of the Gypsum Industries (Inc.) and the National Lime Association. Sound transmission measurements were made on some 30 panels representing types of partition-wall construction in general use. Measurements of sound absorption were also made on certain of these panels and on a dozen or more substances commonly occurring in construction. These values of sound absorption are of importance in predetermining the acoustic qualities of a proposed auditorium.

Scientific Paper No. 526 on transmission and absorption of sound by some building materials was issued during the year.

Phonetics.—The sound laboratory has cooperated with a member of the staff of Purdue University in researches in phonetics. Photographs of different vowel sounds have been made and analyzed for their harmonic components. Similar assistance has been extended to a member of the National Research Council in work in the education of deaf-mutes.

Substitution of tuning fork for chronometer.—Investigations have been made at the request of the Coast and Geodetic Survey with the purpose of finding, if possible, some means of substituting a tuning fork for a chronometer in gravity determinations.

INDUSTRIAL RESEARCH (\$174,120)

Battery investigations.—During the year work has been continued on the effects of impurities in electrolytes, and wide publicity given the results in order to protect the public from loss through use of fraudulent battery dopes. This work is also providing information which is needed by manufacturers on the degree of purity required in both electrolyte and other storage-battery materials. Desirable physical properties and dimensions of battery plates for special uses have been determined. Studies of performance of different forms of caustic soda primary cells have provided a basis for specifications of such cells for railway and similar purposes, in which their use is growing rapidly.

Electrical insulating materials.—The work on electrical insulating materials has developed during the year along three lines: (1) The

specific conditions to be met in order to find a practicable substitute for gutta-percha in submarine cables; (2) electrical properties of rubber and rubberlike materials in general, and the conditions which cause deterioration and breakdown of insulators in service; (3) co-operation with committees of the American Society for Testing Materials in the development of testing methods and specifications for insulating materials, including thermal, mechanical, and chemical tests, as well as electrical.

Electrical recording strain gauges.—The carbon pile instruments devised at the bureau for showing and recording strains and other small displacements have found many important applications. In 1926 they have been installed in the experimental arch dam at Stevenson's Creek, Calif., have been used for measuring pressures in rolling mills, and the distortion of welded street-car rails in service, and are being considered for a number of other applications for which no other instruments are available.

Thermal conductivity of insulating materials at high temperatures.—The apparatus for determining the thermal conductivity of insulating materials at high temperatures was completed during the early part of the year.

Thermal conductivity of commercial insulating materials.—Thermal conductivities and densities of a large number of commercial insulating materials have been measured.

A standard of thermal conductivity is being developed to aid in intercomparing results of different laboratories.

Heat transfer through building walls.—Data were obtained on heat transfer through building walls, but it was thought advisable to defer publication of this until a few more walls were included, permitting the calculation of a large number of others without actual tests.

Critical review and recalculation of the data in the literature brought to light certain discrepancies which may be cleared up by additional tests. A new constant temperature room has been built and equipped.

Properties of refrigerating brines.—A complete report has been prepared on the properties of refrigerating brines.

Thermal properties of steam.—An investigation of the thermal properties of steam forms part of an extensive program sponsored by the American Society of Mechanical Engineers, which has maintained two research associates at the bureau throughout the year. The work has been brought to the stage of assembling the completed experimental equipment.

Measurement of fuel volatility.—Considerable progress has been made in the development of a method of measuring fuel volatility, which consists essentially of an equilibrium distillation in the presence of air. Preliminary tests indicate that the method can be handled without appreciable difficulty and will give directly the information desired. This method supplements the present form of distillation, the results of which can not be readily translated into expected performance in the engine and do not permit of direct, quantitative comparisons of fuels.

Antifreezing solutions for automobile radiators.—The bureau has shared in the activity regarding new antifreeze solutions by de-

termining the freezing points of many of these solutions, by investigating their corrosive properties, and by incorporating essential information concerning these solutions in a letter circular dealing with the subject.

Bearing wear.—An investigation has been made of the effect of viscosity on bearing wear when an abrasive is in the oil, and a report of this work has been completed.

Automobile tires for Government use.—The purchase of tires by the Government constitutes an item of expense which during the past year amounted to approximately \$1,000,000. The bureau's equipment has been of immense value in testing representative tires offered for delivery, thus insuring that the tires purchased meet the specification requirements. Tests have also been made for several States and municipalities, as well as for tire manufacturers who were not equipped to make the tests. In addition to the obvious value of these as a check on the quality of tires purchased, the bureau's work has been of material assistance to manufacturers, and in a number of instances the design of tires has been improved as a result of some weakness developed under the bureau's test.

Motor-car brake-lining performance.—The performance of brake linings on a car has been studied with respect to the influence upon the coefficient of friction of the temperature of the brake lining, the presence of water, and the presence of oil. The standard test for brake linings developed by the bureau is now being used by about 20 manufacturers, including several makers of automobiles.

Behavior of synthetic tanning materials.—The investigation of synthetic tanning materials was completed during the year. Publications were issued dealing with studies of various coal-tar crudes with respect to their suitability for producing materials with tanning properties. A report also was issued showing the behavior of these materials toward hide substances with respect to solvent action and rate and amount of combination. Two additional reports are about to be published which relate to the action of sodium sulphate in certain syntans, and methods of analysis. The information will be useful to users and producers of these new materials which are being slowly developed for the tanning industry.

Sulphite cellulose extracts for tanning.—Researches during the year show that a treated and concentrated extract made from the waste liquors discarded in the manufacture of paper pulp can be satisfactorily used for tanning hides, particularly when blended with the ordinary vegetable tanning materials. These extracts were found to contain usable amounts of material which would firmly combine with hide to form leather, to give satisfactory color, and to be suitable for blending with vegetable extracts on an equal tanning basis. The leather made had satisfactory chemical, physical, and aging properties. The use of these extracts, which are low in cost would benefit the tanner to the extent that they could be substituted for more costly materials and be of direct benefit to the paper pulp producer through the utilization of a waste product. The increased use of these materials in the actual tanning processes may be predicted in view of the fact that the source of chestnut-wood extract, the cheapest and most widely used domestic material, is at present being destroyed by blight.

Orifice gas meters.—The work on the standardization of orifice meters has been continued. Meters of this type are used in the measurement of natural gas obtained from Government reservations, involving revenues amounting to millions of dollars annually. In order to obtain the required accuracy it is necessary to standardize orifice meters by measuring the gas flow through them by some independent method. From such a comparison a coefficient is obtained which is applicable to other orifice meters of the same kind used under similar conditions.

Comparisons of this kind have been undertaken by the bureau, the work falling under three heads: (a) Cooperation with the American Gas Association in experiments with manufactured gas at Chicago; (b) experiments by the bureau at Edgewood Arsenal using compressed air; (c) cooperation with the Natural Gas Association of America in experiments with natural gas at Cleveland. (a) The experiments at Chicago were performed in 1924, but it has not yet been possible to attack the task of preparing the results for publication. (b) The experiments at Edgewood Arsenal were concluded in 1925 and it is expected that the results will be ready for publication within a year. (c) Some preliminary work was done at Cleveland in 1925.

Melting points of metals and alloys.—The melting points of iron and a series of typical iron alloys were determined in response to urgent demand from the industries. Preliminary work on the melting point of platinum has consisted in the development of refractory materials in which this metal can be melted and kept pure.

Expansivity measurements.—Research in thermal expansivity of solids, precision screw cutting and ruling, and a preliminary investigation of dental materials have been conducted.

