ANNUAL REPORT

OF THE

DIRECTOR
BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1917

WASHINGTON
GOVERNMENT PRINTING OFFICE
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CONTENTS.

	Page.
Chart showing functions of Bureau.....facing..	11
I. Functions, organization, and location.....	11
1. Standards of measurement.....	11
2. Physical constants.....	12
3. Standards of quality.....	12
4. Standards of performance.....	13
5. Standards of practice.....	14
6. Relation of the Bureau's work to the public.....	14
7. Relation of the Bureau's work to the Government service.....	16
8. Organization.....	17
9. Location.....	18
II. Scientific and technical divisions.....	19
1. Weights and measures.....	19
Length measures.....	19
Linear expansion of materials.....	19
Standard screen scale.....	20
Gauge work.....	20
Optical protractor.....	21
Leather measuring machines.....	21
Capacity measures.....	22
Volumetric glassware and hydrometers.....	22
Hæmacytometers.....	22
Liquid-measuring pumps.....	22
Gas-measuring instruments.....	23
Weights and balances.....	23
New type of balance.....	24
Testing scales by use of water.....	24
Track-scale work.....	24
Location, condition, and ownership of track scales tested.....	25
Reports on track scales tested.....	25
Technical information regarding track scales.....	26
Building for housing master scale.....	27
Density determinations of materials.....	27
New sugar tables.....	27
Barometry, and aeronautic instruments.....	27
Watch testing.....	28
Lime-barrel act.....	28
Rules and regulations for barrel laws.....	28
Uniformity in inspection of weights and measures.....	29
Annual Conference on Weights and Measures.....	30
Cooperation with State and with local officials.....	30
Information furnished on weights and measures subjects.....	31
2. Heat and thermometry.....	31
New regulations governing tests of clinical thermometers.....	31
Standard temperature scale.....	32
Copper-constantan thermocouples.....	32
Depression of the ice point of thermometers.....	32
Standard boiling points.....	33
Standard heat samples for use in calorimetry.....	33
Standard samples for thermometric fixed points.....	33
High-temperature investigations.....	33
Low-temperature laboratory.....	34
Mercury vapor pump.....	35
Refrigeration constants.....	35
Calorimeter for the determination of latent and specific heats of fluids.....	35

II. Scientific and technical divisions—Continued.
2. Heat and thermometry—Continued. Page.
Specific heat of liquid ammonia ... 36
Latent heat of vaporization of ammonia ... 36
Latent heat of pressure variation of liquid ammonia ... 37
Specific volumes of ammonia in the liquid and vapor phases ... 38
Compressibility of liquid ammonia ... 38
Density-temperature-concentration relations of aqua ammonia ... 38
Pressure-temperature relation for vapor in equilibrium with aqua ammonia ... 38
Temperature-concentration relation for vapor in equilibrium with aqua ammonia ... 39
Specific heats of sodium chloride brines ... 39
Chemical investigations relating to refrigeration constants ... 40
Thermal conductivities of insulating and structural materials ... 40
Fire-resisting properties of structural materials ... 40
Fire tests of building columns ... 40
Fire tests of reinforced concrete columns ... 42
Thermal efficiencies of column coverings ... 42
Strength of steel at high temperatures ... 43
Panel-testing furnace ... 43
Building codes, information, cooperative work, etc ... 43
Activities in technical societies, etc ... 44
Information furnished, reports, etc ... 44
Heat and thermometric apparatus tests ... 45
3. Electricity ... 45
Scope of the electrical work ... 45
Relation of the electrical work to the military services ... 46
Silver voltameter ... 47
Standard cell work ... 47
Investigation of inductance coils ... 47
Study of the electromagnet moving-coil galvanometer ... 47
A. C.-D. C. comparator ... 48
Bridge for testing precision resistance standards ... 48
Electrically operated tuning fork for time measurements ... 48
Instrument transformers ... 49
New method of testing current transformers ... 49
Remote control system for motor generators ... 49
Electrolytic cleaning of silver ... 49
Electrical properties of silver sulphide ... 50
Methods of testing transformer oils ... 50
Radio service to the Government ... 50
Fog signalling ... 50
Radio direction finder ... 51
Radio instruments and measurements ... 51
Radio testing ... 51
Magnetic uniformity of straight bars ... 51
Development of a new permeameter ... 52
Calibration of bismuth spirals ... 52
Study of the magnetic susceptibility of feebly magnetic substances ... 52
Magnetic analysis ... 52
Magnetic compass investigation ... 54
Increase in the Bureau's stock of radium ... 54
Radium emanation ... 54
Radium luminous preparations ... 54
Radium testing ... 55
X-ray testing ... 55
Improved methods of measurement in photometry ... 55
Life testing of gas-filled lamps ... 56
Investigation on flames and gas-mantle lamps ... 56
Tests of miscellaneous illuminants ... 57
Inspection and life-test of lamps for the Government ... 57
Electrical testing ... 58
Information furnished on electrical subjects ... 58
New fee circular ... 59

II. Scientific and technical divisions—Continued.
3. Electricity—Continued. Page.
Publications on electric units and standards 59
Public utility investigations 60
Gas service rules 60
Standards for gas service as affected by war-time conditions 61
Gas laboratory methods 61
Relation between heating value of gas and its usefulness 62
Inspections of gas mantle lighting 62
Proposed national gas safety code 63
Economic importance of the national gas safety code 63
Electrical service rules 64
Street-lighting service 65
National electrical safety code 65
National electrical safety code in practical use 66
Scope and application of the electrical safety code 67
Inspections under the electrical safety code 67
Organizations cooperating in the preparation and revision of electrical safety code 68
Electrical protection for householders 68
Special problems in overhead lines and industrial installations 68
Electrolysis problem among public utilities 69
Economic importance of the electrolysis problem 69
Inconvenience and hazard due to electrolysis 70
Methods of mitigation of electrolysis 71
Recent electrolysis work of the Bureau 71
Leakage of current from electric railways 72
Advice to municipalities and corporations 72
Lightning protection 72
Investigations on grounding of secondary electrical circuits 72
Experimental study of telephone apparatus 73
Telephone service standards 74
Submarine telegraphy 74
Relation of the Bureau to municipalities and public-service commissions 75
Necessity for increasing the public-utility work of the Bureau. 75
4. Light and optical instruments 77
Determination of standard wave lengths 77
Infra-red photography 77
Refractive index and dispersion of air 79
Spectroscopic analysis 79
Rare gas discharge tubes 80
Solubilities in the sugar group 80
Influences of temperature on the speed of inversion of sugar 81
Specifications for commercial grades of sugar 81
Basis of saccharimeter standardization 81
Constants of the quartz-wedge saccharimeter 82
Rotation of quartz at high temperatures 82
Magnetic rotation by magnetic substances 82
Bureau of Standards Baumé scale 83
Standard glassware for customs laboratories 84
Circular on polarimetry 84
Polarimetric tests of raw sugars 84
Sampling molasses in tank cars 84
Polarimetric tests of molasses 85
Information furnished on polarimetry 85
Polarimetric testing 85
Standard samples 85
Installation of sugar laboratory at Savannah, Ga 85
Supervision of the customs laboratories of the Treasury Department 85
Color standards investigation 86
Testing, extension, and improvement of spectrophotometric methods 86
Fundamental data needed for reference in colorimetry 87
Establishment of working standards of color 88
Design and construction of colorimetric apparatus 89

II. Scientific and technical divisions—Continued.
4. Light and optical instruments—Continued. Page.
Information furnished on color and color specifications 90
Tests of color, spectral transmission and transparency 90
Turbidimetry 90
Interference methods for measuring thermal expansion 91
Investigation of the performance of American-made photographic and projection lenses 91
Telephoto lenses and distance photography 91
Development of optical systems 92
Testing of optical systems 92
Refractive indices 92
Information furnished on optical systems and optical glass 92
Optical constants of chemical glassware 93
Radiometry 93
Constants of radiation of a uniformly heated inclosure 93
Visibility of radiation of the average eye 94
Mechanical equivalent of light 94
Emissive properties of tungsten 94
Glasses for protecting the eyes from injurious radiations 94
Photoelectric properties of various substances 95
Information furnished on radiometric subjects 95
Publications on radiometry 95
5. Chemistry 95
Rapid electrolytic determination of carbon in steel 95
Nitrogen in steel 96
The Goeren's method for determining the gas content of steels. 96
Determination of gases in steel by the Goutal method 96
Determination of oxygen in steel 96
Oxygen content of steels deoxidizable in various ways 96
Ladle ingot test investigation 96
Preparation of iron-carbon alloys 97
Platinum investigation 97
Variation of commercial gases from Boyle's law 97
Specific gravity of gases 97
Preparation and properties of hydrogen 98
Balloon gas investigation 98
Combustion gas detectors 98
Chemical work on balloon fabrics 99
Chemical work on refrigeration problems 99
Chemical work on the standard cell 99
Electrotyping and electroplating investigation 100
Renewal of work on various analytical problems 100
Paint and varnish investigations 101
Nonferrous alloys and coated materials 101
Bituminous materials 102
Chemical work on cement 102
Chemical tests of lubricants 103
Chemical work on leather 103
Chemical analysis of rubber 103
Chemical work on paper 103
Tests of chemical glassware and porcelain 103
Standard analyzed samples 104
Chemical testing 104
Miscellaneous chemical tests and investigations 104
Chemical publications 104
New chemistry building 105
6. Engineering research and testing 105
Water-current meter rating stations 105
Different forms of cable suspension for current meters 106
Depth of submersion of current meters 106
Fire extinguisher investigations and tests 107
Fire extinguishing equipment for wooden submarine chasers .. 107
Radiator traps used in vacuum heating systems 107
High-pressure gauges 108
Sounding tubes 108
Spirits meter 108

II. Scientific and technical divisions—Continued.
6. Engineering research and testing—Continued. Page.
Patrol lanterns for the United States Coast Guard service..... 108
Gasoline intensifiers for automobile engines..... 108
Miscellaneous tests of instruments and devices..... 108
Cooperation with scientific and technical societies..... 109
Investigations relating to mechanical appliances..... 109
Spark-plug investigations..... 109
Aeronautic radiator investigations..... 109
Installation of aeronautic engine testing laboratories..... 110
Testing of aeronautic engines under conditions of reduced atmospheric pressure..... 110
Liberty engine..... 111
7. Metallurgy..... 111
Railway materials investigation..... 111
Chilled car-wheel investigation..... 111
Iron-carbon system..... 112
Second ingot investigation..... 112
Ladle test ingot metallurgical investigation..... 112
Gases and oxides in steel..... 112
Gun erosion and allied phenomena..... 113
Temperature measurements in metallurgical practice..... 113
Thermocouple nichrome-constantan..... 113
Failure of brasses and bronzes..... 113
Corrosion of brasses and bronzes..... 114
Impurities in cast bronze and brass..... 114
Properties of commercial cast brasses and bronzes..... 114
Foundry sands..... 114
Deterioration of tinned copper roofing..... 115
Properties of electrolytically deposited copper..... 115
Protective metallic coatings on metals..... 115
Fusible boiler plugs..... 115
Melting points of refractory elements..... 115
Cooperation with military Government departments..... 115
Cooperative work in metals..... 116
Activity in technical or scientific societies..... 116
Metallurgical tests..... 117
Information furnished to the Government and the public..... 117
Circulars of information on metallurgical subjects..... 117
Metallurgical publications..... 118
8. Structural, engineering, and miscellaneous materials..... 118
Investigation of structural steel columns..... 118
Physical investigations of railway material..... 119
Investigation of the physical properties of zinc..... 120
Investigation of methods of calibration of testing machines..... 120
Investigation of the effect of kiln-drying spruce..... 120
Airplane strut investigation..... 121
Resistance of wood to alternating stress..... 121
Study of strains in car wheels..... 121
Machine-tool investigations..... 121
Strength of galvanized wire..... 122
Strength of latticed aluminum columns..... 122
Failure of bridge material..... 122
Strength of bridge material..... 122
Failure of hull material..... 123
Investigation of material from experimental bulkheads..... 123
Investigation of wire rope..... 123
Strength of brick piers..... 123
Investigation of the physical properties of earths..... 124
Information furnished regarding strength of metals and alloys. 125
Tests of a semi-investigative nature..... 125
Investigation and testing of materials for the Signal Corps..... 126
Tests on the strength of materials..... 126
Investigation and testing of cement, concrete, and stone..... 127
Standard specifications for Portland cement..... 127
Foreign specifications for Portland cement..... 127
Effect of fine grinding of Portland cement..... 127
Minor constituents of Portland cement..... 128

II. Scientific and technical divisions—Continued.
8. Structural, engineering, and miscellaneous materials—Contd. Page.
Constitution of Portland cement 128
Granulometric air analyzer 128
Air separator for cement 128
Standard cement sieves 129
Standard fineness sample 129
Hydraulic cements other than Portland cement 129
Durability of concrete in sea water 130
Durability of concrete in alkali waters 130
Investigation of integral waterproofing compounds 131
Development of an accelerator for hardening concrete 131
Cast-iron reinforced concrete columns 132
Floor construction tests 132
Investigation of composition flooring 132
Value of various materials as concrete aggregate 133
Effect of moisture and temperature changes on concrete 133
Tests of field-made concrete for Lincoln Memorial 133
Investigation of building stones of the United States 133
Stucco and plaster investigation 134
Information furnished concerning cement and concrete 135
Publications on cement and concrete 136
Routine cement inspection and testing of cement and concrete. 136
Miscellaneous tests of stone, sand, gravel, etc 137
Sand-lime brick 137
Hydrated lime in concrete 137
Measuring of plasticity and sand-carrying capacity of lime 138
Properties of hydrated limes 138
Decomposition of calcium and magnesium hydroxides 138
Investigation of gypsum 138
Architectural terra cotta 139
Investigation of tile and tile walls 139
Silica-brick investigation 139
Study of American clay refractories 140
Special refractories for high furnace temperatures 140
Study of ceramic kilns 140
American plastic bond clays 140
Sizing of calcined clay 141
Clay tests 141
Porcelain investigations 141
Porcelain for spark plugs 141
Enameled-iron investigations 142
Optical-glass investigation 142
Investigation of lubricating oils 142
Information furnished regarding lubricating oils 142
Investigation of leather 143
Investigation of shark and other fish-skin leather 143
Experimental rubber plant 143
Investigation of solid-rubber tires for motor trucks 144
Rubber eye shades for the range finders of battleships 144
Cooperation with technical societies, manufacturers, and consumers 144
Assistance rendered Government departments 144
Information furnished on physical tests of rubber and leather 145
Special tests of miscellaneous materials 145
Tests of miscellaneous materials 146
Comparison of cotton and wool flags 146
Identification of textile fibers 146
Sewing-machine stitches 146
Tensile strength of fabrics 146
Textile conference 147
Information furnished regarding textiles and textile testing 147
Testing of textiles 147
Buttermilk casein as a paper-sizing material 147
Domestic clays in the paper industry 148
Paper-testing devices 148
Utilization of waste paper for remanufacture into paper 148
Paper bags for shipping cement, lime, and gypsum 148

II. Scientific and technidal divisions—Continued.
8. Structural, engineering, and miscellaneous materials—Contd. Page.
Manufacture of filter paper 149
Information furnished concerning paper 149
Paper testing 150
III. Office 151
Publications 151
Technical library 152
Personnel 152
Appropriations statements 152
Summary of tests 154
Metric system 154
Exhibits of the activities of the Bureau 155
IV. Recommendations 156
Increase in scientific staff 156
Increase in salaries 156
Additions in the clerical, operating, and construction staffs 156
Increases in special funds 156
Buildings 158
New refrigerating machine 158

PURPOSE

NATIONAL BUREAU OF STANDARDS

Washington, D. C.

1917

FUNCTIONS

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

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

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

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REPORT

OF THE

DIRECTOR, BUREAU OF STANDARDS.

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
Washington, July 1, 1917.

SIR: There is submitted herewith a report of the work of the Bureau of Standards for the fiscal year ended June 30, 1917.

I. FUNCTIONS, ORGANIZATION, AND LOCATION.

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

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

1. STANDARDS OF MEASUREMENT.

A standard of length may be taken as an example of a standard of measurement. It must be a length which is unchanging, reproducible, and capable of being compared with the working standards used in the most precise scientific work or with those used in commerce and industry. The fundamental standard must be subdivided and working standards prepared of these parts, and for the measurement of greater lengths standards must be prepared which are multiples of the fundamental standard. This process of subdividing and multiplying the standard involves difficulties as great as those met with in the preparation of the fundamental standard itself.

The construction of a set of standard weights from a single unit is also an illustration; a whole set of standard weights must be prepared before the standard weight of the Government can become available to the public. When the standard of length or weight has been found with as many desirable qualities as possible, and before the working standards of the subdivisions or multiples can be prepared, the question as to the method of comparison arises, which again involves the solution of difficult scientific problems in connection with the balance or the methods used. These balances range from that capable of measuring the thousandth part of a milligram

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FUNCTIONS

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STANDARDS

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

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

to the large testing machine capable of measuring a load of thousands of tons. The complete range must be covered, which involves not only a large number of working standards, all of which must agree with the fundamental standard, but apparatus suitable for the comparison of these standards with all of the lengths or weights found in practice.

These steps and equipment are absolutely essential in order to secure uniform measurements of length or weight throughout the country, and they have their counterpart in every quantity that has to be measured, whether it be length, weight, temperature, heat, light, or the various electrical measurements or other standards of measurement. These standards in one form or another are involved in practically every scientific investigation, industrial process, engineering structure, or commercial transaction.

2. PHYSICAL CONSTANTS.

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

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

3. STANDARDS OF QUALITY.

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

it of good or poor quality: How are its properties to be measured or its constituents determined? These are questions for the laboratory to answer and involve physical and chemical investigations of the most difficult sort.

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

The actual testing of materials by the Bureau of Standards to ascertain whether or not they comply with specifications is confined almost exclusively to Government purchases, but in making these tests (in which the Bureau has had the hearty cooperation of practically all the departments of the Government service) it is compelled to make many investigations concerning the properties of materials, their specification and measurement. While this work is of great value in placing Government purchases on a correct business basis, the results of the investigations as to the properties of materials and the information gained in testing Government supplies are even more important to the general public and are distributed in the form of suitable publications.

The Bureau does not compete with private testing laboratories, but endeavors to assist them by the development of standard specifications, methods of measurement, and other matters where uniformity is desirable, much of which information, as stated above, is secured in connection with the testing of materials purchased by the Government and a close observation of their use.

The time is not far distant when it will be required that all materials bought or sold shall be as represented, but it should be kept in mind that this is impossible except in the case of those materials where proper standards of quality and methods of measurement have been developed. It must not be assumed that the purchaser or user is the party principally benefited in the development of such standards; on the contrary, the manufacturer, first of all, is interested in the quality of all things which affect the quality of his product, and while the Bureau's efforts in this field are devoted principally to the pointing out and measurement of those properties upon which the quality of the materials depends, it is to be regretted that its force and equipment are insufficient to render more assistance to manufacturers with a view to a direct improvement of those parts of the process upon which the quality of the output depends.

4. STANDARDS OF PERFORMANCE.

The value of an instrument, device, or machine almost always depends upon the efficiency of its performance. In such cases it is necessary to state the performance desired or guaranteed in terms which are correct and susceptible of measurement. As in the case

of standards of quality, the standard involved is more often in the form of a specification, but specifications are useless unless based upon correct scientific and mechanical principles and supplemented with a statement of the method to be used in ascertaining whether or not the specifications or guaranties have been complied with.

The performance of an engine or boiler, a pump, an electrical generator or motor, a weighing device, or a telescope can usually be measured, but the quantities to be measured and the method used must be specified correctly and understood by all the parties concerned in the construction, purchase, or use of such apparatus. To do this properly involves the use of standards of measurement, standard values of constants, and standards of quality. The Bureau of Standards does not attempt to cover this field completely, but only those cases where there is a lack of definite information upon which to base specifications and only to the more important classes of apparatus. To secure this information involves investigations quite as scientific in character and as difficult as in the case of other standards, as well as a knowledge of technical and manufacturing processes.

The Bureau's activities in this field have only been developed to a slight extent and almost entirely in connection with Government purchases. It has had in this, as well as in the field of the properties of materials, the most hearty cooperation of the various Government experts, manufacturers, engineers, and technical societies.

5. STANDARDS OF PRACTICE.

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

6. RELATION OF THE BUREAU'S WORK TO THE PUBLIC.

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

The Bureau compares with its own standards of measurement the standards or measuring instruments of States, cities, scientific laboratories, educational institutions, manufacturers, Government bureaus, or the public, for which a nominal fee is charged, except in the case of the National and State Government institutions. It gives advice concerning these standards or their use, whether it be in connection with the enactment of laws, regulations, or ordinances concerning the weights and measures of everyday trade or in con-

nection with precision standards used in scientific work and the industries. It gives advice upon request to State and city officials, public-service commissions, and public-utility corporations regarding the standards of measurement, or quality, or performance involved in legislation or regulation pertaining to the public utilities. Many questions of disagreement between the public and utility companies as to these matters are referred to the Bureau for advice or adjustment, often avoiding unfair or inconsistent regulations, as well as long-drawn-out and expensive litigation. There is a great need on the part of the public for unbiased and reliable information pertaining to the standards entering into the regulation and sale of the services of public utilities. As far as possible such information is given in the form of publications upon definite subjects.

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

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

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

scientific and technical standards other than weights and measures; and the Prussian Government maintains the Materialprüfungsamt, a large institution devoted to the investigating and testing of structural, engineering, and other materials.

It is generally recognized that these institutions have been exceedingly important factors in the industrial progress of these countries.

7. RELATION OF THE BUREAU'S WORK TO THE GOVERNMENT SERVICE.

The bureaus of the Government engaged in scientific and technical work are necessarily dependent upon standards of measurement of every variety. In addition, many of them are engaged in the design, construction, and specification of a great variety of special apparatus, in which the principles of mechanics, heat, optics, electricity, and chemistry are involved and are vital to their efficiency and successful operation. In such matters the Bureau has been consulted most freely by the War and Navy Departments, the Post Office Department, the Department of Agriculture, the Public Health Service, and others.

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

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

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

Many bureaus of the Government service are charged with the administration of laws and the establishment of regulations in which scientific data are vital. This is true to a much greater extent than is generally supposed. The Bureau of Standards has cooperated freely with such branches of the Government and the service rendered has involved every department of physics and chemistry covered by the Bureau's activities. The neglect of such matters in the past has been a frequent source of misunderstanding and litigation between the Government service and the public. Conspicuous examples of bureaus to which such assistance has been given are the Customs and Internal Revenue Services; the Steamboat-Inspection and Coast Guard Services, in the promulgation of safety regulations; and the Bureau of Navigation of the Department of Commerce, in the administration of laws regulating the use and inspection of radiotelegraphy.

8. ORGANIZATION.

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

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

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

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

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

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

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

The division of engineering research makes investigations and tests regarding the performance and efficiency of such instruments, devices, or machinery as the Bureau may take up that do not fall directly under one of the scientific divisions. The division is a small one and its work is devoted almost exclusively to assistance given other departments of the Government and the General Supply Committee in designing, specifying, or testing equipment. It should in time form one of the more important branches of the Bureau's work.

The questions pertaining to the manufacture, specifications, testing, and use of the metals and their alloys have become so important that a division known as the metallurgical division has been formed of the experts engaged in these problems.

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

9. LOCATION.

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

II. SCIENTIFIC AND TECHNICAL DIVISIONS.

1. WEIGHTS AND MEASURES.

[Length, area, volume, mass, density, pressure, and time, including researches on units and standards, measuring methods and instruments, specifications and tolerances, and the standardization incident thereto for inspectors of weights and measures, manufacturers of measuring appliances, scientific and technical laboratories, Government bureaus, engineers, and the general public.]

Length Measures.

About 1,035 articles were measured for length during the year, of which 731 were polariscope tubes and 156 were tapes of steel, invar, or linen. The remainder included 65 gauges and calipers, an increased number over last year, 7 line standards, 2 level rods, 58 sieves and samples of sieve cloth, and 16 miscellaneous pieces of apparatus.

Linear Expansion of Materials.

During the year there were made 107 expansivity tests, 77 of which were incident to research work carried on by the Bureau; the remaining tests were made on specimens submitted by the Federal Government and from outside sources.

In connection with the research work on the linear expansion of materials, 12 specimens of bronze, 6 of the alpha and 6 of the beta phase, were thoroughly studied, involving temperature ranges extending from 20° C. to 600° C. This work was carried out as an investigation of a theory that the differential expansion between the alpha and beta particles, ordinarily evenly distributed in bronze, is sufficient to cause the ruptures so commonly met in this class of material. The results of this study indicate that the difference in the expansion of the two phases is sufficient to cause these ruptures. Many interesting details were observed in connection with this investigation. Specimens of the alpha phase are regular in their expansion and after being heated return to their original length, whereas specimens of the beta phase exhibit peculiarities which are quite constant and they fail to return to their original length after being heated to 300° C. or above.

Research work on rolled brass was carried out as part of a study for the determination of the effect of the direction of rolling on the properties of brass. Twenty-nine samples of varying thickness were tested, a part of which were measured parallel and a part perpendicular to the direction of rolling. The expansion varied somewhat with the thickness of the material and a permanent set resulted after the samples were heated to 300° C., which amounted to as much as 0.4 millimeters per meter for the thin samples. This permanent set was either an increase or decrease in the length of the specimen according to whether it had been cut longitudinally or transversely with the direction of rolling.

A preliminary test has been made of six representative specimens of 109 samples of copper alloy submitted by a large commercial company in order to determine the probable behavior of these samples. Research work is being undertaken in connection with these samples for the purpose of determining the expansivity properties of the alloy from which they are made, and the results so far indicate that the expansivity of this material is a regular function of its composition; in fact, both the first and second terms of a quadratic equation representing the expansion of each alloy vary regularly with the composition.

The unusual behavior of marble under heat treatment seems to have received little, if any, consideration by those interested in this material. A study of marble subjected to heat treatment reveals the fact that the coefficient of expansion increases from about 0 to 0° C. to 28×10^{-6} at 300° C. Moreover, after the marble has been expanded by heat, it does not return to its original dimensions, but a permanent increase results, the magnitude of which depends upon the temperature to which the specimen has been heated. A permanent increase in length amounting to as much as 4 millimeters per meter has resulted from heating a specimen to 300° C. This work has a very important bearing on some of the marble industries, and is especially important in connection with the manufacture of electrical standards where coils are wound on marble bases.

The results obtained from investigations on nickel steel, begun during the fiscal year 1916, were checked up and data were found to be in close agreement, both with the Bureau's previous results and with those obtained by Guillaume, wherever it was possible to draw a comparison. This research has been completed and the results are now in course of preparation for publication.

It recently became desirable to make expansion tests to as high as 1,000° C. A new furnace has therefore been designed for this purpose, the special features of which consist of methods of making and mounting the resistor so that it is readily accessible and easily replaced in case of an interval break in the electric circuit.

Standard Screen Scale.

The standard screen scale for testing sieves, adopted by a conference of representatives of various technical societies, Government bureaus, and private firms interested in sieving tests of materials, has been issued by the Bureau, together with specifications and tolerances under which the Bureau will test and certify sieves of this series. This screen scale has a wide range of openings, from 8 to 0.044 millimeter (0.315 to 0.0017 inch), and is intended to cover practically all materials upon which fineness tests are made. Its adoption will unify the results of sieve tests and will reduce the varieties of sieves required for such work.

Gauge Work.

As soon as it became evident that the United States would be compelled to expand its military activities, the Bureau profiting by the experience of the national testing laboratories of Europe, began to make preparation for the certification of gauges used in the manufacture of munitions. Representatives from the Bureau visited a

number of the munitions plants in the country, and the methods of gauging employed in these plants were carefully studied. A representative was also sent to Canada for the purpose of studying the operations of the gauge department of the Ministry of Munitions, a department organized entirely since the beginning of the war.

The Bureau then submitted an estimate for an appropriation to cover this work, to be immediately available, and the proposed appropriation was made a part of the act making appropriations to supply urgent deficiencies in appropriations for the Military and Naval Establishments, which was approved June 15. The Bureau immediately ordered some of the more important pieces of apparatus that would be required in the work and in the securing of which the element of time was of great importance.

A temporary building, constructed some years ago in connection with experiments on the use of various kinds of cement and lime coverings for outside walls and which had never been finished inside, was assigned to the gauge work, and immediate steps were taken to prepare it for occupancy. This building was almost ready to occupy by the end of the fiscal year, and a large amount of apparatus and the force needed to carry on this work had been secured.

Optical Protractor.

In preparing for the testing of munition gauges in large quantities, it became necessary for the Bureau to design a number of special instruments in order to carry on this work. Notable among these is the optical protractor. This instrument consists of a microscope containing a knife-edge in the ocular plane which can be turned about an axis practically coincident with the optical axis of the microscope. In use the knife-edge is made coincident with the other side of the thread and a second reading on the circle taken, the difference between the two readings giving the thread angle. The principal advantage of this protractor over previous designs is in the increased accuracy with which settings can be made. It is possible to set the knife-edge parallel with the general direction of the sides of the screw thread being measured within three minutes of arc under good optical conditions.

Leather Measuring Machines.

At the request of various associations of tanners and shoe manufacturers, the Bureau undertook an investigation of the machines and methods used in the leather trade for the measurement of the area of hides and skins, the major portion of shoe leather other than that for soles being purchased on the basis of superficial area. The area of the skins is generally determined by passing them through one special type of measuring machine. The investigation showed that the methods hitherto used in the testing of these machines have been inadequate. It was found that, in general, the readings of the machine were seriously in excess, due partly to over-speeding of machines, and partly to faults in their design. These errors have resulted in many cases in serious overcharges, amounting to large sums of money annually.

A detailed and constructive series of reports were prepared, intended to correct faulty methods of test and inspection, and to indi-

cate points of design requiring special attention. The brief investigation enabled a beginning to be made on the theory and design of these machines, and it is probable that during the coming year a code of specifications governing their use and test can be issued. Some information was collected regarding the shrinkage of skins from the time of tannage, a factor which results in an appreciable reduction in area, and is therefore important for consideration in connection with the standardization of methods for leather measurement.

Capacity Measures.

The number of capacity measures submitted for test during the year was 56. These included standards for State governments, city governments, and for private firms.

Volumetric Glassware and Hydrometers.

The volumetric apparatus submitted for test during the year consisted of Babcock bottles, burettes, cylindrical graduates, flasks, measuring pipettes, Giles flasks, specific gravity flasks, and transfer pipettes. About 1,370 pieces of apparatus were submitted for test, 61 per cent of the total passing the regular tests. There were about 980 hydrometers submitted, of which 683, or 70 per cent, passed the test. The number of pieces of special apparatus tested was 30.

Blue prints of a set of cone graduates, conforming to the specifications adopted by the Eleventh Annual Conference on Weights and Measures, were made and sent to various manufacturers.

Hæmacytometers.

The manufacturers of hæmacytometers, instruments for determining the number of corpuscles in a given quantity of blood, suggested that the Bureau issue tolerances and specifications for this type of apparatus and take up the testing of such instruments regularly. This suggestion led to an investigation of the accuracy of the various type of hæmacytometers in use. It was found in the majority of cases that the user assumed a greater degree of accuracy for the results obtained than was warranted by the apparatus. In some instances the instrumental inaccuracies were of such magnitude as to cause errors in a count of from 25 to 100 per cent. This plainly indicated the necessity for accurately measuring the dimensions of hæmacytometer chambers and for calibrating hæmacytometer pipettes. Tentative tolerances and specifications have been issued which are meeting with general approval. Methods have also been devised for shortening the time required to test this type of apparatus.

Liquid-Measuring Pumps.

The work begun last year on the investigation of liquid-measuring pumps, with especial reference to the gasoline pumps commonly used for dispensing motor fuel, was continued and extensive tours of inspection and test were made, principally in Illinois and Pennsylvania. The majority of the pumps tested were found in unsatisfactory condition, and in the aggregate a very decided and significant tendency toward a shortage of measurement was indicated. The Bureau has given considerable aid to weights and measures officials in developing

a routine for the testing of this type of apparatus and in detecting and correcting the defects developed.

Numerous inquiries were received from manufacturers, weights and measures officials, and users relating to the design and test of measuring pumps, and the preparation of the information sought in many cases required considerable investigation and study.

An extended code of measuring-pump specifications, in tentative form, has been drawn up and is about ready to be issued.

Gas-Measuring Instruments.

During the past fiscal year a number of laboratory gas meters for both commercial and experimental work have been calibrated for State government, city, and industrial laboratories. Some of these instruments were calibrated at various rates of gas discharge, the results yielding valuable data as to the behavior of this type of apparatus under various conditions.

The investigation of gas-meter testing apparatus, continued from last year, has been carried on only to a very limited extent, due to lack of available time. This investigation has included the study of gas-meter provers and apparatus for testing the same.

The improved type of portable cubic-foot apparatus for calibrating meter provers designed and developed by the Bureau and which was mentioned in the report of last year has been further improved. A patent, dedicated to the public, has been granted on this apparatus. The cubic-foot apparatus in use in the past was extremely cumbersome, whereas the new apparatus can be easily carried about by one man and therefore will be of special value to the State inspector of meter-testing apparatus.

An important part of the work of the Bureau in this connection has been the instruction of officials of various cities in the methods of testing different types of laboratory and commercial gas-measuring instruments.

Weights and Balances.

The shortening of the time required for testing ordinary analytical weights, begun last year, was carried out even more successfully than was expected when the work was first undertaken. The new balance for weights from 1 to 100 grams, when used under better conditions than had been tried before, had such constant sensitiveness that average values could be adopted for different loads, and these values needed to be checked only once or twice during a test. This reduced the number of readings by from 10 to 30 per cent. It also became possible to introduce the method of weighing by substitution in such a way as to reduce still further the number of readings required and at the same time to reduce the amount of handling of the weights. The computations are also greatly lessened in amount and much simplified. New forms were developed in which the complete work of observation and computation appear on the same sheet. These new forms were tried out in actual practice, perfected, and are now being printed for use in the laboratory. With a satisfactory balance for the smaller weights it will be possible to reduce the time required for testing by at least 30 per cent.

The Bureau tolerances for high-grade analytical weights were adopted by one of the large scientific apparatus houses and also by

a large commission association, through which about 30 of the constituent firms have been supplied with sets of standard weights such as are needed in their work. The adoption of these tolerances will enable manufacturers to furnish weights to distributors of scientific apparatus which will meet the specifications adopted by the Bureau. Consequently, when such weights are submitted to the Bureau for test they are more likely to be within the tolerances prescribed than if no attempt were made by manufacturers to comply with the specifications adopted by the Bureau, and thus a great saving in time is made in testing the weights.

Preparation is being made to test immediately any weights needed for war purposes which may be submitted by the various departments of the Government or by outside firms. To this end every effort is being made to keep the regular work as nearly up to date as possible, and extra balances are being overhauled with a view to using them should occasion arise.

New Type of Balance.

A novel type of balance, characterized by a high sensibility and yet very simple and inexpensive to manufacture, has been developed by a member of the staff and described in an article in a leading engineering periodical. The results of a preliminary test showed exceedingly good operation, and it appears that this simple and inexpensive balance compares in many respects very favorably with the more elaborate and costly analytical balances.

Testing Scales by Use of Water.

In compliance with a request for information as to the practicability of testing scales by the use of known volumes of water, determined by filling standard capacity measures, an investigation was carried out and very promising results were obtained. The object of using known volumes of water for testing scales is to enable a weights and measures inspector who does not have facilities for transporting large quantities of standard weights to test scales of large capacities.

Track-Scale Work.

The railroad track-scale work consists of that carried on at the Bureau and that done in the field. The work at the Bureau consists of the collection and distribution of information, the preparation of tolerances and specifications on track scales and other weighing devices, the development of the correct theory of scale design and construction, development of special devices and methods of tests, investigations of various problems that arise, and a study and selection of the problems to receive attention. An important feature of this work has been the interpretation, classification, and arrangement of the data collected in the tests made in the field.

The field equipment in operation during the year consisted of two test-weight cars of Bureau design, which have been described in previous reports. The field work comprised the testing of scales by means of the equipment provided, making a careful inspection of the scales and reporting their condition so that the owners may be advised by the Bureau what repairs or changes are necessary to

put the scales in proper condition. In addition to the testing of railroad-track scales and master scales, other scales of large capacity are tested when occasion arises. Additional field equipment has been purchased by the Bureau, but owing to war conditions it has not yet been delivered.

Representatives of the Bureau have cooperated with the various States in the preparation of specifications for railroad-track scales and have rendered advice to State officials in reference to technical details relating to their equipment. Assistance has also been given to various organizations, such as the National Scale Men's Association and the American Railway Association, in the preparation of reports, papers, specifications, and other matters pertaining to railroad-track scales.

Location, Condition, and Ownership of Track Scales Tested.

Tests have been made in 21 States and the District of Columbia, the States being Alabama, Connecticut, Georgia, Illinois, Indiana, Kansas, Kentucky, Louisiana, Missouri, Minnesota, North Carolina, New Jersey, New York, Ohio, Oklahoma, Pennsylvania. Tennessee, Texas, Virginia, West Virginia, and Wisconsin. In these States there were tested during the past fiscal year a total of 508 track scales, of which 158, or 44 per cent, passed the tolerance adopted by this Bureau. This tolerance is based on the maximum allowable error of a weighing of 200 pounds in weighing a car of 100,000 pounds gross weight. The results obtained from the test of 149 scales included in the total number mentioned above have not yet been compiled.

In cooperation with the American Railway Association, 15 master scales were tested on a schedule submitted by them and agreed to by this Bureau. Three of the 15 master scales tested were found to be within the tolerance during the test, and of the remainder 5 were not in condition to make the adjustment within the tolerance practicable. The tolerance applied to these master scales allows an error of 10 pounds in weighing a test car of 100,000 pounds.

These master scales are the practical means available to the railroads and to the various States for the standardization of test cars, which in turn are used for testing commercial scales.

The scales tested belonged to the Federal Government, State governments, corporations, railroads, and industrial concerns.

Reports on Track Scales Tested.

Reports of track-scale tests had been rendered to the owners of these scales, the officials of those States which have organized departments of weights and measures, officers of weighing and inspection bureaus having jurisdiction over the scales, and to chambers of commerce. It became necessary, on account of the great pressure of other work to discontinue this practice toward the close of the fiscal year, but it will be resumed as soon as the present national emergency has passed.

These reports represent a very important phase of track-scale work. They give the results of tests in detail, show the conditions found by careful inspection, and make recommendations for correcting such faulty conditions as are present.

The owners of the scales have been given every opportunity to witness the tests, and the recommendations included in the reports have been for the most part carefully carried out. In many cases new scale installations have been made as a result of the tests and recommendations. The work thus carried on by the Bureau reduces the amount of shortage in weight due to faulty scales; creates confidence in the correctness of the scales between the railroads, shippers, and consignees; and tends to prevent disputes as to the correctness of the weights.

Technical Information Regarding Track Scales.

Several communications were prepared on various technical matters relating to scales and weighing mechanisms, which were distributed to a general mailing list of people interested in this subject. One of these, "Specifications for Class C slotted counterpoise weights for scale testing," Communication B423, gave specifications for weights which had been found particularly suitable for conducting tests on railroad-track scales and railroad master scales, as well as being adapted for testing other kinds of scales, such as wagon scales, platform scales, etc.

One of the most serious problems that has to be met in maintaining a railroad-track scale is the corrosion of the parts induced by their being located in damp pits. This subject is covered in Communication B420, entitled "Protection of track-scale parts from corrosion," and is supplemented by Communication B426, giving specifications for paint for use on railroad-track scales. This is a compilation of information collected by the Bureau from outside sources and from work which is being carried on by the Bureau in other lines.

Communication B419, under the title of "General inspection and overhauling of track scales," gives the recommendations of the Bureau in regard to the character and frequency of scale inspection and overhauling.

Communication B421, under the title of "Alignment," points out and emphasizes the need for keeping the scale parts properly aligned and makes suggestions respecting certain details.

Communication B422, "Maintaining the multiplication of track scales," calls attention to some of the mechanical principles controlling the action of railroad-track scales, points out where an improvement can be made by eliminating certain faulty methods of adjustments, and shows how the test can be made in conformity with correct principles.

Communication B425, "Determination of actual sectional errors in railroad-track scales," points out how information necessary for the efficient adjustment of railroad-track scales can be obtained and properly employed.

Communication B424, entitled "Chart for adjusting levers of railroad-track scales," furnishes the practical scale mechanic in the field the information needed by him in making adjustments without employing mathematical computations.

Communication B414, "Types of construction to be avoided," points out certain defects, or incorrect principles, which have been used in many scales and which should be avoided.

Communication B413, "Explanation of reports on tests made of railroad-track scales," explains the method of presenting the information obtained in the various details of the test and inspection as reported to the owners of the scales.

Communication B430, "Weighing by substitution," explains a method whereby accurate weighing can be carried out on a scale which is not in itself accurate or is not intended for weighings of such precision as can be obtained by this method.

Building for Housing Master Scale.

In order to provide a place for installing the 100,000-pound master precision scale purchased by the Bureau and to provide facilities for housing the field equipment while undergoing repairs and while being standardized, a suitable building is very urgently needed. This master scale will afford facilities both to the Government and to the railroads for standardizing their railroad-track-scale equipment and would also be available for the standardizing of any railroad-track-scale equipment such as is now owned by some of the weights and measures departments of the States. The installation of this master scale and building would also furnish a correct and efficient means of weighing and standardizing large projectiles, such as are occasionally submitted by the War and Navy Departments, and large guns can be weighed with precision.

Density Determinations of Materials.

During the year density determinations of 156 samples of materials were made. These included samples of wood and special materials whose physical properties were investigated for the purpose of determining their suitability for airplane construction.

An investigation of the density and thermal expansion of sea-water and sodium-chloride solutions was carried out, the results of which were used for calibrating some instruments to be used in the rapid and accurate determination of the density of sea water.

New Sugar Tables.

A new sugar table was calculated and will be included in Circular No. 44 of this Bureau when reissued. This table shows the relation between percentage of sugar, specific gravity of solution, and degrees Baumé, and is based on the work of Dr. F. Plato.[a] The Baumé degrees are according to the modulus 145.

Barometry, and Aeronautic Instruments.

A short time before the close of the fiscal year the barometry section was extended in scope to include aeronautic measuring instruments in general, with the intention of placing all aeronautic measuring instruments on the same basis of scientific testing as was previously the case with altitude-measuring instruments only. A number of conferences with military officials, practical aviators, and manufacturers regarding the status of aeronautic instruments, both here and abroad, together with laboratory experiments on various types of instruments, have served to accumulate considerable information. The information thus gathered has enabled the Bureau

[a] Wiss. Abh. der Kaiserlichen Normal-Eichungs-Kommission 2, p. 153; 1900.

to answer frequent inquiries and be of assistance, in turn, to other manufacturers and military authorities. As a single example, at the request of the joint trial board of the Army and Navy air services, a simple and definite system was prepared for the determination of airplane altitudes during acceptance test on airplanes. The cooperation had with manufacturers of aneroid barometers has led to definite improvements in the quality of the instruments produced, as is shown in detail by the records available in the laboratory.

On account of the large demand for information on aeronautic measuring instruments, it seems highly desirable to issue a circular of general information on these instruments, summarizing their uses and sources of error, and announcing the procedure governing tests at this Bureau. An outline which will form the basis of such a circular has been prepared.

Laboratory investigations in cooperation with military authorities have been commenced. This work has included a comparative study of the errors in the gauges used as speed indicators and also in various tachometers.

The Bureau is represented on the appropriate subcommittee of the National Advisory Committee for Aeronautics in connection with this work.

During the fiscal year routine tests were made on 2 mercurial barometers, 2 katanoscopes, 6 statoscopes, and 345 aneroid barometers. The latter number includes weather aneroids, surveying aneroids, thermobarographs, altimeters, and altigraphs.

Watch Testing.

Forty-five watches were submitted for test during the past year, about the same number as the Bureau received for test the previous year. All of these were submitted for the class A test, and 36 per cent of the total number passed the requirements and received a class A certificate. Thirteen of the 16 watches receiving certificates were of American make. The rate of the Riefler clock has continued satisfactory during the year.

Lime-Barrel Act.

At the first session of the Sixty-fourth Congress an act to standardize lime barrels was passed and was approved on August 23, 1916. The general provisions went into force and effect at once, and the penal provision became effective on January 1, 1917. This law regulates the sale of lime by establishing two mandatory standard barrels for use in interstate commerce, containing, respectively, 280 and 180 pounds net, and by requiring that packages of less capacity shall have the net weight of the contents stamped upon them. The Bureau is greatly in favor of the sale of commodities by weight, whenever such a method of sale is practicable, and it heartily assisted the committee of the National Lime Manufacturers' Association in drafting the original bill introduced into Congress and endorsed the principles represented therein.

Rules and Regulations for Barrel Laws.

The lime-barrel law provided that rules and regulations for the enforcement of the act, including tolerances to be allowed, should be made by the Director of the Bureau of Standards and approved

by the Secretary of Commerce. As soon as the law was passed, the Bureau conducted an investigation of the manner of sale of lime in barrels and packages, and rules and regulations were finally promulgated in accordance with the provisions of the law. These have met with the approval of the trade and are regulating the subject satisfactorily. A representative of the Bureau attended the annual meeting of the National Lime Manufacturers' Association and explained the provisions of the law and of the rules and regulations. The great majority of the manufacturers show a most commendable desire to understand these provisions and to comply with them.

The Bureau found the preparation of rules and regulations for tolerances, authorized by the standard-barrel act, a difficult undertaking on account of the dearth of information on this subject as well as the fact that it was necessary that those adopted be simple in their application, since the tests on barrels must be made in the field quickly and with rough apparatus. It became necessary to conduct investigations into the formulas heretofore published, and when these were found to be inaccurate for the type of barrel established by law a satisfactory metal standard barrel was constructed and a new formula derived applicable to this type of barrel.

A convenient method has been developed for representing on a single plane the variations of a quantity which depends on several variable quantities. This method has been applied particularly to the problems of representing the capacity of standard barrels corresponding to given measurements of the head diameter, the distance between heads, and the bulge circumference. Charts for this purpose which will be useful for those making inspections under the new standard-barrel act have been prepared and blue prints of them were made. The method has also been applied in slightly different form in the preparation of charts which will be of value to the manufacturer of barrels.

With the results so obtained as a basis, simple rules were worked out for field inspection by means of which it can be rapidly and accurately determined whether or not barrels in use comply with the requirements of the law. The rules and regulations thus formulated have been completed and approved, and they are now in the hands of the printer. When these are distributed, it is believed that the strict enforcement of the law will become practicable and that such enforcement will not result in any hardship to manufacturers or shippers.

Uniformity in Inspection of Weights and Measures.

With the rapid spread of the inspection of commercial weights and measures throughout the country during the last few years, as evidenced by the passage of State laws and city ordinances on the subject, and the consequent appointment of official inspectors, the necessity of uniformity of laws, of specifications and tolerances for commercial apparatus, and of inspection methods is becoming more and more evident each year. The Bureau has succeeded in the past in making satisfactory progress in regard to uniformity of laws and of specifications and tolerances through the medium of the Annual Conference on Weights and Measures. There has now developed a great demand for a manual of inspection of apparatus to the end

that the specifications and tolerances adopted be uniformly interpreted and enforced and the practice standardized in the various jurisdictions. Many requests have reached the Bureau for a publication along these lines. There has been no publication heretofore issued which could be recommended as satisfactory. To meet this need and to satisfy these demands, the Bureau has prepared material on this subject, which is now about ready to go to the printer. This publication will probably be issued in the form of a compact manual designed especially for field use. It is believed that this publication will satisfy the existing demand and will do much to bring about a standard practice throughout the country, and a marked increase in efficiency should therefore result.

Annual Conference on Weights and Measures.

The Bureau had planned to hold the Twelfth Annual Conference on Weights and Measures in Washington during the month of June. After the date had been fixed upon and preliminary details had been worked out, the declaration by Congress that a state of war existed caused a complete revision of the plans. It appeared to the Bureau that no time could be devoted to this meeting by the members of the Bureau staff on account of the great press of very urgent business which was rapidly developing. It also appeared questionable, in view of the general necessity of economy in expenditure of money, time, and energy, whether the results which could be accomplished at this time would compensate for the expenditure involved in the holding of the meeting.

These matters were placed before the executive committee of the conference by the Bureau, with the recommendation that the contemplated meeting be postponed. The result was that the committee voted unanimously to postpone the proposed meeting indefinitely, and the Bureau believes that this was a wise decision. The meetings will be resumed when it appears that this can profitably be done.

Cooperation with States and with Local Officials.

During the past year the Bureau cooperated with State and local weights and measures officials by sending representatives to meetings of officials in the States of Indiana, Michigan, New Jersey, Pennsylvania, and West Virginia. Addresses were given on subjects connected with the work of the Bureau and the State and local departments, such as the test of railroad-track scales, the enforcement of the Federal barrel laws, etc. On account of the postponement of the national conference, the State meetings were of especial importance this year. The State of New Hampshire joined the list of States having adequate laws on the subject of weights and measures by passing a bill drafted and recommended by the Bureau and based on the model law heretofore adopted, establishing a State-wide inspection service. This State was the last one in New England which did not furnish such protection to its citizens. Several other States passed bills strengthening their local laws, and in still others bills recommended and indorsed by the Bureau were considered but failed of passage through various causes. A number of State and local officials visited the Bureau for the purpose of obtaining assistance and information, and as usual much information was furnished and many problems considered through the medium of correspondence.

Information Furnished on Weights and Measures Subjects.

Much information and advice on technical matters have been furnished, of which the following may be mentioned: Use of spring scales in the United States, especially with reference to the general points to be considered in permitting the spring scale to be used in trade; weighing scales and gasoline-measuring pumps furnished to writers for use in articles for technical magazines; the design of weighing scales furnished on request of manufacturers and private individuals; the relative precision of equal arm balances and platform scales with reference to the weighing of precious metals; the design of certain weighing scales for use in the Philippine Islands; and tolerances and specifications applying to apparatus used in the testing of water meters. Specifications were furnished for a large automatic scale, a scale for weighing paper to be used in the Division of Supplies of the Department of Commerce, and a weighing apparatus listed in the Government schedule of supplies. A great amount of information has been furnished on the density, pounds per cubic foot, and pounds per gallon of various substances; the design of an epicyclic train for an automobile speedometer; the adaptability of a certain device for the measurement of molasses in tanks; the graphical methods of calculation used by the Bureau; and the mechanical design of a paper-reeling device.

2. HEAT AND THERMOMETRY.

[Temperature, heat, heat constants, melting and boiling points, critical points, specific heats, conductivities, and other thermal properties of materials, including researches on heat units and standard temperature scales, standardization of instruments and methods for measuring temperature, determination of refrigeration data and the fire-resisting properties of materials and other experimental work of specific value to the refrigerating and heating industries, in the manufacture of thermal appliances, in scientific testing and laboratories, in fire-safety engineering, and in the industries and sciences requiring precise knowledge of temperature measurements and heat constants.]

New Regulations Governing Tests of Clinical Thermometers.

New regulations governing the testing of clinical thermometers have been adopted, effective July 1, 1917. The former regulations provided for tests at four points—96°, 100°, 104°, and 108° F.—and certificates giving the corrections found were issued, provided that the corrections did not exceed 0.3° and that the thermometers were free from defects. Extensive inquiries among users of clinical thermometers had shown that the corrections given on such certificates were rarely applied, and that most users preferred a "blanket" certificate stating that the readings of the thermometers were correct. The new regulations provide for tests at two points—98.6° F. (37° C.) and 104° F. (40° C.)—and the thermometer is certified as correct if the corrections at the lower and upper test points do not exceed 0.1° and 0.2° F., respectively. The certificate also states that the thermometer has been aged at least one month and that subsequent changes due to aging will probably not exceed 0.1°. The latter statement would be true only if the bulbs of the thermometers were made of a suitable thermometric glass, for if the bulbs were made of soft glass the indications of the thermometer might change by a degree within a year. However, by making two tests at intervals of a month, the inferior thermometers can be detected and rejected.

A new and distinctive certificate bearing the seal of the Bureau of Standards has been prepared by the Bureau of Engraving and Printing. A number of manufacturers had been issuing their own certificates upon forms similar in appearance to those used by the Bureau, and the wording of some of these certificates was such as to give the impression, at first sight, that the certificate had actually been issued by the Bureau of Standards. It is hoped that the Bureau's new certificate will become so well known that its distinctive character will prevent such deception.

Circular No. 5, Testing of Clinical Thermometers, has been revised to include the new regulations and will be ready for distribution early in July, 1917.

Standard Temperature Scale.

For a number of years the standard scale of temperature used by the Bureau in the intervals −50° to 0° and +100° to 500° C. has been the scale defined by the platinum resistance thermometer calibrated at three points, 0°, 100°, and 444.6°, the boiling point of sulphur. The standard scale in the interval 0° to 100° has been the hydrogen scale of the International Bureau of Weights and Measures and is represented by the corrected indications of a number of verre-dur thermometers which had been calibrated by the International Bureau.

The great precision and reproducibility of the scale defined by the resistance thermometer have led to the adoption of this scale over the whole range from −50° to +500°. It has long been known that this scale does not differ appreciably in the range 0° to 100° from the hydrogen scale previously in use by the Bureau. It has been considered desirable, however, to determine as definitely as may be the outstanding difference between the two scales, and some of the intercomparisons have been made.

Since the work involves the determination of a minute difference, no statement as to results will be of value until the work is completed. Assurance may be given, however, that the adoption of the new standard scale will produce no recognizable change in the temperature scale distributed by the Bureau through the medium of its testing work.

Copper-Constantan Thermocouples.

Some progress has been made during the year in the design of a suitable inclosure for copper-constantan thermocouples and in the preparation of couples to be used in determining a standard calibration curve for such couples in the temperature range from −200° to +300° C. The great utility of thermocouples and their extensive use would make such a calibration very valuable.

Depression of the Ice Point of Thermometers.

The work on the depression and recovery of the ice points of thermometers has been practically suspended during the year, due to difficulty in obtaining suitable thermometers made of American thermometric glasses, which should be included in such an investigation. It is hoped that this work will be finished in the near future.

Standard Boiling Points.

The method referred to in the annual report for 1916 for determining the variation with pressure of the boiling point of sulphur has been used to determine the variations for naphthalene, benzophenone, and anthracene, over the pressure range from 700 to 800 mm of mercury. The suitability of the boiling points of naphthalene and benzophenone to define standard temperatures was well known. Anthracene has been found to be satisfactory in that a given sample has a definite boiling point not changing with continued boiling, but the samples used differed considerably. With the aid of the chemical division, it is proposed to determine whether it is feasible to purify anthracene so that its boiling point may serve to define a thermometric fixed point. The results of this work will probably be ready for publication within a year.

Standard Heat Samples for Use in Calorimetry.

The Bureau has continued the distribution of naphthalene and sucrose as standard heat samples. The stock of naphthalene was renewed. Owing to inability to renew the stock, the distribution of benzoic acid has been temporarily discontinued. A total of 239 samples, consisting of 32 of benzoic acid, 118 of naphthalene, and 89 of sucrose, was issued during the year. These samples serve an important purpose in enabling commercial laboratories and others to obtain reliable results in fuel testing. Cases of dispute between buyer and seller, due to discrepancies between results of their tests, were not infrequent a few years ago, but no such cases have come to the attention of the Bureau for a number of years.

Standard Samples for Thermometric Fixed Points.

In addition to the service which the Bureau is able to render scientific workers and the industries by calibrating pyrometers, there has been a demand for some means by which the user of pyrometers might be able to calibrate his own instruments. Pure metals of known melting points provide a satisfactory means for this purpose, and during the past two years the necessary materials were obtained. The Bureau now has available for distribution samples of pure tin, zinc, aluminum, and copper. The melting points of these materials have been accurately determined with standardized platinum resistance thermometers, and chemical analyses showing a very high degree of purity have been made. These materials are intended for use primarily in the standardization of rare metal thermocouples and the samples are of suitable size (50 to 80 cubic centimeters) for this purpose. Circular No. 66, describing the preparation and methods of use of these samples, is now in press. The distribution of the samples will begin about August, 1917.

High-Temperature Investigations.

Some work was done on the standardization of pyrometer lamps that had also been carefully calibrated at several industrial laboratories as a basis for the intercomparison of the high-temperature scale actually being used in the several laboratories in important researches, the temperature scale being that defined by the optical pyrometer up to 2,500° C.

On account of its important bearing on the use of optical methods of temperature measurements, some work was done, as time would permit, on the change in the effective wave length of pyrometer color screens.

Considerable progress has been made on the construction of an electric furnace, capable of operation up to 1,800° C., for work on the melting points of palladium and platinum, two very important fixed points of the high-temperature scale.

New methods have been developed and introduced into the laboratory for testing thermocouples, which not only increase the accuracy but very materially reduce the time required for the tests. These have made possible large increases in the testing work accomplished.

Work has been done on the development of a "neutral" absorbing screen for optical pyrometers, such screens being generally made of foreign glasses not now available.

In conjunction with the metallurgical division, standard melting-point samples have been prepared for distribution, as explained in the preceding section.

Low-Temperature Laboratory.

The carbon dioxide system has been operated almost continuously to supply refrigeration to the thermostatically controlled baths used for the refrigeration constants investigations and to the low-temperature thermometer comparator.

The capacity of the air liquefier has been brought up to 12 liters per hour. Liquid air has been made 34 times during the year, as required by the various Bureau and other Government and college laboratories. A number of demonstrations have been given to technical societies visiting the Bureau, to science classes of several educational institutions, and to other public organizations.

The air compressor has in addition been operated on 23 occasions to supply compressed air for the low-temperature baths of the thermal expansion laboratory. The large air compressor is at present operated by steam. Electric power should be substituted to relieve the heavy demands on the Bureau's boiler plant.

The electrolytic gas generator has maintained a supply of hydrogen and oxygen for general use throughout the Bureau. The acetylene generator has been kept in operation to supply acetylene gas as needed.

A hydrogen liquefier was made in the laboratory, and an old compressor that was purchased with the plant was overhauled, a small compressor was improvised into a vacuum pump for precooling air, and liquid hydrogen was produced in this laboratory during the year. Six liquid hydrogen runs were made.

Good progress has been made by the instrument shops on the construction of a new hydrogen liquefier, the designs for which were worked out last year. To produce liquid hydrogen in such amounts as to be of real use to the Bureau's laboratories, as well as to other investigators who may desire to avail themselves of this unusual laboratory facility, a new 4-stage compressor, two gas storage tanks, and some lesser equipment should be provided.

Considerable time has been given to overhauling the extensive mechanical equipment of the laboratory. Some time has also been

given to preliminary experiments in connection with military problems.

Mercury Vapor Pump.

An improved mercury vapor pump has been developed which will give a high vacuum when used in conjunction with any pump which will evacuate to a primary pressure of 4 centimeters or less. The pump works by two stages in connected units, each operated by mercury vapor from a single boiler, a single gas burner being used to evaporate the mercury. The pump is simple in construction and can be built by a reasonably skilled glass blower. Pressures much lower than 0.0001 millimeter may be quickly reached with the pump.

Refrigeration Constants.

This extensive series of investigations, undertaken at the request of American refrigeration engineers, expressed through their national associations, includes the determination of the fundamental constants of refrigeration engineering. The work is being carried out with the cooperation of committees of the American Association of Refrigeration and the American Society of Refrigerating Engineers, the members of which have kept in close touch with the work by visits to the Bureau and by means of the reports presented before the annual meetings of these societies by members of the Bureau's staff. The complete series of investigations contemplated under this topic was outlined in the annual report for 1916. The work done during the year is briefly summarized in the following sections.

Calorimeter for the Determination of Latent and Specific Heats of Fluids.

The principle of the unstirred or "aneroid" type of calorimeter has been embodied in an instrument especially designed for determinations of the specific heat and latent heat of several substances in general use as refrigerating media.

Heat developed electrically in a coil located in the central axis of the cylindical shell comprising the calorimeter is distributed by conduction to the calorimeter and contents, whose initial and final temperatures when in thermal equilibrium are measured by a platinum resistance thermometer.

Heat from other sources is excluded by enveloping the calorimeter with a metal jacket separated from it by an air space and keeping this jacket during measurements at the same temperature as the calorimeter surface, using multiple thermocouples to indicate this equality.

The calorimeter is adapted for use between −50° and +50°C. and for pressures up to 70 atmospheres in experiments where the measured heat added is used either to change the temperature of the contents or to evaporate a portion of the contents withdrawn as superheated vapor, in the first case the specific heat and in the second the latent heat of vaporization being obtained when proper corrections are made.

A paper is now in press describing the details of construction of and the special features embodied in this instrument, the methods

of manipulation in making measurements of the heat capacity, and giving the results of an extended series of observations in the temperature range from —50°C. to +50°C. to determine the heat capacity of the empty calorimeter.

Specific Heat of Liquid Ammonia.

Using the above described calorimeter, the specific heat of liquid ammonia has been determined throughout the temperature interval —45° to +45° C. under saturation conditions.

Two distinct and independent methods were used, each of which avoids sources of error possessed by the other. In the first method measurements were made of the heat added to a fixed amount of ammonia confined in the calorimeter at saturation conditions, and also the resulting changes in temperature. By using data for the specific volumes of the two phases and the latent heat of vaporization, the corrections for vapor are applied, giving the specific heat of the liquid, kept saturated, as a function of the temperature.

In the second method the calorimeter is kept full of liquid at a constant pressure. The heat added to a variable amount in the calorimeter and the resulting change in temperature were measured. A correction for the heat absorbed by the expelled liquid, depending on the lag of this part with respect to the entire contents, was determined by a novel thermometric device. By use of data for the latent heat of pressure variation of the liquid, obtained from separate measurements made with the same apparatus and material, the corrections for pressure variation were applied, giving an independent determination of the specific heat of the liquid, kept saturated, as a function of the temperature.

The greatest difference between the mean results of both methods, and the results of either method as represented by empirical equations, is less than 1 part in 1,000.

A form of empirical equation was found which, in addition to representing closely the results in the range of temperature covered experimentally, conforms to several theoretical considerations regarding the behavior of substances in general when approaching the critical temperature.

As a final result the specific heat σ, in joules (international electric watt-seconds) per gram per degree centigrade, of liquid ammonia, kept saturated, in terms of the temperature ϑ, in centigrade degrees, is expressed in the interval —45° to +45° C. by the equation

$$\sigma = 3.1365 - 0.00057\vartheta + \frac{16.842}{\sqrt{133 - \vartheta}}$$

A paper giving all the necessary details of this investigation has been prepared and sent to press.

Latent Heat of Vaporization of Ammonia.

Using the above-described calorimeter, the latent heat of vaporization of ammonia has been determined throughout the temperature interval —42° to +52° C.

An analysis of the process occurring in the calorimeter during an experiment leads to a method of calculation of the results whereby data from other sources than the direct calorimetric observations

enter only in the computation of correction terms which can by careful manipulation be made small.

Variations in manipulation were introduced as a means of detecting possible systematic errors, particularly in regard to the matter of dryness of the vapor withdrawn.

The results of each of the 34 determinations agree with the mean result as expressed by means of an empirical equation within 1 part in 1,000. An empirical equation was found which, in addition to representing closely the results in the range of temperature covered experimentally, conforms to what is known about the behavior of substances in general when approaching the critical temperature.

As a final result the latent heat of vaporization of ammonia—that is, the heat required to convert saturated liquid into saturated vapor at constant temperature—in joules per gram is expressed in the range —42° to +52° C. by the equation:

$$L = 137.91\sqrt{133-\vartheta} - 2.466\ (133-\vartheta)$$

If the latent heat of vaporization be expressed in calories$_{20}$ per gram, taking 1 calorie$_{20}$=4.183 joules, the equation becomes

$$L = 32.968\sqrt{133-\vartheta} - 0.5895\ (133-\vartheta)$$

Using the results obtained for the latent heat of vaporization of ammonia together with the specific heat of the saturated liquid, the specific heat of the saturated vapor has been computed for various temperatures and given in a table.

A paper giving all the necessary details of this investigation has been prepared and will be sent to press shortly, after final revision by the editorial committee.

Latent Heat of Pressure Variation of Liquid Ammonia.

The latent heat of pressure variation of liquid ammonia—that is, the heat gained or lost per unit pressure change at constant temperature—has been determined as a supplement to a series of specific-heat measurements upon the same material, in order to furnish data for correlating the measurements made at constant pressure with those made under saturation conditions.

Three independent methods were used in the present investigation, the first by direct calorimetric measurement of the heat transformed in consequence of a change of pressure, the second by computation from the expansivity directly observed with a dilatometer, and the third by computation from the specific volume of the saturated liquid at various temperatures and the compressibility.

The aparatus used in the measurements consisted of the aneroid calorimeter with accessories.

The results of the three independent methods were in agreement to the order of precision of the measurements. In temperature interval —40° to +40° C. and range of pressures from 20 $\frac{\text{kilograms}}{\text{square centimeters}}$ to saturation, the results are represented by the empirical equation

$$l = 0.037 - \frac{15}{120-\vartheta}$$

where l is the latent heat of pressure variation in joules per gram for a pressure variation of 1 kilogram per cubic centimeter. The variation of l with pressure in the range here covered was found to be small enough to be negligible in the application of the results to the specic-heat investigation.

Specific Volumes of Ammonia in the Liquid and Vapor Phases.

The specific volumes of ammonia in the liquid phase were measured in the temperature interval −45° C. to +45° C. with an accuracy of about 0.01 per cent. A large number of measurements of the specific volumes in the vapor phase were made in glass containers in the temperature interval −50° C. to +50° C., most of the work being confined to the low temperatures. Experiments were made to determine the magnitude of the adsorption of ammonia on glass surfaces. The insertion of a large number of small, thin-walled glass tubes within the largest glass container used in these specific volume experiments increased the surface area by a factor of approximately 10. Measurements made in these two tubes of such different surface areas, in the interval −50° C. to +50° C., showed that the measurements of the specific volumes of the vapor in glass containers were not affected by adsorption by an amount exceeding the experimental errors of the specific volume determinations.

The additional measurements at the higher temperatures (above 0° C.) required to complete this investigation will, it is expected, be completed during the present summer.

As an independent check on the results found by the above method, an apparatus is being constructed for the determination of the refractive index of the vapor throughout the above temperature interval, making use of the well-known relationship between refractive index and specific volume. It is hoped that this method will accelerate the work and increase the accuracy attainable, especially at the lower temperatures.

Compressibility of Liquid Ammonia.

The compressibility of liquid ammonia is required in computations relating to other important refrigeration constants of this fluid. The special apparatus required for this work was completed, and the preliminary measurements made with it indicate that the more important experimental difficulties have been overcome so that the investigation can probably be completed at an early date.

Density-Temperature-Concentration Relations of Aqua Ammonia.

Work has been continued on the determination of the density-temperature-concentration relations of aqua ammonia for solutions of 5 to 30 per cent by weight of ammonia over the temperature interval from their freezing points to about 40° C. The experimental work in connection with this investigation has been nearly completed.

Pressure-Temperature Relation for Vapor in Equilibrium with Aqua Ammonia.

The apparatus required for the determination of this relation, of importance in the design and operation of absorption refrigerating systems, has been nearly completed. Aqua ammonia of known con-

centration, as determined by volumetrically measuring its constituents, is introduced into a glass vessel provided with an electromagnetic stirrer which operates in the completely closed vessel without mechanical connection to the outside. A connecting tube filled with mercury transmits the pressure to the pressure gauge, while the temperature control is obtained by immersing the vessel in a thermostatically controlled bath. A temperature range of —40° C. to +125° C., a concentration range of 0 to 50 per cent, and a pressure range of 0 to 15 atmospheres are provided for by the apparatus designed.

It is hoped that the necessary measurements may be made within the near future.

Temperature-Concentration Relation for Vapor in Equilibrium with Aqua Ammonia.

Most of the instrument shop work in connection with the apparatus required for the determination of this relation, of importance in the design and operation of absorption refrigerating systems, has been completed, and it is hoped that an opportunity will be found to make the necessary measurements during the next fiscal year.

Following is a brief description of the method adopted. The steel container, half full of aqua ammonia, is immersed in a thermostatically controlled bath. Vapor is drawn off from the top, run through a condensing coil, and returned to the bottom of the container. When equilibrium is established, the concentration of the vapor phase is determined from measurements of the density of the condensate, and of the liquid phase by density measurements of a sample drawn from the container. Densities are determined in slightly enlarged hydrometer cells forming part of the circulating system. The hydrometer consists of a glass float inclosing a silicon steel magnetic armature. Gravity control, with a series of removable platinum weights, serves to determine the large steps in density, and interpolation by means of the force exerted by a current in a solenoid acting on the steel armature gives the small steps.

To insure equilibrium of the vapor and liquid phases, a special device has been designed and constructed which will not only thoroughly agitate the liquid but expose a large fresh liquid surface to the vapor. The device consists of a paddle resembling a lawn-mower cylinder operated by a nutating rod through a flexible diaphragm which eliminates stuffing boxes.

Specific Heats of Sodium Chloride Brines.

The measurements of the specific heats of sodium chloride solutions were carried out with the large Dewar flask calorimeter previously used in the work on calcium chloride solutions. Measurements were made with solutions of chemically pure salt of 5, 10, 15, 20, and 22.5 per cent of salt by weight, respectively, with solutions of several commercial samples of sodium chloride of 20 per cent of salt by weight, and in the temperature interval —20° C. to +30° C. The pure salt was especially prepared for this work in the chemical division, and the work on the density-concentration relation of these sodium chloride solutions was carried out in the division of weights and measures. The experimental work in connection with

this investigation has been completed, but time has not been available to prepare it for publication.

Chemical Investigations Relating to Refrigeration Constants.

Two investigations under the program of refrigeration constants have been carried out in the chemical division, one relating to the composition and testing of commercial anhydrous ammonia and the other to the formation and avoidance of noncondensing gases in ammonia refrigerating systems. The preparation of the pure material,—anhydrous ammonia, sodium chloride and its solutions, ethyl and methyl chlorides,—for use in the determination of the physical properties, has also been carried out in the chemical division. These results of these investigations are summarized elsewhere in this report.

Thermal Conductivities of Insulating and Structural Materials.

The results of measurements of the thermal conductivities of a number of insulating materials were published in the September issue of the Journal of the American Society of Refrigerating Engineers. Since the date of that publication, measurements have been made on several other materials and on some 10 samples of panel board.

The greater part of the elaborate equipment required for the determination of thermal conductivities of structural materials has been completed in the instrument shops. The apparatus is being adapted for measurements up to 800° C. (1,500° F.).

Fire-Resisting Properties of Structural Materials.

The object of the investigations on the fire-resisting properties of structural materials is to furnish architects, construction engineers, builders, State and city building bureaus, insurance interests, and others with fundamental engineering data relating to the behavior and safety of various types of building material and construction when exposed to different conditions met with in fires.

Fire Tests of Building Columns.

Many millions of dollars are spent annually on the construction of buildings, the integrity of which, in the event of fire, is dependent on the behavior of the steel columns supporting the structures. Very little engineering data are available which would permit of any certain conclusions as to the thickness and kind of fireproof covering required to render these columns safe under various conditions of fire hazard. The requirements of city building codes on these questions are so different that it is evident that either some codes are requiring unnecessarily thick fireproof coverings, with undue increase in construction costs, or else other codes are requiring too thin coverings, with undue increase in danger to the stability of the structure under the existing fire hazards.

The fire tests on building columns are being conducted jointly by The National Board of Fire Underwriters, the Associated Factory Mutual Fire Insurance Companies, and the Bureau of Standards. The present program of tests was formulated after consultation with many engineers and architects interested in fire-resisting building construction.

Types of Columns.—The types of columns being tested include rolled steel sections, built-up steel sections, round cast-iron sections, steel pipe filled with concrete, vertically reinforced and hooped concrete columns, and wooden columns. At least one of each of the sections is unprotected, others are partially protected by filling the reentrant portions with concrete, and others are completely protected by various thicknesses of concrete, clay tile, filled and unfilled gypsum blocks, plaster on metal lath, and common brick, in accordance with the methods commonly employed in practice.

Materials.—The materials used in the construction of the test columns and protective coatings have been obtained from various sections of the country and have been selected with a view to obtaining those representative of their respective classes.

The column coverings have been applied by experienced men in accordance with plans and specifications drawn to secure average results obtainable under ordinary commercial conditions.

Methods of Test.—In the fire tests the column, mounted within a gas-fired furnace and kept under normal working load applied by a hydraulic ram of special construction, is exposed to a predetermined furnace temperature rise until the column fails. A record of the temperature at different points within the furnace and at various points within the test sample is obtained by means of suitable thermocouples. The deformation of the column from time to time is determined by means of pairs of nichrome wires inserted into the column at a known distance apart and extending horizontally outward through the walls of the furnace, the wires being run coaxially through fire-clay protecting tubes.

In the fire and water tests, the column is exposed to a furnace temperature built up at the same rate—i. e., in accordance with the standard time-temperature curve that has been adopted for these tests—until the desired temperature rise in the furnace is attained, when two opposite walls of the furnace are rolled out of position by means of trolleys provided for this purpose and the hose stream applied.

Status and Sequence of Tests.—The column coverings have all been applied. During the latter part of the present fiscal year, the preliminary work incident to adjusting burners to secure uniformity of temperature, to securing satisfactory operation of the ram, to calibrating gauges, etc., and to making several preliminary fire tests on filled pipe columns, was conducted, and on June 28 the first fire test of the regular program was successfully completed. Several fire tests have been made, and they give promise of yielding results of far-reaching importance in building construction.

The following tabulation shows the fire tests and the fire and water tests, classified according to the type of covering:

	Number of tests.
Fire tests of columns:	
Partial concrete protection	9
Full concrete protection	24
Reinforced concrete	6
Plaster on metal lath	5
Filled pipe	4
Clay	18
Gypsum	5
Common brick	2
Timber columns	4
Fire and water tests of columns: various types of coverings	13

No schedule has been decided upon for testing the unprotected columns, it being the present plan to test them as opportunity affords.

Witnessing Tests.—Underwriters, engineers, architects, and others having a proper interest in the subject are cordially invited to visit the laboratories, when in Chicago, and witness one or more of the tests in progress. The time for the tests is scheduled each week in advance and may be ascertained through inquiry by letter, telegraph, or telephone addressed to Underwriters' Laboratories, 207 East Ohio Street, Chicago.

A brief prospectus of the proposed tests containing somewhat fuller information than the present brief report is about to be issued.

Fire Tests of Reinforced Concrete Columns.

The program of cooperative tests, now under way at Chicago, includes but six columns of the reinforced concrete type of construction. When this program was prepared, it was, of course, realized that the number of such tests included at the time was wholly inadequate to determine the many possible variables that enter as important factors into reinforced concrete column construction. At that time, however, the several laboratories cooperating in the tests referred to did not see their way clear to laying out a program more extensive than the one adopted, which would require at least three years for its completion. Accordingly, the question of planning a comprehensive series of fire tests of reinforced concrete columns was deferred until the tests of the structural steel columns should be completed.

Whatever action may finally be taken with respect to the preparation of an elaborate program of fire tests of reinforced concrete columns, the Bureau concluded that the preparation of such a program, when it is finally taken up, would be very greatly facilitated if there were available fire tests of a number of such columns of representative types of construction. Accordingly, during the present year, the panel furnace at the Pittsburgh laboratories of the Bureau has been modified to adapt it to such tests, a 600-ton hydraulic ram has been installed to apply a continuous follow-up load to the column in the furnace, and about 30 reinforced concrete columns have been cast. The columns include square and round sections, 16 by 16 inches and 18 inches diameter, respectively, by 8 feet in length, aggregates of different types, and different methods of reinforcement. The temperature within the column, during the progress of the test, while the temperature of the furnace is being raised at the predetermined rate called for by the standard time-temperature curve adopted for all such tests, is measured by means of thermocouples imbedded in the columns at various distances from the surface.

During the last few weeks of the fiscal year, several successful preliminary fire tests were made on some extra columns that had been cast for the purpose, in order to test the new equipment and to standardize the procedure.

Thermal Efficiencies of Column Coverings.

A comparison of the thermal efficiencies of the materials commonly used for column coverings has been completed at the Pittsburgh Laboratories of the Bureau during the year. A short paper giving a summary of this work and entitled "A comparison of the heat

insulating properties of materials used in fire-resistive construction" was communicated to the annual meeting of the American Society for Testing Materials in June, 1917. This comparison of the materials themselves was preliminary to the investigations relating to the fire-resistive properties of structural units.

Solid cylindrical test specimens, 20 centimeters (8 inches) diameter by 40 centimeters (16 inches) length, were given the same heat exposure in a special gas-fired furnace. The rates of temperature rise at four depths within the specimen were measured by means of thermocouples mounted in 6-millimeter (¼ inch) holes extending longitudinally through the cylinder. Cylinders, similar to the cylinder under test, were placed at each end of the latter, in good contact with its end faces, to minimize the disturbing effects of heat losses from the ends. The materials included in these tests were: (1) Clays of the type used in the manufacture of hollow-tile fireproofing; (2) concretes, including two proportions of a number of aggregates; (3) gypsums; (4) lime mortar; (5) one specimen of a new material. The results are now being prepared for publication.

Strength of Steel at High Temperatures.

Some preliminary tests made in these laboratories two years ago on the ultimate compressive strength of short lengths of steel tubing showed that at 600° C. the ultimate compressive strength had decreased to 60 per cent, and in the next 50° C.—that is, at 650° C.—to about 30 per cent of its value when cold. On account of the great importance of such data in their bearing on the behavior of structural steel building construction when exposed to fire conditions, special apparatus has been designed for a more complete investigation of the elastic properties of metals at high temperatures. Contracts were placed in June for the construction of this apparatus, and it is expected that measurements with it may be started in the early winter.

Panel-Testing Furnace.

This furnace, together with its accessories, designed to test wall and partition structural units as large as 12 by 16 feet, was installed last year, and was described in the last annual report. Seven additional panel frames required to complete the plant should be installed as soon as the necessary funds can be provided. Arrangements have been made with a committee of ship constructors and operators to make a few fire tests of specially constructed panels with a view to improvement in the fire-resisting construction of passenger-carrying ships.

Steps have been taken to secure the cooperation of prominent engineers, representatives of engineering and technical societies, and manufacturing associations in the formulation of a comprehensive program of tests of the fire-resisting properties of various types of partition and wall construction. These tests are necessarily expensive, requiring as they do the test to destruction of large structural units. Very little progress on such an elaborate program of tests is possible until the appropriations available for the work are secured.

Building Codes, Information, Cooperative Work, etc.

Considerable correspondence has been carried on with engineers, State fire marshals, fire department officials, and others interested in

fire-prevention work, and the Bureau has cooperated with committees of the National Fire Protection Association in their several lines of work, especially with the committees relating to State building codes, safety to life, etc., and with the Bryn Mawr Fire Prevention Committee in their investigations on the fire hazard in relation to factories in which women are employed.

Work has been done in preparing an index for collating information relating to the fire-resisting features of building construction and in collecting data on the causes of fires.

A section entitled "Fires in the home" has been prepared as a part of a new Bureau circular, "Safety for the household," now in course of preparation.

Activities in Technical Societies, etc.