Accurate knowledge of materials of low thermal expansivity is becoming of increasing importance in industry, and much work has been done in this field. Special study has been given to fused silica, graphite, tungsten, and nickel steel alloys.

A linear dividing engine suitable for ruling gratings and linear scales, which has been under construction at the bureau for several years, is nearing completion.

Specifications for dental materials.—The work on dental materials has made possible the writing of definite specifications for dental amalgams, and has also been of material assistance to the Veterans' Bureau and other Government departments in securing of high-grade gold alloys for dental purposes.

The bureau's work on dental materials has already been productive of such results that the American Dental Association has promised cooperation and financial support.

Industrial metallurgical problems.—Heat-resisting alloys have been studied with improved and considerably augmented equipment, and a paper on flow in a low-carbon steel published. This work is carried on in cooperation with the American Society of Mechanical Engineers and the American Society for Testing Materials.

Quenching media were examined, papers published on the origin of quenching cracks, and on initial temperatures and mass effects in quenching, and apparatus was assembled for the study of temperature distribution.

Gases in metals were studied chiefly from the analytical viewpoint, and projects on hydrogen in steel, on vacuum-fusion methods for oxygen and hydrogen, and on the oxygen content of cast iron were completed and published, while work on vacuum fusion and other methods for nitrogen, and on the fusible alloy metal for oxygen was brought well toward completion.

Technique was developed for the collection of gases in "blistered" metals and for the analysis of minute amounts of gas. A research fellow from the Swedish Engineers' Academy and a guest worker from an American manufacturing company were in attendance part of the year for work on gases in metals. Additions were made to the specialized equipment for this project.

Metal spray work was continued, especially on the preparation of surfaces for the reception of adherent deposits. Cooperation was given to the Navy in connection with metal spray.

Industrial chemistry.—Investigations have been conducted on methods of electroplating with nickel, copper, silver, gold, chromium, and platinum. Pure dyes have been prepared and their transmissivity for light determined. Methods for analyzing dyes have been studied, and an investigation, in cooperation with the American Society of Textile Chemists and Colorists, is now under way to determine the strength and purity of dyes and their fastness when used to dye textiles. Proposed methods of labeling commercial fabrics to indicate the fastness of color under various conditions have been considered, as well as the relation between the chemical constituents and the color of dyes. A method for the separation of gases by fractional distillation has been developed with the object of providing an analytical method for the natural gas and petroleum industries. A fundamental study has been made of the chemistry and physics of gas flames, and a helium recorder has been developed for the War Department.

Spectrochemical analysis.—During recent years the early expectations, for a long time unfulfilled, that the spectroscope would eventually become a powerful aid in quantitative chemical analysis, have been realized in a most important way. For instance, the spectroscope has been used to determine small percentages present as impurities in alloys, thereby permitting the correlation of these impurities with anomalous behavior on the part of the alloy. During the year over 200 such investigative analyses have been made, one result of which was the correlation of the anomalous behavior of steel with minute quantities of impurities present, especially aluminum. Three publications were issued.

Atomic structure and X rays.—The bureau has conducted, in cooperation with the National Research Council, investigations in which quantum dynamics and the radiations of atoms have been applied to determine both their ionization potentials and their structure. Ten publications have been issued in this connection.

An X-ray outfit has been installed in a special lead-lined X-ray chamber. An investigation of barium sulphate plaster as a protective screen against X rays was made and a paper published giving the results.

Determination of salinity of sea water.—In cooperation with the Bureau of Fisheries an investigation of the accuracy, reliability, and convenience with which the refractometer can be used for test-

ing the salinity of sea water, has been made. It was found that, after eliminating common errors, the accuracy obtainable is much greater than that of present standard tables, and this taken with the extreme convenience of the method demands a revision of the tables which assume to give the indicative figures.

Improved photographic emulsions.—Progress in the science of photography is possible through either the lens which forms the image or through the emulsion which records it. The science of lens design has received a great amount of attention which is almost classical in character. The preparation of photographic emulsions, on the other hand, is largely a secret and empirical art known to relatively few. There is probably room for ten times more improvement in making emulsions than in making lenses. During the past year the bureau has made over 400 batches of emulsion and tested them. As results of this work a method was developed for enhancing the color sensitivity of panchromatic emulsions without loss in their keeping qualities and progress was made toward replacing customary "ripening" of emulsions by processes susceptible of more exact control.

A scientific paper was issued, describing a new nonintermittent sensitometer (time-scale exposure machine) for testing photographic plates.

Precise measurements of pressures.—Special precision dead-weight pressure gauges designed and built at the bureau for use in other researches have shown an absolute accuracy of better than 1 part in 10,000 from 1.5 to 100 atmospheres.

Wind pressures on structures.—A scientific paper (No. 523) on the subject of the effect of wind pressures on structures was issued during the year. The report contains a general discussion of the many variables on which the pressure of the wind depends and gives general recommendations as to wind-pressure coefficients for structures of various shapes. In addition, values of the pressures on a model of a tall building are given for a large number of points on the walls and roof, as obtained by measurements in the 10-foot wind tunnel of the bureau at speeds up to 70 miles per hour.

Measurements have been made on cylinders of the general proportions of the tall chimneys used on power plants. The work begun last year on a cylinder 8 inches in diameter and 5 feet high was completed and a detailed study was made of the distribution of pressure for a larger cylinder, 12 inches in diameter and 5 feet high. It was found that results which were directly applicable to full-scale chimneys could not be obtained even with the 12-inch cylinder, owing to the persistence of scale effects. However, the data offer a basis for reasonable estimates of the total loads and give information as to the character of the distribution of load over the surface.

At present, measurements are in progress on prisms of various lengths in order to find the effect of height on the loads of a tall building. It is planned to study next models of the mill-building type with monitor and sawtooth roofs.

Cooperation with industry.—One of the most effective ways in which the bureau cooperates with American industries is through its system of research associates, briefly referred to in the first part of this report.

During the past year there were stationed at the bureau 62 of these associates, representing 36 industries. The research associate plan has proved most successful in making available to our industries the unusual research facilities of the bureau. Since the results are all published for the benefit of everyone interested, the work has influence, the amount of which is hard to estimate.

The large building-materials industries have availed themselves of the advantages of the research associate plan to the fullest possible extent. For instance, the Portland Cement Association maintains a corps of seven physicists and chemists, under the direction of a recognized expert, at the bureau to work on fundamental problems in the cement industry. The Hollow Building Tile Association supports two associates who are working on problems connected with the fire-resistance of hollow tile. Several important papers dealing with this work have already been published. The National Terra Cotta Society also maintains two experts at the bureau who are working on special problems affecting this widely used material.

The National Association of Dyers and Cleaners has three associates at the bureau, and has obtained some very valuable results on cleaning of silk, particularly the effect of acids and cleaning solvents on weighted silk. A paper on this subject will be published within a few months.

The Society of Automotive Engineers is represented by four experts who are carrying out fundamental research on fuels for internal-combustion engines, a matter that is becoming of greater importance each year.

These are only a few examples selected at random. Many more of equal importance might be cited.

A circular (No. 296) fully describing the research associate plan was issued during the year and has been in great demand.