Members of the heat and thermometry division have cooperated with committees of the Society of Automotive Engineers on various aeronautical problems; committees of the American Society of Refrigerating Engineers on various problems relating to refrigeration engineering, several papers being presented before that society on the refrigeration constants investigation under way in the laboratories of the Bureau; committees of the National Fire Protection Association, the American Society of Testing Materials, and the Bryn Mawr Fire Prevention Committee on various problems relating to the fire hazard, safety to life, standardization of fire tests, etc.; the American Society of Testing Materials on the standardization of a new flash-point tester; the joint committee of the Bureau of Standards and the Bureau of Mines on Standardization of Motor Fuels; and with similar bodies.

Information Furnished, Reports, etc.

Several hundred special letters and reports relating to the work of the heat and thermometry division were prepared during the year in compliance with requests for information addressed to the Bureau by engineers and technical men, scientific investigators, national, State, and municipal bureaus and laboratories, etc. The subjects are treated in detail below.

Instruments, Apparatus, Materials and Methods of Test.—Mercury thermometers, resistance thermometers, thermocouples, optical and radiation pyrometers, including such questions as specifications, choice of instrument, installation and protection, methods of use, precautions in use, etc., thermometer bridges and thermocouple potentiometers, thermostats, thermometer comparators, annealing ovens, electric and gas furnaces, gas and fuel calorimeters, high-vacuum pump, refractories, methods of testing insulating materials, refractory materials, fire-resisting properties, heat-resisting properties of glass, etc.

Scientific Data.—Thermal conductivities of metals and insulators, freezing points, melting points, specific and latent heats, heats of reaction, heat losses by convection, and transmission of heat through air spaces.

Properties of Materials.—Resistance of materials to heat, expansivity and melting points of fire brick, properties of mica, heating values of fuels, insulating value of various materials, and properties of porcelain.

Gasoline and Oils.—Addition agents for gasoline, danger of explosion in filtering gasoline, gasoline substitutes, motor fuels, aero engine tests, specifications for oils and gasoline, etc.

Miscellaneous.—House heating, control of temperature and humidity, refrigerators, radiators, impurities in commercial ammonia, liquid air, freezing of fire extinguishers, fireproof safe cabinets, manufacture of various materials, etc.

Heat and Thermometric Apparatus Tests.

During the year, 2,303 mercurial thermometers of various kinds were submitted for test, of which 2,189 were certified. Among those submitted were 215 ordinary calorimetric thermometers, 68 precision calorimetric and Beckman thermometers, 16 clinical standards, and the remainder laboratory and special thermometers of various types and ranges from below 0° to 500° C. About 2 per cent were received broken and about 0.8 per cent were broken in the process of testing.

Twelve thousand four hundred and six clinical thermometers were submitted for test; of these, 11,670, or 94.1 per cent, were certified. The percentage rejected amounted to 5.9 of the total number submitted; 1.2 per cent were rejected on account of defects of construction, 0.15 per cent because of too great difficulty in throwing back index, and 0.6 per cent on account of retreating of index; 0.7 per cent were received broken; 0.15 per cent were broken in testing; and 3.1 per cent exceeded the limits of allowable errors.

In addition to the above there were tested in the thermometer laboratories 14 platinum resistance thermometers, 6 thermocouples, the melting point of 11 samples of naphthalene as a basis for custom duties, and the freezing point of 4 fire extinguisher liquids.

Among the calorimetric tests were 2 gas and 1 adiabatic calorimeters. Two hundred and thirty-nine standard heat samples were furnished during the year.

In the high-temperature laboratories there were tested 2 radiation pyrometers, 6 optical pyrometers, 13 pyrometric lamps, 10 base-metal thermocouples, 55 rare-metal thermocouples, 10 pyrometer galvanometers, 5 homogeneity tests of thermocouples, 2 resistance thermometers for high temperatures, 20 melting points of refractories, and 7 special high-temperature tests. In addition there were tested 621 base-metal thermocouples for the fire tests on protected steel building columns now being carried out in Chicago.

The total amount of testing done has increased very considerably over that of any preceding year. This work was done by a somewhat smaller staff and was made possible in part by improved methods and in part at the sacrifice of progress on important technical investigations.

3. ELECTRICITY.

[Electromotive force, resistance, current, inductance, capacity, conductivity, insulation, magnetic permeability and hysteresis, and radioactivity, including researches on electrical units and standards, measuring instruments, and methods of measurement, and the cooperation with standardizing committees of technical societies, with testing laboratories, the electrical industries, public-service companies, and public utility commissions, municipalities, and engineers upon problems of electrical standardization, including standards of adequacy and safety of electric service.]

Scope of the Electrical Work.

One of the most important functions of the Bureau with respect to electricity and allied subjects is the establishment and maintenance of the fundamental standards upon which all measurements

in these fields are based, including cooperation with similar institutions in other countries so as to secure international uniformity. This includes the intercomparison of standards and extensive research in methods of measurement and the development and improvement of subsidiary and derived standards. These standards are utilized and the results of the researches are immediately applied in the testing of reference standards and instruments for manufacturers, testing laboratories, universities, research institutions, electric utilities, utility commissions, engineering and other interests, and various agencies of the Government.

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

The research work has mainly to do with methods of measurement, the determination of the electric and magnetic properties of materials, and the development of those phases of engineering science in which measurement plays an important rôle. Electrical, radio, and illuminating engineering interests are all served by these investigations. The Bureau also renders important service, both directly and indirectly, to manufacturing and other industries. Some of this investigational work is on the more fundamental aspects of the principles involved, so that the results may be applicable to a class of problems, rather than being limited to the one specific problem under investigation. The work in measurement of lights of different colors, the correlations of magnetic and mechanical properties of iron and steel, and study of galvanometers are examples.

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

Relation of the Electrical Work to the Military Services.

Toward the end of the fiscal year there was a very great increase in the number of electrical investigations of a military character. Most of these investigations are made at the request of the War and Navy Departments, and are in general of a confidential character. The special fund granted to the Bureau by Congress toward the end of the fiscal year for military investigations has made it possible

to add a considerable number of scientific experts and assistants and greatly to increase the work carried on. A large portion of this work is of direct and immediate military value, and much of it will be of permanent scientific value apart from its military usefulness.

Silver Voltameter.

The final voltameter paper mentioned in the annual report of last year has now been published as Scientific Paper No. 285. This paper summarizes the Bureau's investigations on the silver voltameter, which is the primary standard for the measurement of electric current; it also contains the specifications for the voltameter, which the Bureau has proposed for international adoption, and a bibliography of the subject. It has not been possible during the past year to make further progress toward the adoption of specifications by international agreement.

Standard Cell Work.

Some further work has been done on the Weston normal cell, especially in regard to the methods of efficiently washing mercurous sulphate, which material is the chief source of variation in the cell.

In connection with an investigation relating to the cause of the cracking of Clark cells and the best method of preventing the same, a number of cells of this type were set up, blanks being employed in which the platinum terminals of the zinc limbs were subjected to the action of zinc amalgam before being sealed into the cell wall. Although nearly a year old, none of the cells are cracked. A number of portable unsaturated Weston cells have been made, primarily with a view to insure to the Government an adequate supply for emergency use.

Investigation of Inductance Coils.

The research on the inductance and resistance of standard coils at different frequencies has been continued. A careful study has been made of the factors which cause the inductance of a coil to decrease and the resistance to increase with increasing frequency of current. The most important of these are (1) electrostatic capacity between the windings, (2) energy loss in the insulating material caused by dielectric hysteresis, (3) skin effect in the conductors, and (4) eddy currents in neighboring masses of metal. The effect of all of these can be reduced by proper design.

A large number of coils have been constructed and measurements made to determine the change of resistance and inductance with frequency. Methods have been devised for determining the effect of each of the factors enumerated above on these coils. The experimental determination of the skin effect has been found most difficult. In order to check the experimental values on skin effect theoretical formulas are needed. At present the only satisfactory formulas are those which apply to a straight wire. By means of a new method other formulas are being developed.

Study of the Electromagnet Moving-Coil Galvanometer.

The study of the electromagnet moving-coil galvanometer for use in alternating current measurements has been completed and the results published. (See Scientific Paper No. 297.) These instru-

ments are similar to the moving-coil galvanometer except that use is made of the magnetic field of an electromagnet instead of the field of a permanent magnet. The electromagnet is excited from a separate source with alternating current of the same frequency as the current to be detected or measured. A steady deflection approximately proportional to the current is produced and the motion can be made deadbeat by use of the proper external resistance. Instruments with sensitivities comparable with those for the best moving-coil galvanometers for direct current have been constructed.

A. C.-D. C. Comparator.

Precise alternating-current measurements are usually made with an electrodynamometer which is calibrated by reference to direct current standards. An instrument has been devised by means of which reference is made directly to direct current. This consists of an electrodynamometer whose two fixed and two moving coils are connected to form a balanced Wheatstone bridge. Both the alternating and the direct current pass through the same coils at the same time in such a manner that there is no resulting torque when the effective values of the currents are equal. A comparator of this kind has been subjected to a variety of tests, and the performance is such as to indicate an accuracy better than 0.01 per cent. This comparator can be used to measure currents up to 0.2 ampere directly, and, by the use of standard alternating-current resistances and standard current and potential transformers, voltages and larger currents can be measured.

Bridge for Testing Precision Resistance Standards.

A resistance measuring bridge, designated especially to meet the Bureau's needs in the accurate comparison and testing of precision resistance standards, has been constructed in the instrument shop and laboratory. It has been thoroughly tested and found to be highly satisfactory. In its design special attention was directed to shielding and thermostatic control of the temperature of the containing oil bath in order to obtain the highest precision attainable. Its large range and convenience of operation permit the comparison of resistance standards to be made with a minimum expenditure of time and energy. A publication is in progress describing the bridge and the methods used in comparing standards.

Electrically Operated Tuning Fork for Time Measurements.

This device, which has been in use in meter testing for about five years, reads directly to 0.05 second. An electrically operated tuning fork having a period of 0.05 second closes a contact which controls an electromagnetic counting device. By using a key in this circuit the arrangement acts as a stop watch. Special care has to be used to drive the fork at a uniform rate. This has now been accomplished by operating it directly from a chronometer circuit. With slight modification it has been found feasible to use commercial "cycle counters" in place of the special counters previously used. It has also been found that the method can be used with a fork having a frequency of 100, thus reading to 0.01 second. Several meter-testing laboratories have installed duplicates of the Bureau apparatus.

Instrument Transformers.

The accurate testing of instrument transformers is of increasing importance on account of their use in measuring electric energy, especially where it is sold in large quantities or at high voltages. Some of the State public utility commissions now require the periodic testing of all instrument transformers used in the sale of electric energy. For precision laboratory work, the potentiometer method with a vibration galvanometer as detector, has been used for several years. For voltage transformer testing, precision card-wound resistances have now been installed, aggregating 500,000 ohms, which enables direct measurements to be made up to 30,000 volts. A similar and equal resistance used as a protecting guard wire eliminates leakage and errors from capacity currents to earth.

A very considerable amount of assistance has been given to some of the State commissions and to the larger central stations and manufacturers of apparatus in equipping their laboratories for the testing of instrument transformers. In some cases simplified apparatus for using the precision potentiometer method is being installed, and in other cases methods devised at the Bureau for readier adaptation to commercial use have been used.

New Method of Testing Current Transformers.

A new method of testing current transformers, particularly adapted to central-station conditions, has been developed, and the results are now ready for publication. The same current is passed through the primaries of the transformer under test and of a standard transformer whose ratio and phase angle are known. The secondaries are connected in series, aiding, and the vector difference between the secondary currents flows in an auxiliary circuit and is measured directly. Either a null or a deflection method may be used, and the sensitivity is sufficient to permit the use of portable instruments.

Remote Control System for Motor Generators.

The somewhat elaborate system of remote control of the special motor-generator sets has proved to be very satisfactory, and a description of it has been published during the year. (See Scientific Paper No. 291.) The system includes five motor-generator sets, and is permanently wired to nine laboratory rooms, so that by plugging in a special jack one may have complete control of the speed and voltages of the set. The phase relation between voltages is included, and in some cases rheostats for the control of auxiliary direct current and voltage also.

Electrolytic Cleaning of Silver.

At the request of the Department of Agriculture, the Bureau undertook an investigation of the electrolytic reduction of silver sulphide with particular reference to household methods of cleaning silverware by this process. This investigation has been interrupted by more urgent work of a military character, but will be resumed as soon as possible. As an outgrowth of this work, a process was discovered for preparing silver sulphide in a metallic form.

Electrical Properties of Silver Sulphide.

Silver sulphide may be prepared in the form of short wires and thin strips like a metal. The wire, which must be drawn hot, has been found to conduct electricity like a metal of high resistivity and practically zero temperature coefficient. The strip of sulphide rolled at room temperature has a large temperature coefficient and shows both metallic and electrolytic conduction at the same time. It has a volt-ampere curve characteristic of a pyro-electric conductor. The resistance of these strips has been examined with both alternating and direct current with the result that the alternating-current resistance was nearly always found to be higher than that with the direct current, and the passage of a small alternating current of a frequency as low as 60 cycles increased temporarily the resistance of the sulphide while a small direct current produced the opposite effect. The results of this investigation are now in progress.

Methods of Testing Transformer Oils.

In cooperation with a committee of the American Society for Testing Materials, a comparative study is being made of disk and sphere spark gaps for testing the dielectric strength of transformer oils. A carefully prepared schedule of tests on different gaps and different spacings is being carried out in four different laboratories. It is expected that data will be obtained which will permit results obtained on one form of gap to be interpreted in terms of other forms of gaps, or possibly a uniform method of testing may be agreed upon.

Radio Service to the Government.

Cooperative work with other departments and bureaus of the Government has continued during the past year as heretofore. The lighthouse tender *Orchid* and the Coast Survey steamers *Isis* and *Surveyor* were equipped during the year with complete radio outfits designed and constructed by the Bureau for the special service required. At the request of the Bureau of Navigation, an investigation of radio interference in the vicinity of Boston was made.

The Bureau was represented on the interdepartmental committee to consider new radio legislation and took an active part in the discussion and drafting of the bill which was presented to the committee for consideration.

Additional men and funds will enable the laboratory to expedite the work on military problems and to make the laboratory more efficient in its cooperation with the military departments of the Government. Radio signaling is playing an extremely important part in the war, and the radio laboratory staff is taking an active part in the development and improvement of radio apparatus for military purposes and is endeavoring to make the work of the laboratory as useful as possible.

Fog Signaling.

Practical tests of the radio fog-signaling apparatus and radio-direction finder developed by the Bureau were made at the Navesink Light Station. These tests were very successful and proved conclusively that the use of radio signaling for this purpose is a valu-

able and effective means of promoting safety at sea. A board or committee representing the Navy and Commerce Departments has been created for the purpose of considering and recommending matters relating to the immediate equipment of several light stations with fog-signaling devices. The Bureau will shortly equip the Navesink Light Station with a permanent installation.

Radio Direction Finder.

Considerable testing and designing has been done during the past year in connection with the direction-finding apparatus with the view of improving its usefulness and adapting it to various practical purposes, particularly those of military importance. A large number of equipments have been manufactured and put into actual use.

Radio Instruments and Measurements.

In connection with the testing of radio instruments and equipment, studies have been made of the methods of measurement at radio frequencies. These studies continue in progress, and include measurements of wave length, inductance, capacity, resistance, and current over wide ranges at radio frequencies. In order to describe the radio work of the Bureau and to present general information on radio measurements, a circular on the subject is in preparation. In this publication and its subsequent revisions it is planned to give accurate and useful information on radio instruments for the benefit of Government officers, engineers, manufacturers, and operators. Its scope and grade of presentation are intermediate between elementary books for amateurs and the more elaborate treatises on radio theory and practice. It includes descriptions of instruments and methods of measurement, collections of useful formulas and data, a development of the essential theory of high-frequency measurements from simple but precise low-frequency theory, the use of reactance curves in the rapid solution of problems, and a statement of the radio work of the Bureau.

Radio Testing.

An unusually large amount of radio testing and calibration work has been done during the past year for the Government departments, for commercial concerns, and for amateurs. The facilities of the radio laboratory have been improved as rapidly as possible to meet the increasing demand for radio-frequency measurements, and arrangements are being made to improve still further the methods of testing in order that such work may be done with greater efficiency and rapidity. Standardization and accurate testing become more and more necessary and important as the art of radio communication progresses, and as new devices appear new methods of testing must be developed.

Magnetic Uniformity of Straight Bars.

The effect of nonuniformity in a specimen on the accuracy of magnetic measurements has been studied and a method has been developed for the determination of the degree of magnetic uniformity of straight bars. (See Scientific Paper No. 295.) A large number of bars have been examined for magnetic uniformity, and

it has been found that only a very few are satisfactory for use as standards. The bars which have been found to be satisfactory have been carefully standardized and are used for calibration and comparison work.

Development of a New Permeameter.

A new permeameter has been developed which makes possible the rapid determination of normal induction and hysteresis on a single specimen. (See Scientific Paper No. 306.) This permeameter utilizes the principle of the magnetic potentiometer. The magnetizing force is read in terms of the magnetic potential between the ends of the bar by means of the deflection of a ballistic galvanometer connected to an air coil upon reversal of the magnetizing current. The induction is determined in the usual way by means of a test coil surrounding the specimen. The apparatus is accurate within 5 per cent of the magnetizing force necessary to produce a given induction. This accuracy is sufficient for most work on commercial materials.

Calibration of Bismuth Spirals.

A method has been developed for the calibration of bismuth spirals. This consists of an electromagnet with means of inserting either a standard test coil or a bismuth spiral in the magnetic field between its poles. The strength of field is determined by a ballistic galvanometer deflection when the standard coil is withdrawn from the field.

Study of the Magnetic Susceptibility of Feebly Magnetic Substances.

A method is being developed for the determination of the magnetic susceptibility of feebly magnetic substances. The susceptibility will be determined by measuring, by means of a sensitive balance, the pull exerted on a sample of standard form due to current in a solenoid surrounding it.

Magnetic Analysis.

Magnetic analysis consists of the determination of one or more of the magnetic properties of steel which may be taken as criteria of its mechanical properties. The methods of magnetic analysis may be applied to the raw material or to the manufactured product at any stage of its manufacture, provided the test specimen is of suitable form. Even objects whose forms do not permit of accurate magnetic measurements may permit of comparative determinations which, by comparison with a standard, will serve as a basis for judging their quality. The magnetic properties that may be used are normal induction, one or more points on the hysteresis loop, such as residual induction or coercive force, energy loss due to rotary hysteresis, and magnetic leakage under standard conditions. In a general investigation on a particular class of steel, as many of these quantities as possible are determined for a series of different heat or mechanical treatments, together with the corresponding mechanical properties, such as hardness, proportional limit, ductility, ultimate strength, etc.

Magnetic analysis is still in the investigational stage, but considerable progress has already been made. The one-to-one correspond-

ence between the magnetic and mechanical properties has been established and a number of special cases have been investigated. In particular cases a single magnetic value may be sufficient as an index of the mechanical properties. If more information is desired, it may be necessary to make more complete determinations. For example, it has been found that the coercive force is a good index of hardness. For steel of a given chemical composition, the harder piece gives a higher coercive force. In addition, it may be possible to judge of the internal stress from the shape of the normal induction curve. In the course of the general investigation on magnetic analysis, a number of special cases have been studied, including the following:

One Per Cent Carbon Steel.—The investigation on 1 per cent carbon steel has been finished. The complete results will be presented in a paper now in course of preparation. A series of sample bars were given different heat treatments and complete normal induction and hysteresis measurements made in the Fahy permeameter and afterwards the mechanical properties were determined. Any difference in mechanical properties was invariably accompanied by a corresponding difference in magnetic properties.

Steel Rails.—The investigation on steel rails has been made by means of a permeameter specially designed for the purpose and exploration apparatus consisting of a motor-driven magnetizing solenoid which moves along the rail at a constant rate and carries test coils for determining leakage. A photographic record is made of deflections of the galvanometer connected to test coils. Any deviation from a straight line in this record indicates a nonhomogeneity in the rail. By means of this exploration apparatus records have been obtained clearly showing the strain effects due to gagging, or cold straightening, commonly applied to rails. By means of the permeameter it was possible to distinguish between rails cooled in summer and rails cooled in winter, and therefore likely to be in a state of mechanical strain.

Ball-Bearing Races.—An investigation has been started for the development of a shop method for testing the hardness of finished ball-bearing races. Measurements of coercive force have been made by means of an electromagnet with special pole pieces and suitable test coils connected to a ballistic galvanometer. It has been found that the coercive force is a good index of the hardness of the ring. Experiments are also being made on the measurement of rotary hysteresis. This is found by measuring the torque on a ring when placed in a rotating magnetic field. The torque is proportional to the energy loss of rotary hysteresis and increases with the hardness of the ring.

Small Tools.—An apparatus has been built especially adapted to the making of magnetic measurements on small tools, such as drills, taps, reamers, gravers, etc. Several sets of measurements of coercive force have been made on drills, reamers, milling tools, and the like, and it has been found that the coercive force gives a good indication of mechanical performance and uniformity of product.

Steel Cables.—An extended investigation is planned on steel hoisting cables. It is proposed to study the effects of various factors which may reduce the "factor of safety" of a cable and develop, if possible, a method for determining this reduction of the factor of

safety. It is also hoped to be able to develop a method of judging the quality of a new cable.

Repeated Stress.—A study is being made of the effect of repeated stress on the magnetic properties of steel. The stress is applied by means of an electromagnet device similar to an electrically driven tuning fork. The bars are removed from the apparatus at intervals and determinations made of normal induction, residual induction, and coercive force. It is hoped in this way to be able to follow the course of progressive failure and that this may prove to be a useful method for checking design.

Magnetic Compass Investigation.

At the request of the compass division of the Naval Observatory, the joint Army and Navy Board on Specifications and the Shipping Board, an investigation has been begun on magnetic compasses. The investigation is for the purpose of developing a standard method of testing compasses and the preparation of specifications for the purchase of compasses by the Government. A special form of magnetometer has been devised for the determination of magnetic moment and a rotation test for pivot friction is being investigated. It is expected that several thousand compasses will be tested in the course of the next year.

Increase in the Bureau's Stock of Radium.

A 49-milligram tube of radium which was loaned by the Bureau of Mines has been of great assistance in the routine testing during the year as well as in the study of the methods of testing. This tube and a second tube containing about 91 milligrams of radium have been permanently transferred by the Bureau of Mines to the Bureau of Standards, and constitute a very valuable addition to the Bureau's equipment for radio-activity measurements. The radium contained in these two tubes has a market value of about $14,000.

Radium Emanation.

The study of apparatus for impregnating water with radium emanation has been continued, and the radium emanation contents of a few therapeutic solutions have been determined. Radium solutions to serve as standards in the measurement of radium emanation have been supplied to scientific investigators desiring them.

Radium Luminous Preparations.

Owing to the fact that the luminescence of radium luminous preparations persists for months or years and is not dependent upon a previous exposure to light, such preparations are of great value in the illumination of signs and dials that have to be read in the dark. They are largely used on instruments employed in aviation and for other military uses.

The Bureau began the investigation of these preparations during the year, and now has under study 50 specimens obtained from various sources. A photometer for the measurement of the brightness of these preparations has been constructed and described, and apparatus for the measurement of the material after it has been applied and for the routine testing of prepared dials is being designed.

The manufacturers and users of these materials are cooperating with the Bureau in this work. Conferences concerning the military use of these materials have been had with members of the Aviation Corps and of the French Scientific Commission. Preliminary reports of the work have been furnished on request to the National Advisory Council for Aeronautics and to the Signal Corps.

Radium Testing.

The amount of radium measured during the year was about 50 per cent greater than that measured last year. It amounted to a little over 6.6 grams, which, at $100 per milligram, is worth about $660,000. This radium was contained in 288 preparations, submitted by 24 individuals or firms, and was distributed to over 79 individuals and institutions. Of these preparations, 1 was for Porto Rico, 2 for the Philippine Islands, 6 for Argentina, 18 for Spain, 10 for Russia, and 2 for Japan. A number of the preparations were shipped to distributing companies; in such cases the Bureau has no information regarding the ultimate destination of the material.

X-Ray Testing.

The Bureau is installing an equipment for X-ray testing, and it is expected that this testing will be under way by August, 1917. The Bureau has been requested from time to time, for the past several years, to undertake such work, but until now it has been unable to do so on account of a lack of funds. The work will include not only the testing of apparatus and materials employed in the surgical and therapeutic applications of X-rays, but also the use of X-rays in various other problems of military value.

Improved Methods of Measurement in Photometry.

In continuation of the work in this line reported last year, attention has been given to the further development of methods of measurement applicable to the new types of electric lamps which are coming into very extensive use.

Little new experimental work has been done in the past year on account of the difficulties arising from the fact that these lamps give light differing in color from that of the standards. However, the methods of meeting these difficulties and of correction for the peculiarities of vision of the individual observer have been tried out in a considerable variety of practical problems. This experience has confirmed the conclusion that the flicker photometer, used under proper conditions, provides a fairly satisfactory means of measuring lights of every color. Consequently, the Bureau has submitted to the Illuminating Engineering Society a proposal to adopt the flicker method as the standard one for measuring the brightness of all lights which differ in color from the fundamental standards. A considerable part of the work on which this proposal is based has been published in Scientific Paper No. 299.

In rating and testing ordinary incandescent lamps, it has been customary to measure only the mean horizontal candlepower, which is obtained by rotating the lamps while they are being measured. This procedure can not be used with the new gas-filled lamps, because the rotation changes the convection currents in the gas and

consequently affects the candlepower. Moreover, these lamps have filaments of irregular form, and the horizontal candlepower does not bear any definite relation to the total amount of light produced. Consequently, the only instrument suitable for measuring these lamps is the integrating sphere, which shows by one measurement the total amount of light sent out by a lamp in all directions. The 90-inch reinforced concrete sphere built at the Bureau has proved very satisfactory. During the year attention has been given to the conditions of operation which may affect such measurements, and a paper incorporating the results, together with a description of this sphere, has been nearly completed.

Spheres have come into regular use in many lamp factories, and one of the great practical difficulties has been to obtain a strictly colorless material for coating the inner surface. Much time has been spent in testing commercial paints and experimental mixtures for this purpose; this work is not yet completed, but the use of barium sulphate with a cellulose binder made up in proper proportions promises to be a solution for the difficulty.

In connection with the above investigation, many measurements of the reflection factor of materials have been made, and for such measurements new methods have been devised which it is hoped can be developed further during the coming year.

By using the flicker method to overcome the difficulties of color, and the sphere for comparison of spherical candlepowers of vacuum and gas-filled standards, sets of secondary standards of the gas-filled type have been established and the candlepowers repeatedly checked by independent comparison with the Bureau's standards of horizontal candlepower. The performance of these gas-filled standards has so far been very good, and similar standards have been furnished to a number of other laboratories and to lamp factories.

Life Testing of Gas-Filled Lamps.

The life testing of gas-filled lamps was begun during the year. These lamps have peculiarities which necessitate special methods in the life test as well as in the measurement of candlepower. Vacuum lamps are usually tested at voltages considerably higher than normal, thus shortening their actual life in order to get results more quickly and to reduce the cost of the testing. The proportion in which the life is reduced by a given increase of efficiency has been carefully determined, so that the normal life can be quite accurately computed from such "forced tests." In the case of the gas-filled lamps, however, this method can not be used because at the higher temperature the filaments are likely to sag and open up the spirals in which they are formed. This lowers the temperature and, consequently, the lamp operates at lower efficiency and has a life very different from what it would have if the filament retained its normal shape. It is therefore necessary to life test these lamps at their normal operating efficiency, although this makes the test extend over a long time.

Investigation on Flames and Gas-Mantle Lamps.

A large amount of work has been done on gas lamps. The photometric methods developed for the electric lamps are applicable also to gas lamps; the difficulties to be met are not in the mere measure-

ment of the light produced, but rather in the adjustment and performance of the lamps themselves. Economic conditions are forcing a change in the quality of gas supplied in most American cities, and the proper readjustment of standards of quality is an urgent problem which can not be solved without knowledge of the efficiency with which different gases can be used. As a part of a general investigation of this subject by the public utility staff of the Bureau, an extensive study has been made of the effects of variation of heating value and composition of gas on the candlepower and efficiency of mantle lamps at various pressures and rates of consumption. The results of this investigation are now in course of preparation for publication.

In order to compare measurements made on mantle lamps at different times and places, it is necessary to know the effects of atmospheric conditions on the candlepower; these effects have been determined, and the results together with similar determinations on some flame lamps have been incorporated in a scientific paper which is nearly ready for publication. A comparison of the results obtained by the Bureau on the pentane lamp with those obtained in England has shown that the outstanding differences with regard to correction factors are undoubtedly due to the existence of a temperature coefficient, which is, however, small as suggested in previous papers of the Bureau.

Tests of Miscellaneous Illuminants.

As an outcome of the tests made last year on self-lighting emergency lights for life buoys, the Steamboat-Inspection Service adopted new specifications for such lights, and this Bureau has been called upon to test a number of them to determine whether they fulfilled those specifications.

A number of experimental searchlights intended for use on airplanes were tested for the Navy Department, and suggestions were made regarding the construction and operation of special lamps for such lights.

A comparative test of 12 types of hand lanterns for the United States Coast Guard was made as a basis for specifications, which were drawn up to cover the purchase of lanterns by the service.

Measurements were made on a large number of street-series lamps from various municipal lighting plants, to obtain information on the performance in actual service of the newer types of lamps.

Measurements have also been made on all the common sizes of street-series lamps to determine the variation of candlepower with current; in these measurements lamps from several different factories have been included.

Inspection and Life-Test of Lamps for the Government.

During the year there were inspected for the various Government departments nearly two million lamps; of these about five hundred thousand were carbon. Rejections on account of various defects were unusually large, amounting to about 10 per cent of the tungsten and to about 25 per cent of the carbon. Sample lamps amounting to 2,451 (2,076 tungsten and 375 carbon) were life tested. In comparison with recent years the results of the tests for the year show, in respect

to both carbon and tungsten lamps, a depreciation in quality, not only in life, but also in the mechanical features of the lamps. This depreciation is attributed by the manufacturers to the unusual condition of increased production, shortage of competent labor, difficulty in obtaining satisfactory raw materials, etc.

Realizing that these conditions were beyond the control of the manufacturers, the Government lowered the efficiency requirements of the specification in order that the manufacturers might be able to meet them.

Electrical Testing.

Instruments.—Tests of electrical instruments for the public during the year included the following: Four voltmeters, 2 ammeters, 14 wattmeters, 11 watthour meters, 11 voltage transformers, 22 current transformers, 1 inductance coil, 8 condensers, 8 wave meters, 17 decremeters, 1 buzzer, 7 air condensers, 49 mica condensers, 78 resistance standards, 1 resistance box, 9 resistance bridges, 3 potentiometers, 59 standard cells, 50 incandescent lamps life tested, 44 incandescent standards furnished, 41 incandescent standards tested, one portable photometer, 6 pentane lamps, 15 street-series lamps, 3 gas-mantle lamps, 4 lamps for certain colors of light, 77 spherical-candlepower standards, 1 diffusing globe, and 2 lighting fixtures.

Tests of electrical instruments made for the Government during the year included the following: Eleven voltmeters, 17 ammeters, 2 wattmeters, 6 watthour meters, 2 voltage transformers, 13 current transformers, 93 dry cells, 50 electrical fans, 99 inductance coils, 9 condensers, 14 decremeters, 1 resistance bridge, 2 potentiometers, 68 standard cells, 2 air condensers, 5 mica condensers, 65 airplane compasses, 489,821 carbon lamps inspected, 1,292,223 tungsten lamps inspected, 2,451 incandescent lamps life tested, 14 incandescent standards furnished, 30 incandescent standards tested, 48 reflectors, 3 searchlight reflectors, 9 life-buoy lights, 2 portable photometers, 6 electrical standard lamps, and 2 acetylene standard lamps.

Materials.—Materials tested for the public during the year, involving electrical measurements, included the following: Seventy conductivity samples, 14 inductance tests, 21 iron samples for normal induction, 4 hysteresis samples, 26 core-loss samples, 3 miscellaneous magnetism tests, 198 tubes of radium, 3 emanation specimens, 1 standard radium solution, 6 activators, 2 radio-active waters, 50 luminous materials, 3 X-ray tests of powders.

Materials tested for the Government during the past year, involving electrical measurements, included the following: Fifty transformer oils, 275 rubber gloves, 31 samples of insulating tape, 11 battery renewals, 11 fuses, 23 miscellaneous insulation tests, 460 conductivity samples, 10 inductance tests, 2 hysteresis samples, 1 core-loss sample, 10 permanent magnets, 25 tubes of radium, 17 samples of kerosene oil, and one sample of signal oil.

Information Furnished on Electrical Subjects.

A large part of the work connected with the various investigations and tests consists of correspondence, in which scientific and technical information is furnished by the Bureau. Information is also frequently furnished as a result of particular requests. Assistance and

advice have thus been rendered on electrical subjects to a number of Government departments, to various scientific institutions, manufacturers, public utilities, universities, and engineers.

The Bureau cooperated with various electrical engineering, technical and scientific societies, and is represented on many of their technical committees, particularly where electrical standardization is involved, such, for example, as the American Institute of Electrical Engineers, the American Society for Testing Materials, and similar bodies.

Assistance has been rendered the Post Office Department and the Department of Justice in several legal cases, involving questions of physics and engineering, and in which fraud was charged. Sometimes the cases lead to ordinary court processes, and sometimes to postal fraud-order procedures. In some cases a considerable amount of work was involved in investigating the various technical factors involved.

Tables and other data were furnished for a new reprint of the Smithsonian physical tables. An elaborate handbook on electrical wire was reviewed and corrected for a large commercial company. Information was furnished on the available sets of tables for mathematical calculations. As a result of a request from the War Department, the Signal Corps copper-wire specifications were carefully studied and information supplied with a view to harmonizing them with commercial conditions.

There has been a marked increase during the past year in the number of requests for specifications and detailed information on the setting up of standard cells. Many users of cells have been faced with the necessity of making their own cells because of the increased demand and a shortage in the supply.

New Fee Circular.

The seventh edition of Circular No. 6, Fees for Electric, Magnetic, and Photometric Testing, has been prepared and issued. The principal new features of the edition are a rearrangement of the instrument schedules; the addition of considerable explanatory matter regarding the testing of instruments, meters, transformers, and resistance apparatus; and the provision of a separate section for radio apparatus.

Publications on Electric Units and Standards.

Two publications have been issued on the general subject of the fundamental electric and magnetic units and standards. The available information on this subject has hitherto been scattered over an extensive literature. Circular No. 60, Electric Units and Standards, gives a comprehensive and up-to-date treatment of the various units and the standards by means of which the units are maintained. This compendium will be of use to teachers and students, to testing laboratories, and to electrical engineers. It takes the place of certain previous publications of the Bureau dealing with special aspects of the subject. It includes a history of the units and the evolution of the definitions upon which the laws on electrical standards are based. The present status of the fundamental electrical standards is described, and the laws on electrical units in the various countries of the

world are given. The laws of the different countries are in substantial agreement, and the various national bureaus of standards cooperate in maintaining the fundamental standards. The circular gives conversion factors, by means of which measurements may be expressed in any desired unit, and also gives a selected bibliography of previous writings on electrical and magnetic units and standards. In connection with the preparation of this circular, a critical study was made of the various systems of units which have been proposed from time to time as having noteworthy advantages over the commonly used system. The results of this study were published in Scientific Paper No. 292, International System of Electric Units and Standards. Diverse units are used to some extent at the present time, and are a source of confusion to the student and to the engineer. As a result of comparing all of these systems, it appears doubtful whether any of the proposed systems of electrical units is materially superior even in its theoretical aspects to the international system of units in general use, and it is concluded that there would be no compensating advantages to justify the trouble and confusion which would attend a change of units.

Public Utility Investigations.

A large and important field of work, including more of engineering and field work than most of the electrical work so far described, is concerned with the various public utilities, particularly the electric light and power, gas, street railway, and telephone companies. The work includes (1) scientific and engineering research, (2) the study of public-relations questions, (3) the preparations of specifications regarding the quality of public-utility service, (4) methods of testing and inspection employed by municipalities and commissions, (5) safety rules for use by the utility companies to safeguard their employees and the public, and (6) the collection and distribution of information by published papers and through correspondence.

This work is a natural outgrowth of the research and testing work done by the Bureau of Standards for the public-utility companies for several years. The testing of electrical instruments and meters, of gas lamps and the standard employed in measuring the candlepower and heating value of gas, the life testing of electric lamps, the testing of instruments used in telephone work, research on electrolysis mitigation, and similar investigations and tests connected with the public utilities have all involved to a greater or less degree questions of standards of service in the various public utilities and hence the Bureau gradually accumulated a considerable amount of information on these questions. Such information on several phases of the work has been collected and published from time to time, and other publications are in preparation. The work in recent years has been considerably enlarged through special appropriations for this purpose.

Gas Service Rules.

During the past year the usual amount of work in correspondence and conferences has been given to questions of standards for gas service and of rules in force or proposed for adoption by cities or States. The proposed revision of the rules of the State of Washington and the new rules proposed for the State of Colorado were

both examined and commented on by the Bureau during the year. A report was also rendered after investigation of gas service conditions in Rome, Ga., covering the questions of the needed improvements in the plant and distribution system in order that satisfactory gas service be rendered in that city. This report was rendered at the request of the Georgia Railroad Commission, which has jurisdiction in the matter.

Bureau of Standards Circular No. 32, Standards for Gas Service, has been reprinted in the third edition because of the lack of time for preparation of a fourth edition. The fourth edition is urgently needed in order to bring up to date the compilation of rules and ordinances now in force and also to take account of developments in this field brought about by improvements in gas-making methods, changed economic conditions, and numerous other engineering and economic influences. Particularly it is desired that this circular be supplemented by a publication covering special standards for fuel-gas service. This proposal, which is made to the Bureau by certain representative gas companies, contemplates the adoption of standards based upon novel principles. Particularly it is proposed to charge for gas on the basis of a certain number of cents per million heat units and to eliminate any specific requirements as to the heating value per cubic foot. Extended laboratory investigations as to the relative usefulness of the different gases which might be supplied under such a standard are necessitated by this request for the cooperation of the Bureau; it is also desired by those proposing this new type of standard that the Bureau lend the force of its support to the new system of charging for gas. This could only be done, however, after a careful and rather extended investigation. This investigation is under consideration, but as yet no arrangements have been made to undertake the work.

Standards for Gas Service as Affected by War-Time Conditions.

The abnormal condition of the labor and coal supply, unusual high prices for raw materials, and the demand for toluol, which can be successfully recovered as a by-product from the city gas supplies, has given unusual importance to questions of standards for gas quality at the present time. At the request of several States and cities, the Bureau has given special attention to these matters, and at the request of the Council of National Defense the Bureau has rendered one preliminary report to it upon the scope and importance of this subject. During the coming months a large amount of time must be devoted to these questions in order to meet the pressing need for information that will permit prompt adjustment of matters where changes are essential or to determine in the other cases whether any change in standard is either expedient or necessary.

Gas Laboratory Methods.

Continuing the service rendered in past years, the Bureau has furnished information from time to time as to gas-testing methods for cities, State, and company laboratories, by answering correspondence, by inspection of laboratories, and by conference with city and State representatives. As one example of this work, a representative of the Bureau spent a week or 10 days in the laboratory of the city of

Cleveland and made an extended report on the improvements in laboratory apparatus and methods which would be desirable in order to make entirely adequate for local conditions the gas-testing facilities of these laboratories.

Relation Between Heating Value of Gas and Its Usefulness.