TESTING RAILROAD-TRACK AND OTHER SCALES (\$39,000)

Railroad-track scales.—During the last fiscal year tests were made of 980 railroad-track scales located in 39 States and on 79 railroad systems. On 172 scales adjustments were made to reduce the error of weighing, a service feature which is included with tests whenever considered practicable. Of all the scales tested 65.4 per cent were found to be within the bureau's tolerance and the mean error of all scales was 0.29 per cent. These figures are virtually identical with those of last year. However, a notable improvement over results of previous years is observed in the southern district where 61.9 per cent of all scales tested passed the tolerance as compared with 47 per cent in 1925. Further evidence of betterment in that district is to be found in the mean error. Excluding 1 scale with an exceptionally excessive error, the mean error was only 0.30 per cent as compared with 0.42 per cent the preceding year. No appreciable improvement is discernible in other districts. The general conclusion drawn is that maintenance efficiency and replacement rate have reached, for the present, a peak level in the eastern and western districts, while in the southern district, where such factors have heretofore been deficient, the work done has drawn attention to their value with gratifying results.

Master-track scales.—The 15 master-track scales calibrated and, when necessary, adjusted during the year were found to be correct

within allowed limits. Five master scales in the southern and eastern districts remain untested in consequence of personnel shortage and necessity for repairs to testing equipment. These tests will be brought up to date in the very near future.

Railroad-track scales in grain-weighing service.—Included in the general track scale testing program were tests of 90 scales used for weighing grain. Of this number 37 were within the special tolerance adopted for this class of service and 15 more were adjusted to reduce the errors within the tolerance limits. Very few of the large grain terminal markets possess equipment adequate for properly testing these scales, and the services of the bureau's units for that purpose are in increasing demand. In view of intimations made to bureau representatives during the year, it is not unlikely that the bureau will shortly be requested to enter the field of testing automatic and hand-operated grain-hopper scales. This would be a logical field for bureau investigation and one in which very valuable work could be accomplished, but special equipment and additions to the staff would be required.

Test-car calibration.—Twenty-seven test cars operated by railroads and industrial plants at points remote from a regular master scale were standardized during the year. A commendable trend toward acquisition of approved types of test cars is apparent and is interpreted as being a direct result of bureau recommendations for improved testing practice and facilities.

Specifications.—Two section track scales of the knife-edge type have lately been placed on the market and their advent has aroused a considerable degree of interest and controversy as to their merits and adequacy. Issuance of specifications for the guidance of manufacturers, purchasers, and builders is contemplated and the necessary preliminary data have been compiled.

General.—As in past years, the field work suffered interruption and delay occasioned by lack of funds, resignation of inspectors, and repair of equipments. No. 1 unit was withdrawn from service in February for a necessary overhauling and was not thereafter operated. In spite of this and other unfavorable circumstances the aggregate number of field tests exceeded by 10 per cent the number for last year. Prosecution of essential phases of the work at the bureau was necessarily neglected. If the section is to pursue a consistent policy of improving the commercial weighing situation and is to develop related projects successfully, additional personnel must be acquired and salaries of field men brought up to a plane where the bureau's schedules will not be so frequently disrupted by resignations of inspectors who receive more attractive offers from other agencies.

STANDARDIZATION OF EQUIPMENT (\$110,000)

Simplified practice recommendations accepted.—Up to the present time simplified practice recommendations have been accepted by manufacturers, distributors, and users of the following commodities:

No.	Item	Reduction in varieties		Per cent reduction
		From—	To—	
1	Vitrified paving brick (fourth revision conference).....	66	4	94
2	Beds, springs, and mattresses.....	78	4	95
3	Metal lath.....	125	24	81
4	Asphalt (penetrations).....	88	9	87
5	Hotel chinaware.....	700	160	77
6	Files and rasps.....	1,351	496	65
7	Rough and smooth face brick.....	75	2	97
8	Common brick.....	44	1	98
9	Range boilers.....	130	13	90
10	Woven-wire fencing.....	552	69	87
11	Woven-wire fence packages.....	2,072	138	93
12	Milk bottles and caps.....	78	10	87
13	Bed blankets (sizes).....	78	12	85
14	Hollow building tile.....	36	19	48
15	Structural slates for plumbing and sanitary purposes.....	98	48	51
16	Roofing slates, descriptive term (thicknesses and sizes).....	251	25	90
17	Blackboard slates, slab heights and sizes.....	665	351	47
18	Lumber (first revision) ¹	665	351	47
19	Forged tools.....	665	351	47
20	Builders hardware:			
21	Items.....			26
22	Finishes.....			71
23	Asbestos paper (sizes, widths, weights of rolls).....	14	8	43
24	Asbestos millboard (sizes, thicknesses).....	10	5	50
25	Steel barrels and drums.....	66	24	64
26	Brass lavatory and sink traps.....	1,114	72	94
27	Paper.....	(³)	(³)	(³)
28	Plow bolts.....	1,500	840	44
29	Hospital beds:			
30	Length.....	33	1	97
31	Width.....	34	(⁴)	91
32	Height.....	44	1	97
33	Hot-water storage tanks.....	120	14	88
34	Steel reinforcing bars (cross-sectional areas).....	40	11	73
35	Cotton duck (widths and weights).....	460	94	80
36	Sheet steel (first revision).....	1,819	263	85
37	Eaves trough and conductor pipe.....	21	16	24
38	Terne plate (weights).....	9	7	22
39	Loaded shells (first revision).....	4,076	1,758	57
40	Concrete building units (length, width, and height of blocks, tile, and brick).....	115	24	80
41	Cafeteria and lunch-room chinaware.....	668	177	73
42	Warehouse forms.....	(⁵)	15	74
43	Steel lockers.....	65	17	74
44	Milling cutters.....	(⁵)	3	35
45	Commercial purchase forms.....	14	3	79
46	Sand-lime brick (length, width, and height).....	700	113	84
47	Hospital chinaware.....	6,280	4,700	25
48	Paper grocers' bags.....	244	60	75
49	Box board thicknesses.....	715,200	255,800	64
50	Grinding wheels.....	428	181	58
51	Cut tacks and small cut nails:	423	121	71
52	Sizes.....	120	6	95
53	Packing weights.....	80	5	94
54	Sidewalk lights:	10	2	80
55	Sizes.....			75
56	Styles.....			
57	Shapes.....			
58	Die-head chasers (for self-opening and adjustable die heads).....			

¹ Average reduction.² Standard nomenclature grades and sizes for softwood lumber.³ Indeterminable.⁴ 1 standard, 2 specials.⁵ Thousands.

Recommendations in process of acceptance.—Simplified practice recommendations for the following items have been proposed and approved at a general conference of manufacturers, distributors, and users, and are now in process of acceptance by the various groups interested.

No.	Item	Reduction in varieties		Per cent reduction
		From—	To—	
39	Dining-car chinaware.....	700	113	84
41	Insecticides and fungicides (packages).....	38	21	45
43	Paint and varnish brushes.....	480	138	71
46	Tissue paper:			
	Roll tissue.....	13	3	77
	Shoe tissue.....	21	6	72
48	Shovels, spades, and scoops.....	5,136	2,178	57
50	Checks, notes, etc.....	(1)	(2)	(2)
53	Steel-reinforcing spirals.....	7	3	58
54	Sterling-silver flatware.....	190	62	67
55	Tinware, galvanized and japanned ware.....	1,154	873	24
56	Carbon brushes and brush shunts.....	(3)	(3)	(1)
57	Wrought-iron and wrought-steel pipe, valves, and pipe fittings:			
	Sizes of valves and fittings.....	20,000	19,238	4
	Sizes of pipe.....	62	49	21

¹ Thousands.² One size for each instrument.³ Indeterminable.