An extended series of experiments has been made during the past year to determine the relation between the usefulness of gas for mantle lighting, cooking, water heating, and other purposes, and the heating value of the gas. This work was conducted at the time primarily to answer the question addressed to the Bureau jointly by the city of Chicago and the Peoples Gas Light & Coke Co. of that city, namely, what is the relative usefulness of gas of 565 Btu per cubic foot and gas of 22 candlepower. The investigation included a determination of the influence of pressure, pressure variation, rate of gas burning, adjustment of appliances, heating value and composition of the gas, and variation of heating value upon the efficiency with which the gas could be utilized by the customer. As a result of this investigation a report was rendered to the city and gas company of Chicago, answering specifically the questions which they had asked. It is concluded that if the appliances are properly adjusted and the quality of the gas is uniform the heating value is a direct measure of the usefulness of the gas for ordinary purposes within the range investigated. The principal advantage or disadvantage of one quality of gas as compared with another is therefore the result only of the greater ease of adjustment or lesser likelihood of getting out of adjustment of appliances when using one kind of gas than another. The Bureau, for purposes of its report, estimated the importance of this factor for the particular gas in question.

The further work contemplated in connection with the investigation of the advantage of modified fuel-gas standards, as above described, will also develop further information along these lines. Especially it is desired to study the relative usefulness of different gases such as might be made commercially if the variable heat unit standard were adopted. These would be particularly gases of low heating value as compared with the present commercial supplies, and very little information is thus far available to determine whether or not they could be used with entire satisfaction for various applications of gas. The practicability of the proposed standards depends largely upon the result of this investigation and it is, therefore, of great importance that this work be pressed by the Bureau in the near future in order that the very great advantages claimed for the new standard may be made possible in case it proves practicable to adopt such modified requirements.

Inspections of Gas Mantle Lighting.

In connection with the investigations thus far conducted an extended series of inspections of gas mantle lamps in actual service have been made in order to determine as far as is possible the relation between laboratory experiments and practical conditions. In

this work about 10,000 mantle installations have been inspected in 10 large cities, and the results have been summarized in a report now in press entitled "Gas Mantle Lighting Conditions in Ten Large Cities in the United States." This report also develops information of great interest as bearing upon the advantages to the customer of regular maintenance service by gas companies. It is demonstrated that lamps not so maintained regularly are much more likely to be out of order than lamps regularly cared for by the company.

Proposed National Gas Safety Code.

During the past year the proposed "National gas safety code" has received considerable attention by the gas engineering staff, but not as much progress has been made as was anticipated because of the necessity for interrupting this work in order to carry out the investigation, already referred to, on the subject of the relative usefulness of different qualities of gas. The part relating to gas fitting has been submitted to representative architects and engineers, and their comments have been received. The parts dealing with the manufacture and distribution of gas and the design of gas appliances are nearly completed in manuscript form but have not yet been submitted to the advisory engineers. Information for the users of gas has been substantially covered in the gas section of the circular on Safety in the Household, and the completion of this part of the code will be a comparatively simple matter. It has not been possible as yet to undertake the remaining parts of the code.

Economic Importance of the National Gas Safety Code.

The Bureau of Standards in carrying out this investigation desires to serve as a national coordinating agency to the end that the resulting code will be acceptable and adequate, not only from the standpoint of the user of gas but also of the casualty and fire-insurance interests, the gas companies and their employees, and the gas appliance, manufacturing, and selling interests.

The need and value of such a code is so great that the various national organizations dealing with subjects covered by the code have appointed special committees and expert representatives to assist in the investigation. The following organizations are now cooperating in this work: The American Gas Institute, the National Commercial Gas Association, the Natural Gas Association of America, the National Fire Protection Association, the American Institute of Architects, the National Safety Council, and the National Association of Master Plumbers. In order that the Bureau may have the fullest information on every detail of the subjects discussed, the American Gas Institute has appointed 12 committees, 4 in each of the three principal sections of the country—East, Middle West, and Far West. One committee in each district is intrusted with the work bearing upon one of the principal phases of the investigation.

It has been estimated that avoidable accidents due to ignorance, carelessness, or faulty installation result in the loss each year of hundreds of lives and the destruction of property of large aggregate value. It may reasonably be expected that many of these losses will

be eliminated when the code has been completed and adopted throughout the country, both because of the official enforcement of the code and because of its educational value to gas fitters, appliance manufacturers, utility operators, and the general public.

The code will also serve to unify practice in gas installations and gas-company operation work throughout the country, and it is anticipated that much needed reforms will result. This uniformity of practice will not only tend to greater safety but will also contribute to higher efficiency. In many cases differences between the insurance and gas-company officials can be settled by reference to the code and thus more harmonious cooperation of the two parties can be expected. Already several important instances have been referred to the Bureau for consideration with a view to the settlement of differences in insurance-inspection practices or questions as to the magnitude of the fire hazard in certain types of gas installations. In this field the services of a recognized national authority are essential in order to standardize the practices and to make available to all the experiences obtained in the various localities. The effort of the Bureau has therefore been directed not only to the preparation of the code, but to the collection of such information as will enable it to serve as a national coordinating agency in this field.

Electrical Service Rules.

For several years the Bureau has been studying the questions of specifications for electric light and power service, and the requirements that should be made by municipalities or by State public-service commissions of the public-utility corporations engaged in furnishing such service. This study was published early in the fiscal year as Bureau Circular No. 56, Standards for Electric Service.

The demand for this circular has been large, and it is gratifying to note that the rules, specifications, and ordinances proposed have been made the basis for State rules and city ordinances in the instances named below. During the three years that the circular was in preparation, representatives of the Bureau attended hearings in various States upon invitation by the commissions interested, and assistance was given to the commissions in Connecticut, District of Columbia, Maryland, Missouri, New Hampshire, Oregon, and West Virginia in drafting their rules for electric service. In a number of the States where no public-utility commission is established, city authorities have been assisted in drafting ordinances on the regulation of electric and gas service. Louisville, Ky., has an ordinance based on the proposals made in Circulars Nos. 32 and 56. Since the Circular No. 56 has been issued, the proposed State rules, with necessary local changes, have been adopted by the Public Service Commission of Colorado, and are being made the basis of the revision of rules now under consideration in Illinois, New York, and Washington. The Public Utilities Commission of the District of Columbia has adopted the Bureau's proposed specifications for the acceptance of types of electric meters, as given in Circular No. 56, without change.

In addition to the proposed State rules and specifications for acceptance of types of meters, the circular contains three regulatory ordinances, suggested for cities of various sizes, descriptions of commission standardizing laboratories, and a complete and exhaustive

digest of all State rules heretofore adopted and ordinances now in force in various cities. A revised edition is now in course of preparation, and the Bureau again wishes to acknowledge the continued cordial cooperation of public-service commissions, municipalities, and public-service corporations, the National Electric Light Association, and the Association of Edison Illuminating Companies.

Street-Lighting Service.

For a year or more the Bureau has been engaged in a study of street lighting in its technical and engineering aspects, with particular reference to the requirements that should be put into contracts between municipalities and public-service corporations for furnishing gas and electric street lighting. A number of municipal and private plants have been inspected, photometric measurements made, and conferences had with managers and illuminating engineers.

The Bureau has been receiving the hearty cooperation of municipalities and lighting companies, but the war has necessitated a discontinuance of much of the work on the part of the Bureau, and public-utility companies also find themselves unable to cooperate as fully as they would like to do. A special committee of the Edison Association of Illuminating Companies on street lighting will resume its cooperation with the Bureau at a later date.

The manuscript of a circular on "Standards for street-lighting service" is partly completed in a preliminary form. The scope and completeness of this study of street lighting are indicated by the following proposed table of contents:

1. The purpose and problem of street lighting.
2. The measurement and distribution of light and illumination in street lighting.
3. Lamps and accessories used in street lighting.
4. General principles governing the design of a street-lighting system.
5. Description of typical street-lighting systems.
6. The economics of street-lighting systems.
7. Discussion of contracts for street-lighting service.
8. Suggested street-lighting contracts.
9. Statistical appendixes.

As in the case of Standards for Electric Service the Bureau seeks, while representing the public interest, to get the utilities' point of view also, and the study of street lighting will not be published until full discussion and cooperation can be had from public-utility corporations, technical societies, municipalities, and other interested parties.

National Electrical Safety Code.

The Bureau has been engaged for four years in a study of the life hazard in electrical practice and in the preparation of the National Electrical Safety Code. In this work it has had the cooperation and assistance of a large number of engineers, many of whom are connected with the electrical operating and manufacturing companies, others being engineers and inspectors of State commissions and municipalities. The various national associations connected with the electrical industry have also cooperated effectively in this work. The importance of having a national code uniform in all the States

is realized to be quite as great for accident-prevention rules as for fire-prevention rules, and the advantage of having such a code prepared and presented by a national agency that can study the subject thoroughly and consult all the interests affected is obvious.

The safety code consists of four principal parts, as follows:

1. Rules for the installation and maintenance of machinery, switchboards, and wire in central stations and substations.

2. Rules for the construction and maintenance of overhead and underground lines for the transmission and distribution of electrical energy and intelligence.

3. Rules for the installation and maintenance of electrical apparatus and wiring in factories, residences, and wherever electricity is utilized for light, heat, or power.

4. Rules to be observed by employees in working on or near electrical machines or lines.

This code does not include the matter covered by the Underwriters' Fire Code, but is parallel to the latter and consistent with it.

The code is intended to be adopted by State industrial and public-service commissions and municipalities, and to be complied with by public-service and industrial corporations. It is also intended to be adopted voluntarily by electrical interests when the code has not been adopted by any administrative body having jurisdiction in their district.

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

The code was published originally in two installments for examination and criticism; the operating rules were published in August, 1914, and revised in May, 1915; the construction rules were published in April, 1915. Both operating and construction rules, again revised after a general conference of all interests in Chicago in the summer of 1916, have now been combined in a single volume which was published in November, 1916, with a recommendation for actual field trial. It has been the intent of the Bureau as well as the desire of all branches of the industry, that the rules should be revised and extended as experience in their use and the progress of the electrical industry shows revision and amplification to be to the public advantage.

National Electrical Safety Code in Practical Use.

The electrical safety code has now been adopted in one form or another, in part or in whole, by some 14 State administrative bodies, and is also being used by the inspection departments of many cities and boards of underwriters. It is being utilized as a basis for a merit-rating schedule by the casualty interests, just as the Under-

writers' Fire Code has been used by the fire underwriters for some years. Such schedule rating should result in emphasizing both the merits and demerits of particular installations from the safety standpoint, and tend to reduce accidents by proper financial recognition of each improvement made. The code is also being voluntarily applied by a large number of utilities and industrial concerns in their own practice. It is receiving the general approval of all these interests as rapidly as its usefulness is becoming recognized, and its advantages are seen to be greater than any minor present inconvenience which its introduction may cause. It is becoming generally understood that the stability in electrical practice provided by such a national standard also conduces greatly toward the general economy, the necessity for which is becoming emphasized during this period of national stress.

Scope and Application of the Electrical Safety Code.

In view of the fact that some 80 State administrative bodies and many cities have electrical departments, it is necessary that the Bureau send engineers frequently to different parts of the country to assist and cooperate with these administrators and other officials who are considering the adoption of the safety code, or as sometimes has occurred, are considering the adoption of other electrical safety rules prepared locally.

To aid in presenting the safety code in cases where conference is not possible with the limited staff of the Bureau, and to assist in explaining the intended application of the code, a publication has been prepared and is about to be issued entitled "The scope and application of the national electrical safety code." In this are included brief summaries of the different parts of the code, reasons for the character of treatment employed, some discussion of the measures taken to secure adequacy and reasonableness, and some recommendations for the method of conducting inspections of intallations to secure compliance with the safety-code provisions. The publication also contains descriptions of a number of typical accidents, repetition of which would largely be prevented by observation of the national safety code rules for construction and operation.

Inspections Under the Electrical Safety Code.

Partly to aid in further revisions of the safety code, and partly to assist in bringing it into actual use, the Bureau is conducting a number of inspections of different electrical systems in order to compare electrical practice in a large number of typical cases with the requirements of the code. These comparisons are demonstrating the general adequacy and reasonableness of the rules and their value in promoting reliability of service as well as safety. Such comparisons have also had the important result of interesting many engineers in the more active application of the safety code.

The three years' preliminary study that was given to the subjects treated in the code, the many public conferences held in all sections of the country, and the immense amount of work done by the engineers who have cooperated with the Bureau, including the representatives of the large number of national and State associations connected with the electrical industry, probably constitute a more

thorough study and discussion than was ever given to a similar set of rules for practice before they were finally promulgated for use. The trial of the code is now proving the great value of this very extended preliminary study, since no important errors or oversights in the safety code have so far been brought to the attention of the Bureau, although a number of points have arisen where minor amendments can be made in a subsequent edition. The rules are proving generally clear and workable. Revisions will, of course, be necessary as experience accumulates and electrical applications increase, and these will be made after full discussion with all the affected interests.

Organizations Cooperating in the Preparation and Revision of the Electrical Safety Code.

Among the national organizations actively cooperating with the Bureau in the preparation, development, and introduction of the safety code are the American Institute of Electrical Engineers, the American Electric Railway Association, the American Institute of Architects, the American Railway Association, the American Telephone & Telegraph Co., Association of Railway Telegraph Superintendents, the Bureau of Mines, the International Association of Municipal Engineers, the International Brotherhood of Electrical Workers, the National Electric Light Association, the National Fire Protection Association, Postal Telegraph Co., Underwriters' Laboratories, Associated Manufacturers of Electrical Supplies, the National Electrical Contractors Association, the Electric Power Club, Association of Edison Illuminating Companies, Workmen's Compensation Bureau, and the National Safety Council. It is largely through the cooperation of these organizations that the preparation and introduction of the code have been thus far so successful.

Electrical Protection for Householders.

The Bureau has conducted a study of electrical hazards in the household and the means for reducing them to a minimum. The results have been incorporated in an illustrated electrical chapter to the "Household safety" circular, now practically ready for publication. In this study the cooperation and criticisms of lighting utilities and underwriters have been received, and the publication is in popular language, calculated to appeal to the understanding and interest of school children as well as to the intelligent householder.

Special Problems in Overhead Lines and Industrial Installations.

As an outgrowth of the work of the National Electrical Safety Code, a study of the mechanics of overhead line construction has proven necessary, and extended tests and field measurements have been conducted on wires and supporting structures, the results of which will be brought together later in a publication entitled, "Engineering data on overhead lines." Work on this publication, which will be of use to engineers of utilities, and particularly to engineers of administrators, has been delayed by the limited appropriation for studies of this kind. The advantage of these investigations for promoting the safety of the public and the advantages to the industry in securing greater uniformity of practice are obvious, and the studies along this line are being continued as rapidly as the facilities permit.

A study is being made of the best methods of providing industrial control equipment with guards or otherwise meeting the requirements of the safety code, and manufacturers' associations are heartily cooperating with the Bureau in this work.

Electrolysis Problem Among Public Utilities.

The majority of the street railways of the country are operated on the single overhead-trolley plan, with the electric current flowing into the rails through the car wheels, after it has passed through the car motors. The current then flows back to the generating station or substation by way of the tracks and earth, some of it, however, often flowing through underground gas and water pipes and the lead sheaths of underground telephone and electric-light cables, and sometimes through reinforced concrete structures. The earth conducts electricity by virtue of its moisture and the salts dissolved in it, which render it an electrolyte. Hence, when the electric current flows away from iron pipes or lead-cable sheaths, it carries away iron or lead by electrolytic action, and this in time corrodes the pipes and shortens their useful life and sometimes completely destroys them in a relatively short time. The property damage caused by these earth currents when they are considerable, affects to a greater or less degree all the public utilities.

The trouble is the more serious in places where the soil has a greater conductivity than usual, and where the conductance of the tracks is small in proportion to the current, and the distance the current travels back to the stations is relatively great. Many remedies have been proposed and tried, but no standard practice for the handling of the return current has ever been agreed upon in this country. As the electric railways have been extended and traffic has become heavier, the volume of current handled has increased very greatly, and the resulting destructive effects, which are cumulative with time, have become increasingly evident. In some cases litigation has resulted between the pipe-owning companies suffering damage and the railway companies whose current causes the trouble. But although the courts have considered the question of legal responsibility, these cases did very little to prevent the trouble in an effective and economical manner.

Economic Importance of the Electrolysis Problem.

The subject of electrolysis of underground pipes, cables, and other metal structures is one which has been given more attention in recent years than formerly, but it still does not receive the attention in many quarters that its importance deserves. When one considers the enormous value of the pipe and cable properties buried in the streets of cities and forming in many cases transmission networks between cities throughout the country, and considering further that there are very few water, gas, or lead-cable systems which are not more or less subject at some points to electrolytic damage from stray currents, it is possible to better form a judgment of the practical importance of this subject. The water and gas pipe systems of this country alone have an aggregate value at the present time in excess of a billion of dollars, and in addition to this there is a vast extent of underground lead-cable systems belonging to telephone and elec-

tric power companies and to municipalities. In addition to these vast properties in the earth, a considerable part of which may be more or less subject to electrolytic damage, there are possibilities of trouble in the case of bridge structures, portions of steel frame buildings, and piers, which are occasionally exposed to damage from this source.

While the total losses due to shortening of the life of underground pipes and cables must be considerable, such loss does not by any means represent the total annual damage due directly to electrolysis. It is well known that the annual loss due to leakage of water and gas from distribution systems is very great. It is true that only a part and probably a small part of the total leakage is due solely to electrolysis, but it is only necessary to assume that a few per cent of the total is due to the more rapid developments of leaks caused by electrolysis in order to make the total loss resulting from this cause run well into the millions annually.

In making a valuation of underground pipe systems, as, for example, in the case of a valuation to be used as the basis for a transfer of property or for rate revision, it is necessary to consider possible deterioration of the pipes due to electrolysis, since in those localities in which the pipes have suffered from electrolysis the actual physical value of the system will be materially reduced.

Inconvenience and Hazard Due to Electrolysis.

It is not alone the property loss, however, that makes the electrolysis problem one of importance. An important fact is the inconvenience to consumers of water, gas, and telephone service due to the interruption of the service when repairs are made necessary by electrolytic damage. Possible interruption of the service of police and fire-alarm systems is also one of considerable importance to almost every municipality.

Wherever currents are permitted to flow on the underground pipe systems there is the possibility of electric arcs being formed when pipes are disconnected, or when different pipe systems make momentary contact. Accidents of this kind are rare, but they have sometimes occurred, resulting in the loss of life and a considerable damage to property. Cases have occurred also in which leakage of gas resulting from electrolytic corrosion of the pipe has given rise to explosions with disastrous results. Many gas explosions in basements and manholes have occurred, and although it is difficult to determine what proportion is due to electrolysis, undoubtedly some of them are due to this cause.

A water-pipe line weakened by electrolytic corrosion may even present a fire hazard much greater than would result from interruption of water supply at normal times. In many cities it is quite common practice during bad fires to increase temporarily the water pressure in the district adjacent to the fire. It is very obvious that a badly corroded water main might be capable of withstanding the normal pressure on the system and thus give no warning of the weakened condition of the pipe, but at the critical juncture during a bad fire when the pressure is suddenly increased the pipe may burst, and thus seriously hamper the work of fire fighting. It will readily be appreciated that in any region in which electrolysis damage is known to be in progress to a greater or less extent the mains

are far more likely to break at these critical times than at any other period, and thus a real, though indirect, fire and life hazard due to electrolysis must be recognized.

Methods of Mitigation of Electrolysis.

While actual dangers resulting from the presence of stray currents on underground pipe and cable systems may readily be obviated, the use of improper methods may aggravate rather than relieve the seriousness of the trouble. In not a few cases so-called mitigative measures which were actually harmful in their effect, either to the system to which the measures were applied or to neighboring structures, have been installed. Altogether more than 25 separate and distinct methods of dealing with the electrolysis problem have been proposed and experimented with from time to time. Some of these are very beneficial when properly used or may become harmful when improperly used; and others, while harmless in their effects on the pipes, may be of no appreciable value and, hence, a useless expenditure of time and money. It is easy, therefore, to appreciate the difficulties confronting the nontechnical man, or even the engineer who has not given special study to the electrolysis problem; and this emphasizes the need for a more general understanding of the fundamental principles of electrolysis by officials of utility companies operating underground pipe and cable systems.

The Bureau has been studying the electrolysis question for the past seven years and has done a large amount of work in connection with it. The first problem investigated was that concerning the effects of electrolysis in reinforced concrete, after which special attention was given to electrolysis of underground pipes. This has included laboratory investigations concerning the effects of electric current on concrete and metal pipes, tests of pipe coverings, the corrosion of metals in the soil, methods of measuring soil resistance and various other experimental phases of the work; methods of electrolysis mitigation that have been used or proposed; field studies in actual practice with the application of remedies; and a determination of the cost and results obtained.

Extensive investigations have also been made into methods of electrolysis testing in the field for the purpose of establishing the best methods of procedure in diagnosing the cause of troubles actually experienced, determining the extent to which the underground metallic structures are being affected, and securing engineering data on which to determine the most effective and economical measures that may be applied in any given case to mitigate the trouble.

Recent Electrolysis Work of the Bureau.

The Bureau of Standards has made a number of electrolysis surveys in various cities with the view of making detailed studies under typical conditions, the results of which could be published for the benefit of the public. These investigations have been made in cooperation with utility companies and municipalities concerned and largely at their expense. Complete mitigative systems have been installed by several cities, demonstrating the most effective means of meeting the problem under various conditions. The Bureau makes somewhat detailed tests in each of these places about once a year to make sure that the protective systems are being properly maintained.

Arrangements have been made for carrying out investigations on the three-wire system of electric railway operation. A system of this kind has been installed at Omaha, Nebr., and a comprehensive series of tests have been made with very gratifying results. An account of these tests will be published during the coming year. The same system is now being installed in Springfield, Mass. This latter system was projected more than a year ago, but owing to local conditions it was necessary to defer installation until now. It is expected that this system will be in operation by October, and a careful examination of it will be made by the Bureau.

During the past year brief electrolysis investigations have been made in about 10 southern cities. Complete electrolysis investigations have been made in Montgomery, Ala.; Hamilton, Ohio; and Omaha, Nebr.; and reports have been submitted to the municipalities and public utilities operating in those cities. A similar investigation is now in progress in the city of St. Paul, and arrangements have been made for undertaking an investigation in Duluth, Minn.

At the present time the amount of this work which the Bureau is doing has been greatly restricted because the majority of the members of the staff who have been engaged in this work have been needed for work in connection with urgent military problems. Precedence will be given to these military problems as long as it is deemed necessary, but the electrolysis work will be resumed after the existing emergency has passed.

Leakage of Current from Electric Railways.

The Bureau has continued work in regard to the effect of treated ties on the leakage of current from electric railway lines. This work is being done in conjunction with the forest products laboratory.

Advice to Municipalities and Corporations.

In addition to the work of the Bureau outlined above, the results of which are being published from time to time for general distribution, the Bureau renders an important service to the public through the advice given to municipalities and corporations by correspondence and personal consultation. Frequently representatives of utility companies and cities come to Washington for personal interviews relating to various phases of the electrolysis and public-utility problems.

Lightning Protection.

Considerable work has been done in the direction of preparing specifications for the protection of buildings against lightning, but owing to the emergency growing out of the military situation it has been necessary to suspend this work temporarily. A little later, as soon as opportunity affords, this work will be continued and specifications will be prepared for protecting different kinds of buildings and other structures, so as to make it easier for architects and owners who wish to place lightning protection on different types of structures to do so as efficiently and economically as possible.

Investigations on Grounding of Secondary Electrical Circuits.

Grounding the secondaries of transformers and other parts of electrical systems to protect persons and property from electrical

dangers has, in recent years, become an important item of consideration to power companies. In view of the lack of readily accessible information on this subject the Bureau began in 1915 an investigation with the object of presenting in a suitable form the data then available, and supplementing it as far as seemed necessary with laboratory and field work. This investigation has been carried far enough to enable the preparation of the technological paper, soon to be published, which covers the following topics: (1) Resistance of ground connections; (2) their uses and service conditions; (3) different forms of ground connections and the electrical characteristics of each; (4) mechanical construction; (5) inspection and testing; (6) fire hazard and interference with service; (7) costs; (8) bases for specifications; and (9) field measurements of the resistance of ground connections.

Experimental Study of Telephone Apparatus.

With the funds at present available, progress in this important and most widely used branch of public-utility service must necessarily be slow. The increasing attention devoted to the subject by public-service commissions and the general public interest in this field make it desirable that increased funds be provided for this work.

Attention has first been directed to the establishment of a standard for the measurement of telephonic transmission efficiency, which in the interest of uniformity and in order to avoid all possibility of dispute relative to transmission measurement, should be in the custody of the Federal Government. The Bureau is now in position to make measurements of transmission efficiency and has made considerable progress in the development of an improved standard of transmission.

A large number of comparisons of the efficiency of transmitters and receivers of different makes have been made when using the voice as a source of sound, and in addition a study has been undertaken of the effect of the length of subscriber's lines in common battery systems with relation to the efficiency of transmitters of various types and makes.

In order to interpret the results of transmission measurements intelligently, even in the case of the relatively simple circuit employed in the definition of the transmission standard and particularly in the much more complicated circuits met with in actual practice, a thorough understanding of the theory of transmission engineering is necessary. A study has been made of the theory of transmission over uniform and composite lines; artificial lines; the effect on transmission of the electrical constants of the terminal apparatus in their relation to the constants of the lines to which they are connected; the effect of line apparatus such as repeating coils, and other means of connecting two portions of a telephone circuit, as well as signalling apparatus. Such studies lay the foundation for the formulation of the conditions to be met to give the maximum transmission efficiency at a given frequency.

This work must be supplemented by experimental work which has already been begun at the request of operating and manufacturing interests. Owing to the complexity of the present-day telephone

circuits, this is a laborious undertaking, involving not only the development of suitable methods of measurement and the making of measurements under the manifold conditions met in practice, but also the determination of the electrical constants of representative types of telephone apparatus under service conditions. Such work will not only be of great general value, but its bearing on the consideration of questions raised before commissions as to the feasibility of physical connections between different telephone systems is also manifest. The work involves the measurement of alternating currents, voltages, frequencies, and phase relations in the telephonic range.

The development of a method for determining telephonic transmission efficiency by other than speech tests is deemed essential. Such a method is much needed because speech tests are not entirely satisfactory on account of relatively large errors of measurement (due in considerable part to variations in the carbon transmitter of the standard circuit), especially where it is a question of determining the effect of small differences such as those involved in determining the influence on transmission of repeating coils, condensers, and other apparatus used in talking circuits.

On account of resonance phenomena, especially in receiver and transmitter diaphragms, single-frequency measurements can not be satisfactory. It is therefore necessary to base results on measurements at three or more selected frequencies combined in accordance with the amplitude and frequency characteristics of speech. The determination of these characteristics is a fruitful field for further investigation.

In order to carry on effectively the investigations outlined, considerable specially designed apparatus must be acquired, and the personnel in charge of this work must be considerably enlarged.

Telephone Service Standards.

The investigation of the principles underlying the definition of telephone-service standards is of the greatest importance to State public-utility commissions as well as to the millions of telephone users throughout the United States. In order to secure results of greatest value, it is necessary to enlist the cooperation of the telephone industry, which will of course be benefited by such work. In view of this fact the Bureau confidently counts upon its wholehearted support.

Submarine Telegraphy.

In connection with a fraud order case of the Post Office Department in which the Bureau was asked to cooperate, a study of cable signaling and a portion of the broader field of transient phenomena were taken up. Of particular interest in this connection is the effect of terminal apparatus, cable relays, and amplifiers and the Squier method of alternating-current signaling, especially as related to the speed of working. Experiments were made to demonstrate the impossibility of claims to the effect that telephonic communication could be had over long lengths of submarine cable of the types now in use. Numerous tests by the aid of a 1,000-mile artificial cable clearly indicated that the telephonic transmission apparently obtained is not true cable transmission and is easily explainable by

leakage and unbalanced capacities to ground. The results obtained are all in conformity with theory.

Relation of the Bureau to Municipalities and Public-Service Commissions.

In many States the public-service commissions have set standards of service, and the Bureau has cooperated with most of those that have done so. In other States the railroad or public-service commissions have taken no action in the matter, although having authority to do so. Again, in some States there are no public-service commissions to issue regulations or to inspect the quality and safety of the service rendered by the various utilities. In any case the cities and towns must look after their own interests, in whole or in part, and frequently have taken up such matters very successfully. Where there are well-equipped and active State commissions, which have adopted rules and are ready to hear complaints regarding rates or service, a very large responsibility rests even in such cases upon the municipalities. Few State commissions will ever be likely to have a force of engineers and inspectors large enough to enable them to take the initiative in every case and relieve the municipalities of all responsibility. On the contrary, if the municipalities are active and enterprising in their own behalf, and if the larger ones have well-equipped public-utility departments which can prepare the city's complaints or requests and take them up to the State commissions for hearing and adjudication, the State commissions would be better able to serve all the municipalities of the State, and the municipalities would enjoy in large measure the advantages as well as the responsibilities of home rule without its greatest disadvantages.

But for most cities and many commissions it is a difficult matter to judge as to the quality of service rendered by its utilities. The studies made by the Bureau are a great help in this connection, but much remains to be done. It will conduce to fairness and a good understanding to have the subject studied further and as definite and complete specifications as possible made available for all branches of public-utility service.

Obviously, it will never be practicable for any State commission or city to handle these questions alone. Though they possess large and able engineering staffs or employ specialists for each separate problem, the question of what is good service or whether the service in any given case is adequate, safe, and satisfactory can be settled only by reference to what is done under similar circumstances elsewhere in the country. In other words, standards of good practice and good service are largely determined by general experience and should be studied comparatively, using the experience of the entire country. The Bureau has been doing this for several years, and although it has not been able to do as much as it would have liked to do, it has done enough to demonstrate the practicability and acceptability of the method. The success and approval which the work has met so far fully justify its greater development.

Necessity for Increasing the Public-Utility Work of the Bureau.

The sum available for the public-utility work of the Bureau during the current fiscal year, including a special appropriation for the safety work, is $65,000. Many of the States spend more than this and

some States 5 or 10 times as much. The people of the United States spend about $2,000,000,000 a year for the service of the public utilities, or $20 per capita per annum. This includes the telephone, gas, electric light and power, electric-railway transportation, and miscellaneous utilities, not including the steam railways. The States through their public-utility and railroad commissions spend about $4,000,000 a year regulating the utilities and railroads and the cities a large amount in addition, but very little of this is spent for research. A considerable sum could profitably be spent annually in an efficiently conducted cooperative study of the conduct of such utilities, defining standards of service, preparing safety rules, assisting in local studies as to service, acting as referee or adviser in cases of dispute, serving as a clearing house of information on all public-utility and associated engineering questions, helping to secure uniform methods of accounting (especially where public-service commissions are not yet established), carrying out laboratory tests and investigations to answer difficult questions, and making it possible for rules as to service and safety to be kept revised up to date after they have once been formulated and adopted. Such work carried on with the cooperation of the utility companies and commissions requires a great many conferences and discussions and the harmonizing of differences of opinion. Many such differences of opinion are due to lack of precise information. Often experimental or other studies clear up such differences and bring about uniformity of practice.

A Federal bureau well equipped with men and apparatus, and permitted to work in the very wide field of public utilities (outside of railroad transportation and such subjects as the Interstate Commerce Commission is concerned with) can accomplish great good for the public. It does not appear to be overestimating the value of such work to say that an average benefit equivalent to 5 per cent of the sum now paid for the service would result. It seems conservative to suppose that such benefit in improved efficiency and better service would seldom be less than 2 or 3 per cent and sometimes as high as 10 per cent. Five per cent of $2,000,000,000 is $100,000,000 per year, and this appears to be a reasonable estimate of the possible value of the service being considered, assuming such service to be efficient and ample. One cent a year per capita is only a hundredth part of this sum, and this does not seem too much for the people to spend cooperatively through the Federal Government to accomplish this result. Considering the enormous cost of public-utility service, it does not appear to be desirable to continue spending so much without a greater effort to derive the benefits possible from a just and adequate system of public-utility regulation.

The money value of proper regulation of the utilities is not the only benefit to be derived therefrom, however. The increase of safety is another consideration difficult to estimate in dollars and cents. Still another advantage, more difficult to appraise but not difficult to appreciate, is the favorable influence on State and municipal government. Unregulated utilities sometimes control municipalities; improperly regulated utilities are sometimes forced to resort to questionable methods of self-defense. Public officials charged with the duty of regulating public utilities, but not provided with the means of doing it equitably and effectively, are at a serious dis-

advantage and frequently can accomplish nothing. The eagerness with which public officials with whom the Bureau has cooperated in the past have sought reliable information and their appreciation of the work of the Bureau indicate that if this work could be greatly enlarged and made available in a larger number of cities and States, it would be of immense economic importance and by establishing a better understanding between utilities and the representatives of the public would have a salutary effect upon municipal government. It would also benefit the public utilities themselves, partly by increasing their efficiency and partly through the increased confidence of the public in the fairness and efficiency of this arrangement.

4. LIGHT AND OPTICAL INSTRUMENTS.

[Wave length of radiation (visible and invisible); color, relative emissivity, reflectivity, and absorption of materials for light and other radiation; transparency; and radiation constants, including experimental researches required in determining the optical constants of materials and of radiations; in developing optical standards of performance or quality of optical products for manufacturers, technical experts, and research laboratories; in the standardization and testing of sugar and other materials by optical means; and in standardizing the measurement and specification of colors for such industries as dyes, paints, ceramics, paper, inks, etc.]

Determination of Standard Wave Lengths.

A considerable number of very accurate determinations of wave lengths of light is required for spectroscopic work. Such wave lengths will serve as standards for the accurate measurement of wave lengths corresponding to lines in the spectra of the chemical elements. These standard wave lengths are measured by the interferometer method and are expressed in terms of the red radiation of cadmium which is the fundamental spectroscopic standard. During the past year the Bureau has increased the existing number of secondary standards by measuring the wave lengths of 12 cadmium lines, 21 helium lines, 56 neon lines, and 24 argon lines. These lines are quite sharp and it has been possible, therefore, to measure the wave lengths with an accuracy of one part in four or five millions. They are scattered throughout the spectrum from the ultra-violet, at 2900A, into the infra-red to 8500A. The abbreviation for angstrom is A and its length is one ten-millionth of a millimeter.

The study of numerical relations between different spectrum lines has been begun in connection with these accurate wave-length measurements. A well-known series formula has been tested with the helium wave lengths and the results are contained in Scientific Paper No. 302. In the neon spectrum it was discovered that frequencies corresponding to several groups of lines are the same to one part in about five millions. These are no doubt the most exact numerical relations ever observed among spectrum lines and are of great importance from both practical and theoretical standpoints.

Infra-red Photography.

A large part of the spectroscopic investigations of the Bureau during the past year has been in the longer wave regions of spectra to which ordinary photographic plates are insensitive. These regions were recorded on ordinary plates which were stained with certain photographic dyes. The comparative efficiency of several dyes as

red and infra-red sensitizers for photographic use has been investigated; pinacyanol was found best in the orange and red, and dicyanin most valuable in the adjacent infra-red spectral regions. With the use of these dyes the wave-length interval which may be photographed with ordinary plates is easily doubled and extended to about 2000A beyond the visible limit in the red. The value of these dyes has been demonstrated by the photography of the infra-red spectra of laboratory sources, of the stars, and of the sun. At present these photographic dyes are not made in this country, although their importance in scientific work and in the industries warrants the expenditure of a large amount of effort upon their production and upon the search for new ones.

Up to the present there has been comparatively little accurate spectroscopic investigation of light waves longer than those of yellow light. The important red and infra-red regions have never been explored with the same completeness as the other regions. It is very desirable that this be done in order to establish a broader basis for spectroscopic chemical analysis as well as for more general reasons. Ordinary plates stained with dicyanin have been used at the Bureau to photograph the arc spectra of 20 of the chemical elements, including the alkali metals, the alkaline earths, and elements commonly found in iron as impurities. The photographs were made with a large concave grating and the wave lengths were determined relative to the international secondary standards in the spectrum of the iron arc. The wave lengths photographed with these stained plates range from 5600A to 9600A and the results for 10 chemical elements are published in Scientific Paper No. 309. Frequency differences of pairs of lines in the spectra of sodium, potassium, rubidium, caesium, and copper are shown by these wave-length measurements to be constant, in most cases, to 1 part in 100,000 in the number of waves per centimeter. Comparison of the spectra made it possible to detect many impurities in the elements, and this feature of the work will, no doubt, be of considerable importance in chemical analysis. The spectra of neon, argon, krypton, and xenon gases were also photographed in the infra-red by means of the grating and dicyanin-stained plates. Many new lines were thus recorded and some striking similarities in the spectra of these gases were found. In the xenon spectrum what appear, by analogy with the other rare gases, to be the principal lines were observed for the first time.

Through the courtesy of Director E. C. Pickering, of Harvard University, the 24-inch reflector of the Harvard College Observatory was used for the purpose of extending the photography of long wave lengths to stellar spectra. The results have shown the feasibility of extending observations on stellar spectra to greater wave lengths than has heretofore been possible. A new absorption band was photographed at the end of the visible spectrum and later laboratory experiments at the Bureau have confirmed the conjecture that this is due to titanium oxide. There is found in this experience another example of the stimulating effect of celestial spectroscopy on laboratory investigation. The general conclusions of this work may be stated as follows: (1) Many stellar spectra possess sufficient intensity in the region of wave length 8000A (infra-red) to enable this portion of the spectrum to be photographed on plates

sensitized with dicyanin; (2) in favorable instances stellar spectra can be recorded to wave length 8500A or possibly to even greater wave length; (3) the region of stellar spectra beyond 7000A contains features of importance to astrophysics, especially in the case of the red stars.

The Johns Hopkins University kindly placed at the disposal of the Bureau, a suitable grating and auxiliary apparatus for the photography of the solar spectrum. Dicyanin-stained plates made it possible to record the spectrum of the sun from the red at 6800A into the infra-red at 9600A. The dispersion and fine detail of these photographs is nearly comparable with that of Professor Rowland's map of the solar spectrum from the ultra-violet limit to the visible red. The measurement of wave lengths corresponding to the absorption lines and comparison of these with the lines obtained from laboratory sources will make possible additional identifications of chemical elements in the atmosphere of the sun.

Refractive Index and Dispersion of Air.

It has become necessary to investigate the optical properties of the air, since they have not been determined with sufficient thoroughness for the reduction of some of the wave-length measurements. For example, the difference in the index of refraction of the air for different wave lengths must be taken into account in the measurement of secondary standards of wave length, and for the proper discussion of numerical relations among spectrum lines it is necessary to reduce wave lengths which have been measured in air to their value in a vacuum. This requires a knowledge of the index of refraction of air of various densities for a large range of wave lengths. Over 1,000 observations have been made on the index of refraction of air for wave lengths from 2500A to 9000A, which is the entire spectrum range easily recorded by direct photography. These observations were made for several temperatures between 0° C. and 60° C. and for several pressures ranging from zero to one atmosphere.

Spectroscopic Analysis.

The spectroscopic method of analysis has some advantages, within certain limits, over the chemical method of analyzing chemical compounds. In some cases the quantity of the sample is too small for a successful analysis by chemical means. The spectroscopic method can be used to test the presence of all the constituents of a compound in a single small sample, while the chemical method often requires several portions of the material, each one of which is separately examined for a certain element or group of elements. Furthermore, a spectroscopic analysis can generally be made much more quickly and easily than a chemical analysis. For these reasons considerable time has been given to developing both qualitative and quantitative analyses by spectroscopic methods.

A large number of standard samples of alloys were prepared by metallurgists and carefully analyzed by chemists. The spectra of these definitely prepared and analyzed samples were then compared with the spectra of samples of unknown content. In this way the unknown specimens were analyzed with accuracy. This method has been especially valuable in the analyses of boiler safety plugs of

fusible tin. Several hundred such plugs have been examined and found to average 0.2 per cent copper, 0.1 per cent lead, 0.05 per cent zinc, and 0.07 per cent iron. The specifications for these plugs allow 0.3 per cent total impurities and the spectroscopic method is now very simple if the impurities fall within this range. An analysis of 10 plugs can be made in about 90 minutes in this way, while the chemical methods require about three days. Thirteen aluminum alloys were examined spectroscopically and the type of alloy determined. Thirteen samples of zinc ore, electrolytic zinc, and muds from electrolytes were examined for rare elements by spectroscopic means. A number of iron, steel, brass, platinum, and glass samples have also been examined. All the glass samples contained lithium and it was found possible to make comparative determinations of the sodium and potassium content which were roughly in accord with the chemical analyses.

The spectroscopic method of analysis is extremely sensitive and often detects impurities which escape the chemical method. In cases where the chemical quantitative analysis can not be replaced by the spectroscopic method, a rapid preliminary spectrum qualitative analysis often saves the chemist much time.

Rare Gas Discharge Tubes.

The spectra of the rare gases can only be examined by confining small quantities of the gases in glass or quartz tubes and sending an electrical discharge through them. The design of these tubes is a matter of much importance and has received considerable attention at the Bureau. Both glass and fused quartz tubes containing hydrogen, helium, and argon have been made. Some of these tubes were required in work at the Bureau, and several were furnished to other Government bureaus and to scientific institutions. It was found possible to make excellent discharge tubes of argon directly from the air. A small bulb of quartz or Pyrex glass was filled with calcium chips and attached to a tube containing air. Maintaining the calcium at a temperature of about 300° C. for several hours abstracts all of the nitrogen and oxygen and leaves quite pure argon in the tube at about the proper pressure for spectroscopic work. The frequent requests for the rare gases and their great importance and promise in scientific work demands the production of neon, argon, krypton, and xenon on a larger scale.

Solubilities in the Sugar Group.

The data obtained on the solubilities of sugars and on the influence of foreign substances upon these solubilities have an industrial as well as a scientific importance. The preparation of the sugars of commerce always involves their crystallization from impure solutions. The quantity of sugar which can be obtained by a crystallization depends upon its solubility in the presence of the particular impurities which occur in the crude materials. Cane and beet molasses are simply solutions of sugar in water containing large quantities of mineral salts and invert sugar.

During the past year the Bureau has investigated the solubility of sucrose in the presence of glucose and invert sugar (invert sugar, obtained by the decomposition of sucrose, is a mixture of glucose

and levulose), and the solubility of glucose in the presence of sucrose and levulose. The results thus far obtained show that the conclusions reached by previous investigators are incorrect. The investigation is being continued and the influence of mineral salts is being studied. In this manner it is intended to study individually the constituents that make up the complex systems in molasses.

Influences of Temperature on the Speed of Inversion of Sugar.

Under the influence of acid, sucrose decomposes to form a mixture of two sugars, namely, glucose and levulose. This mixture is called invert sugar. The decomposition or "reaction" occurs with a measurable velocity which is very sensitive to temperature influences. This reaction is used to estimate sucrose quantitatively when other optically active substances are present. The technique of this method is in need of improvement on account of its wide application in the analyses of sugar mixtures. As a first step the velocities of the reaction for the range of temperature employed have been determined. The experiments consisted of measurements of reaction velocities at relatively great velocities. The results of the experiments showed that the velocities could be expressed by a mathematical formula which had been derived theoretically by previous workers.

Specifications for Commercial Grades of Sugar.

One of the most important problems confronting the sugar industry, both from the standpoint of the manufacturer and the public, owes its origin to the absence of definitions or specifications of the various grades of commercial sugars. This matter has been brought to the attention of the Bureau a number of times. Considerable difficulty has been experienced by manufacturers of candy due to variations in the sugar, it frequently being necessary to modify the formulas of candies on this account. In another instance the Navy Department was furnished with an inferior grade of sugar by a contractor. Recently the question of specifications which would define the different grades of commercial sugars, both white and brown (or soft) sugars, has been brought up by domestic producers.

From preliminary investigations the Bureau is convinced that, owing to the variations in quality which now exist, the work of preparing rigid specifications for the grades currently on the market will be considerable, but once such specifications are established the uncertainties of quality in the different grades of sugar will be practically eliminated. The Bureau hopes to be able to carry out this important investigation in the near future.

Basis of Saccharimeter Standardization.

The results of the Bureau's investigation of the present basis of standardization of saccharimeters were set forth in the last annual report. The most important item was the correction of an error of over one-tenth per cent in the 100-degree sugar point of the saccharimeter scale, the net result being the saving of $60,000 annually in the revenue of the Government from imported sugar and a much larger gain to the producers of sugar. Owing to the present conditions in Europe, the Bureau has abandoned hope for the present of a correction of this error by the international committee which

was appointed to make a recommendation regarding the matter. Despite this fact the Bureau has concluded that it is no longer warranted in standardizing sugar-testing apparatus on a basis now known to be in error. Accordingly, certifications will be changed at an early date to the new value of the 100-degree sugar point of the saccharimeter.

Constants of the Quartz-Wedge Saccharimeter.

The Bureau has described, in Scientific Paper No. 268, the preparation of pure sugar and the many critical tests made to establish its purity. This substance was used to fix accurately the 100 per cent point of the saccharimeter in order that sugar analysis in connection with the sugar industry and for tariff assessment purposes might rest on a proper basis. Sugar in common with a large class of other substances alters or "rotates" the plane of vibration of plane-polarized light by an amount almost exactly proportional to its concentration. This property has been utilized for the exact analysis of these substances in instruments called saccharimeters and polarimeters.

It is now proposed to extend the investigation to the remainder of the sugar scale in order to ascertain the corrections to be applied for changing concentration of sugar. Thus the 80, 60, 40, and 20 per cent points on the scale will be determined with the same precision as the 100 per cent point. It is hoped in this way to establish a valid working basis for accurate sugar analysis.

At the same time precision measurements of the rotations of the sugar solutions will be made on the polarimeter. These measurements will supply data for the calculation of the variation of the specific rotation with changes of concentration of the sugar solution.

Rotation of Quartz at High Temperature.

The natural and magnetic rotation of light by crystalline and quartz, and the magnetic rotation of light by the amorphous quartz have been studied at high temperatures. Additional knowledge of the properties of quartz is of special importance from the theoretical standpoint, because of its extensive use in polariscopes and other optical instruments and because of its relation to the problems involved in the study of the history and formation of the earth. Crystalline quartz has a transition point at about 575° C.; at this temperature the crystal changes over into another crystal form. This is shown in the experimental curve of the natural rotation by an abrupt change of direction. Above this point the temperature has little effect upon the rotation, while just below it a small change in temperature causes a large change in the rotation. On the other hand, the magnetic rotation of both the amorphous and crystalline forms is found to be practically independent of temperature, increasing very slightly as the temperature rises and showing no change at 575° C.

Magnetic Rotation by Magnetic Substances.

A research has been undertaken on the magnetic rotation of metallic films, namely, iron, iron oxides (hematite, magnetite, etc.), and nickel, from room temperature to temperatures as high as possible (about 1,000° C. in some cases). This work has opened a field

which has heretofore been unexplored. The behavior in this region of the substances mentioned is of great theoretical importance, existing theories having been based on the experimental facts observed at ordinary temperatures.

The experimental difficulties involved in carrying on the work are necessarily numerous and difficult to overcome. A powerful electromagnet placed between the polarizer and analyzer of a very sensitive polariscope was used, the pole pieces being perforated to allow the beam of light to pass parallel to the lines of force through the substance in the magnetic field. Specially constructed furnaces to obtain the high temperatures were required. These furnaces had to be small enough to go in between the poles of the magnet and yet give a uniform temperature. Thermocouples and a sensitive electrical apparatus were utilized for taking temperature measurements. A gas-tight furnace was necessary for the work on the metallic films, so that the film could be kept in an atmosphere of hydrogen, oxygen, or other gas during the experiment, a long quartz and glass tube extending through the magnet being used for this purpose. The film to be observed was placed inside this tube, and the furnace was slipped over the outside of the tube containing the film in such manner that the film was in the center of the furnace and in the center of the magnetic field.

The results obtained show that the magneto-optical effect (rotation of the plane of polarized light) becomes zero in the ferromagnetic substances at the temperatures at which their magnetic properties are lost. This effect is especially clear and sharp in the case of nickel, the rotation falling abruptly to zero at about 360° C., the temperature at which nickel loses its magnetism. In the case of iron, the phenomena are much more complex. With the increase of temperature from room temperature, the magnetic rotation begins to decrease rapidly. It rises again somewhat at about 300° C., indicating that some change or transformation is taking place, then gradually falls off again to practically zero at about 780° C., the A_2 transformation of iron. The films were deposited electrically on thin quartz plates placed in a high vacuum.

Bureau of Standards Baumé Scale.

The existence and use of over 20 different Baumé scales have caused considerable confusion and misunderstanding in the industries. These are arbitrary scales, used indiscriminately, in the determination of the density and the percentage of sugar in solutions. The great importance of correcting this situation is shown by the action of the Association of Official Agricultural Chemists at their last meeting in recommendng that the Bureau of Standards make a study of the problem, with the object of establishing a suitable standard Baumé scale for use in the sugar industries. The Bureau has already recognized the need of such a scale and had previously conferred with several persons prominent in the field of sugar analysis. The matter was taken up in cooperation with the division of weights and measures of this Bureau and a new Baumé scale, together with tables for its use giving equivalents in per cent sugar and specific gravity, was constructed. The new scale is to be used at 20° C., the standard temperature in sugar analysis.

The advantages of the new Bureau of Standards Baumé scale are shown by the following: (1) It is based upon the specific gravity values of Plato, which are considered the most reliable of any available; (2) it is based on 20° C., the most convenient and widely accepted temperature for sugar work; and (3) it is based on the modulus 145, which has already been adopted by the Manufacturing Chemists Association of the United States, the Bureau of Standards, and by all American manufacturers of hydrometers.

Standard Glassware for Customs Laboratories.

The Bureau has undertaken to interest American manufacturers in the production of standard glassware, owing to the difficulty experienced by the Treasury Department in obtaining suitable glass apparatus for use in the testing of raw sugars. Specifications were sent to a number of makers and very favorable replies were received. It is thought that, in future, the American manufacturers will be able to meet the demand for these supplies.

Circular on Polarimetry.

There has been a rapid growth in recent years in the applications of polarimetry to the arts and sciences, with a proportionate increase in the requests made upon the Bureau for information. Circular 44, on Polarimetry, which includes a résumé of the work done at the Bureau of Standards and elsewhere, has to a large extent furnished the desired information. It has been revised and considerable matter added in the appendixes. The new material comprises 10 tables, including the new Bureau of Standards Baumé scale for liquids heavier than water, results of recent researches, a consideration of the polarization of low-grade products, a résumé of the work of the International Commission for Uniform Methods of Sugar Analysis, and amendments to the United States Treasury Department Sugar Regulations.

Polarimetric Tests of Raw Sugars.

The present disturbed conditions in freight transportation have resulted in raw sugar importations being entered at unusual points. However, the samples received by the Bureau were mainly from the larger customs ports. There were 1,243 samples of raw sugar tested. About 50 per cent were direct polariscopic determinations of the quantity of sucrose present, and the remainder were tested for the percentage of moisture in addition to the direct polarization.

Sampling Molasses in Tank Cars.

Owing to the conditions prevailing in water transportation, large quantities of molasses are now shipped in tank cars from Cuba by way of Key West. The merchandise is loaded in the cars at Habana and transported to Key West by ferries and, thence, to numerous points in the country by rail. The securing of representative samples of molasses in the tanks has proven a difficult matter, and a member of the Bureau was sent to Key West to study the subject. This study has resulted in the preparation of suitable regulations covering the sampling of molasses in tank cars, and these regulations will be issued as soon as their preparation has been completed.

Polarimetric Tests of Molasses.

The constantly increasing use of Cuban molasses in the United States has made it imperative that the Bureau give further consideration to the testing of this material. A number of samples have been studied and reported on. As yet, however, no satisfactory method for an accurate determination of the density of molasses has been found.

Information Furnished on Polarimetry.

A further increase in the diversity of the information requested by the general public was noted during the past year. A considerable demand for information regarding older types of saccharimeters and other apparatus has arisen. The abnormal domestic sugar production and the scarcity of all kinds of sugar-testing equipment has made it possible for the Bureau to furnish much valuable assistance to the industry. In special cases the Bureau has departed from its established policy and made accurate adjustments on saccharimeters so as to render them fit for service. The manufacture of polariscope tubes and cover glasses, inaugurated by the Bureau in this country, has been continued with success. Present conditions have emphasized the importance of having all classes of scientific apparatus manufactured in the United States.

Polarimetric Testing.

During the year there were tested about 500 cover glasses for optical homogeneity, and 24 quartz-control plates were standardized.

Standard Samples.

Seventy-three standard samples of sucrose and seven samples of dextrose were distributed during the year. These materials are used principally for industrial and scientific purposes, such as the standardization of saccharimeters and for the determination of the heat value of fuels.

Installation of Sugar Laboratory at Savannah, Ga.

A large sugar refinery was completed during the past year at Savannah, Ga. This made it necessary to establish a customs laboratory at that port for the purpose of collecting the revenue on sugar. The Bureau was requested to supervise the equipment and installation of this laboratory, which it did satisfactorily.

Supervision of the Customs Laboratories of the Treasury Department.

The work of supervising the operation of the customs sugar laboratories has been continued with gratifying results. It was found necessary to modify the existing regulations owing to abnormal sugar importations, and as far as data are available, this has apparently been accomplished with no diminution in the accuracy of the tests. The port of Savannah has been added to the list of those ports sending samples daily to the Bureau for check analysis. The work of assisting the Treasury Department in improving the equipment, personnel, and efficiency of its general customs laboratories is progressing very satisfactorily.

Color Standards Investigation.

For several years past urgent demands for advice and assistance in measuring and specifying the colors of light sources and materials have been made on the Bureau by various industrial and commercial interests. To enable the Bureau to develop methods and instruments to meet these needs, Congress made a special appropriation for the fiscal year ended June 30, 1917. Some of the fundamental work necessary in this investigation has been initiated and is in progress.

While some of the tasks comprehended in this investigation may be said to be completed or nearly so, the investigation is of such nature and magnitude that it must be continued several years before a general definitive report can be made. Besides undertaking the fundamental research problems in this investigation, a great deal of time and attention has been given (1) to the technical application of colorimetry and spectrophotometry to specific problems in industry, (2) to routine colorimetric testing by methods already established, and (3) to furnishing, on request, information and advice in regard to color measurements and color standards. In fact the aggregate attention necessarily given day by day to specific tasks and current correspondence of this kind is so great as to impede very much the progress on the main investigation and delay its completion. The instruments and methods used in this work are also applicable to certain military and naval problems; and in the present emergency these resources of the Bureau are being utilized, even though it involves delay in carrying out the fundamental work of the color standards investigation as originally planned. Some features of the colorimetric work are reported upon in the following paragraphs.

Testing, Extension, and Improvement of Spectrophotometric Methods.

The physical basis of color specification is spectrophotometry. By this is meant the measurement of photometric intensities as a series of points through the spectrum. For example, suppose a yellow glass is to be tested; qualitative examination by means of a spectroscope will show that it transmits red, yellow, and orange light quite freely, while transmitting less green and little or no blue and violet. The function of spectrophotometry is to determine quantitatively the transmission (ratio of light transmitted to light falling on the glass) for each kind of colored light separately. Now each kind of colored light in the spectrum can be specified definitely by its wave length; and the result of such a test is a curve showing the relation of transmission to wave length. Such a curve determined with accuracy by reliable methods constitutes a unique specification of the color of the sample.

As mentioned in the report for last year, there was need of improving the methods for these determinations, particularly in the blue. This work has been undertaken as planned, and the spectrophotometric methods in use at the Bureau have been further tested and checked. Test specimens of various colors of glass have been carefully prepared and measured on one instrument (König-Martens spectrophotometer) at the Bureau. Through the courtesy of the

physics department of Cornell University, these same specimens have been again measured by a representative of the Bureau on an instrument of another type (Lummer-Brodhun) at Cornell and their transmissions for blue, violet, and ultra-violet also determined by a photographic method (Hilger sector apparatus). This procedure makes possible the detection of small errors and gives much more confidence in final results. Such counterchecking of results will be continued and elaborated. Apparatus is being installed for spectrophotometry by another independent method using the photo-electric effect.

Fundamental Data Needed for Reference in Colorimetry.

The establishment of color standards and standard methods of color specification will require the compilation, systematization, and publication of a great deal of data and information, some of which is now available in the literature, and some of which will have to be obtained experimentally. It is planned to publish a circular and other special papers on this subject as soon as such matter can be put in proper form.

A great deal of time has already been given to compiling, computing, tabulating, and plotting data so as to have it in form convenient for reference in colorimetric investigations and tests. Among the data so prepared in tabular and graphic form during this year are the following:

(1) *Spectral Distribution of Radiant Power in Various Light Sources.*—The color of a light source is determined by the relative amounts of radiant power of different wave lengths which it emits. Thus, if the power emitted by a source consists entirely of radiation of a single definite wave length, it will give rise to a saturated color sensation corresponding to that wave length. If it contains radiations of various wave lengths, the color will be determined by the relative amounts of radiant power of these different wave lengths. The sun and all incandescent solids (carbon particles in oil and gas flames, the filaments in electric lamps, etc.) emit radiation of all wave lengths over a wide range but in very different proportions for the different wave lengths. Thus, while all of these lights are approximately "white," some are very bluish relative to others. It is of fundamental importance in colorimetric work to have available for ready reference curves showing the radiant power of various sources as a function of wave length (spectral distribution curves). Such data have accordingly been collected and plotted to a uniform standard scale. Also, the theoretical distribution of a perfect radiator at various temperatures, as given by the formulas of Wien and Planck, has been newly computed and plotted, using most recent data. The compilation of these data is of special interest because its consideration and discussion are necessary preliminaries to the definition of "white light," one of the first steps in the establishment of color standards.

(2) *Spectral Distribution Computed from the Rotatory Dispersion of Quartz.*—"Color screens" of known spectral transmission—that is, having a known transmission for light of each wave length in the visible spectrum—are of great importance in colorimetry. Colored glasses and dyed gelatine films are used to some extent for this

purpose, but they have the disadvantage that their spectral transmissions and, consequently, their colors are not readily adjustable at will nor conveniently and certainly reproducible. An optical system composed of a quartz plate between two nicol prisms may be used as a color screen, and the color is adjustable by varying the thickness of the quartz plate and the angle between the principal planes of the nicol prisms. The spectral transmission of such a system can be computed a priori with great precision, but such computations are exceedingly long and tedious. It has therefore seemed advisable to compute a great number of such curves for different constants and preserve them for ready reference. About 600 curves of this kind have now been computed and plotted.

(3) *Special Tables of the Trigonometric Functions Used in Photometry.*—In some photometric and colorimetric work the computations require frequent use of the square of the sine of an observed angle read in degrees and hundredths of a degree. There being no tables of this kind of sufficient accuracy available, a set has been computed as follows:

(*a*) 0° to 10° at intervals of 0°.02 to six decimal places.
(*b*) 10° to 80° at intervals of 0°.02 to four decimal places.
(*c*) 80° to 90° at intervals of 0°.1 to four decimal places.

The computation and copying of these tables has been carefully checked and photographic copies made for current use in the laboratory. They will possibly be published later. In the meantime a limited number of photographic copies may be supplied to those in need of such tables.

Less extensive tables of the fourth power of the sine and the square of the tangent have also been prepared.

Establishment of Working Standards of Color.

Although the ultimate terms of a color specification should be absolute without reference to material colored standards or particular apparatus, nevertheless, working standards are important and essential. Some of the working standards of color to which attention is being given are the following:

(1) *Light of Known Standard Color.*—For the time being, working standards of light of known color have been provided by empirically color matching (by voltage adjustment) a number of vacuum tungsten lamps with a standard acetylene flame of previously known spectral distribution. These lamps have been numbered and marked and are preserved as the laboratory working standards for light of this color.

(2) "*Artificial Daylight.*"—Another necessary working standard is "artificial daylight." There are on the market several combinations of lamps and colored glasses intended to give "artificial daylight." These have been developed by different experts on the basis of somewhat different definitions of "daylight." It is important that these be intercompared and that a standard "artificial daylight" be adopted. An investigation of these "artificial daylights" is now in progress at the Bureau.

An original method of producing "artificial daylight" has also been devised at the Bureau and developed theoretically and experimentally. It has been found by theoretical computations that the

spectral distribution of daylight can be approximately matched by light from an artificial source modified by transmission through a quartz plate between nicol prisms. The constants for such apparatus have been determined theoretically and the color match verified experimentally. A paper on this subject is in preparation for publication.

(3) *Colored Solutions.*—Various colored salts and other substances in solution have some value as working standards of color. It is important that substances used for this purpose have their spectral transmissions accurately determined. During the year the spectral transmissions of a number of such solutions, submitted to the Bureau and proposed as color standards, have been determined. A few other solutions have also been examined, and it is planned to extend this investigation to include as many as possible reproducible colored solutions of known purity and concentration. While there exist considerable previous data on this subject, they are largely qualitative or only crudely quantitative. The purpose of the present investigation is to obtain quantitative data of the highest possible accuracy.

(4) *Colored glasses.*—Colored glasses are also important as working standards of color. An extensive collection of colored glasses of standard manufacture is being made. The specimens are carefully prepared, marked, and filed in a systematic way. Their spectral transmissions are also being carefully determined by different methods and filed so as to be available for ready reference. It is intended to continually extend and augment this collection of glasses and data.

Design and Construction of Colorimetric Apparatus.

The design and construction of new instruments and apparatus are important features of the color standards investigation. The construction of the variation of thickness color comparator, mentioned in the report of last year, has been completed in the instrument shop of the Bureau, and the instrument has been installed and adjusted in the laboratory. The construction of a new trichromatic colorimeter is in progress.

Specific Technical Applications of Colorimetric Methods.—The end and purpose of the color standards investigation is to provide standard methods and apparatus needed to make color specifications possible in science, industry, and trade. The following are the important specific problems to which attention has been given this year.

1. *Specification of the Saturation of Yellow Tints in Butter and Oleomargarine.*—Frequent and persistent demands have been made on the Bureau to draft a form of specification which would be suitable to define rigorously in law a limiting value of what, in common parlance, may be called the "color," the "depth of color," the "strength of color" or the "yellowness" of butter and oleomargarine. In compliance with this demand, methods have been developed and definitely formulated, and a report on this subject has been published. (See Technologic Paper No. 92.)

2. *The Photometry of Lights of Different Colors and the Specifications of Their Colors.*—The determination of the relative candlepowers of lights of different colors is one of the most difficult problems of photometry, while the convenient specification of the color

of a light is the fundamental problem of color specification. A method which greatly facilitates the solution of both of these problems has been developed and tested. Reports upon this method have been made to the American Physical Society, December, 1916, and April, 1917, and published in the proceedings of those meetings in the Physical Review.

3. *Examination of Glasses Intended to Protect the Eyes from Harmful Radiation.*—There are on the market a number of glasses recommended to protect the eyes. At the request of the American Medical Association, the Bureau has undertaken to determine the spectral transmissions of a considerable number of these glasses. A great deal of this work has been done and a report will probably be published during the coming year.

4. *Color Grading of Cottonseed Oil.*—The investigation of the color of cottonseed oil has been continued, but has been delayed owing to the impossibility of securing certain needed apparatus. The effect of temperature on the rate of fading of the oil has been studied. It is found that the color fades, even in vacuum-sealed cells, somewhat more rapidly at temperatures from about 20° to 35° C. than below this temperature.

5. *Transparency of Paper and Tracing Cloth.*—To meet the demands of purchasers and manufacturers, a standard method for grading the transparency of paper and tracing cloth has been formulated and published. (See Circular No. 63.)

Information Furnished on Color and Color Specifications.

Information relative to color, color specifications, and related topics has been given to many applicants, both in personal conference and by correspondence. Among those to whom such information was furnished are the following: Refiners of oils, railway officials, architects, teachers of art, packing companies, textile manufacturers, paper manufacturers, manufacturers of optical apparatus, chemists, physicians, and the following departments and bureaus of the Government: Bureau of Chemistry, Navy Department, Bureau of the Census, Bureau of Lighthouses, Interstate Commerce Commission, Bureau of Entomology, and other branches of the service.

Tests of Color, Spectral Transmission, and Transparency.

A considerable number of tests of color, spectral transmission, and transparency have been made during the past year for the Navy Department, the Post Office Department, the Department of Agriculture, and other branches of the Government service, as well as for a number of industrial concerns and other interests.

Turbidimetry.

Turbidimetry is the quantitative measurement of turbidity. A medium is made turbid by the presence of minute particles in suspension, which scatter light in all directions. The quantity of scattered light can be taken as a measure of turbidity. A turbidimeter based upon this principle has been designed and constructed by the Bureau. With it every liquid examined, even the purest doubly distilled water, has been found turbid. The turbidity of relatively clean air is quite appreciable. The instrument measures a definite optical quantity, namely, the fraction of the incident light scattered by the turbid medium in a particular direction. This is the simplest quantitative

meaning that can be attached to the word turbidity used in an optical sense. The turbidimeter can, therefore, be used to define a new standard of turbidity.

The turbidity standard used in water analysis, as a guide to the efficiency of the filtration of municipal water supplies, has long been unsatisfactory. The Bureau has requested samples of standard turbidity from water laboratories representing the State and city boards of health. These have been received and are now being intercompared. The results will show the variation in the standard now in use, and will give the relation between the present and the proposed new standard. The Bureau will then be in a position to furnish a uniform standard of turbidity to the entire country.

Interference Methods for Measuring Thermal Expansion.

The apparatus, using the interference of light waves to measure thermal expansion, has been thoroughly tested and found to work satisfactorily. The expansion coefficients of several different makes of chemical glassware have been determined, the purpose being to find the relation of thermal expansion to breakage on sudden change of temperature.

The investigation of a new method for measuring the expansion of very small samples has been completed. The advantages of this method consist (1) of the smallness of the sample required; (2) the elimination of the difficulty of obtaining the interference fringe data, it not being necessary to count the passage of fringes during the temperature change nor to make measurements on fringes of more than one wave length; and (3) the very troublesome correction for change in the refractive index of air with temperature is eliminated. The results of this study were communicated to the Philosophical Society of Washington, and it is expected that a full description of this method will appear later as a scientific paper of the Bureau.

A method for determining the difference in expansion of these samples from the same specimen simultaneously has been devised and tested. It has been successfully applied in testing the relative expansions of various parts of rails in connection with the Bureau's investigation of the cause of failure of rails. This investigation is being continued.

Investigation of the Performance of American-Made Photographic and Projection Lenses.

An investigation was started on the relative performance of American-made photographic and projection lenses. European-made lenses have been very popular in this country, as they were supposed to be of the highest type of perfection. Very little is known of American-made lenses, as no comparative data have ever been published. A survey of American lenses would show where they could be used to best advantage. Several lenses were examined and measured, but it was considered impracticable to continue this work for the present, due to the difficulties under which the lenses have to be manufactured and the scarcity of good raw material.

Telephoto Lenses and Distance Photography.

Several types of lenses and cameras are being investigated in connection with their proposed utilization for photographing at great

distances. Certain data, such as the appearance of the rocks on an inaccessible mountain peak, become possible only when they can be photographed from an accessible point. One type of camera was developed which gave very good results in the laboratory. It will be further tried out under actual working conditions. Other types of lenses show very good promise and will be given further trial.

Development of Optical Systems.

The constants of some telescopes for use by the Navy Department were measured, and further work will be carried on to adapt the design to American-made optical glass. The different types of glass required for the Navy were reduced to four well-defined types. The standardization of the types of glasses used and of the types of telescopes will make possible production in the required quantity in the shortest time.

Testing of Optical Systems.

The Bureau has received a great many binoculars and telescopic instruments, both from the Navy and Army and from manufacturers with a view to improving the output. Especially has the amount of light let through been interesting. The early part of the European war forced the manufacturers to use inferior opaque glasses, thus producing binoculars with very low light transmission. Many tests were performed, and during the last year an improvement of over 50 per cent has been noticed. The field, resolving power, and general definition were well up to the standard.

Refractive Indices.

The amount which a ray of light is deviated in passing into a piece of glass is known as the refractive index. The refractive index changes with the wave length of light used, this change being known as the dispersion. These two constants determine the type of optical glass and the uses to which it is put. The manufacture of glass in this country has made measurements of this type very important, and a great many tests have been carried out for opticians and optical manufacturers. These constants are also very important in those industries where oils and liquids are used, where it is necessary to test the purity of these substances. Several tests were performed on oils at the request of manufacturing companies.

Information Furnished on Optical Systems and Optical Glass.

A great many inquiries have been received and answered regarding the adaptability and the practicability of optical instruments. Much time has been spent with the Navy Department in drawing up suitable specifications for various kinds of optical glass and optical instruments.

Many samples of optical glass have been tested for strain, striæ, refractive index, and transparency, to obtain an idea of the progress being made in their manufacture. The results are very gratifying.

The methods of testing optical glass for strain and striæ and the method for measuring the transparency of glass were requested by several manufacturers, so that they could be in a position to gauge their own progress. These methods are being fully developed in

order to make them commercially more practicable, and will be published in a circular as soon as completed.

Optical Constants of Chemical Glassware.

In connection with the determination of the types of glassware in this country for chemical purposes, the strain has already been determined. An attempt was made to correlate the heat resistivity and physical strength with the strain and the refractive index of the glass, but it has been found very difficult, as composition and expansion of the glass and the thickness of the vessel play a very important part.

Radiometry.

Various investigations have been continued in the general subject of radiometry, including the improvement of instruments for measuring radiant energy.

The application of the photoelectric cell as a precision instrument in radiometry was investigated. Several potassium photoelectric cells, made by Kunz, were compared with a bismuth-silver thermopile by determining the transmission of colored glasses in the blue and violet. This type of radiometer is not so easily affected by thermal disturbances as is a thermopile, and is therefore well adapted for certain special investigations.

A high resistance iron-clad Thomson galvanometer was constructed to replace the electrometer in photoelectric work. The device is from 35 to 40 times as sensitive as a low resistance galvanometer and a sensitivity of $i=1\times10^{-12}$ ampere is easily attained on a three to four seconds swing. This galvanometer combined with a photoelectric cell is especially adapted for transmission and reflection measurements in the part of the spectrum extending from the blue into the ultra-violet.

A determination of the energy distribution in the visible spectrum of several gas-filled tungsten lamps, to be used as color standards, required considerable investigational work.

Constants of Radiation of a Uniformly Heated Inclosure.

During the past year several investigations have been made of subsidiary problems connected with a further determination of the constants of radiation of a black body. An absolute thermopile for measuring the constant of total radiation in a vacuum was constructed and tested, as well as a vacuum-linear thermopile. The circle of the spectro-radiometer and its reading microscopes were modified and calibrated. New tungsten lamps were prepared for the optical pyrometer mentioned in the report of last year.

Measurements were made to determine the absorption of a 50-centimeter column of dry air, and of air containing water vapor, to determine whether there is a correction to the constant of total radiation data previously published. The results obtained indicate no correction when using air which is free from water vapor. The corrections to the observed data for losses by reflection from the radiometer receiver were recomputed and the value of the coefficient of total radiation was found to be the same as previously reported. These data are of importance in determining the scale of temperature at

high temperatures, and they are of interest in view of their intimate relation with the fundamental physical constants.

Visibility of Radiation of the Average Eye.

It is important to know how the eye responds to lights of different colors but of the same energy value. During the past year the investigation of the relative sensibility of the average eye to light of different colors was completed. The visibility of radiation of 130 subjects was determined, and various applications were made of these data to problems in radiometry.

A solution of salts was prepared which has a transmission curve coinciding very closely with the visibility curve of the average eye. Using a cell containing this solution, interposed between a thermopile and a source of light, further tests were made of this combination as a physical photometer. Using these visibility data, computation shows that the eye is so sensitive that the minimum perceptible light is probably less than one billionth erg.

Mechanical Equivalent of Light.

A mathematical equation was obtained of the above-mentioned visibility curve of the average eye. This equation was combined with Planck's equation of spectral radiation of a black body. Using the radiation constants of a black body and its brightness at various temperatures, it was possible to obtain the luminous equivalent of radiation or the so-called mechanical equivalent of light.

Independent checks of this constant were obtained by measurements upon an incandescent lamp of known candlepower, using the physical photometer mentioned in the preceding section. The data obtained by various methods indicate that the mechanical equivalent of light is of the order of 1 lumen=0.0016 watt of luminous flux of maximum visibility, or 1 watt=49 candles.

These data are of use in various physical problems and will have an important practical application should the time arrive when "light" is purchased as radiant power, just as electrical energy is purchased at the present day.

Emissive Properties of Tungsten.

The emissive properties of tungsten were investigated by two methods. One investigation consisted in the determination of the selective reflection of plane, highly polished mirrors of tungsten in the visible and in the infra-red spectrum. A depression was found at 0.8 in the reflectivity curve, which is the cause of a marked selective emission band found in incandescent tungsten.

The second investigation was on the selective emission of straight and helical filaments of tungsten, in which it was shown that the increased brightness within the helix is due almost entirely to multiple reflection. The most important deduction is that the radiation from within the helix is not sufficiently close to that of a uniformly heated inclosure to be used in the calibration of pyrometers.

Glasses for Protecting the Eyes from Injurious Radiations.

Attention has been called in previous reports to the importance of this subject, and during the past year data were published on the protective properties of typical glasses.

It will no doubt be understood that radiometry is the logical basis upon which to specify what constitutes ample protection from injurious radiations, whether ultra-violet or infra-red. At present information is quite lacking concerning the energy density and time of exposure necessary to produce injurious effects upon the eye.

Photoelectric Properties of Various Substances.

Conditions have arisen which make it desirable to determine the photoelectric sensitivity of substances in different parts of the spectrum, the energy measurements being made with a thermopile, which is a nonselective radiometer. Such an investigation is in progress and the results seem very promising.

Information Furnished on Radiometric Subjects.

In addition to experimental work, considerable information has been given in compliance with specific requests for information on radiometric matters, such, for example, as the radiative properties of materials suitable for covering radiators; the reflective properties of metals; Patent Office inquiries; standard sources of light; the effect of the heat of the moon upon plant life; thermal-radiodynamic signaling devices; selenium cells; the design of greenhouses to be maintained at a uniform temperature; and the application of radiometric methods to physiological and psychological problems.

Publications on Radiometry.

During the past year the following papers on radiometry were published: Technologic Paper No. 93, Glasses for Protecting the Eyes from Injurious Radiations; Scientific Paper No. 300, Emission of Straight and Helical Filaments of Tungsten; Scientific Paper No. 303, Relative Sensibility of the Average Eye to Light of Different Colors and Some Practical Applications to Radiation Problems; Scientific Paper No. 305, Luminous Radiation from a Black Body and the Mechanical Equivalent of Light; and Scientific Paper No. 308, Reflecting Power of Tungsten and Stellite. Experimental data were furnished for Scientific Paper No. 304, Calculation of the Constants of Planck's Radiation Equation: An Extension of the Theory of Least Squares.

5. CHEMISTRY.

[Chemical composition and purity of material, chemical properties and constants, including researches upon methods of analysis, specifications for technical materials, and preparation of pure materials for standardization work for the Government and for industrial and scientific laboratories.]

Rapid Electrolytic Determination of Carbon in Steel.

The method developed for the rapid estimation of carbon in steel, referred to in the report for last year, has been improved and the results will soon be described in a forthcoming paper. The method is extremely rapid and seems to be well adapted for control work in steel plants; at the same time its accuracy is high. The carbon dioxide formed by burning the steel in oxygen is collected in a solution of barium hydroxide of known strength and conductivity. The resultant decrease in conductivity of the solution is a measure of the carbon burned.

Nitrogen in Steel.

A direct method for determining gaseous nitrogen in steel has been devised and experimentally tested. The nitrogen (which may be admixed with any other gas or vapor that is free from nitrogen) is brought in contact with vapor of metallic calcium in a suitable apparatus and under reduced pressure. The nitrogen is immediately absorbed by the calcium as nitride. When this is dissolved in hydrochloric acid ammonium chloride is formed, and in this the nitrogen is determined by the usual methods. Experimental tests on synthetic mixtures were very satisfactory.

The Goeren's Method for Determining the Gas Content of Steels.

The Goeren's method for determining the gas content of steels depends upon melting the steel mixed with metals which lower its melting point to a convenient working temperature, in an evacuated tube, and analyzing the gases evolved.

Much progress has been made in constructing the complicated apparatus required by this method, and when assembled the method will be given a thorough trial.

Determination of Gases in Steel by the Goutal Method.

In pursuance of a plan to investigate sources of error in present methods for determining gases in steel and to originate new methods, if needed, the Goutal method was made the subject of study. This method consists in dissolving the steel in a solution of copper-potassium chloride in an apparatus which permits the gases given off during solution to be absorbed. Contrary to Goutal's conclusions, it has been found that the gas content thus obtained is an entirely fictitious one so far as concerns carbon monoxide and carbon dioxide, since these gases are generated by the oxidizing action of the cupric salt on the carbides present and there is, therefore, no relation between the observed percentage of these gases and the amounts actually present in the metal. A paper on this subject is in course of preparation.

Determination of Oxygen in Steel.

A study of the Ledebur method for determining oxygen in steel has been completed and a paper on the subject is in preparation. This paper will contain results of tests for oxygen in a number of steels and irons by the Ledebur method, with special precautions to avoid all known or suspected sources of error.

Oxygen Content of Steels Deoxidizable in Various Ways.

The improved Ledebur method referred to in the preceding section is being used to examine for oxygen content several heats of steel made (1) by ordinary commercial methods and (2) by variations of commercial practice with regard to deoxidation methods. The results of this investigation will be embodied in a paper.

Ladle Ingot Test Investigation.

The work begun a year ago on ladle ingots has been continued and four sets of ladle test ingots made in molds typical of American practice have been cast under uniform conditions of customary prac-

tice at two steel plants. Two sets were of "rising" steel and two of "nonrising" steel. To the former aluminum was added in the mold at the time of pouring and the effect was to produce physically sound steel. All these ingots are being examined metallographically and later will be tested chemically for segregation.

Preparation of Iron-Carbon Alloys.

The general problems relating to the preparation of alloys of iron and carbon and the development of new alloy steels are discussed in the report of the metallurgical division. These problems involve much cooperation in research and testing on the part of the chemistry division.

Platinum Investigation.

It has been impossible to take up the extended research upon the chemical and physical properties of the platinum metals which was referred to in the report of last year, but provision has been made for beginning it during the coming year unless the exigencies of the war situation should make it expedient to postpone the work still further.

Several substitutes to replace platinum ware for chemical and physical uses have been proposed, and one of these has been submitted at the Bureau to a series of tests which show it to compare very favorably with platinum for most chemical uses. This is an alloy of 80 parts gold and 20 parts palladium. Alloys of quite different composition which have been submitted for test or soon will be submitted may prove suitable for use in other ways but are not likely to find extended use by chemists.

The New York assay office, continuing its cooperation of the past year, has made for the Bureau over 20 crucibles and a few miscellaneous articles of platinum which have given satisfaction. It is hoped that the Government laboratories generally will soon be able to draw their supplies from this source.

Variation of Commercial Gases from Boyle's Law.

The variation of natural gas from Boyle's law is of sufficient importance to introduce important differences in the apparent volume of gases measured at high pressure, as, for example, in connection with orifice meters, proportional meters, and other commercial metering equipment. At the suggestion of the Bureau, a means for taking account of this variation has been tried out in practice by certain natural-gas engineers and considerable success is anticipated in the further application of this method for correcting for the variation in compressibility of the gas from the theoretical values.