Field surveys in progress.—Surveys of existing varieties are in process for the following industries:

Seeds, hospital linen, trap-screw ferrules, radiators, registers, horseshoes, casket hardware, hollow-metal doors and trim, steel sash, wire-bound boxes, office furniture, hardwood lumber, millwork, tires, knitted underwear boxes, waxed paper, explosives, pyroxylin plastics, metallic cartridges, refractories, vitreous china plumbing fixtures, sterling-silver flatware, porcelain-enamel table tops, brake lining, piston rings, ball bearings, taper-roller bearings, spark plugs.

American Marine Standards Committee.—This organization is controlled by the marine industry but administered as a unit of the division of simplified practice. Its membership is now composed of 312 member bodies and is increasing. The technical activities are carried on by special committees, technical committees, and subject committees, the aggregate number of which is at present 45 and most of which are active. Its work has perceptibly advanced during the year and the prospects for progress are good. Twenty-eight standards have been promulgated and there are numerous others nearing completion. Encouraging interest is being manifested in the organization's program and activities.

General.—Eighteen general conferences of manufacturers, distributors, and users, and 58 preliminary conferences with manufacturers were held during the year. Also 11 revision conferences were held during year, revealing the fact that there is an average adherence to simplified practice recommendations of about 82 per cent. Thirty-eight new fields requested the cooperation of the division in connection with a simplification program. Thirty-four projects (commodities) have developed to the point where there is reasonable expectation of their completion into simplified practice recommendations. Forty-five articles were prepared by members of the staff for printing in outside publications.

A total of 3,461 acceptances of simplified practice recommendations have been received to date from associations, manufacturers, distributors, and consumers. Approximately 250,000 copies of simplified practice recommendations have been sold through the Government Printing Office up to July 1.

The outstanding event of the year has been the appointment of simplified practice committees by a number of the State manufacturers associations, to cooperate with the division of simplified practice, in circularizing their membership for recommendations as to items in greatest need of simplification. This has resulted in a large number of requests for information, and many items were suggested as being fertile fields for the application of simplified practice.

Considerable attention is being given abroad to the subject of simplification, as it is being introduced and practiced among American manufacturers. Many foreign publications are carrying editorials and articles on the "waste elimination program" as being promulgated by the Department of Commerce in cooperation with American industry.

National Directory of Commodity Specifications.—In September, 1925, copies of the National Directory of Commodity Specifications were received from the Public Printer. This book contains references to about 27,000 specifications for more than 6,000 commodities, there being listed therein the current specifications of the Federal Specifications Board, the separate departments of the Federal Government, the State and city purchasing agents, public utilities, technical societies, and trade associations. The book is now in its third printing, the first and second supply having been exhausted within a month after coming from the press.

Specification manuals in progress.—Considerable progress has been made in the preparation of manuscript for three books that can be looked upon as companion volumes to the directory, namely, Specifications for Household Commodities, Encyclopedia of Specifications, in which will appear actual copies of certain nationally recognized specifications for the more important commodities, and Treatise on Specifications, dealing with the selection, use, and limitations of commodity specifications and testing methods.

Certification plan.—With the object in view of facilitating the use of United States Government master specifications by purchasers who are not equipped to test deliveries under these specifications, compilations are being made of lists of manufacturers desiring to supply material in accordance with specifications of the Federal Specifications Board and willing to certify to purchasers upon request that the material thus supplied complies with requirements and tests of the specifications.

List of testing laboratories.—In recognition of the desirability under present conditions of independent commercial testing service and in anticipation of a marked increase in the demand for such service in both domestic and export trade, there is being compiled a classified list of all of the laboratories throughout the country that are prepared to test various kinds of commodities to determine whether or not they comply with purchase specifications. In this list will be included the laboratories of universities and colleges that are equipped for doing commodity acceptance testing on either a purely commercial basis or for the purchasing officers of the States, municipalities, public institutions, or the schools themselves.

Heretofore purchasers not individually equipped to make their own acceptance tests have been reluctant to adopt the specification

method of buying commodities because of the fixed belief that many manufacturers work off "seconds" on such customers. The knowledge that they can at any time, when they so desire, call upon testing laboratories to check the deliveries made to them on contracts, based on specifications with which certificates have been issued by the manufacturers, will induce a large number of such purchasers to take full advantage of the so-called certification plan.

Radio standardization.—Considerable work has been done on specifications and standards for radio apparatus suitable for both Government and public use. Definite standardization in this field is difficult on account of its rapid development, but the general principles are being established through cooperation with the manufacturers' organizations, the Institute of Radio Engineers, and the American Institute of Electrical Engineers. Definite standards for a Government standard receiving tube have been established and considerable progress has been made on specifications for power tubes.

Automobile headlight standards.—During the past year the bureau has furnished consulting service for various States in the establishment of their requirements and procedure for approval of types of automobile headlight devices. It has made tests of many devices for some of the States, particularly Oregon and the District of Columbia. Circular 276, Motor-Vehicle Headlighting, has been widely distributed and the headlight adjusting chart issued with it has been used by thousands in various places where an improvement in the headlight situation has been actively sought.

Safety standards.—The bureau's engineering and consulting service in the preparation of safety codes includes cooperation with representative committees dealing with the construction and operation of industrial equipment of many kinds. This work also includes regular examination of Underwriters' Laboratories reports on electrical devices and advice to State industrial commissions and local authorities regarding safety requirements. During the year the first edition of the Aeronautic Safety Code has been issued, the elevator inspector's handbook has been nearly completed, a code of colors for traffic signals has been published, and a study of desirable colors for tail lights has been begun.

Battery standardization.—During the year extensive tests of the product of all important manufacturers of dry cells have been made with a view to the establishment of Government qualification lists and the revision of specifications. A new and much enlarged automatic battery-testing equipment has been designed and its installation nearly completed.

Handbook on optical design.—The first (100 pp.) of three parts of a handbook on optical design has been prepared for publication. This handbook is intended to lead to standardized methods in the design of optical parts and thus save a great amount of time and labor in this field.

STANDARD MATERIALS (\$10,000)

Distribution of standard samples.—Sixty-four different kinds of standard samples were distributed, 4 new samples prepared, and 8 samples renewed. Approximately 5,500 samples were sold to private

establishments for which \$11,000 was received for deposit in the United States Treasury. In addition, 500 samples with a value of \$1,000 were issued free of charge to Government and State laboratories and State universities. The total return to the Government was, therefore, \$12,000 or \$2,000 more than the present appropriation. Standard samples comprise ores, metallurgical products, and pure chemicals. They are used to check methods of analysis that control the manufacture and sale of metallurgical and agricultural products, to calibrate instruments, and to further research. A direct result of their use is a saving of thousands of dollars a year through improved manufacturing operations and the avoidance of litigation based on faulty analysis.

INVESTIGATION OF RADIOACTIVE SUBSTANCES (\$10,680)

Beta-ray spectroscopy.—With the cooperation of the National Research Council apparatus was designed and constructed for investigations in Beta-ray spectroscopy. Two minor publications have been issued.

Tests of radium preparations.—Over \$800,000 worth of radium preparations were tested, the sale price being determined by these tests, eliminating controversy between buyer and seller. The fees received in this service amounted to \$6,715.50.