Specific Gravity of Gases.

The work reported a year ago on the specific gravity of gases has been continued and the specific gravity balance devised at the Bureau has been given field trials and certain improvements indicated as desirable have been made. The perfected apparatus has been constructed for use by a considerable number of natural-gas companies, and these are employing it regularly in their laboratories. Arrangements have been made for marketing this balance by one of the makers of physical-chemical apparatus, and the number of requests

for information on the subject indicates that wide application of the instrument is to be expected. The full investigation and its results are reported in Technologic Paper No. 89, A Specific Gravity Balance for Gases.

The closely related work on the effusion method for specific gravity determination has also been carried to a very successful conclusion and a report on this work has been made in Technologic Paper No. 94, Effusion Method for Gas Density. The theoretical aspects of this work have been developed in cooperation with one of the other divisions of the Bureau and a paper covering the conclusions is practically completed. This theoretical consideration of the subject has demonstrated the relation between the various properties of a gas and its apparent specific gravity as determined by the effusion method with apparatus of different characteristics. A most interesting theoretical development is that the effusion phenomenon is one of stream-line flow and not a molecular phenomenon as ordinarily believed.

Preparation and Properties of Hydrogen.

Additional determinations of the heat of combustion of pure hydrogen have been made, but until the heat division of the Bureau can give more time to this subject, little progress can be made in the preparation and the study of the properties of pure gases. It is inadvisable to begin work on carbon monoxide and carbon dioxide until the work on hydrogen has progressed further.

Balloon Gas Investigation.

At the request of the Signal Corps and of the Navy Department the Bureau is investigating methods for the generation of hydrogen, making certain tests of the materials from which this gas will be generated and cooperating in the drafting of instructions for the personnel which will operate and maintain the field and service equipment. This work will include study of hydrogen generation and compression and the filling of balloons, both to prevent explosions and to maintain the highest operating efficiency feasible under service conditions.

Combustion Gas Detectors.

An important research, in cooperation with one of the other divisions of the Bureau, on detectors for combustible gases has led to results of importance. Four types of detectors have been perfected which are suitable for various locations and uses. The type recommended to the Navy Department for use on submarines has proven so satisfactory in tests at the Bureau and the Brooklyn Navy Yard that it has been adopted for use on certain vessels. A report on this subject has been requested by and made to the naval authorities of Great Britain and Italy on the types of detectors specially recommended for naval use.

The question of the application of these devices for the detection and determination of carbon monoxide in the air has also been considered, but it is doubtful if the practical apparatus for use outside the laboratory can be made sufficiently sensitive to detect less than 0.1 per cent of carbon monoxide, which is the maximum quantity

that is considered safe to permit in the atmosphere where persons are working.

Chemical Work on Balloon Fabrics.

At the request of certain branches of the Navy and War Departments, the Bureau undertook to make tests on the permeability of fabrics for balloon construction to hydrogen and other balloon gases. This work indicated at once the need for more precise information than was available as to methods of permeability determination, the significance of these tests, and for other work on balloon fabrics. As an outgrowth of this testing the Bureau has undertaken an extended investigation of testing methods, life test on fabrics, and the improvement of fabrics in order to increase their life or to improve them in certain characteristics.

As a result of this work there has been developed a tentative specification for characterization of fabrics, covering permeability, weight, and strength, and including methods for performance of tests to determine compliance with these specifications. These will supersede other specifications that contained certain requirements which seemed impossible of interpretation or were meaningless and will probably make possible more satisfactory relations between the Government and the makers of these fabrics. The tests on permeability are almost completed, so that it is now possible to define with considerable accuracy the relation between tests under one set of conditions and those under another set and to eliminate the uncertainty in the significance of these test results.

The exposure test planned to determine the life of fabrics includes heating, exposure to light and radiation, exposure to weather, and comparison with actual service tests of the fabric in aircraft. The test involves experiments on glues and protective coatings for both balloons and other aircraft. The cooperation of manufacturers, the Signal Corps of the Army, and the Navy Department in this work will make the results of wide interest and value.

Chemical Work on Refrigeration Problems.

The work on refrigeration problems has made satisfactory progress and will be continued the coming year unless interrupted by more urgent demands in other directions. This work has involved the preparation and testing of pure materials and the study of gas formation in ammonia refrigeration systems. Specifications for anhydrous liquid ammonia have been prepared, and a report has been made on methods of testing and the composition of commercial samples.

Chemical Work on the Standard Cell.

The standard-cell work has developed in such a way that it has been possible to furnish practical results in the construction of standard cells, which are necessary and very difficult to obtain in the market.

A series of Clark (zinc) cells was prepared in August, 1916, which show great constancy. They were set up with the special object of avoiding gas formation and the cracking of the amalgam limb. A paper on the subject is now in preparation.

A considerable number of unsaturated cadmium cells have been prepared for the purpose of meeting the public demand, in view of the inability of manufacturers to supply them under present conditions. Such cells are quite necessary in work depending on high-temperature measurements and are essential in the prosecution of certain phases of war work. The results accumulated will form the basis for several papers.

Electrotyping and Electroplating Investigation.

Largely as a result of the work conducted by the Bureau upon the use of American ozokerite, there has been placed upon the market molding wax which appears to be satisfactory for electrotyping. This has not yet, however, come into extensive use, owing in part to the difficulty of adapting any one mixture to the variable conditions existing in different establishments.

During the year some progress has been made in cooperation with the electrical division upon the study of the conductivity of copper solutions. The results indicate, however, that there is a need for an extended and fundamental investigation of the methods of determining the conductivity of such solutions.

It is hoped to make more rapid progress upon some of the specific electrotyping problems during the next year through the cooperation of the International Association of Electrotypers, who have agreed to pay the salary and traveling expenses of a chemist to work upon their problems at and under the direction of the Bureau.

No definite progress has been made in the general study of electroplating problems. Numerous requests for information and for tests have come from the public and from Government departments. One of the most pressing needs in this industry appears to be the formulation of specifications for various kinds of plating, based upon chemical and metallographic examination, and possibly upon accelerated corrosion tests, such as, for example, the "salt spray test." In most cases, however, intelligent formulation of such specifications will involve a more or less detailed study in plant and laboratory of the conditions affecting the properties of the deposits.

In order to make such investigations at the Bureau on a semi-commercial scale, a plating laboratory is now being installed, provided with a 3-kilowatt generator and a number of small stoneware tanks. As the work progresses it will be necessary to increase this equipment to include apparatus for cleaning the articles and for polishing the deposits, etc.

With the present staff assigned to this work, it will probably be possible to study the above and any other plating problems of military importance likely to be referred to this Bureau. Rapid progress upon the more general and fundamental problems of electroplating will, however, require additional assistance.

Renewal of Work on Various Analytical Problems.

Arrangements have been made to renew the work on various analytical problems undertaken some time ago but discontinued because of press of work in other fields. Among such problems are the study of volumetric standards, the analysis of phosphate rock, and the study of the quality of reagents. The latter subject is now

so urgent that the American Chemical Society has taken steps to secure the active assistance of the Bureau in this work. It is recognized that with the limited force available under present abnormal conditions it will not be possible to make very rapid progress on these problems.

Paint and Varnish Investigations.

A number of investigations on paints and varnishes have been conducted during the past year in cooperation with a committee of the American Society for Testing Materials, some of which are the practical testing of varnish; a study of unusual drying oils (Lumbang and Perilla); a determination of foots in linseed oil; a determination of the flash points of paint thinners; specifications for paint pigments; the preparation of standard methods of analysis of paint materials; and others.

A large number of service tests of paint and varnish was made for the federal General Supply Committee.

A convenient color scale of varnishes has been devised by making use of solutions in strong sulphuric acid of varying amounts of potassium bichromate.

A circular of information on paint and varnish, giving descriptions of raw materials, methods of manufacture, and methods of application of paint and varnish has been prepared for publication.

A satisfactory formula has been evolved for a paint that should be extremely white, dry flat, and adhere to cement, wood, or cloth surfaces.

An important line of work that should be taken up is that of field tests. This comprises the systematic study of various paint materials by inspections of painting operations on large scales in various localities, and of occasional check panels of similar materials made at the Bureau.

Nonferrous Alloys and Coated Materials.

The major part of the work on nonferrous alloys and coated materials has been confined to routine testing of material for the Panama Canal and the Supervising Architect of the Treasury Department.

More or less research was involved in the following items: Study of the efficiency of the Parker Rust Proof Process to prevent corrosion of iron and steel; work on metal lathing in connection with the Bureau's stucco investigation; testing of fusible boiler plugs; examination of a failed fuse box cover from a locomotive in the Canal Zone; analysis of copper for an industrial concern; analysis of copper cable for the Argentine Naval Commission, and a determination of the zinc coating on galvanized wires. Of three methods used in connection with the last problem, namely, the antimony-hydrochloric acid method, the lead acetate method, and stripping in dilute sulphuric acid with correction for iron dissolved, it appears that the second and third yield results that are in fairly close agreement, while the first gives results which are too high.

A comparative corrosion test on brass and monel metal confirms commercial experience that the monel metal ordinarily gives better satisfaction.

At the request of the War Department, tests were made to determine the comparative durability of certain sherardized and electrogalvanized steel castings. Samples prepared by four companies were tested by the "salt spray" method. The tests showed the electrogalvanized samples to be superior to those that were sherardized.

Bituminous Materials.

The work on bituminous materials has developed materially. The number of samples has increased and those of new type are being submitted which require the development of special methods of testing.

About 400 samples of the important brands of roofing and waterproofing felts from about 40 manufacturers have been received and filed for reference, both as an aid in identifying these materials and to enable the Bureau to keep in touch with what is to be found on the market. The samples will also prove of value in passing on prepared roofings to be used on the various cantonment buildings recently constructed or under construction. The office of the Quartermaster General, United States Army, requests that the Bureau should be familiar with all of these materials. After these roofings have been in place a year or two they will be inspected, and it is believed that much valuable information will be gained.

Samples of authentic tars from various sources have been obtained from which it is proposed to distill creosote oils. These oils will then be studied as authentic oils to serve in grading oils that are received for test. It is also planned to ascertain whether or not the Forest Service method of distillation produces an undue amount of "cracking" of the oil.

Arrangements have been made to study a number of samples of "ship's insulating felt," known commercially as "Irish felt," with the object of developing a satisfactory specification.

The melting point of asphalt has been the object of some study and the ring and ball method of determining it, since adopted as standard by the American Society for Testing Materials, has been submitted for the cube method in an air bath.

A representative of the Bureau visited the asphalt lakes in Trinidad and those in Bermudez State, Venezuela, and gathered much information that will be of value in testing the asphalts from these sources. The same representative returned by way of the Canal Zone, where materials in service which the Bureau had tested were inspected. The information so gained is of great value in determining the fitness of materials for this climate and for the uses to which they are put.

Chemical Work on Cement.

In addition to the regular routine work on cements, limes, and plasters, much work has been done in cooperation with the cement division in investigations of the chemical changes occurring in mortar and concrete when exposed to sea water, "alkali" waters, and under abnormal conditions. Further cooperative work is planned on the problem of drain tile disintegration in other than "alkali" waters. A number of concrete floor-hardeners were examined for the cement division preliminary to a more extended study of the use and utility of such materials.

Chemical Tests of Lubricants.

The demand for tests of lubricants has been so very great during the past year that it has been impossible to take up the contemplated study of certain problems along this line. Cooperative work with the American Society for Testing Materials has continued in this direction.

Chemical Work on Leather.

For some time physical tests of leather have been made at the Bureau and the need for chemical control has become evident. The chemical division is now engaged on this work and, in addition, the National Tanners Association is cooperating with the Bureau on the subject. A rapid and sufficiently accurate method for determining the specific gravity of leather has already been devised.

Chemical Analysis of Rubber.

The method devised at the Bureau, referred to in a previous report, for the direct determination of rubber by combustion of the nitrosite involved many difficulties, even when compounds containing new rubber were analyzed. These difficulties have been overcome and it is now possible to obtain correct results even when reclaimed rubber and lampblack are mixed with new rubber. A paper describing the method is now in preparation.

The factors which influence the determination of rubber and an accelerated aging test are under investigation and have yielded preliminary results of promise.

The Bureau has assisted in the work of the Joint Rubber Insulation Committee and its method for the determination of total sulphur in rubber has been adopted by the committee as an alternative procedure.

Chemical Work on Paper.

Hydrocellulose, in powdered form, prepared from waste parchment paper, has been purchased and used as a filler instead of the clay and other mineral matter commonly used. Samples of paper made at the Bureau were tested in a wet plate press and gave excellent results.

A form of colloidal cellulose, not described in the literature, has been prepared. It is hoped to use it as a sizing for paper.

Work has been started, and is still in progress, on paper containers to be used as substitutes for tin cans. A bulletin on this subject has been issued jointly with the Bureau of Foreign and Domestic Commerce.

There has been considerable demand for Technologic Paper No. 87, describing the method for recovering pulp and paraffin from scrap paraffin paper.

An investigation of the precipitation of rosin sizing, after considerable progress had been made, had to be dropped temporarily because of more urgent work.

Tests of Chemical Glassware and Procelain.

Comparative tests of a number of brands of domestic and foreign glassware and porcelain for chemical use have been made and the results will soon be published.

Standard Analyzed Samples.

Another great increase is shown in the demand for the Bureau's standard samples. The number called for during the fiscal year 1917 was 3,536, as against 2,697 in 1916, and 1,826 in 1915. The distribution was as follows: Irons and steels, 2,867; brass, 54; ores, 229; sodium oxalate, 139; naphthalene, 120; benzoic acid, 30; sucrose, 76; dextrose, 6; metals for melting points, 13; cement for testing sieves, 2. Six samples under the last two items are new and have been issued only during a part of the year. An Alabama iron sample is also new. Three steel samples have been renewed.

The rapid growth in the demand for the samples makes it increasingly difficult with the means at command, to replenish exhausted stock and to add to the list of samples. Hence, it happened more than once that considerable time intervened between the exhaustion and renewal of a sample. A special fund should be available for the purchase and preparation of materials, apparatus, and appliances.

Chemical Testing.

Somewhat over 9,000 tests were made in the chemical laboratories of the Bureau during the year. They involved the following materials: Ferrous metals (irons and steels), 319; coated metals, 832; nonferrous metals and alloys, 912; material from electrotyping baths, 27; cement materials, 1,205; coal tars, asphalts, and saturated felts, 984; burlap and building paper, 53; linseed oil, turpentine and driers, 562; varnish and shellac, 495; red lead, white lead, and putty, 371; paint materials, 407; greases, 109; soaps, 203; nondrying oils and metal polishes, 130; lubricating oils, 431; inks and ink materials, 368; flax packing, 17; asbestos, 60; paper, 761; rubber, 281; sealing wax, 11; wools and textile materials, 121; miscellaneous, 382; total, 9,041.

The above tests were made for about 80 Government bureaus and establishments, including, practically, all the executive departments, and for States, municipalities, and private parties, as follows: Agriculture, 19; Commerce, 1,380: Interior, 152; Labor, 20; Navy, 293; Post Office, 346; Treasury, 2,462; War, 350; Panama Canal, 2,574; Government Printing Office, 680; General Supply Committee, 423; other Federal institutions, committees, and commissions, 65; State, municipal and other institutions and committees, 150; and private parties, 126.

Miscellaneous Chemical Tests and Investigations.

Many miscellaneous tests of interest have been made upon a great variety of subjects and materials, in part as follows: "Glasso," a material intended to prevent clouding of wind shields and goggles by rain or mist; Columbian Spirits, recommended as superior to ethyl alcohol for analytical purposes, and found not to be as suitable for soap analysis as ethyl alcohol; "Safetch," a material said to be excellent for use on aluminum plates used in map printing; and similar preparations.

Chemical Publications.

The following papers, circulars, and addresses emanating from the chemistry division have been published during the year or are nearly ready for publication: Technologic Paper No. 87, Recovery

of Paraffin and Paper Stock from Waste Paraffin Paper; Technologic Paper No. 89, A Specific Gravity Balance for Gases; Technologic Paper No. 88, Studies on Paper Pulp; Technologic Paper No. 94, Effusion Method for Gas Density; "Our analytical chemistry and its future" (Chandler Foundation lecture, Columbia University); "Determination of gas density," to be published in a technical journal; "Calibration of the gas interferometer," to be published in a technical journal; "Gas investigations of the National Bureau of Standards"; proceedings of the Sixteenth Annual Convention of the Wisconsin Gas Association, March 13, 1917; "Reducing matter extractable from filter paper," Journal of the American Chemical Society, volume 39, page 928, 1917; Technologic Paper No. 98, The Effects of Heat on Celluloid and Similar Materials; "Composition and testing of commercial liquid ammonia," Journal of the Society of Refrigerating Engineers, volume 3, page 30, March, 1917; Circular No. 25 (revised), Standard Samples—General Information; Circular No. 62, Specifications for and Methods of Testing Soaps; and Circular No. 69, Paint and Varnish Materials.

New Chemistry Building.

Delays due to certain differences with the contractor for construction and inability to obtain certain materials for equipment and labor for installation made it impossible to occupy the new chemistry building early in 1917, as had been expected. The transfer of men and working equipment began in June and will be completed, it is hoped, before the end of July. The occupation is progressing under difficulties, for not all of the necessary piping and fittings are in place even now, but the transfer is rendered necessary by the pressing demands for the space now occupied by the chemistry force in four other buildings.

The additional emergency appropriation of $35,000 recently provided will probably permit the whole building to be fully equipped. However, the equipment installed thus far provides no more than for the present force of chemists, which is being rapidly increased to meet the needs of the war situation.

6. ENGINEERING RESEARCH AND TESTING.

[Operative efficiency of mechanical appliances, accuracy of engineering instruments, conditions affecting their effective use, e. g., structure and design as related to durability and efficiency; methods of standardization and test, standards of performance, and fundamental researches on the scientific principles involved in speedometers, pressure gauges, water-current meters, anemometers, tachometers, gasoline and other motors, propellers, and other airplane parts and materials, etc.]

Water-Current Meter Rating Stations.

One of the most important engineering services rendered by the Bureau is the furnishing of accurate calibration of current meters. These instruments are used by civil and hydraulic engineers in the measurement of the velocity of flowing water in rivers, irrigation canals, and other open channels, to secure data for the computation of the quantity of water discharged through such channels in a given time, data necessary in the development of the water resources of the country in power development, irrigation, flood prevention, and similar projects. To secure accuracy in these measurements, the instruments must be calibrated from time to time. A

body of still water must be available for this purpose, together with equipment for towing the instrument through the water at different uniform speeds and for accurately recording the observations.

Adequate installations of this character are costly and are necessarily confined almost entirely to Government stations and large university laboratories, which are not always available for this purpose. In the new rating station designed and constructed by the Bureau especially for this work, exceptional facilities are afforded for the calibration and study of these instruments. Since the entire flume was housed in a year ago, the station is in continuous operation throughout the year. While a majority of the ratings made are for the different engineering bureaus of the Government, this service is also performed for engineers in private practice, a rating curve and table being furnished for a nominal fee.

During the past fiscal year 277 current meter ratings were made. Of this number 203 were for the Government departments and 74 for engineers outside the Government service. The latter figure shows an increase of about 80 per cent over the number for the previous year. A number of special tests were also made, including tests of six meters of a new type for an instrument manufacturer, a special rating for the Canadian Geological Survey, and tests of meters for research work by Government bureaus.

Different Forms of Cable Suspension for Current Meters.

In making measurements of current velocity in deep streams, the current meter is suspended from a cable on a hanger, to which are also attached weights of a standard form to keep the cable in an approximately vertical alignment. The number and size of weights used vary for different conditions met in the field. At the request of the United States Geological Survey, an investigation was conducted of the deviations from the rating made with its standard form of cable support, produced by each of several arrangements of weights commonly used in the field differing from the ordinary standard in the size of weights and in their position on the usual strap hanger relative to the meter.

Factors were obtained by means of which the standard rating table can be used without a special rating of the meter for each particular case. The results of this investigation have been embodied in a circular issued to its field engineers by the Geological Survey. This investigation has been extended at the request of the Geological Survey to obtain similar data for new equipment which has recently been adopted for field use.

Depth of Submersion of Current Meters.

An investigation has been in progress to determine the effect of the depth of submersion on the rate of rotation of the small Price current meter. Tests have been made for depths of from two-tenths of a foot to 2 feet for velocities from one-half foot to 6 feet per second. This work has been practically completed. The results thus far obtained indicate that for the same velocity the rotation of the meter is in general increasingly retarded as the meter approaches the surface, but that this effect practically disappears at depths greater than 1 foot.

Fire-Extinguisher Investigations and Tests.

A report has been made to the Steamboat-Inspection Service, embodying the results of an examination and test of 75 different makes of hand fire extinguishers, in compliance with a request from that Bureau. Included in these different makes were extinguishers of the dry powder, soda and acid, and carbon tetrachloride types. The various devices submitted have been classified and the limitations and particular fields of service of each type have been outlined. Each extinguisher was tested from the standpoint of safety and reliability in operation and effectiveness as a first-aid fire appliance.

The Steamboat-Inspection Service has been furnished with data for use as a basis for the future approval of devices of this character used on vessels under its jurisdiction. As a result, a number of extinguishers which do not embody the most modern practice in the construction of these devices will not be included in the list of approved extinguishers. It was found, for example, that a large proportion of the small hand extinguishers which use extinguishing fluids consisting principally of carbon tetrachloride were, owing to their principle of operation or defects in their construction, unreliable and not suited for first-aid fire-extinguishing purposes.

The testing of extinguishers which have been submitted since the first report was made and the retest of those which have been modified since the first tests and resubmitted is still in progress.

A more extended investigation of several types of fire extinguishers with especial reference to their use on vessels has been planned for the coming year.

Advice has also been furnished to other Government bureaus in connection with the purchase of fire extinguishers.

Fire-Extinguishing Equipment for Wooden Submarine Chasers.

At the request of the Navy Department, the Bureau is investigating the subject of fire protection for the engine compartment of wooden submarine chasers. The unusual conditions to be met on board these small wooden vessels introduce a fire hazard requiring special fire-extinguishing equipment of the most reliable and efficient type. The problem is being studied in the light of all available data on the subject and experiments are being conducted to determine the kind of fire-extinguishing equipment that is best suited for the purpose.

Radiator Traps Used in Vacuum Heating Systems.

The testing of different makes of radiator return line valves, undertaken at the request of the Supervising Architect of the Treasury Department, has been continued. These valves are used in vacuum heating systems. One of these devices is installed at the outlet of each radiator in such a system, its function being to keep the radiator at maximum temperature by the continuous removal of the air and water of condensation, and to prevent the escape of uncondensed steam into the return pipe. The economical and satisfactory operation of a heating system of this character is largely dependent on the successful operation of these valves. Thousands of these devices are annually installed by the Treasury Department in public buildings under its control. Samples of the greater number of the many

valves of this character on the market have been tested. Data have been secured to determine a standard of performance for these devices and to enable the Government to select for its use the best valves available.

High-Pressure Gauges.

While inexpensive apparatus for the checking of pressure gauges for the measurement of the ordinary range of working pressures is available, the same is not true for pressures in excess of 1,000 pounds per square inch. During the past year, the Bureau has been called upon to calibrate 22 of these instruments designed for maximum pressures from 1,000 to 30,000 pounds per square inch. This service was performed principally for gauge manufacturers and munition makers.

Sounding Tubes.

A series of tests were made for the Coast Survey to secure data for establishing a scale for a new form of sounding tube being developed by that service.

Spirits Meter.

A series of tests were made for the Internal Revenue Service of a new type of meter for the measurement of distilled spirits to determine its suitability for customs purposes.

Patrol Lanterns for the United States Coast Guard Service.

Tests were made for the Treasury Department to determine the effect of high wind velocities on 12 different types of patrol lanterns for use by the Coast Guard service. The tests were conducted in the wind tunnel at the Washington Navy Yard, where it was possible to subject the lanterns to wind velocities up to 60 miles per hour.

Gasoline Intensifiers for Automobile Engines.

There are a number of materials on the market known as gasoline intensifiers, for which the claim is made that when added in small quantities to gasoline, an increased engine efficiency is secured. Six of these materials were tested with a six-cylinder automobile engine driving an electric absorption dynamometer, and a sample of gasoline alleged to be treated by a secret electrochemical process was tested in the same way. The apparatus used was very sensitive and capable of indicating small differences in power developed, but in no case was there any noticeable increase in power or efficiency of the engine when using the treated gasoline as compared with its performance when using straight gasoline under the same operating conditions.

Miscellaneous Tests of Instruments and Devices.

The routine tests of the engineering instrument section amounted to 439, including 277 current meters, 22 high-pressure gauges, 64 pressure and vacuum gauges, 10 anemometers, and 66 miscellaneous tests of instruments and devices, including tachometers, indicators, air pumps, fire extinguishers, valves, paper testers, speedometers, etc.

Cooperation with Scientific and Technical Societies.

The Bureau is cooperating with the National Fire Protection Association in developing standard requirements for the design and installation of automatic sprinkler equipments, including "dry pipe" systems which are used in buildings when the temperature falls below the freezing point of water, and chemical sprinkler systems in which liquids other than plain water are used as the extinguishing agent and whose operation involves chemical reactions. The Bureau is also cooperating with this association in establishing standard specifications for pipes and pipe fittings, and in encouraging the general adoption of the National Standard Fire Hose Couplings. A revised edition of Circular No. 50, National Standard Hose Couplings and Fittings for Public Fire Service, has been published and there is evidence that municipal fire departments throughout the country appreciate more fully than ever before the advantages of fire-fighting equipment that is made interchangeable by the use of standard connections.

Investigations Relating to Mechanical Appliances.

The investigations summarized under the following topics are illustrative of a general type relating to mechanical appliances, which are now carried out in several divisions of the Bureau, but which will probably be combined into a new section of work relating to mechanical appliances.

Spark-Plug Investigations.

Work has been done in cooperation with the electrical division and with the Pittsburgh laboratories of the Bureau in an investigation of the causes of failure of ignition spark plugs in aeronautic engines, with a view to remedying the difficulties.

Study of the behavior of many different makes of spark plugs, both by laboratory experiments and service tests in an aeronautic engine, have in part led to the preparation and adoption of acceptance specifications by the Signal Corps. Tests are being made under these specifications at the Bureau.

Test samples covering the whole range of possible porcelain composition, have been made up at Pittsburgh and are being tested for their thermal and electrical behavior.

Arrangements have been made for the construction of spark plug porcelain from the most promising of these compositions.

The temperature conditions to which spark plug porcelains are subjected are being investigated by direct temperature measurements in actual service with a view to devising means to meet satisfactorily the conditions of high temperature and extreme temperature gradients which occur in aeronautic engines.

Aeronautic Radiator Investigations.

Work was started in May on an investigation of the relation between the geometric form of radiator cells and the cooling capacity and head resistance of radiators under varying conditions of air velocity and air pressure.

The program includes (1) a study of the fundamental laws of air flow and heat transfer in cellular types of radiators by means of

measurements on all typical radiators now in use and other forms, which are necessary to complete the series of practicable cell dimensions; (2) application of the results to the design of radiator cell dimensions for maximum efficiency under various conditions of pressure and velocity; and (3) the establishment, if possible, of designs for standard radiator units which can be readily built and made interchangeable.

Equipment for this investigation, including a miniature wind tunnel with a section 20 cm. square, built within a vacuum chamber, has been substantially completed.

Installation of Aeronautic Engine Testing Laboratories.

In cooperation with the Signal Corps, the Bureau has built a dynamometer laboratory comprising equipment for the testing of aeronautic engines up to 400 horsepower by means of an electrical dynamometer. A separate installation for running service and endurance tests of engines of practically any output is also under construction. In this latter installation, the engine is connected to a test propeller to permit the taking of observations on the effectiveness and durability of various devices and auxiliaries under service conditions. In both of these plants provisions were made for an accurate study of engine performance, by the application of means for measuring power output, fuel input, speed, heat balances, etc.

The object of this equipment is to provide a means of studying the fundamental elements of the design and operation of aeronautic engines with the immediate view of eliminating minor operation difficulties and improving the construction of aeronautic power plants, by furnishing reliable and accurate data.

One of the points to be determined by investigations of this character is the maximum compression ratio that can be used with safety in practice (this quantity determines the maximum power output that is attainable with a given type and size of engine). This work requires an exact knowledge of the behavior of spark plugs and ignition devices, as well as accurate measurements of the amount of heat which must be taken care of by the raditor system. Another important problem is the design of the radiator itself, an investigation of which is being made in cooperation with the National Advisory Committee for Aeronautics. The data hitherto available regarding the heat-dissipating capacity of given radiator designs, have been inadequate to give designers a sure basis upon which to work. Another is the problem of proper lubrication of the aeronautic motor, both as to quantity, quality, operating characteristics, and the oils to be used, including the temperature at which those oils may be safely run. Still another is the effect of various fuels and carburetion systems and of different designs of intake and exhaust manifolds, all of which have a marked effect on the efficiency and reliability of the aeronautic power plant.

Testing of Aeronautic Engines Under Conditions of Reduced Atmospheric Pressure.

In cooperation with the subcommittee on power plants of the National Advisory Committee for Aeronautics, the Bureau is building a laboratory for the testing of aeronautic engines under conditions of reduced atmospheric pressure, in order to determine among other things, the effect of different grades of fuel with respect to the

variations of atmospheric air pressure encountered under conditions of actual flying. It may be that for high altitude service considerable improvement in power, climbing ability, and speed can be obtained by the use of special fuels. The same laboratory will serve for testing out other methods and applicances, such as carburetion accessories, which have been proposed for increasing the power output at high altitudes. All of this work is of the utmost military significance.

Liberty Engine.

Since the middle of June, the design work on the Liberty Engine, which is to be produced on a large scale for use on American-made airplanes, has been temporarily quartered at the Bureau of Standards. All divisions of the Bureau have cooperated to the fullest extent in supplying technical information of every character and, where necessary, have conducted investigations to aid in the production of this motor.

7. METALLURGY.

[Thermal analysis and structure of metals, heat treatment and its effect upon the properties of metals and alloys including the researches involved in determining the causes of metal failures, cooling and heating curves; the investigation of hardening, annealing, tempering, cementation; the determination of critical ranges; and the preparation of pure metals and alloys.]

Railway Materials Investigations.

The main outstanding rail problem from the standpoint of safety in railroad practice is that of the prevention of transverse fissures. The work of the past year has been directed in a number of ways toward the determination of the nature and causes of such fissures.

A number of fissured rails furnished by various railway companies have been thoroughly studied and reported to the companies; the investigation included physical, chemical, and metallographic examination.

More work has been done on the distribution of temperature in cooling rails of different sections, as throwing light upon the behavior of rails upon the hot beds.

A study has been made of the steel at various parts of the head of fissured and normal rails in order to detect any evidences of lack of thermal equilibrium (delayed transformation) which might account for the brittleness usually associated with the steel at the center of the head of fissured rails. This study included determinations of density, thermal analysis, and microscopic examination. Determinations of the coefficients of thermal expansion at various locations near a fissure has failed to indicate any significant variations.

The investigation to date indicates that none of the ordinary characteristics, including structure, expansion and chemical analysis of fissured rails (except possibly the mechanical properties), exhibit any variation from the normal condition in which cause might be sought for the abnormal service behavior of the rail.

Chilled Car-Wheel Investigation.

Measurement has been made of the stresses developed in the plate of the three standard master car builders wheel (625, 675 and 724 pounds) by heating of the rim or tread of the wheel. Such heating

in service is produced by the friction of the brake shoe on the wheel tread and leads to numerous wheel failures by the cracking of the plate. The present investigation will furnish information regarding the magnitude and distribution of such stresses in different weights and designs of wheels and should be a basis for rational alterations in such weights or design as may later be undertaken through the proper associations. Stresses were produced in these tests equal to 20,000 to 24,000 pounds per square inch; these are close to the ultimate breaking strength of the cast-iron of the wheel plate.

Work is being continued on the annealing characteristics of cast-iron, particularly of car wheel compositions. This work is at present concerned with the effect of variation in sulphur and manganese content in the velocity and temperature of the decomposition of the white iron carbide. A paper is now in preparation dealing with certain phases of the analytical methods for the determination of carbon.

Iron-Carbon System.

Several ingots of pure iron and of iron-carbon alloys have been cast in the new large vacuum furnace. These ingots have been forged, rolled, or drawn into shape for various physical measurements and supplied to other divisions of the Bureau or to outside laboratories for tests. Further thermal analyses have been made of the various carbon compositions. After the furnaces and transformer are moved to the new chemistry building, it is hoped that greater progress may be made in this work, and that several new phases may be taken up, including a study of the equilibria of systems other than the iron-carbon one. In this manner the effect on steel of different elements, such as sulphur, manganese, and phosphorus, may be studied under ideal conditions, including the elimination of the elements not being studied.

Second Ingot Investigation.

The results of the tests made in cooperation with the Pennsylvania Railroad of rails manufactured from different types of ingots are in shape for the preparation of a published report. The results include determination of physical properties, microstructure, segregation, etc., and indicate the effect of type of ingot upon the finished rail.

Ladle Test Ingot Metallurgical Investigation.

Work is being continued in cooperation with the chemical division, with a view to determining the best form of test ingot, as well as the amount of segregation which may be expected in steel ingots.

Gases and Oxides in Steel.

The work on gases and oxides in steel should be extended as soon as the analytical methods are sufficiently adequate to include a thorough investigation of the effect of these impurities on the properties of steel. This will include also a study of the effect and efficiency of various commercial deoxidizers for steel.

The chemical features of this work, which include a study of the best methods for the analytical work involved in such investigations, are covered in the report of the chemical division.

Gun Erosion and Allied Phenomena.

The Bureau has been asked several times by the War Department for information concerning certain aspects of the gun erosion problem, and therefore the Bureau has undertaken a preliminary laboratory investigation of the behavior of metals when very quickly cooled from high temperatures. It is believed that practical field investigation of this problem can be much aided by a laboratory study of those properties of different metallic materials which are concerned in their service behavior in the form of gun linings. This will involve a study of certain properties of these materials at high temperatures.

Temperature Measurements in Metallurgical Practice.

Within the past three years studies have been made of the feasibility of temperature measurements in steel plants with particular reference to the measurement of rolling temperatures and those of the molten steel in the open-hearth furnace, in the Bessemer converter, and during pouring and teeming. It has been shown (see Technologic Paper No. 91) that the measurement and pyrometric control of furnace casting and ingot teeming temperatures present no serious difficulties or uncertainties. For this purpose the most satisfactory type of instrument is one of the special pyrometers using monochromatic light and permitting observations from a distance of streams of metal. For streams of liquid iron or steel, the most probable value of the emissivity to take, using red light ($\lambda=0.65\ \mu$), is $e=0.40$. The value of e for liquid slag is usually about 0.65, but it varies with the composition. Determination of the temperature of charge of Bessemer converters is not deemed practicable by such pyrometric methods. The temperature of the open-hearth bath is usually kept between 1,600° and 1,670° C.

Thermocouple Nichrome–Constantan.

In connection with work on the distribution of temperature in a cooling rail, a study was made of the suitability of various materials for thermocouples operating up to 1,000° C. Tests showed that for immersion in steel at 1,000° C., thermocouple nichrome-constantan is very satisfactory. It maintains a calibration constant to within 10° C. at 1,000° C. throughout its life; the calibration curve is nearly linear and shows no departure from a smooth curve.

Failure of Brasses and Bronzes.

During the year publication has been made of the results described in the report of last year on the subject of the failure of brasses and bronzes. In addition, the investigation of the thermal expansion of alpha and of beta brass has been completed, and progress is reported in the stress corrosion tests of manganese bronze.

The thermal expansion of beta brass, although at ordinary temperatures equal to that of alpha brass, is, at temperatures from 400° to 450° C., approximately 50 per cent greater than the latter. The beta grains in a rapidly cooled 60:40 brass containing both alpha and beta will be in a state of local tension, the alpha grains in compression. This initial stress may be responsible for subsequent failure and

cracking in failed brass bolts which have come to the attention of the Bureau and are known to have been quenched in water. It is shown also that these local stresses lower the proportional limit of a brass.

The samples of annealed manganese bronze subjected to corrosion in a water tank at the Bureau for over six months, while under tensional stresses equal to their proportional limits, have so far shown no signs of cracking, although slight corrosion has set in. These tests are to be extended and amplified.

Corrosion of Brasses and Bronzes.

Study has been made of the microstructural features of corrosion in cast bronzes and in wrought 60:40 brass of the type of Muntz metal. This work is being continued with the purpose of ascertaining the structural electrolytic potential differences and the effect of such differences upon corrosion. A study is also being made of the effect of stress upon corrosion. It is apparent from the metallographic studies made, both at the Bureau and abroad under the auspices of the British Institute of Metals, that the corrosion of brasses and bronzes is most intimately related to the features of structure.

Impurities in Cast Bronze and Brass.

An investigation has been undertaken of the specific effects of the usual impurities in cast brass and bronze upon its properties, chiefly physical—tensile, hydraulic, resistance, etc. The results of this investigation will indicate the extent to which scrap may be used in producing castings of these metals and will be a basis for establishing chemical specifications for them. Defects and failure of castings are frequently attributed to the presence of small amounts of impurities, which should, probably, more properly be attributed to improper foundry practice in melting and pouring the alloys.

Properties of Commercial Cast Brasses and Bronzes.

Numerous tests have been made at the Bureau's foundry of both 88:10:2 and 88:8:4 (copper-tin-zinc) metal cast into a form of test bar recommended by the Naval Gun Factory (Washington Navy Yard). This is a core sand cast, cast to size specimen fed along its whole length. This form of test coupon gives very uniform results for these medium shrinkage metals. These tests will be continued with the cooperation of five commercial foundries and with that of the Naval Gun Factory. The results will form a basis for the defining of specifications for the metals so tested.

Foundry Sands.

Comparison has been made of the mechanical properties of fine French facing sands and of American ones used as substitutes for these. It has been shown that one or two American sands are equal to the imported French sands in every respect except that of tensile strength. Samples made up of the various sands have indicated that the tensile strength of the French sands is superior to that of the American ones. A report is to be made before the American Foundrymen's Association at its fall meeting.

Deterioration of Tinned Copper Roofing.

The tinned copper roofs of certain buildings have, within some 8 to 10 years after installation, become quite badly pitted. Investigation showed that this pitting is primarily due to the structure of the tin coating. This coating, produced by the application of molten tin to the surface of the sheet, contains an alloy layer next to the copper which is slightly electronegative to it. Such a coating, therefore, gives only a mechanical protection; as soon as the copper is exposed, galvanic action sets in and the copper is attacked. Plain copper on some of the buildings had suffered no deterioration under the same service conditions. Tinned copper must be looked upon as a quite unreliable material for roofing purposes, inferior to plain copper, and in most cases inferior also to tin plate.

Properties of Electrolytically Deposited Copper.

A preliminary report has been published of the studies of copper electrodeposition in electrotyping baths. These studies have resulted in establishing tentative specifications for the deposition of such copper, concerning the composition of bath, current density, etc.

In connection with this work there has been published (Transactions of American Institute of Metals, 1916) an article, giving a description of the microscopic structure of electrodeposited copper. The occurrence and effect of twinned copper crystals or grains as deposited are discussed. The conclusion is reached that the grain size of such deposits does not alone determine the physical properties.

Protective Metallic Coatings on Metals.

In connection with the general work on protective metallic coatings on metals, a report has been made giving a comparison of the basic lead acetate and the hydrochloric acid-antimony chloride methods of determining zinc on galvanized iron. This work is to be continued in the direction of comparative service tests (salt spray test) of zinc coating applied by different methods—sherardized, galvanized, and electrogalvanized.