INVESTIGATION OF AUTOMOTIVE ENGINES (\$25,000)

Supercharging of aircraft engines.—This project has as its purpose the determination of the maximum improvement in engine performance to be expected as a result of supercharging. By means of the altitude laboratory equipment it has been possible to test both a Liberty 12 and Curtiss D-12 engine over conditions of temperature and pressure corresponding to altitudes up to 25,000 feet. The performance which these engines would give if equipped with an "ideal" supercharger has been determined and the foundation thus laid for tests of actual superchargers to determine the extent to which they meet this ideal.

Economic volatility of motor fuels.—The bureau for several years has cooperated with the American Petroleum Institute, National Automobile Chamber of Commerce, and Society of Automotive Engineers in an investigation of the economic volatility of motor fuels. A marked increase in the use of closed cars and a nation-wide program of road development have increased greatly the winter operation of automobiles. Starting cars in cold weather is one of the outstanding difficulties of winter operation. The bureau has studied this problem both from the standpoint of improvements in fuel and improvements in engine design which would help the situation. Three reports covering the findings to date have been presented to the cooperating societies and at their request the work is being continued.

Fuels for high-compression engines.—The development of cracking processes by oil refiners during the past year has resulted in a considerable increase in the amount of antiknock fuels available. As the bureau has done a great deal of work in the past, particularly as regards the use of high-compression ratios with antiknock fuels in aviation engines, it has been called upon not only to test these fuels

but to furnish information as to the proper field for their use. Considerable work has been done, therefore, in showing the application of the results obtained in previous years to motor-car problems. This work has emphasized the fact, frequently overlooked, that an increase in compression ratio makes it possible to use a smaller engine and thereby improve fuel economy considerably more than would be anticipated from the effect of the compression ratio upon thermal efficiency. It is evident that development along these lines will be even more rapid during the coming year and the bureau expects to render even greater service along these lines.

Lubrication of aviation engines.—In cooperation with the Bureau of Aeronautics, the bureau has studied the lubrication of aviation engines under the low temperatures which prevail when starting such engines in the winter time. Many engine failures are attributable to faulty lubrication under such conditions. The flow of oil in the various elements of the system has been investigated separately and the flow in an actual engine mounted in a cold chamber has been measured. Various oils have been compared in the same engine. The work has emphasized the seriousness of the problem by showing how extremely small the flow of oil is at low temperatures and at the same time has indicated how engine design may be modified to improve conditions, and what characteristics an oil should possess to be most satisfactory under these critical conditions.

Oxidation.—The oxidation test for lubricating oils which the bureau developed has continued to prove very satisfactory as a measure of the stability of such an oil in service. An obstacle to the adoption of this test, however, was the fact that several experimenters had reported explosions as a result of it. The explosion hazard in connection with this test has therefore been investigated and found to be due to a lack of proper precautions in drying the flasks used in the test before use. The accidents therefore were not due to difficulty in drying the flasks, but to a lack of appreciation of its importance. It is believed, therefore, that the way is now clear for the widespread adoption of this method of test.

TRANSFERRED FUNDS (\$173,250)

Oil pollution.—A member of the bureau's staff has served as technical adviser to the Interdepartmental Committee on Oil Pollution. Several voyages have been made on oil-burning vessels so as to study the behavior of oil and water separators under service conditions. The bureau presented a comprehensive report to the international conference showing that several types of separators now in use can be made to save practically all the oil now thrown overboard.

Radio-direction finder for Coast Guard.—At the request of the United States Coast Guard, the bureau designed a special direction finder for use in connection with the radio receiving sets installed on small motor-driven patrol boats. Only one movement of a hand-wheel is necessary to determine the position of a vessel sending radio signals, as a sharp minimum signal is obtained for all positions of the direction-finder coil by means of a special balancing condenser operated automatically.

Helium recorders.—At the request of the Navy Department, the bureau has designed several sets of apparatus to be used in helium-

recovery plants to control the manufacturing process, for analyzing the gas in the gas bags of airships, and for determining the amount of leakage from the gas bags.

Chromium plating.—A process for plating steel printing plates with chromium has been developed for the Bureau of Engraving and Printing. Chromium is the hardest metal known, and a thin coating of this material greatly increases the life of the steel plate. The quality of the resulting impression is likewise improved. A great saving will result in the cost for replacement of plates, and the better impression will render counterfeiting more difficult.

Corrosion, fatigue, and embrittlement of duralumin.—In cooperation with the Army, Navy, and National Advisory Committee for Aeronautics a thorough investigation is being made of all possible causes of deterioration of duralumin used in aircraft construction. The factor of safety employed in building aircraft is necessarily much smaller than would be the case in other work, so absolutely accurate information on the strength of materials is essential.

Electrically charged dust.—At the request of the Bureau of Entomology of the Department of Agriculture, experiments have been made of spraying electrically charged dust from airplanes in order to destroy insect pests. However, it was found that the method was not a practicable one and the work was discontinued.

Optical glass.—Thirty-six pots of optical glass, each containing approximately 1,000 pounds, were melted during the year. All glass of satisfactory quality is turned over to the optical shop of the Navy Department to be used in making periscopes, range finders, officers' binoculars, and other optical instruments.

Miscellaneous.—Other work which has been performed for the Government on transferred funds includes: Study of performance of machine guns, investigation of bomb ballistics, general radio problems, and causes of embrittlement of duralumin for the War Department; investigation of stresses in aircraft structures, corrosion of duralumin, development of substitutes for parachute silk and goldbeater's skin, investigation of storage batteries for submarines, study of internal combustion engine fuels and lubricants; development of aircraft instruments and improved photographic emulsions, investigation of stresses in riveted ship-plate joints, and stresses in rope and cordage for the Navy Department; miscellaneous chemical and metallurgical tests for the Shipping Board; and development of airplane instruments, wind-tunnel tests of models, investigation of aircraft engine performance, study of velocity of flame in explosive gaseous mixtures, development of substitute for parachute silk, and study of fatigue and corrosion of duralumin for the National Advisory Committee for Aeronautics.

GENERAL RECOMMENDATIONS

Needed increase of funds.—The visiting committee has in the past three years strongly recommended increased funds for the bureau to enable it more adequately to fulfill its functions as a standardizing and national research laboratory, in order that it may keep pace with the industrial development of the country and the demands from other Government departments. The upkeep of standards is seriously in arrears and it is also impossible for the

bureau to meet many of the legitimate requests for testing service which can not be met elsewhere. In many lines of work there are urgent demands for the determination of physical and chemical constants which are not now known with the accuracy that industry and engineering require and which can only be determined satisfactorily in a national laboratory.

In view of the increased governmental requirements for testing of commodities for the Government departments, largely as a result of the establishment of unified specifications promulgated by the Federal Specifications Board, provision should be made for the bureau more adequately to meet the constantly increasing demand for this service. The situation is particularly serious in the branch laboratories, in view of the fact that the comptroller is very properly insisting that materials purchased by the Government establishments be tested in a Government laboratory. Provision for an adequate testing service for all purchases has many times been shown to be economical in the end. I therefore recommend that most serious consideration be given to increasing the bureau's appropriations for the establishment, maintenance, and upkeep of standards, testing work for industry and the Government, and the determination of fundamental constants and the properties of materials essential to progress in industry.

Coordination of Bureaus of Mines and Standards.—The entrance of the Bureau of Mines into the Department of Commerce has made possible the coordination of the work of the Bureaus of Mines and Standards. The oil testing heretofore done by the Bureau of Mines has been transferred to the Bureau of Standards, and provision will have to be made to care for this work on our funds. The ceramics work of the bureaus was also concentrated at the Bureau of Standards with reduced appropriations. The committee representing the ceramic industry is strongly recommending substantial increases in the ceramics work of the bureau and provision should be made to meet this situation.

Industrial utilization of waste farm products.—Looking ahead into the future the time will undoubtedly come when it will be necessary to utilize more effectively the enormous quantities of waste products of the farm, such as stalks and straw. I recommend that a survey be made of the possibilities in this field, and that if it seems warranted the Government take the initiative in this activity. There would appear to be great possibilities in the recovery of gums, sugars, and cellulose products from these materials now wasted, and it is possible from our present knowledge to work over these recovery products into derivatives of great economic value and importance. The end products include a great variety of chemicals, cattle feed, and also fuels, and a large variety of cellulose products.

Heating and power plant.—Congress at the last session authorized the erection of a power-plant building to cost \$200,000, and I recommend that this appropriation be made as soon as possible, as our present heating and power plant is obsolescent, inefficient, and in some respects unsafe. Provision should also be made for installing operating equipment which will cost about \$300,000. It is expected that when the new plant is in operation there will be a saving of \$25,000 a year, with greatly enhanced service to the bureau. The

setting in operation of this plant is the most urgent need of the bureau.

Master-track scale.—Congress has authorized an appropriation of \$50,000 for the installation of a master-track scale and heavy test weight depot on a site to be acquired by gift. It is important that this site be acquired and the authorized building erected and the equipment installed at the earliest possible date to meet the demands on this most important service.

Medical aid.—I again recommend that provision be made for the establishment at the bureau of a first-aid station in care of a competent physician, preferably detailed from the Public Health Service. Such a station is an imperative need at an institution of the type of the bureau where there are so many accident hazards. Also there are several lines of work, including radium and furnace operations, requiring medical oversight of the physical condition of the operating personnel.

Care of buildings.—As stated last year, the number of janitors, laborers, and watchmen necessary properly to care for the buildings and grounds is entirely inadequate. There is actual danger in this situation, and it should be remedied at once. The safety of the valuable buildings and equipment of the bureau is often dependent on this service, which is now very much below the standard set for ordinary office buildings belonging to the Government, in which no unusual risks are housed.

Congress has authorized the retransfer to the jurisdiction of the bureau the custody, maintenance, protection, and operation of the bureau's plant and buildings.

Care of grounds.—Under the present appropriation for care and upkeep of the bureau's grounds it has been impossible to put them in a satisfactory condition. Likewise, it has not been possible to install drains which are urgently needed, make necessary repairs and additions to roads, or make provision for a suitable entrance. It is therefore recommended that the appropriation for grounds be substantially increased.

Important legislative proposals affecting the bureau.—Among the bills before Congress affecting the bureau are the following: Clinical thermometer bill, metric bill and resolutions, misbranding bill, paints, oils, etc., truth-in-fabric bill, hampers and basket bill, wheat-mill products, etc., and bread bill.

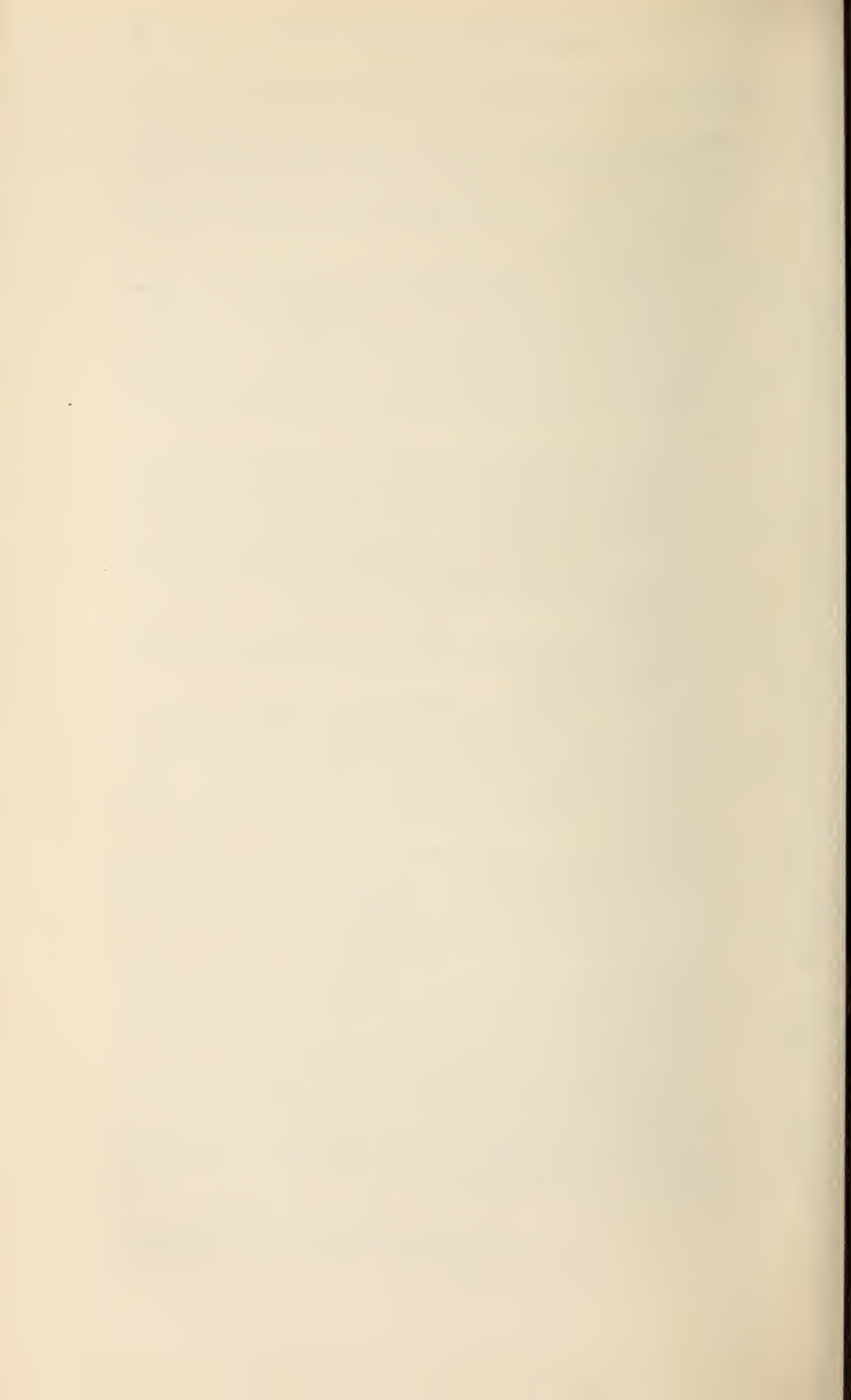
At the first session of the Sixty-ninth Congress, Senator Copeland introduced two bills relating to the accuracy of clinical thermometers entering into interstate commerce or imported into the country. One bill provides for compulsory tests, while the other proposes to set up a system of licensing manufacturers.

The bureau has tested clinical thermometers upon request ever since its organization and the experience thus gained as well as testimony adduced from various sources has convinced us that there is a very real need for some legislation on this subject. The bill contemplating compulsory tests has been passed by the Senate (S. 2142).

Very truly yours,

GEORGE K. BURGESS,
Director, Bureau of Standards.