Fusible Boiler Plugs.

Further investigation has been made within the year of the mode of introduction of impurities, such as lead, copper, and zinc, into the tin fillings of fusible boiler plugs. The effect of heating the tin and the casing to different temperatures on the copper content of the filling has been determined, and manufacturers have been advised of these results in order that they may meet the Steamboat-Inspection Service specifications.

Melting Points of Refractory Elements.

Several additional determinations have been made of the melting points of the most refractory elements, chromium and manganese, and apparatus assembled for the completion of the work. The melting points of some 140 steels of different composition have also been determined by optical pyrometer methods.

Cooperation with Military Government Departments.

One of the features of the work of the metallurgical division has been its greatly increased contact during the last year, and particu-

larly during the past three months, with the military Government departments.

The Bureau is cooperating with the Bureau of Construction and Repair of the Navy Department and the Signal Corps of the War Department in an extensive investigation of light aluminum alloys for rolling and casting. It is hoped that alloys may be developed of greater specific mass tenacity than those at present in use.

The Bureau has been of some service in connection with the setting of certain Navy Department specifications for brasses.

Besides a number of routine tests for the Government military departments, this division has, often in cooperation with other divisions, conducted special investigations and investigative tests of very interesting character. Typical instances are corrosion of Muntz metal bolt, for Boston Navy Yard; examination of samples of Duralumin alloy used in Zeppelin construction, for Bureau of Construction and Repair, Navy Department; investigation of failed metal parts, for Signal Corps, War Department; examination and comparison of zinc coatings on shrapnel tinning leads, Office of Ordnance, War Department; cracking of steel rivets (submarine hull construction), for Bureau of Construction and Repair, Navy Department; identification tags of Monel metal for seamen, for Bureau of Identification, Navy Department.

Cooperative Work in Metals.

A feature of the work of the metallurgical division has been its method of cooperation with technical societies or industries in the prosecution of its investigational work. In this manner the work it undertakes may proceed upon the very broadest lines and with full pertinence to industrial practice.

A committee of the American Institute of Metals and other technical societies meets twice a year at the Bureau and discusses the Bureau's work in nonferrous metals.

Through the membership of its staff members in various committees of the American Society for Testing Materials it cooperates with this association in its standard work. Such committees are: The chilled car-wheel subcommittee; the subcommittee on preservative metallic coatings for metals; the nonferrous metals committee; and the subcommittee on the methods of analysis of steel.

It cooperates with five commercial and one Navy Department foundry in its investigation of the properties of commercial brasses and bronzes, with the Pennsylvania Railroad in its work on sound ingots, and with the Aluminum Co. of America in its investigation of light alloys.

Activity in Technical or Scientific Societies.

The results of the Bureau's metallurgical work have been presented in papers and discussed before the following societies: American Chemical Society, American Electrochemical Society, American Institute of Metals, American Society for Testing Materials, Iron and Steel Institute of Great Britain, American Foundrymen's Association, Washington Academy of Sciences, American Institute of Mining Engineers, and The Franklin Institute. Several members of the metallurgical staff are serving actively as officers or as members

of committees of those technical or scientific societies cooperating with the Bureau on metallurgical subjects.

Metallurgical Tests.

A summary of the metallurgical tests is given below; their total value in fees is $3,666.25. Of these test items, 94 per cent were for the various departments of the Government and 6 per cent for private individuals and corporations. Many of these tests were of a very important nature, involving considerable investigation and special installations, and some have served as starting points for special experimental research.

Name.	Heat treatment and thermal analysis.		Metallographic.			Fusible plugs.	Brass and bronze failure.	Miscellaneous.	Grand total.
	Irons and steels.	Non-ferrous metals.	Identification of metal and process of manufacture.	Metal failures.	Miscellaneous.				
For the Government:									
Bureau of Standards	88	.....	.....	1	17	.....	.....	20	126
Navy Department	13	.....	.....	9	25	.....	2	.....	49
Panama Canal	2	.....	270	2	4	11	.....	14	303
Steamboat - Inspection Service	.....	.....	.....	.....	.....	547	.....	.....	547
Treasury Department	.....	2	.....	.....	6	.....	.....	11	19
War Department	.....	.....	9	2	19	.....	.....	1	31
Total	103	2	279	14	71	558	2	46	1,075
For the public	.....	.....	3	4	17	.....	34	6	64
Grand total	103	2	282	18	88	558	36	52	1,139

Information Furnished to the Government and the Public.

Requests are constantly being received for information concerning metallurgical topics. Often these are of unusual nature and require much time in preparation. During the past year information on some 200 different topics has been furnished. In view of this, steps have been taken to prepare a comprehensive metallurgical bibliography and file of information to facilitate the preparation of replies to such requests.

Circulars of Information on Metallurgical Subjects.

A rather extensive circular of information on copper has been prepared, dealing primarily with its physical properties, and with the effect of variations in composition and in the conditions of the process of manufacture upon these properties.

The circular on metals for pyrometric standards is in press.

Requests for information on certain subjects have been so numerous that letter circulars have been prepared; the following subjects have been covered or are being taken up: The "hardening" of copper; the heat treatment of steel; welding; brass and bronze; and light aluminum alloys.

Metallurgical Publications.

The following metallurgical publications and special papers, most of which have been reprinted in foreign or American technical or scientific journals, have been issued during the year: Technologic Paper No. 91, Temperature Measurements in Bessemer and Open-Hearth Practice; Scientific Paper No. 296, Thermoelectric Measurement of the Critical Ranges of Pure Iron; Technologic Paper No. 82, Failure of Brass: 1, Microstructure and Initial Stress in Wrought Brasses of the Type 60 Per Cent of Copper and 40 Per Cent of Zinc; Technologic Paper No. 83, Failure of Brass: 2, Effect of Corrosion on Ductility and Strength of Brass; Technologic Paper No. 84, Failure of Brass: 3, Initial Stress Produced by the "Burning-in" of Manganese Bronze; Technologic Paper No. 90, Structure of Coating on Tinned Sheet Copper in Relation to a Specific Case of Corrosion; "The embrittling action of sodium hydroxide on mild steel," published in Metallurgical and Chemical Engineering, May, 1917; "Notes on the thermocouple nichrome-constantan," published in Metallurgical and Chemical Engineering, June, 1917; "Some problems in physical metallurgy at the Bureau of Standards," published in the Journal of the Franklin Institute, July, 1916; "Note on the occurrence and significance of twinned crystals in electrolytic copper," published in Transactions of American Electrochemical Society, 1916; "Preliminary studies in the deposition of copper in electrotyping baths," published in Transactions of American Electrochemical Society, 1917.

There are also in press or in course of preparation papers on the following subjects: Thermal expansion of alpha and beta brass; copper; some unusual features in the microstructure of wrought iron; typical case of the selective corrosion of Muntz metal; comparison of basic lead acetate and the hydrochloric acid-antimony chloride method for determining zinc coatings on sheets and wires; preliminary report on fine-facing molding sands; determination of oxygen in steel; determination of gases in steel; determination of cadmium in brass; and determination of graphite in cast iron.

A number of investigations have been concluded within the past year or brought to such a state as to warrant soon the publication of results.

8. STRUCTURAL, ENGINEERING, AND MISCELLANEOUS MATERIALS.

[Strength, hardness, elasticity, plasticity, permeability, composition, structure, and other physical and chemical properties of structural and miscellaneous materials, such as cement, stone, clay, lime, paper, textiles, rubber, etc., including laboratory and field work in developing methods of test, standards of quality, and the relation of quality to the efficient utilization of such materials.]

Investigation of Structural Steel Columns.

An important investigation on the strength of steel columns has been conducted for the past few years in cooperation with committees of the American Society of Civil Engineers and the American Railway Engineering Association.

The columns comprising the series investigated for the American Society of Civil Engineers were designed primarily to study the effect of cross section. Nine different types were fabricated in both light

and heavy sections. The original series as outlined comprised three different lengths of each type and three columns of each length in both light and heavy sections. This program was later extended to five different lengths for certain of the types and three different weights of material.

The series tested for the American Railway Engineering Association were designed primarily to study the effect of lattice bars and batten plates, as well as different end conditions. In this series both light and heavy sections, each with three different lengths and three columns for each length were tested.

The work of testing of the columns of these two series was completed during the year, and reports on the tests were furnished to the committees of the two societies.

An exhaustive program has been outlined with a view to determining the quality of the metal from which the columns were fabricated. The results obtained to date on this supplementary program seem to account for some of the rather startling results obtained on the columns tested. This supplementary program is about one-third completed.

This investigation, comprising a total of 240 columns, is the most comprehensive investigation that has ever been undertaken on the strength of steel columns and the results obtained therefrom will be of great value to engineers and architects as soon as the results become available.

The publication of preliminary reports of the results of these investigations have appeared from time to time in the proceedings of the respective societies as progress reports. Work is now under way for the publication of a final report of these committees on these investigations during the coming year.

During the past year the Bureau has received 233 steel columns by transfer from the Watertown Arsenal. These represent columns purchased in 1908 for an investigation originally intended to be conducted at that place. The work of testing these columns has been postponed until the results of the series just completed may be thoroughly studied.

Physical Investigations of Railway Material.

The work done during the past year on railroad materials has been that of investigating the cause of failure of rails previously submitted by various railroad companies. This investigation has included the determination of the physical properties of various parts of the rail, as well as tests on complete heads, webs, and bases. In connection with this work, the division has had the cooperation of the chemical and metallurgical divisions in chemical analyses and microscopic examinations. A number of rails have thus been investigated and reports of these investigations with conclusions have been furnished the various railway companies interested.

In addition to a study of the physical, chemical, and metallurgical problems, as usually made, a preliminary study has been made on the distribution of internal stresses in the various parts of a rail. A sufficient amount of work has not as yet been done to warrant the drawing of any definite conclusions.

Investigation of the Physical Properties of Zinc.

The investigation on the physical properties of cast zinc has been carried on during the past year upon material submitted by a commercial company which represents exceedingly pure zinc, and material submitted by another company which represents a grade of zinc containing considerably greater impurities. The investigation comprised tensile, compressive, torsional, cold bend, and hardness tests. This investigation has been very illuminating in regard to the effect of small quantities of impurities in zinc. The zinc representing the pure material was found to be almost entirely devoid of elastic property, while the zinc containing some impurity showed considerable elastic property. It is hoped to extend this investigation to comprise other pure metals, and the results obtained will be published as a technologic paper.

Investigation of Methods of Calibration of Testing Machines.

During the early part of the year considerable work was done on the ways and means of calibrating testing machines up to full capacity and some very satisfactory results were obtained. Three methods are being investigated to determine their relative merits, namely: (1) The adaptation of the hydraulic support in combination with a suitable portable registering device; (2) calibration of vertical testing machines by the substitution method; and (3) the use of a series of standard bars of different sectional areas, in conjunction with a suitable extensometer. This work has been temporarily suspended due to the pressure of work of a more urgent character.

A chrome-nickel bar 4 inches in diameter and 8 feet long was prepared to be used for checking the constancy of the large Emery machine in tension. A suitable extensometer was also built in the shops of the Bureau for use in measuring the elongations of this bar under stress. This, while far from the ideal, is the only available method at the present time to keep check on this machine. Its use has been found fairly satisfactory.

A number of testing machines have been calibrated up to 50,000 pounds by the use of the sensitive levers possessed by the Bureau. Comparison has also been made of machines of larger capacity up to 800,000 pounds with the large testing machine in the laboratory of the Bureau. The methods adopted in this case consisted of a tension bar and the comparison of the elongations obtained on the machine in question with the elongations obtained for similar loads upon the Bureau's testing machine. This work, in no sense, can be considered as a calibration and must only be considered as a comparison of machines.

Investigation of the Effect of Kiln-Drying Spruce.

The scarcity of good air-dried spruce for the purpose of airplane manufacture has led to an investigation of the effect of kiln drying on spruce timber. This investigation is being carried on in cooperation with several furniture manufacturers who have the necessary facilities for kiln drying the lumber. It is hoped that this investigation will result in a suitable method for kiln drying spruce which will give a material as satisfactory for use in airplane construction as the present air-dried spruce. This work has been outlined and is now in

progress. The results, when obtained, will be communicated to the Aircraft Board of the Government for their immediate use.

Airplane Strut Investigation.

A tentative outline of the investigation of airplane struts was submitted to the various airplane manufacturers for criticism and suggestions before this work was begun. The suggestions made are incorporated into the final program in so far as this was possible.

Work is now under way on an investigation to determine a suitable column formula for use in design of airplane struts. This investigation is being conducted upon air-dried spruce and comprises lengths of L/R from 25 to 250. It is the intention to determine from this investigation an empirical formula to be used as a guide in the design of airplane struts, no formula at present being available for this work.

Resistance of Wood to Alternating Stress.

Investigation on the resistance of various kinds of wood to alternating stress was undertaken some time ago. A few preliminary experiments were conducted on a machine now in the possession of the Bureau, but this machine was found to be wholly unsatisfactory for the work. The results obtained, however, were indicative of the necessity of such an investigation and a machine was designed and has been built in the shops of the Bureau. The investigation is now under way. A sufficient number of tests have not yet been made to warrant the drawing of any conclusions. A battery of these machines is now being built so that the results may become immediately available for use at the present time. These results will be communicated to the proper board, when available, for their guidance in the selection of material for aircraft production.

Study of Strains in Car Wheels.

Work on the strains produced in car wheels under braking conditions has been carried on in cooperation with the metallurgical division. In this investigation, which is of a preliminary nature, the various strains produced in the different parts of the wheel were measured with various temperature conditions of the rim.

As a means of interpreting the measurements made on the wheel under different temperatures, tensile tests were made upon test bars cast from the same melt as the wheel. In this test elongations of the bar were measured for different stresses under a series of temperatures varying from 20° C. to 300° C., representing the range of temperatures used on the wheel.

Machine-Tool Investigations.

An important investigation has recently been inaugurated in cooperation with the research committee of the American Society of Mechanical Engineers on the cutting action of machine tools. It is intended to study exhaustively the manner of chip formation as well as the power consumed in the cutting of metals. This is an investigation of exceedingly broad scope and will require considerable time before any definite results can be obtained. There is at present practically no literature on the subject which might be used as a

guide in outlining such an investigation. It is proposed to study different types of tools, different angles of the cutting tools, and different grades of steels for use in these tools. The Bureau some time ago purchased a planer dynamometer for this investigation, but the work has been delayed, as no suitable planer was available. During the past year an 8-foot by 25-foot planer has been installed and work is now in progress.

Strength of Galvanized Wire.

The Bureau was consulted by a commercial company relative to the reason for loss of ductility in wire due to galvanizing. Samples of this product have been submitted and an investigation is now under way to determine the reason for this brittleness induced by galvanizing and also to determine ways and means to overcome this effect. The results, when obtained, will probably be published as a technologic paper.

Strength of Latticed Aluminum Columns.

This investigation was undertaken at the request of the Joint Army and Navy Airship Board, in order to determine safe working loads for columns fabricated from light aluminum alloys to be used in dirigible construction. Eighteen columns designed by this board have been tested and a report thereon has been submitted to them.

These columns were of doubtful design and suggestions have been made to the board for their modification. These suggestions were acted upon by the board, and other columns are now being fabricated which will be tested by the Bureau some time in the near future.

Failure of Bridge Material.

During the year investigations of the failure of bridge material have been undertaken. A bridge which had been in service for about 20 years recently collapsed without warning, resulting in the injury to life and property. This failure is being investigated in order to ascertain if it is due to the peculiar characteristics of the material itself. This work is now in progress and the results will be published as soon as completed.

Strength of Bridge Material.

The report on the investigation of the strength of large bridge columns was presented for publication and is now in press. The tests were conducted upon 18 columns corresponding to original members in the long-span bridges recently erected at Memphis, Tenn., Metropolis, Ill., and St. Louis, Mo. The columns ranged in length from 15½ to 24½ feet, and in cross-sectional area from 42 to 110 square inches, and were constructed of carbon, silicon, chrome, mayari, and nickel steels. The compression strengths of the columns were found from the tests to vary from 31,000 to 45,000 pounds per square inch for the carbon steels and from 47,000 to 61,700 pounds per square inch for the alloy steels. Most of the columns developed a strength equal to the yield points of their component steels; 6, however, failed by local buckling or by bending at the ends. Numerous supplementary tests were made on lattice bars, pin plates, transverse diaphragms, and other details and the laws of behavior determined.

An investigation was conducted in cooperation with a large bridge manufacturing company to furnish reliable data upon the behavior of columns of built-up trusses used in ordinary building construction. The angle columns were tested in lengths from 3 to 25 feet. The experimental work covering 167 columns is completed and the data are being collated for publication.

Failure of Hull Material.

An investigation of hull material, with a view to determining the cause of failure of a high tensile plate while being handled at the shipping yard, was requested by the Bureau of Construction and Repair. This investigation has been attacked from the standpoint of internal stresses, a large number of measurements having been made upon the plates submitted and some very interesting results obtained. Investigations on the tensile strength and microscopic analysis of this plate have also been made and the results are now being studied. A report embodying certain recommendations on this material will soon be submitted to that bureau.

Investigation of Material from Experimental Bulkheads.

An investigation was also conducted at the request of the Bureau of Construction and Repair upon material from experimental bulkheads. This investigation comprised physical tests including the determination of the ultimate resilience of the materials in question, as well as microscopic and chemical analysis of the material. This investigation has been completed and a report has been submitted to that bureau.

Investigation of Wire Rope.

The report on the investigation of the strength and other physical properties of wire rope has been submitted for publication. This report contains a review of individual tests made upon 275 wire ropes ranging in diameters from $\frac{1}{4}$ inch to $3\frac{1}{4}$ inches, inclusive; also numerous supplementary tests of wires, fibers in the hemp cores, lubricants, and preservatives used in the manufacture of the rope. The investigation covered five of the more important and commonly used classes of American wire rope.

A cooperative investigation was made with a prominent bridge construction corporation to determine the effects of sheaves upon the tensile strength of steel hoisting rope. The specimens were tested under conditions approximating those existing in the case of hoisting blocks of derricks and dredges for comparison with direct tensile tests. The results of the tests showed that the sheaves reduced the strength in some cases as much as 25 per cent, this depending upon the diameter of the sheaves, which ranged from 10 to 18 inches. The report of these tests has been submitted for publication, and it is believed will be of value to engineering, construction, and erecting firms.

Strength of Brick Piers.

An investigation of the load-bearing value and other properties of large brick piers has been completed and is being prepared for publication. This investigation was conducted in cooperation with the National Brick Manufacturers Association, and includes tests of 50

brick piers of large size. In the construction of these piers, three grades of brick from each of four widely separated districts east of the Mississippi River were used.

A study was made of various types of bonding and of different grades of mortar. Numerous auxiliary tests were made on the materials used. The methods used in the erection of the test piers is believed to be representative of modern practice in brick masonry, and the districts represented are such as to give a fair average of clay-brick product east of the Mississippi River. The following conclusions are drawn from the results obtained:

The strength of brick piers depends primarily on the quality of brick and kind of mortar used. Of the mortars used, the cement mortar develops about twice the strength of the lime mortars, of 2,700 and 1,400 pounds per square inch, respectively, for the highest grade of brick. The cement mortar is harder to work, however, and a combination lime and cement mortar which does not appreciably effect the strength of the piers is cheaper, and has much better working qualities. The combination used in the present investigation was 1 part of cement and lime (by volume 65 per cent and 35 per cent, respectively), to 3 parts sand. The strength of piers laid in the combination cement and lime mortar was practically the same as those laid in a 1:3 cement mortar, giving twice the strength of those laid in 1:6 lime mortar and about four times the strength of those laid in 1:3 lime mortar. The type of bond as concerns the number of header courses used has little, if any, effect upon the ultimate compressive strength of the piers. The introduction of wire mesh in the horizontal joints adds strength if used in all the joints. This does not apply, however, if used in every third or fourth course only, and may even decrease the strength of the pier. The transverse rather than compressive strength of the individual brick is believed to bear the closer relation to the ultimate strength of brick masonry.

Investigation of the Physical Properties of Earths.

The investigation of the physical properties of earths was undertaken in cooperation with the committee appointed by the American Society of Civil Engineers to study the subject of a classification for earths suitable for the needs of engineering practice. Numerous experiments have been made to study the behavior of various earths under different conditions of loading, and to determine the most practicable and efficient form of pressure gauges to use in such investigations. The relative frictional resistances, degrees of compression, and cohesive factors in the case of sand and clay when different per cents of moisture are present have been determined. The lateral pressures in earths induced by known vertical loads have been measured and the frictional resistances calculated.

It was shown in the results that a change of density in the earth of but a few per cent is often accompanied by large changes in its physical properties, especially the relative compressibility. The friction and cohesion was generally increased with the addition of different percentages of water in the case of sand. The mean angle of repose for dry standard sand was found to be 39 degrees, a somewhat higher value than that commonly given in engineering treatises. The progress report of this investigation will be given in the August, 1917, proceedings of the American Society of Civil Engineers.

Information Furnished Regarding Strength of Metals and Alloys.

Services of a consulting nature have been rendered on the strength of steel, alloys, woods, and similar materials. These inquiries, covering a wide range of subjects, have come from private individuals, public officials, State and National Government departments, universities and schools, engineering societies, and research laboratories.

The assistance rendered in this connection is entirely distinct from that of making tests for the determination of the physical properties of materials. Many of the inquiries were in the field of design, others asked for advice on suitable testing machinery and methods of tests. In many cases references to technical literature were sought on various subjects. Advice on the interpretation of existing specifications has often been given and in other cases has been requested regarding the modification of existing specifications. Publications of the Bureau have been furnished whenever the information contained therein would furnish an adequate response to the inquiry. In other cases the available engineering literature was searched and references to suitable articles furnished.

Tests of a Semi-Investigative Nature.

A great many tests have been conducted of a semi-investigative nature to determine the physical properties on materials as well as to determine suitable material for certain purposes. Among these may be mentioned the following:

1. An investigation of the efficiency of welded steel plate, welded by means of oxy-acetylene and electric processes. These were tested in comparison with riveted joints to determine the relative merits of the different methods of construction.

2. An investigation was made of the burglar-proof qualities of a chest for the Post Office Department. This safe was not found to possess these qualities and the Post Office Department was therefore advised accordingly.

3. An interesting investigation was conducted for the Panama Canal, in which advice was requested on the purchase of shovels for use on the Panama Canal. A thorough strength test and chemical analysis was made of these shovels. A comparison of the results obtained on the bid sample and lot shipment was made and recommendations forwarded to the purchasing department of that organization. These recommendations proved so satisfactory that a second lot was submitted to the Bureau for investigation before purchase was made.

4. Another investigation conducted for the Panama Canal was a thorough study of machetes and grubbing hoes. This investigation included physical, chemical, and microscopic examination of the machetes, with recommendations regarding the material submitted.

Grubbing hoes were submitted to the Bureau for advice as to the selection of two different qualities of grubbing hoe. After investigation the Bureau advised the purchase of the cheaper grade of hoe; in fact, the only difference ascertainable was that of price. This will mean a considerable saving to the purchasing department of that organization.

5. The question of selection of material for periscope tubing was submitted to the Bureau for decision by a large commercial company.

Extensive tests were made of two different grades of material submitted and recommendations as to their respective qualities were made.

6. Hydrostatic tests on a 12-inch oxy-acetylene welded pipe were conducted, at the request of the Supervising Architect. Suitable recommendations were made.

7. An interesting test conducted for the Navy Department was that of the comparative strength of a copper-plated airplane strut compared with a similar strut not plated. This resulted in an increase in weight of about 64 per cent, due to the copper plating and an increase in strength of about 11 per cent.

8. A number of tests have been made during the past year for the metallurgical division in an investigation on welded bronzes. Different methods of welding were investigated and the efficiency of these determined.

9. An investigation was conducted for the Chief of Ordnance of the War Department on the effect of the substitution of soft material for cold-drawn material used in the manufacture of heads for shrapnel shell. This investigation was conducted to learn what effect this substitution would have on the expansion of the Bourrelet, and also to determine if any danger would arise by jamming of the shell in the gun when fired.

10. Advice was also requested relative to the expansion of materials entering into shrapnel, as well as the method to be employed in determining the yield point of the material. An investigation was made of suitable instruments which might be employed in this determination and specific recommendations were made, both upon the method to be employed and the instruments suitable for this work.

Investigation and Testing of Materials for the Signal Corps.

During the past year the investigations and tests relative to materials used in aircraft construction have reached such magnitude that the office of the Signal Corps has detailed men, assigned to the Bureau and working under its direction, to assist in the execution of this work.

Tests on the Strength of Materials.

The following is a summary of the testing done in the structural materials division representing a very substantial increase over the number and range of tests conducted during the previous year: Tests for all Government departments, exclusive of the Signal Corps (Aircraft Engineering Division) of the War Department, 613; Signal Corps, 627; private parties, 122; and other tests, 26; total, 1,388.

The material tested included steel wire ropes of 2¼ inches and 3¼ inches in diameter, manila rope, steel bars, cold chisels, machine bolts, brass tubing, conduit pipe, turnbuckles, carriage bolts, bolt stock, wire, steel rods, dies, structural steel, wood columns, ash, spruce, safety belts, aluminum alloy piston, propeller wood, fuselage wire, angle steel, galvanized pipe, acetylene welded pipe, nickel steel strut, starter shaft, wrist pin, trolley wire, piano wire, cable, rivets, bronzes, sheet metal, brass spinning rod, copper steam pipe, brass hexagon nuts, bronze bearing metal, steel metal slitting saws, etc.

Tests were also made to determine the strength of flanged unions on pipes of 6, 8, and 10 inch diameters; the strength of couplings on

oil-well casings of the same diameter; two tile walls; 10 individual hollow building tile, and approximately 100 individual brick for compression; 85 wire ropes for tensile strength; 25 14-inch porcelain insulators were tested to a proof load of 500,000 pounds; and a 50-ton double-end crane hook was tested for proof load of 50 tons.

Investigation and Testing of Cement, Concrete, and Stone.

The work done in connection with the investigation and testing of cement, concrete, and stone, and similar materials is of three kinds, namely: (1) The determination of the physical properties of cements, concretes, sands, crushed stone and gravels, building stones, plaster, drain tile, and other so-called cement products; (2) the development and investigation of methods and apparatus for testing these materials; and (3) the investigation of the durability of these materials under various conditions, and to a certain extent the development of improved methods of handling and utilizing these materials in actual construction; for example, in the mixing and placing of concrete, in the application of stucco and plaster, and in the manufacture of drain tile.

Standard Specifications for Portland Cement.

Meetings of the joint conference of representatives of the United States Government, the American Society for Testing Materials, and the American Society of Civil Engineers, held during the year, resulted in the adoption of a standard specification for Portland cement. This specification became effective January 1, 1917, for the use of all offices of the United States Government, and is an improvement over the old specification. Certain essential requirements, such as strength, fineness, and setting properties, have been increased; certain unessential requirements, such as tests of neat cement, 100-mesh requirement, air and water soundness pats, etc., have been omitted. Other limitations which did not improve the quality of cement, but were a handicap to certain manufacturers, such as the low sulphuric anhydride and magnesia limitations have been made more liberal. The new specification, although an improvement over the old, can not be considered as entirely satisfactory, as there is no test which furnishes specific information as to the relative value in concrete of the products of different mills. Further improvement should be possible in the near future with the continuation of these investigations and researches.

Circular 33, third edition, containing the revised specification for Portland cement, was issued January 18, 1917.

Foreign Specifications for Portland Cement.

A collation is being made of all foreign specifications for Portland cement. This information is being obtained through the assistance of the various consular agents. A large number of specifications have been received from different countries and they will be translated and combined in a paper in the near future.

Effect of Fine Grinding of Portland Cement.

As the result of considerable discussion concerning the value of fine grinding of cement, an investigation was started in 1915 to de-

termine the effect of fineness of cement on its strength and other physical properties.

The results of the compressive strength tests of concretes, containing several brands of cement reground to various degrees of fineness, so far obtained tend to confirm the previous conclusions that, on the average, for each per cent increase in fineness the compressive strength is increased 2 per cent.

Minor Constituents of Portland Cement.

There is in process of publication the results of work dealing with the effect of magnesium upon the properties of Portland cement. This is one of the minor constituents which are usually supposed to have little or no effect upon the general properties of cement. However, in this work it was shown that a little less than 5 per cent produces a noticeable change in the softening temperature of the clinker, though otherwise the resulting cement is not deleteriously affected. The early strengths which can be developed above 7 per cent are decidedly decreased. The other minor constituents are now in course of being investigated, especially iron oxide and the alkalis. The former retards the setting to a decided degree, but does not materially affect the later hardening. It appears, also, that the alkalis have the property of making the early setting very erratic, in some cases causing it to turn quick-setting during storage.

Constitution of Portland Cement.

The investigation which is being carried on in the experimental cement plant of the Bureau dealing with the properties of Portland cement as affected by changes in composition has been progressing very satisfactorily during the year. A considerable amount of time has been spent in studying the results at hand, especially through showing the general deportment of the cements in concrete. It appears from these results that the quantity of the various constituents is a factor of great importance, as well as the condition in which they are present.

Thus, it seems that if the same mix is burned at two different temperatures, that temperature which produces the finer grained clinker will produce the most active cement. Very hard-burned clinker, especially when the constitutents are larger grained or crystalline, does not appear as active as clinker burned at a low temperature for a longer period. As a result, thin sections of all clinker in the investigation have been made and are being examined both for the amounts and the character of the various constituents.

Granulometric Air Analyzer.

The granulometric air analyzer which has been in successful operation for three years, continues to demonstrate its usefulness in the quantitative separation of finely ground cements and other powders. Aside from more or less routine mechanical analysis of cements, the analyzer has been employed in the study of foundry clays and moulding sands, and for the separation of carbon, copper, and emery powders.

Air Separator for Cement.

An apparatus has been devised for the separation of "flour" from the coarse material of Portland cement by means of air. Flour of

3 degrees of fineness are now obtained. During the past year improvements have been made in this apparatus, consisting mainly of a new feeding device which increases the efficiency of operation, and a new dust collector has also been designed.

While the air separator is still in the experimental stage, it has already produced a large amount of fine material which has been used in the very important investigation of the value of fineness of Portland cement. Up to the present time this is the only known device capable of separating the fine particles of cement from the coarser material in considerable quantity, and at the same time controlling absolutely the degree of fineness of the separated material. The control both of fineness and gradation is an absolute prerequisite for success in studying the effect of fine grinding of cement on the strength of mortars and concretes, and the chief obstacle to rapid progress in the investigation is the excessive slowness in production of the fine grades of cement of normal granulometric composition. Consequently, it is important that the air separator be developed primarily for larger capacity, and steps have already been taken to meet this requirement.

Standard Cement Sieves.

Thirty-two 200-mesh sieves have been calibrated during the year to determine whether they meet the Bureau's modified sieve specification which was adopted in 1914. This service has been of much assistance to testing laboratories, as a correction factor is furnished with the certificate of test. The application of this correction factor makes possible much greater concordance of results than were previously obtainable, thereby preventing many disputes between the manufacturer and consumer. With the increase in the fineness requirement of specifications for cement this work should be of still greater service to the public. The comparatively small number of sieves tested this year is an indication of the scarcity of high grade sieving cloth, which is entirely an imported product, and also that laboratories and manufacturers are making more and more use of the Bureau's standard fineness samples.

Standard Fineness Sample.

New cement samples of standard fineness have recently been prepared and made available to owners of cement-testing sieves. These samples are used for checking the sieving values of such sieves, and afford a means of comparing the so-called standard sieves with the fundamental standards maintained at the Bureau. The new samples are slightly finer than those previously issued, conforming more nearly to the requirements of the cement specifications adopted January 1, 1917.

Hydraulic Cements Other than Portland Cement.

The investigation of the compounds of lime and alumina with small amounts of impurities of silica, iron oxide, and magnesium have been continued with most gratifying results. Alumina and lime burned in the rotary kiln in the proportion of 1 to 1, or 5 to 3 and then ground, give cements which have much greater strength in concrete than Portland cement. One to 6 gravel concrete gave a

strength of almost 3,000 pounds per square inch at the end of 24 hours. This showed continuous gain up to six months, when a strength of 7,600 pounds per square inch had been attained. Specimens stored in the drying closet showed a decrease after this time to 6,700 pounds, while those stored in the laboratory after this period increased to 8,200 pounds per square inch at the end of a year.

This high strength was due to the quick hardening (but slow setting) of the aluminate which is accompanied by the splitting off of colloidal hydrated alumina. This latter acts as a mineral glue. That the strength developed is greater than that developed by Portland cement is due to the greater amount of colloidal material formed.

Durability of Concrete in Sea Water.

The investigation of the effect of sea water on concrete has been continued and practically all concrete structures on the coasts of North America, Panama, and Cuba have been examined and reports have been issued to the Navy Department on several of the yards. Data are being collated on the condition of concrete and methods employed in construction of concrete structures in various harbors of the world. These data are being obtained through the various consular agents and reports have been received on a large number of structures.

The investigation has shown that all concrete exposed to sea water, irrespective of location, is subject to chemical disintegration unless properly fabricated and protected. If sufficient care is taken and proper designs and methods followed, the concrete will be durable. Practically all reinforced concrete structures, including those owned by the Government and public, in sea water are failing, due to improper design which causes the corrosion of the reinforcement. The conditions found demonstrate that the designs advocated by present engineering practice will not insure permanent or durable structures. It is anticipated that the results of this investigation will be published during the ensuing year.

Durability of Concrete in Alkali Waters.

The investigation of the durability of concrete in alkali waters was started in 1913, and was instituted because of its importance to various branches of the Government using concrete in irrigated districts, where the alkali occasionally becomes concentrated in the soil, and as a result of the many requests received for information on the subject. The investigation is being conducted in cooperation with the Reclamation Service, the drainage division of the Department of Agriculture, and the Portland Cement Association, to determine the durability of concrete of various kinds in concentrated alkali soils and methods of mitigating failure.

As part of the investigation some 8,000 specially prepared drain tile made under the Bureau's supervision were installed in concentrated alkali soils in Colorado, Montana, Wyoming, Arizona, Washington, New Mexico, and Utah. A number of these tile are taken up and tested each year. The results of the first year's tests were published in Technologic Paper No. 44.

As an extension of this work, a large number of concrete blocks were made using aggregates to be found on the various projects as

well as an aggregate of known excellent quality at Denver. These blocks were installed in localities similar to those in which the drain tile were installed and are to be examined from time to time for indications of disintegration.

A second progress report has been prepared, to be published as Technologic Paper No. 95. This paper contains the results of tests of drain tile made during the first three years and a statement of the condition of the concrete blocks after one year's exposure. The results show that concrete and cement drain tile will disintegrate in some of these soils, unless the best of materials are used and special care is exercised in fabrication.

The results of tests made in 1916 showed that many of the tile installed on one of the projects in the Middle West had been attacked by some agent in the soil or drainage water. There is no alkali present in the soil on this particular project and the type of disintegration differs from that found in the western drains, where the drainage waters carry appreciable quantities of alkali salts. Since thousands of miles of cement tile drains installed in the humid regions of the East and Middle West are apparently giving satisfaction after years of service, it is not believed that this type of disintegration is general, although it confirms complaints as to the lack of durability of cement drain tile in widely separated districts of the East and Middle West, where failures have been found and previously explained as being due to the use of poor aggregates and improper methods of manufacture. An investigation is being made to determine the extent and cause of this type of failure. Additional tests are to be made from year to year and the report amended as results are available.

Investigation of Integral Waterproofing Compounds.

In compliance with a demand for more definite information concerning the value of integral waterproofing compounds, an advisory committee was organized in 1916, composed of representatives of the Government, engineering societies, waterproofing companies, and prominent engineers interested in this investigation, to formulate a program. The program which resulted from several meetings of this committee contemplated the construction of concrete tanks by contract, both with and without waterproofing compounds, under conditions simulating actual field conditions. All arrangements were completed for carrying out this program, but the increased work incident to the national emergency has caused the temporary postponement of this investigation.

During the year a number of waterproofing compounds were tested in the laboratory. Special tests were made on Toxement waterproofing compound for a Government department to determine the effect of its addition to concrete upon the density and weight. Its addition was found to materially decrease the density and decrease the weight per cubic foot.

Development of an Accelerator for Hardening Concrete.

At the request of the United States engineer office at Memphis, Tenn., an investigation was made to develop a method of producing a concrete which would have considerable strength in a comparatively short time. The results of tests indicate that the addition of a small

amount of calcium chloride with some cements in 1:2:4 concrete resulted in a strength increase of about 100 per cent in 24 and 48 hours. To further substantiate these results and obtain information as to the durability of concrete containing small amounts of calcium chloride, a comprehensive series of tests have been started. The results obtained to date indicate that concrete gaged with a 6 per cent solution of calcium chloride increases in strength from 60 to 110 per cent in two and three days. The results of tests up to six months do not show any detrimental effect from the addition of the calcium chloride.

Cast-Iron Reinforced Concrete Columns.

There is now being prepared for publication the results of tests of 20 concrete columns which contained as an unusual feature cast iron as reinforcement. This method of reinforcing was proposed by von Emperger, who used the cast iron in the form of hollow cast-iron pipe which formed the core of the column. The concrete is cast around this hollow core, which may, if desired, be filled with concrete, and reinforced with the usual spiral reinforcing.

The results show that this type of column would be very economical so far as cost is concerned. The cast iron is not stressed to more than 60 per cent of its maximum strength when the concrete fails, and also apparently is strengthened by the concrete, so that all local weaknesses are eliminated and there is no sudden failure so common to plain cast-iron columns. The columns were able to carry stresses amounting to 10,000 pounds per square inch and like hooped columns gave pronounced indication of approaching failure.

Floor Construction Tests.

An investigation was made of two types of floors recently introduced in Washington. At the request of the District building department, a loading test was made on a "Schuster" two-way reinforced combination hollow tile and concrete floor. For the Navy Department a test was made on a "Metropolitan" gypsum composition floor reinforced with twisted steel cables. This type of floor combines strength and elasticity with lightness of construction, and has been subsequently used by the Navy Department in some of their new structures.

Investigation of Composition Flooring.

This term is applied to certain noncombustible resilient flooring preparations in which the binder or cementitious material is "Sorel" or magnesium oxychloride cement. The other ingredients of the preparation are certain inorganic fillers, such as very finely ground quartz or limestone, asbestos, wood flour, and coloring agents. The finished floor has certain properties such as resilience, quietness, and lack of changes of volume, which allow it to be used in large slabs.

In order to obtain certain basic information in regard to the effect of foreign bodies in the ingredients and, also, information in regard to the effect of varying the amounts of the ingredients usually used, extended investigations have been started. This Bureau is making use of the active cooperation of a newly formed National Composition Flooring Association which is desirous of having a uniform specification drawn up covering their product.

This problem is of particular interest at the present time in view of a necessary change in the source of the magnesite. This latter material had, until the last two years, been obtained from Greece. When this supply was cut off active prospecting was undertaken in this country and some fairly good deposits located in California. The problem was further complicated by the fact that the imported material was delivered in this country in the calcined form. Since the proper calcination of the magnesite is of fundamental importance, this has been made one of the phases of the investigation.

Value of Various Materials as Concrete Aggregate.

In cooperation with State geologists and others, representative samples of mine tailings, crushed slag, sands, gravels, and stones are being obtained for test to determine their suitability as aggregates for concrete mixtures. A large number of tests have been made on fine and coarse aggregates from various sections of the United States. Comprehensive tests of the value of basalt and other aggregates from the Columbia River district, Washington, were made. The results of the investigations will be published upon their completion.

Effect of Moisture and Temperature Changes on Concrete.