APPENDIX

GENERAL FINANCIAL STATEMENT

During the fiscal year 1925-26 the bureau expended and accounted for funds aggregating \$1,968,332.77, including \$173,250 received by transfer 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., 1926, 1925, and 1924 appropriations

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
1926				
Salaries.....	¹ \$516,760.00	\$495,271.89	\$21,356.21	\$131.90
Equipment.....	70,000.00	47,448.08	22,163.47	388.45
General expenses.....	² 45,418.35	29,028.42	13,729.33	2,660.60
Improvement and care of grounds.....	11,000.00	10,571.48	411.18	17.34
Testing structural materials.....	³ 232,147.29	213,312.10	17,550.13	1,285.06
Testing machines.....	38,000.00	35,619.46	2,196.03	184.51
Metallurgical research.....	⁴ 43,220.00	38,224.10	4,416.27	579.63
Investigation of optical glass.....	20,520.00	18,780.75	1,675.52	63.73
Standard materials.....	10,000.00	9,666.10	333.65	25
Investigation of textiles.....	⁵ 27,560.00	24,888.37	2,279.35	392.28
Sugar standardization.....	⁶ 40,960.00	38,185.51	2,583.25	191.24
Gauge standardization.....	38,320.00	34,375.44	3,496.36	448.20
High-temperature investigation.....	9,740.00	9,124.42	529.18	86.40
Testing railroad scales.....	39,000.00	33,943.24	4,799.47	257.29
Investigation of fire-resisting properties.....	28,100.00	27,132.78	862.35	104.87
Testing miscellaneous materials.....	⁷ 49,090.00	45,136.22	3,706.35	247.43
Investigation of public-utility standards.....	100,000.00	90,249.50	9,261.69	488.81
Radio research.....	44,800.00	43,111.39	1,651.13	37.48
Industrial research.....	⁸ 174,858.13	160,083.47	13,646.56	1,128.10
Sound investigation.....	⁹ 5,655.00	5,574.52	32.00	48.48
Investigation of clay products.....	27,000.00	24,049.66	2,116.24	834.10
Color standardization.....	9,000.00	8,159.59	621.75	218.66
Investigation of radioactive substances.....	10,680.00	9,944.61	444.48	290.91
Standardizing mechanical appliances.....	27,800.00	25,099.43	2,615.23	85.34
Investigation of mine scales and cars.....	14,540.00	13,549.17	1,037.39	153.44
Standardization of equipment.....	¹⁰ 111,634.00	100,287.83	10,664.86	681.31
Investigation of automotive engines.....	¹¹ 30,280.00	26,563.89	3,543.29	172.82
Sugar standardization (1926-27) ¹²	25,000.00	1,268.85	4,908.28	18,822.87
Appropriations transferred from other departments which are available for the current year:				
Compensation of employees, Bureau of Engraving and Printing.....	6,000.00	5,598.08	372.50	29.42
Signal Service of the Army.....	1,800.00	1,635.25	140.57	24.18
Automatic rifles (1926-27) ¹³	2,000.00	1,769.63	130.44	99.93
Construction and repair, Bureau of Construction and Repair.....	5,750.00	3,673.93	1,908.88	167.19
General expenses, Bureau of Entomology.....	3,000.00	2,634.30	260.93	104.77
Advisory committee for aeronautics.....	32,600.00	28,918.74	3,371.24	310.02
Aviation, Navy.....	54,000.00	45,256.37	8,199.66	543.97
Export industries, Department of Commerce.....	4,500.00	3,939.01	397.07	163.92
Air Service of the Army.....	9,100.00	5,866.13	3,123.54	110.33
Incidental expenses of the Army.....	11,750.00	9,243.06	2,135.44	371.50
General expenses, Lighthouse Service.....	10,000.00	8,875.47	1,087.68	36.85
Engineering, Bureau of Engineering.....	2,500.00	1,678.83	759.53	61.64
Appropriations transferred from other departments which are available for a period of two years:				
Ordnance and ordnance stores.....	12,000.00	10,710.94	517.88	771.18
General expenses, Coast and Geodetic Survey.....	1,000.00	-----	-----	1,000.00
Gauges, dies, and jigs, for manufacture.....	2,750.00	276.26	201.24	2,182.50
Air Service of the Army.....	1,000.00	-----	-----	1,000.00
Signal Service of the Army.....	7,500.00	-----	-----	7,500.00
Total.....	1,968,332.77	1,748,526.27	175,327.60	44,478.90

(Footnotes at end of table)

Disbursements, liabilities, etc., 1926, 1925, and 1924 appropriations—Continued

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
1925				
Salaries.....	\$500,000.00	\$496,986.80	\$40.00	\$2,973.20
Equipment.....	71,000.00	64,112.48	6,569.30	318.22
General expenses.....	¹⁴ 45,659.12	39,407.20	1,620.35	4,631.57
Improvement and care of grounds.....	11,460.00	11,297.00		163.00
Testing structural materials.....	¹⁵ 252,317.22	247,345.20	196.87	4,775.15
Testing machines.....	39,460.00	39,359.82		100.18
Metallurgical research.....	¹⁶ 44,513.18	44,313.71	33.20	166.27
Investigation of optical glass.....	25,000.00	24,923.52		76.48
Standard materials.....	10,000.00	9,974.13		25.87
Investigation of textiles.....	27,000.00	26,837.82		162.18
Sugar standardization.....	¹⁷ 41,800.00	41,525.52		274.48
Gauge standardization.....	40,000.00	39,146.77		853.23
High-temperature investigation.....	10,000.00	9,987.64		12.36
Testing railroad scales.....	40,000.00	39,756.83	26.59	216.58
Investigation of fire-resisting properties.....	29,000.00	28,796.63		203.37
Testing miscellaneous materials.....	¹⁸ 47,760.00	46,753.82		1,006.18
Investigation of public utility.....	105,000.00	103,556.94	773.50	669.56
Radio research.....	¹⁹ 46,320.16	46,240.50		79.66
Industrial research.....	²⁰ 176,713.58	174,765.55		1,948.03
Sound investigation.....	5,580.00	5,542.97		37.03
Investigation of clay products.....	²¹ 30,200.00	29,984.57		215.43
Color standardization.....	10,000.00	9,799.14	91.74	109.12
Investigation of radioactive substances.....	11,000.00	10,933.66		66.34
Standardizing mechanical appliances.....	30,000.00	29,935.60		64.40
Investigation of mine scales and cars.....	15,000.00	11,929.79	2,703.75	366.46
Rope investigation.....	8,000.00	7,880.95	2.73	116.32
Standardization of equipment.....	110,000.00	109,749.19		250.81
Investigation of automotive engines.....	²² 36,325.00	35,836.21		488.79
Land.....	173,117.00	173,117.00		
Appropriations transferred from other departments which were available during the fiscal year:				
Export industries, Department of Commerce.....	4,850.00	4,733.83		116.17
Aviation, Navy.....	34,000.00	33,271.89		728.11
Signal Service of the Army.....	3,800.00	3,646.17		153.83
Advisory Committee for Aeronautics.....	32,000.00	31,056.42		943.58
General expenses, Bureau of Entomology.....	5,000.00	4,927.67		72.43
Construction and repair, Bureau of Construction and Repair.....	10,500.00	10,437.57		62.43
Mineral mining, Bureau of Mines.....	5,000.00	4,666.22	19.80	313.98
Manufacture of arms (1924-25).....	950.00	943.12		6.88
Field artillery armament.....	950.00	947.84		2.16
Armament of fortification.....	950.00	865.18		84.82
Air Service of the Army.....	6,300.00	6,037.03		262.97
Incidental expenses.....	14,000.00	13,718.43	119.15	162.42
General expenses, Lighthouse Service.....	5,000.00	4,853.23	55.56	91.16
Conference on oil pollution of navigable waters (1925-26) ²³	8,000.00	5,354.52	230.49	2,414.99
Ordnance stores ammunition (1925-26) ²⁴	3,300.00	2,748.40	447.03	104.57
Washington-Alaska military cable and telegraph system (1925-26) ²⁴	2,000.00	1,878.34	58.32	63.34
Appropriations transferred from other departments which were available for a period of two years:				
Ordnance and ordnance stores.....	12,000.00	11,741.68		258.32
Construction and repair, Bureau of Construction and Repair.....	3,000.00	2,894.25	14.00	91.75
Automatic rifles (1924-1925).....	2,000.00	1,960.26	31.00	8.74
Aviation, Navy.....	2,750.00	303.07	7.00	2,439.93
Air Service of the Army.....	1,750.00	1,388.09	113.32	248.59
Coast Guard.....	2,000.00	1,657.50	144.50	198.00
General expenses, Coast and Geodetic Survey.....	2,000.00			2,000.00
Proving grounds, Army.....	500.00	234.00	6.00	260.00
Engineering, Bureau of Engineering.....	2,000.00	891.30	741.37	367.33
Total.....	2,156,825.26	2,110,952.92	14,045.57	31,826.77
1924				
Salaries.....	²⁵ 396,500.00	386,461.89		10,038.11
Equipment.....	²⁶ 74,000.00	73,111.88	248.00	640.12
General expenses.....	²⁷ 47,374.58	43,067.24	123.35	4,183.99
Improvement and care of grounds.....	10,000.00	9,768.84		231.16
Testing structural materials.....	²⁸ 216,981.59	207,128.55	86.56	9,766.48
Testing machines.....	35,000.00	34,739.51		260.49
Metallurgical research.....	²⁹ 40,831.28	40,729.47		101.81
Investigation of optical glass.....	25,000.00	24,882.36		117.64
Standard materials.....	10,000.00	9,345.08		654.92