Work was continued on the investigation of the action of concrete when subjected to a variation of temperature and moisture conditions. The present work has been confined to making measurements on concrete roads and pavements with the ultimate aim of determining the most effective distance for the spacing of transverse joints in concrete. During the past year numerous measurements have been made on experimental slabs installed on the Bureau grounds and on a Delaware road. These measurements confirm previous results in indicating that the concrete is subject to a rather definite annual cycle of changes in volume; during the wet and warm spring months an expansion occurs in the concrete, and during the drier months the concrete contracts.

A portable comparator is being used to measure accurately the volumetric changes in various cement mortars and plasters. The initial work has consisted of determining the contraction which occurs when a cement mortar obtains its set. Work has been done with mortars of various degrees of richness and results show that lean mixtures contract less than rich, and that mortars mixed when the humidity is high contract less than when mixed at the time the humidity is low. This work is being continued, and it is anticipated that a report will be issued during the ensuing year.

Tests of Field-Made Concrete for Lincoln Memorial.

Concrete cubes and cylinders of varying consistencies were made in the field from the concrete as actually used in the construction of the approaches to the Lincoln Memorial. These specimens were tested at various ages to determine their compressive strength. The results showed that the concrete of a consistency suitable for chuting was of sufficient strength to meet the requirements of the work.

Investigation of Building Stones of the United States.

In connection with the cooperative investigation of building stones which is being carried on with the United States Geological Survey,

Bureau of Mines, and Office of Public Roads, 50 samples of commercial marble have been tested to determine their compressive strength in a dry and wet state, transverse strength, perpendicular and parallel to the bedding, tensile strength perpendicular and parallel to the bedding, percentage of water absorption, specific gravity, porosity, weight per cubic foot, electrical conductivity, coefficient of expansion, resistance to frost action, resistance to the penetration of stains, and chemical composition. A report on these tests is now being prepared for publication.

A collection of the various commercial marbles has been made and placed on file at the Bureau of Standards. This collection at present consists of 75 polished slabs 8 inches by 12 inches and represents the principal commercial marbles of Vermont, Massachusetts, New York, Maryland, Georgia, North Carolina, Alabama, Missouri, Colorado, and California. This collection is now exhibited in suitable cases and may be examined by those interested in studying and comparing the various types of American marble.

Thirty-five samples of sandstone have been collected from the important quarries of the United States and the work of preparing test specimens is well underway. The physical properties of these will be determined in approximately the same manner as those of the marble.

Various samples of building stones submitted by other Government departments have been tested to determine their suitability for particular purposes.

Stucco and Plaster Investigation.

A series of tests, primarily to determine the comparative durability of various types of plastered metal lath on exterior walls, was undertaken in 1911. The results of these tests, obtained from the exposure of small panels, indicated the necessity of carrying out an investigation on a much larger scale. Accordingly a new and more comprehensive series of tests were planned, the program of which was put into the hands of an advisory committee consisting of representatives from the Government, engineering societies, the Associated Metal Lath Manufacturers, the Portland Cement Association, the Gypsum Industries Association, the National Lime Manufacturers' Association, the Hollow Tile Manufacturers' Association, and a number of engineers, contracting plasterers, and specialists. The recommendations of this committee were followed in the construction of a test structure, approximately 200 feet long, 26 feet wide, and 24 feet high, the exterior walls of which are divided into 56 panels approximately 15 feet wide and 10 feet high. These panels are constructed of terra cotta hollow tile, monolithic concrete, brick, gypsum block, plaster board, and wood and metal lath, and are plastered with a number of typical stuccos, the work being carried out under the supervision of the advisory committee. The structure was completed in November, 1915.

The first progress report on this investigation has been published as Technologic Paper No. 70. This report is mainly descriptive, giving the complete history of the test structure and the individual panels, together with a statement of the condition of the panels in April, 1916.

In the summer and fall of 1916 an addition to the test structure was erected, providing 22 new panels, the specifications for which were based largely on suggestions obtained from a study of the original panels, and approved by the stucco committee. A report on the new panels will be embodied in the second progress report to be issued during the coming year, in which it is planned to include a full discussion of the results obtained to date, and a tentative stucco specification setting forth the fundamental requirements of base construction, mixtures, and application. While this tentative specification will undoubtedly be modified in the light of later developments in the investigation, it will nevertheless make available the information gathered by the committee from a more comprehensive study of the subject than has ever before been attempted.

The field examination of stuccos originally planned as a part of the investigation has been begun by a study of stucco structures from 1 to 20 years old, mainly residences, in the vicinity of Philadelphia, New York, Boston, Cleveland, Chicago, and Pittsburgh. It is not planned to publish the results of the field inspection until the country has been more widely covered, but frequent reference to the field observations, so far as available, will undoubtedly be made in the second progress report.

The experimental work on interior plasters, which was to have been begun in 1917, has been postponed, probably for the duration of the war. Greatly as this work was desired by the committee, there was no hesitation on the part of any who had contributed to the funds for erecting the test structure in authorizing its use for laboratory purposes. The temporary and permanent alterations in this building will not interfere with the future carrying out of the original plans.

Information Furnished Concerning Cement and Concrete.

Many inquiries were received during the year from architects, engineers, contractors, and builders who sought information concerning methods of waterproofing concrete, the value of waterproofing compounds, methods of construction to be employed in sea water, effect of using sea water for mixing concrete to be placed in sea water, physical properties of concretes of various mixtures, the cause of staining of plaster walls and ceilings, the relative value of various concrete aggregates, methods of making magnesite composition floors, methods of preventing dusting of cement floors, methods of designing concrete road slabs, suggestions for building code requirements, the cause of failure of concrete structures, durability of cement drain tile, the effect of sewage on concrete, the physical properties of marbles, methods of treating stone to reduce absorption, specification for stucco, fire-resisting properties of structural materials, the corrosion of metal lath, reinforcement of gypsum plasters, the interpretation of cement specifications, methods of coloring concrete, etc.

From the general public requests were received for information on methods of mixing concrete, laying of concrete sidewalks, waterproofing basements, suitability of various materials for use in concrete, durability of concrete in sea water, durability of composition magnesite floors, the physical properties of stone, the cause of failure

of drain tile, the effect of frost action on concrete, suitability of concrete for oil and acid storage tanks, quality of American Portland cements, dampproofing brick and tile walls, dusting of concrete floors, corrosion of metal lath, etc.

From cement manufacturers, architectural stone manufacturers, and commercial testing laboratories requests were received for information on the accuracy of seives, methods of standardizing sieves, the physical properties of concrete, the value of fine grinding, apparatus for granulometric analysis, cause of failure of drain tile, the interpretation of cement specifications, quick hardening concrete, standard methods of testing, etc.

Publications on Cement and Concrete.

The following papers on the subject of cement and concrete were published during the year: Technologic Paper No. 58, Strength and Other Properties of Concretes as Affected by Materials and Methods of Preparation; Technologic Paper No. 70, Durability of Stucco and Plaster Construction; and Circular No. 33, third edition (revised), United States Government Specifications for Portland Cement. One paper is in course of preparation and will be published as Technologic Paper No. 95, Durability of Cement Drain Tile and Concrete in Alkali Soils.

Routine Cement Inspection and Testing of Cement and Concrete.

Cement was inspected during the year at 16 different cement mills, located in Virginia, Maryland, Pennsylvania, and New Jersey. The inspection work included the taking of samples, their testing, and subsequent supervision of packing and shipment to the various departments and offices of the Government. A total of 8,345 samples were tested for the Navy, War, Treasury, Post Office, Commerce, and Interior Departments, Panama Canal, Supervising Architect's Office, District of Columbia, Lincoln Memorial Commission, Smithsonian Institution, State of Massachusetts, etc. Inspection was made of 295,720 barrels of cement for shipment to Panama and 351,650 barrels for shipment to Government departments in the United States, for use in the construction of Federal buildings, river and harbor improvements, and for the State of Massachusetts. Cement was inspected for export for one company and certificates of the quality were furnished previous to shipment to Argentina. The inspection of all cement used by the District of Columbia necessitated that an inspector be stationed permanently at the cement mill in Maryland. Shipments to the District have ranged during construction periods from 1 to 4 carloads daily. During the year 72,000 barrels of cement were rejected on account of failure to meet the Government specifications.

A considerable amount of cement was made and tested at the Pittsburgh branch of the Bureau in cooperation with various societies in the course of formulating new specifications for Portland cement. A very large number of concrete cylinders were also tested, as part of a study the Bureau is making of cement manufactured in its own experimental cement plant.

Seven concrete columns 20 inches in cross section and varying in length from 5 to 10 feet, taken from a collapsed structure, were

tested to determine whether the concrete was of a satisfactory quality. These columns proved of particular interest, as they showed to a very marked extent the effect of excessively wet mixes. The fine material from the concrete had segregated in layers in the column to a depth of several inches, producing planes of practically no strength, although through the main part of the column the concrete was of fair quality.

Miscellaneous Tests of Stone, Sand, Gravel, etc.

During the year a total of 355 miscellaneous samples, consisting of sands, screenings, gravels, stones, asbestos roofing boards, waterproofing compounds, gypsum, magnesite cements, concrete, alkaline soils, waters, etc., were received for test.

Sand-Lime Brick.

It is believed that sand-lime brick of better quality and less cost can be made by improving the methods of manufacture. An investigation was first undertaken to determine the effect of various factors upon the properties of a brick-made lime and sand, both of very fine size of grain, that is, smaller than 200 mesh. A decidedly stronger brick was obtained with a composition of equal parts by weight of lime hydrate and sand than with any other proportion. The best molding pressure was found to be 10,000 pounds per square inch. Maximum strength was attained by steaming from 4 to 8 hours, longer periods causing a decrease in strength. This result in steaming was found to occur also with brick containing 10 per cent lime hydrate and 90 per cent of sand graded from 20 mesh to dust.

The investigation is being continued, using graded sand to replace the 200 mesh sand. The factor now being studied is the effect of the size of grain of the sand upon the compressive strength, transverse strength, and absorption of the brick.

Hydrated Lime in Concrete.

Hydrated lime in small amounts is being added to a great deal of the concrete now being used for various reasons. It is desirable to know the effect of such an addition upon the properties of the concrete, and with this in view an extended series of tests was inaugurated covering the compressive strength, absorption, adhesion to reinforcing, coefficient of expansion, etc., of concrete. A preliminary résumé of the results show as follows:

Compressive strength is in general decreased from 1 to 20 per cent by additions of hydrated lime, but in some instances the strength is increased. Strength tests were made upon 1:1½:3, 1:2:4, 1:2½:5, and 1:3:6 concretes of various ages up to one year. Two-year and five-year specimens remain to be tested.

Additions of lime hydrate increased the absorption of water by concrete from 10 to 50 per cent. The order of increase is indicated by a change of from 6 to 8 per cent absorption in a 1:3:6 concrete.

The adhesion of concrete to steel was decreased from 1 to 40 per cent by additions of from 10 to 20 per cent of lime hydrate.

The effect of lime hydrate upon the expansion of concrete is being determined, using bars 4 inches by 4 inches by 4 feet. It is proposed

to continue the investigation, determining the effect of lime upon segregation of aggregate and resistance to abrasion.

Measuring of Plasticity and Sand-Carrying Capacity of Lime.

The plasticity and sand-carrying capacity of lime are of great importance commercially, but no satisfactory method of measuring these properties has been so far devised. After a considerable number of experiments, an entirely new machine has been constructed for this purpose. A lime paste or mortar is molded into a cylindrical form and pressure applied by means of a paddle pressed against the revolving specimen. The tangential and vertical forces acting upon the specimen are measured and from these the coefficient of friction is determined. The test is repeated, placing the specimen upon a plaster block which absorbs water from the paste, causing a more or less rapid increase in the magnitude of the force acting upon it. From these data the work done upon the specimen is calculated.

A comparatively low coefficient of friction and a low value for work done indicate a plastic lime. The machine is being tested out thoroughly by the use of a number of lime hydrates from various parts of the country.

Properties of Hydrated Limes.

It was found that very few hydrated limes passed the standard specifications adopted in 1915 by the American Society for Testing Materials. Consequently 34 samples of hydrate were collected from various sections of the country and thoroughly tested according to the existing and to certain proposed specifications. The latter were adopted as tentative specifications for masons' hydrate by the American Society for Testing Materials in June, 1917. In order to aid in drawing up final standard specifications, the examination of lime hydrates is being continued. In conducting cooperative investigations of this kind, the Bureau is able not only to make reliable suggestions but also to obtain a very desirable knowledge of the material under consideration as it appears on the market.

Decomposition of Calcium and Magnesium Hydroxides.

The decomposition of calcium and magnesium enters into a number of problems connected with the manufacture, testing, and use of hydrated lime, since the latter is composed chiefly of calcium hydroxide and sometimes contains more or less magnesium hydroxide. The temperature of decomposition of these hydroxides and the rates of decomposition at various temperatures have been determined. From the results a method is being developed for determining the degree of hydration of these two oxides in lime hydrates. This is very necessary, as it has been found that lime hydrate which has been "burned" or had part of the combined water driven off by too high a temperature during hydration loses some of its plastic properties.

Investigation of Gypsum.

This Bureau is cooperating with a number of manufacturers and societies in devising methods of testing and specifications for gypsum and gypsum products. The tests investigated and the methods for conducting them adopted by the committee were: (1) Determina-

tion of free water for raw gypsum only; (2) fineness; (3) chemical analysis of raw or of calcined gypsum; (4) precaution for physical tests; (5) normal consistency; (6) water-carrying capacity; (7) dry bulk; (8) tensile strength; and (9) microscopic investigation.

Architectural Terra Cotta.

The use of certain burned clays in the molded or cast form, known as architectural terra cotta to distinguish it from terra cotta or hollow building tile, is increasing very rapidly, supplanting to a certain degree cut stone and architectural metals. As a larger part of the output is placed on the exterior of buildings, where it is subjected to all the severe weather conditions of this climate, it is very essential that it must have certain weather-resisting properties. It is also in certain unforeseen cases called upon to take stresses induced by movements of parts or the whole of the structure.

Under these conditions it seemed desirable to determine the physical characteristics of terra cotta as now manufactured in order to ascertain if it is possible to improve the present method of manufacture and also to study its use and methods of placement in structures. This investigation will begin with a study of the various clays used and will follow the material through its various stages until its final placement on the structure.

Investigation of Tile and Tile Walls.

A report of the results of tests on about 200 hollow building tile is being prepared for publication. These tile developed strengths ranging from 4,000 to over 10,000 pounds per square inch when tested on end and about one-half to three-fourths of these amounts when tested on edge or flat. The tests made to determine the relative degree of absorption of water showed values ranging from 6 to 11 per cent; a vitrified tile to the same scale of hardness ranging between 1 and 2 per cent. The strength of the tile was found to decrease almost directly with its degree of absorption.

The tile program also includes the testing of walls of widths from 3 to 6 feet; of from 6 to 8, and 12 inches in thickness; and of uniform heights of 12 feet. The strength of a wall tested in this manner varies approximately from 200,000 to 600,000 pounds, depending on the thickness of the wall. About 10 walls have been tested and the work will be continued for the present year. The program is being carried out in concert with other laboratories, each laboratory endeavoring to cover the different geographical clay and manufacturing districts.

Silica-Brick Investigation.

The extensive study of silica refractories, begun in 1916, has been practically completed. Several important facts have been brought out in connection with this work. Thus it has been found that well-burned silica bricks should show a specific gravity of not more than 2.36, and upon refiring to 1,500° C. a linear expansion of not more than 2 per cent in terms of the original length. Simple tests of this kind offer a ready means of detecting inferior products, a fact of considerable importance to the by-produce coke oven and the steel industries, which largely depend upon the use of silica refractories.

Study of American Clay Refractories.

For the purpose of assisting in the classification of American clay refractories, a large number of fire bricks have been examined with reference to their softening temperature, their ability to resist a pressure of 40 pounds per square inch at 1,350° C., and their volume and porosity at various temperatures up to 1,500° C. Since most of the domestic makes are represented in this series of tests, the information should be of a fundamental character and useful in the preparation of specifications governing their use.

Special Refractories for High Furnace Temperatures.

In meeting very severe furnace conditions which prevail when crude oil is used as a fuel, as under marine boilers, the employment of refractories possessing a wide margin of safety would be very desirable, since these would make it possible to force combustion when occasion requires it. A study of special refractories for this purpose was made and resulted in the production of bodies consisting of calcined high-grade flint clay with kaolin as the bonding material, which are capable of standing up under extremely severe conditions, both as to temperature and pressure. Still more refractory bodies were produced from a mixture of kaolin and alumina, partly precalcined, which approach the composition of sillimanite, $Al_2O_3Sio_2$. For very high temperatures a composition was developed consisting of 84 parts (by weight) of magnesite and 102 parts of calcined alumina, intimately blended and fired to a high temperature. Crucibles were made from this mixture, which corresponds to that of magnesia spinel. These were able to resist a temperature of 1,700° C. very satisfactorily. Materials of this type formerly were produced only by the Royal Porcelain Manufactory at Berlin.

Study of Ceramic Kilns.

With the constant increase in the cost of coal the fuel consumption of ceramic kilns and furnaces has become a question of national importance. It is evident that kilns of the greatest thermal efficiency must be employed and the firing processes must therefore be conducted economically. This subject received attention during the past year in the study of a new type of kiln, the so-called tunnel kiln, an installation of which, in New Jersey, was closely examined with reference to its heat efficiency, temperature distribution, and character of heat losses.

A kiln of the older, down-draft type, but fired with producer gas, was made the subject of another study. This kiln, located in Indiana, was tested in a similar manner, and incidentally information was collected concerning the advisability of using producer gas as a fuel for periodic kilns. These reports have been completed and will appear in the form of a technical paper.

American Plastic Bond Clays.

A study of 28 domestic plastic fire clays suitable for use in the manufacture of glass pots and graphite crucibles has been completed. It has been shown that from the standpoint of quality the domestic materials are available, which make possible the replacement of the clays formerly imported from Europe. Attention, however, has been

called to the necessity and desirability of blending two or more clays, thus replacing the old practice of depending upon a single clay.

Emphasis has been placed upon controlling the properties of the mixtures which are impossible when only one clay is used. In spite of the difficulties now being experienced by manufacturers of such refractories, the principles enunciated should prove of value in building up a sound practice. In the paper on this subject now in preparation both the European and the American methods of manufacturing glass refractories and crucibles are reviewed and described.

Sizing of Calcined Clay.

The sizing of the grains of calcined clay in mixtures used for the making of glass pots, crucibles, sanitary ware, etc., has a very important effect upon the resulting structure of the fired product. The results obtained by varying the amount of each size of grain for different purposes have been worked out in an elaborate investigation, which has been completed and is being submitted for publication.

Clay Tests.

Approximately 300 tests of clays have been made for State geological surveys and private individuals, especially with reference to finding new sources of kaolins, plastic bonding, and paper clays. Several new deposits of suitable clay have thus been located in Alabama. A number of clays have also been tested with reference to their adaption to new uses, especially in connection with the manufacture of chemical stoneware. In several instances detrimental properties of clays now being used have been detected and attention called to their defects.

Porcelain Investigation.

In the continuation of the study of porcelains the scope of the work has been greatly extended and now includes practically the entire field of hard-fire porcelains based entirely on the use of domestic clays and kaolins. New features have also been introduced by replacing the quartz (flint) by calcined kaolin, artificial sillimanite, fused alumina, and zirconium oxide. Similarly, the feldspar has been replaced, either wholly or in part, by eutectic combinations of kaolin, quartz, and magnesia. In this manner it has been found possible to produce entirely new types of porcelains with characteristic properties. Such properties as the softening temperature, the vitrification range, and the volume changes which the porcelains undergo are being determined for each of the 90 porcelain compositions.

Porcelain for Spark Plugs.

The insistent demand for spark plugs capable of standing up under severe use in aeroplanes, tractors, etc., has been the incentive for conducting experiments aiming to produce bodies capable of giving maximum service. For this purpose the compositions of the French and German special spark plugs have been reproduced and are now being tested for dielectric strength in the laboratories of the Bureau. Additional hard-fire porcelain compositions are likewise being tried out for this purpose.

Enameled-Iron Investigations.

Two technical papers are in course of preparation on this general subject, one dealing with the manufacture of enameled cast iron and the other of sheet-steel products. Although these industries are rapidly increasing in magnitude and importance, the technical literature relating to the processes involved has been very meager and sometimes misleading. In the work now in preparation the attempt will be made to correlate the information available and to bring out principles not generally recognized. A comparison is also being made of American and foreign enameled products.

Optical Glass Investigation.

The work on optical glass progressed as far as it could with the laboratory equipment available. For this reason, during the latter half of the fiscal year a larger furnace was installed capable of holding one pot carrying a charge as large as 1,000 pounds. With this unit, it has been found possible to make successful melts of crown and prism glass. Experiments are being conducted upon other glasses which are in demand.

In order to increase the rate of progress in this work, a new kiln house with eight melting furnaces and suitable molding and testing equipment is being erected.

Pots for use in connection with optical glass are now being made from domestic raw materials for the purpose of developing suitable compositions for special glasses which are very severe upon the clay mass of the pot.

Investigation of Lubricating Oils.

The test for demulsibility or resistance of an oil to emulsification was reported upon last year. A description of this test, published by the Bureau as Technologic Paper No. 86, aroused so much interest among refiners and consumers that the Bureau's supply of copies for free distribution was exhausted within a month. The Panama Canal has incorporated this test in specifications for steam turbine oil.

The determination of viscosity so that it may be expressed in some rational unit is a matter of much importance, as the vague units in common use frequently lead to confusion. Considerable work has been done toward the standardization of the Saybolt Universal Viscosimeter, but the completion of this investigation has been delayed by the great amount of war work on hand. A preliminary account of this work has been published in a paper presented before the American Society for Testing Materials at Atlantic City and a technologic paper has been prepared which gives a more complete account of the method of determining absolute viscosity.

Information Furnished Regarding Lubricating Oils.

Ordinarily, tests are not made for private parties, but many requests are received from large consumers for advice concerning the testing of oil. A very large amount of correspondence has been conducted during the past year in compliance with such requests. Addresses have also been delivered before associations by representatives of the Bureau concerning the testing of lubricating oils.

Investigation of Leather.

There are differences of opinion among tanners, manufacturers, and consumers regarding the relative value and wearing quality of different tannages of leather used in the manufacture of shoes and no satisfactory specification or method of test has been developed. The problem is of special importance at the present time in view of the large quantity of leather required for military purposes. This situation has caused the Bureau to take up an investigation of the subject and the hearty cooperation of the National Association of Tanners has been secured.

During the past year experiments have been conducted, with very encouraging results, with a machine designed for testing the wearing quality of sole leather. Interesting experimental results have been recently obtained in testing the wearing quality at different parts of the hide. The results obtained, when considered in connection with an examination of the leather tested, were pronounced by a number of leading sole-leather tanners to be in accord with the known variation in wearing quality as learned by years of experience. This fact may be offered as strong evidence in favor of the value secured by the testing machine. If the machine gives true indications of the relative wearing quality at different points of a hide, it may be assumed that its results will indicate correctly the wearing quality of different leathers.

Experiments will be continued to include the different tannages of commercial leather with the view of determining their relative wearing quality. The wearing quality will be studied by comparing the results obtained with the Bureau's testing machine with the results of actual service tests. Other physical properties will be studied and chemical analyses will be made in order to develop standard specifications and methods of testing. Tests will also be made to determine the relative wearing quality of sole leather as compared with the numerous leather substitutes.

Investigation of Shark and Other Fish-Skin Leather.

The Bureau, in collaboration with the Bureau of Fisheries, is investigating the problem of tanning shark and other fish skins. A large number of skins have been distributed among the various tanners who are experimenting with the methods of producing tanned skins of a quality that may be used as a substitute for certain grades of leather. The experiments have not been entirely successful in all cases, but a number of tanned skins submitted for test have given very encouraging results. The Bureau is investigating the physical properties of the different tannages and it is thought that further experiments will develop methods of tanning by which fish skins may be made into leather adapted for many useful purposes.

Experimental Rubber Plant.

Some progress has been made in studying the physical properties of rubber, but a very limited amount of time could only be devoted to this subject on account of the great amount of routine work. Additional data have been secured on the effect of dry heat on rubber stationery bands, rubber insulation of wire, and rubber compounds in general.

The machine designed at the Bureau for testing the wearing quality of sole leather has been used experimentally for studying the relative wearing quality of rubber compounds such as are used for the tread of pneumatic tires. Eighteen compounds have been experimented with and the results indicate that the apparatus may be adapted for testing the wearing quality of tire stock and rubber-composition soles.

The Bureau's experimental rubber-mixing plant has been handicapped to a great extent during the past year by the unusual demands for special tests along other lines.

Eight rubber compounds were mixed and vulcanized into sheets in connection with a study of the aging properties of rubber.

About 50 pounds of crude rubber were washed and dried and 19 rubber compounds were mixed and vulcanized for experimental purposes.

Investigation of Solid-Rubber Tires for Motor Trucks.

The Bureau is investigating the physical and chemical properties of solid-rubber automobile tires for the War Department. Tires of different manufacturers have been secured and experimental work is already under way to ascertain the physical and chemical characteristics of the different rubber compounds used, with the object of establishing definite specifications and methods of testing.

Rubber Eye Shades for the Range Finders of Battleships.

During the fiscal year 1915 the Bureau conducted experiments for the Navy Department with the view of producing a rubber compound that would be suited for eye shades to be used in connection with the range finders of battleships. Numerous trial compounds were mixed and vulcanized into eye shades which, after being subjected to service conditions for about six months, were returned to the Bureau for examination. Several of the samples were found to have given good service and of these a compound which showed no perceptible deterioration was selected as a standard and will be specified in placing orders for eye shades in the future.

Cooperation with Technical Societies, Manufacturers, and Consumers.

The Bureau is actively cooperating with the American Society for Testing Materials and with a number of testing laboratories representing manufacturers and large consumers in the development of specifications for rubber goods, such as insulated wire, rubber hose, rubber belting, valves, insulating and friction tape, etc.

Work of this sort is of a distinct value in keeping the Bureau in touch with the progress of manufacturing practice and the Bureau's research laboratory serves a very useful purpose in affording facilities for careful and accurate determinations of the physical properties of rubber.

Assistance Rendered Government Departments.

The Bureau acts in an advisory capacity for the various Government departments in furnishing specifications for miscellaneous materials and in making reports covering the results of tests in connec-

tion with supplies furnished on contract or submitted with competitive bids. The following instances illustrate the nature of this service:

The Bureau assisted in the preparation of specifications for rubber dredging sleeves by request of the Chief of Engineers, War Department.

A test for the resistance of oils to emulsification, which was developed at the Bureau, has proved satisfactory in specifications and has been adopted by the Panama Canal.

Thirty-two samples of inner tubes for automobile tires were submitted under competitive bids to the Post Office Department. The Bureau's report covering the results of physical and chemical tests of these tubes was used as a basis for awarding the contract.

Fourteen samples of rubber bands were tested for the Post Office Department, the General Supply Committee, and the Panama Canal. The Bureau's reports were used as a basis for the award of contracts.

Information Furnished on Physical Tests of Rubber and Leather.

Numerous requests have been received for information regarding the testing of rubber and leather and for the results of the Bureau's experimental work along these lines. As a rule, these requests come from the more progressive manufacturers who realize the advantages of reliable laboratory tests in developing their products and in maintaining uniformity in the quality of their raw and manufactured materials. In the majority of cases referring to rubber the desired information is supplied by reference to Bureau Circular No. 38, third edition, which illustrates and describes the apparatus and methods of testing rubber developed at the Bureau and also gives the results of experimental work in determining the physical properties of rubber.

Special Tests of Miscellaneous Materials.

There have been made during the past year 136 special tests, some of which were of an experimental nature requiring detailed attention and special equipment. Under this head may be mentioned the following:

Samples representing 500 feet of cotton rubber-lined hose purchased by the District of Columbia Fire Department were tested according to specifications prepared expressly for this material. Five samples of cotton rubber-lined fire hose were tested for the Panama Canal and 20 samples of linen fire hose were tested for the Office of the Superintendent, State, War and Navy Building.

Twelve samples of tanner shark and other fishskins were tested for strength and stretch. In one case many tests were made to determine the relative tensile properties at all points of the skin.

Three tanned calfskins were tested to determine the relative strength and stretch at all points of the hides.

Twenty-four samples of sole leather were tested under different conditions to determine their wearing quality.

Eighteen samples of different rubber compounds were tested for wearing quality.

Three samples of rubber hospital sheeting were tested for a manufacturer of this material.

A sample of pneumatic tire for use in connection with airplanes was tested for the Signal Corps of the War Department.

A sample of cotton rubber-lined fire hose was tested for the Department of Engineering, city of Hartford, Conn.

Tests of Miscellaneous Materials.

During the past year a total of 956 miscellaneous samples were tested, including the following items, which are representative of the materials handled: Rubber hose, 156; packing (asbestos, rubber, etc.), 200; rubber-covered wire, 189; leather belting, 47; canvas belting, 25; hack-saw blades, 122; and sole leather, 19.

The majority of these tests were made at the request of the Panama Canal and the General Supply Committee, in connection with contracts for Government purchases. Numerous tests were also made for the various Government departments and for manufacturers who lack the special facilities offered by the Bureau's laboratory.

Comparison of Cotton and Wool Flags.

A series of exposure tests have been made upon flags made from cotton and from worsted bunting to determine under what conditions it would be desirable to use the cheaper cotton material. The large and increasing consumption of bunting has made this question one of considerable importance. This investigation has been completed and the results will be published soon in a technologic paper of the Bureau entitled "Comparative Durability of Cotton and Wool Flags."

Identification of Textile Fibers.

Any scientific examination of a textile material presupposes a knowledge of the kind or kinds of fiber of which it is composed. This information, when lacking, may usually be best obtained by a microscopical examination. The Bureau has recently purchased a photomicrographic outfit which will greatly facilitate and improve this branch of the work.

Sewing-Machine Stitches.

Two of the more common types of stitches have been compared as to the relative ability of the resulting seams to resist breaking when subjected to tension applied perpendicularly to the direction of the seam. Tests were made both with the seam intact and with one or both of the constituent threads cut at the middle of the test piece. Technologic Paper No. 96, Comparative Tests of Stitches and Seams, gives in detail the methods of test used and the results obtained.

Tensile Strength of Fabrics.

One of the most useful methods of estimating the quality or durability of a fabric is to study the effect upon it of tension applied in the direction of each of its sets of threads. The rate of stretching under uniformly increasing tension is of particular interest in connection with fabrics to be used for structural purposes. A curve-drawing apparatus has been designed and attached to one of the Bureau's strength-testing machines for automatically registering this effect. There has also been designed a new testing machine which

may be manipulated at various speeds, giving a large variety of methods of loading. This machine will be found useful in studying the effect upon the tensile properties of fabric of alternations in the manufacturing processes. For securing the desired atmospheric condition for this work an instrument has been installed which automatically regulates the moisture.

Textile Conference.

During May the second conference relating to the technical consideration of textile materials was held at this Bureau. A large number of technical and scientific men attended the meeting and the papers presented were very well received. A full report of the proceedings will be published by the Bureau shortly. It is expected that a similar meeting will be held next year.

Information Furnished Regarding Textiles and Textile Testing.

A great many requests have been received by the Bureau for information regarding the testing and properties of textile materials. These inquiries are very often suggestive of new phases of research.

The various departments of the Government require specifications to regulate purchases and, when desired, this Bureau assumes the responsibility of writing these specifications.

Testing of Textiles.

This Bureau has made tests of a routine nature upon 3,492 samples of textile materials. Included in these materials were a large variety of commercial grades and kinds of fabrics, twine, thread, yarn, waste, and loose fiber.

Buttermilk Casein as a Paper-Sizing Material.

Casein is the principal proteid in milk and as such has a high food value. Cheese contains both the fat and the casein of the milk, butter contains the fat only. Since the manufacture of butter is more profitable than the manufacture of cheese, there is always a considerable quantity of both skim milk and buttermilk. The skim milk and buttermilk contain the casein of the original milk. The casein may be recovered by various processes, and it finds an extensive use as the adhesive by which a film of clay or other similar material is bound to a sheet of paper. The finished paper, known as coated paper, has a very smooth surface well adapted for the reproduction of photographs and for the printing of high-grade illustrations.

The casein investigation was started at the request of the Dairy Division of the Bureau of Animal Industry, Department of Agriculture, and is a joint investigation with it. Its end of the problem has been a study of the production of skim and buttermilk caseins, while the application of casein in the paper industry is being developed by the Bureau of Standards.

Almost all paper makers express a strong preference for the French caseins. This does not seem to be due to any necessary inferiority of the domestic product, but rather to the fact that domestic producers do not turn out a uniform product. Different users express a preference for casein made in different ways. Casein made from buttermilk or from a mixture of buttermilk and skim milk can be

used, but does not seem to be a standard product. Certain mills claim that they find some of it suitable. Others have not been able to use it at all. Since the origin of a casein can not be told definitely from its appearance, it is likely that the expressed opinions of the industry can not be taken as final. Any investigation which will tend to bring together the user and the manufacturer of casein; to improve the domestic product, both as to quality and to uniformity; and to encourage the use of milk which would otherwise be wasted can not fail to be of benefit. At this time it must not be overlooked that this product has a distinct food value and that it should be the aim of the manufacturer to use for this purpose milk which could not be used for food under the existing circumstances.

The particular purpose of the investigation is to establish the most suitable methods for the production of skim milk and buttermilk caseins, devise methods for testing the finished product, and to study the best methods for its use in the paper industry.

Domestic Clays in the Paper Industry.

The examination of imported and domestic china clays for use as a paper filler and as a coating material for paper is being continued. Its purpose is to determine those characteristics which produce the best results in the paper industry. The clays are being examined, both chemically and physically, together with tests to determine the rate of slaking, color of the clay, and water mixture, etc. It is the purpose of this investigation to replace the imported clay by a suitable domestic clay.

Paper-Testing Devices.

The necessity for standard methods of testing materials has spread to the paper industry, and a demand has been created for testing devices, the results of which may be interpreted in terms of the quality of a paper to be used for a particular purpose. The testing devices now in use are not entirely satisfactory, as they are of the empirical type. Data from a series of comparative tests, using several of the well-known testing devices, have been secured and are now being compiled. Certain changes are also being made in these testing devices, together with a study of some of the more common faults found. The results of this investigation will place the testing of paper on a firmer basis and provide means for securing more accurate data relating to the quality of a particular paper.

Utilization of Waste Paper for Remanufacture into Paper.

The utilization of waste paper for remanufacture into white paper is growing in importance each year. At the present time over 25 per cent of all paper made is collected for remanufacture and a very large part of this material is used in making white papers. The present methods, however, are very wasteful in that a large percentage of the material is lost in the recovery process. It is the purpose of this investigation to study the present recovery methods, particularly with regard to the effect of the chemicals used and the loss due to overheating.

Paper Bags for Shipping Cement, Lime, and Gypsum.

The investigation to determine the most suitable paper for use in the making of cement, lime, and gypsum bags has been completed as

far as the laboratory tests are concerned. This work has involved a long series of tests, including all those tests regularly applied to paper, together with several tests especially devised for the purpose. The results so far are not such as will enable definite conclusions to be drawn. This is due to the fact that it has been impossible to make a satisfactory connection between the laboratory data and actual service conditions.

No reliable information could be secured from either the user or the manufacturer of bags, because no systematic tests were being made. In some cases bags that were condemned as being entirely unsatisfactory proved by a laboratory test to be of a high quality. The reverse of this has also been experienced and such conflicting conditions have made it difficult for the laboratory to put the proper interpretation upon the laboratory results. In several cases it has been shown that proper bags were being improperly used, thereby causing excessive breakage and condemnation of the bag. These conflicting data have necessitated the development of a service test for the laboratory by which it is hoped to interpret the laboratory data into actual service conditions.

Manufacture of Filter Paper.

Filter paper is used in all chemical laboratories and in large quantities in industrial work for filtering out fine suspended particles from a liquid. The highest quality of filter paper is imported and under present conditions it is almost impossible to obtain it. Many inquiries have been received at the Bureau, asking if it was possible to obtain domestic filter papers of suitable quality. None is made in this country and therefore an investigation as to its manufacture has been started at the Bureau. Samples of the best grades of imported papers have been obtained and they are being subjected to a series of tests to determine their physical and chemical properties.

Filter papers must have a very low percentage of ash, a rapid rate of filtering, and must be free of certain constituents. The chemical treatment after manufacture is highly important and, so far, this final chemical treatment has not been satisfactorily worked out. It is proposed to continue the investigation along this line, as the final chemical treatment determines the quality of the paper.

Information Furnished Concerning Paper.

Assistance was rendered in the preparation of definite specifications covering the general needs of the various branches of the Government service. Work of this kind is continuous as there is a constant demand for pulp and paper products to meet special uses and the constantly changing requirements of the Government service. Continuous assistance is required by the Congressional Joint Committee on Printing, the General Supply Committee, and the Post Office, War, and Navy Departments.

Inquiries covering a very wide range have been received from the pulp and paper industry. While most of these have been handled by mail, in many cases the persons interested have visited the Bureau in order to study the methods in use at first hand. Among the visitors have been chemists and engineers of large manufacturing establishments, representatives of trade associations, and persons

engaged in the paper business. Several of them have been interested particularly in the experimental paper-making equipment of the Bureau, with a view to introducing something of a similar nature in their own establishments.

The Bureau always endeavors to aid manufacturers who may have difficulty in making satisfactory deliveries on Government contracts and many suggestions have been made during the year to such manufacturers. Many requests for the standard samples and specifications used by the Government have been received and complied with, and in addition to this many specifications have been prepared to meet the requirements of paper for special uses.

Attention has been given to the utilization of certain waste materials, due to the large number of such inquiries continually being received.

Many visitors have been shown through the paper laboratory and the nature of the work explained to them. This has helped to spread among the trade a knowledge of the facilities of the Bureau and in many cases has shown the manufacturer where the Bureau could be of material assistance to him.

Paper Testing.

During the past year the Bureau has tested 3,095 samples of paper, 3,033 for the Government Printing Office and the Government departments and 62 for public and private interests.

III. OFFICE.

Publications.

During the fiscal year just ended the Bureau issued 67 publications, of which 61 were new and the remainder revised editions. Approximately 56 publications were reprinted, owing to the large demand for those papers. The new publications included 4 numbers of the Bulletin of the Bureau, which completes the thirteenth volume of the scientific papers. There were also issued 28 new scientific papers, 20 new technologic papers, 9 new circulars, and 3 new miscellaneous publications.

The following new scientific papers were issued during the year: A Study of Inductance of Four-Terminal Resistance Standards; Sensitivity and Magnetic Shielding Tests of Thomson Galvanometer for Use in Radiometry; Volume Effect in Silver Voltameter; Constants of Spectral Radiation of Uniformly Heated Inclosure or So-called Black Body, II; Summary of Experiments on Silver Voltameter at Bureau of Standards and Proposed Specifications; Determination of Aluminum as Oxide; Calculation of Planck's Constant C_2; Wheatstone Bridges and Some Accessory Apparatus for Resistance Thermometry; Damping of Waves and Other Disturbances in Mercury; A Variable Self and Mutual Inductor; System of Remote Control for Electric Testing Laboratory; International System of Electric and Magnetic Units; Saccharimetric Normal Weight and Specific Rotation of Dextrose; Freezing Point of Mercury; Determination of Degree of Uniformity of Bars of Magnetic Standards; Thermoelectric Measurement of Critical Ranges of Pure Iron; Study of Electromagnet Moving Coil Galvanometers for Use in Alternating-Current Measurements; Standard Substances for the Calibration of Viscometers; An "Average Eye" for Heterochromatic Photometry, and Comparison of a Flicker and an Equality-of-Brightness Photometer; Emissivity of Straight and Helical Filaments of Tungsten; Aneroid Calorimeter for Specific and