(Footnotes at end of table)

Disbursements, liabilities, etc., 1923, 1925, and 1924 appropriations—Continued

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
1924—Continued				
Investigation of textiles.....	\$25,000.00	\$24,273.93	-----	\$726.07
Sugar standardization.....	²⁹ 41,800.00	41,181.82	-----	618.18
Gauge standardization.....	40,000.00	36,529.33	-----	3,470.67
High-temperature investigation.....	10,000.00	9,465.58	-----	534.42
Testing railroad scales.....	40,000.00	39,406.40	-----	593.60
Investigation of fire-resisting properties.....	25,000.00	24,695.49	-----	304.51
Testing miscellaneous materials.....	40,000.00	39,864.18	-----	135.82
Investigation of public-utility standards.....	95,000.00	93,580.74	\$560.60	858.66
Radio research.....	³¹ 40,300.00	40,132.45	8.14	159.41
Industrial research.....	³² 153,038.64	149,824.63	1.69	3,212.32
Sound investigation.....	³³ 5,430.00	5,302.11	-----	127.89
Investigation of clay products.....	30,000.00	28,264.52	-----	1,735.48
Color standardization.....	10,000.00	9,904.66	.80	94.54
Investigation of radioactive substances.....	10,000.00	9,902.16	-----	97.84
Standardizing mechanical appliances.....	³⁴ 30,125.00	29,684.34	1.25	439.41
Investigation of mine scales and cars.....	15,000.00	9,050.75	-----	5,949.25
Rope investigation.....	20,000.00	19,728.53	-----	271.47
Standardization of equipment.....	100,000.00	99,067.61	54.19	878.20
Replacement of altitude chambers.....	72,000.00	71,329.82	-----	670.18
Investigation of automotive power plants.....	10,000.00	9,749.14	-----	250.86
Claim for damages.....	294.25	294.25	-----	-----
Appropriations transferred from other departments which were available during the fiscal year:				
Air Service of the Army.....	12,840.00	12,559.16	-----	280.84
Engineering, Bureau of Engineering.....	525.00	520.50	-----	4.50
Ordnance stores ammunition.....	4,000.00	3,840.91	-----	159.09
Signal Service of the Army.....	525.00	495.54	-----	29.46
Experiments, Bureau of Ordnance.....	5,000.00	4,950.85	-----	49.15
Advisory Committee for Aeronautics.....	28,000.00	27,583.22	-----	416.78
Aviation, Navy.....	5,125.00	4,950.02	-----	174.98
Party expenses, Coast and Geodetic Survey.....	2,000.00	1,962.30	-----	37.70
Ordnance and ordnance stores.....	2,625.00	2,592.96	-----	32.04
Appropriations transferred from other departments which were available for a period of 2 years:				
Air Service of the Army.....	7,725.00	7,650.70	-----	74.30
Ordnance and ordnance stores.....	10,000.00	9,968.87	2.00	29.13
Aviation, Navy.....	50,000.00	49,634.63	119.00	246.37
Tanks (1923-24).....	3,000.00	2,936.49	4.00	59.51
Field Artillery armament.....	1,840.00	1,786.88	-----	53.12
Party expenses, Coast and Geodetic Survey.....	2,900.00	2,714.96	-----	185.04
Ordnance stores ammunition (1923-24).....	650.00	630.49	-----	19.51
Automatic rifles (1923-24).....	4,920.00	4,850.71	17.00	52.29
Total.....	1,810,350.34	1,760,096.45	1,226.58	49,027.31

¹ Includes supplemental appropriation of \$5,000.
Includes reimbursements and transfers received from other departments and from the States of Oregon and Connecticut, as follows:

² \$1,918.35.

³ \$2,147.29.

⁴ \$80.

⁵ \$1,000.

⁶ \$2,800.

⁷ \$5,000.

⁸ \$738.13.

⁹ \$75.

¹⁰ \$1,634.

¹¹ \$5,280.

¹² \$1,159.12.

¹³ \$17,257.22.

¹⁴ \$513.18.

¹⁵ \$1,800.

¹⁶ \$2,500.

¹⁷ \$640.16.

¹⁸ \$2,593.58.

¹⁹ \$200.

²⁰ \$11,325.

²¹ \$21,981.59.

²² \$331.28.

²³ \$1,800.

³¹ \$300.

³² \$3,038.64.

³³ \$430.

³⁴ \$125.

¹² Supplemental appropriation available for 1927 also.

¹³ Available for 1927 also.

²³ This fund was available during the fiscal year 1926 also, and the unencumbered balance was re-appropriated for the fiscal year 1927.

²⁴ This fund was available during the fiscal year 1926 also.

²⁵ Excludes transfer of \$35,860 to the office of the Superintendent of State, War, and Navy Department Buildings.

²⁶ Excludes transfer of \$20,000 to the office of the Superintendent of State, War, and Navy Department Buildings and \$1,000 to contingent expenses, Department of Commerce.

²⁷ Excludes transfer of \$27,000 to the office of the Superintendent of State, War, and Navy Department Buildings and \$1,000 to contingent expenses, Department of Commerce, and includes reimbursements of \$374.58 received from other departments



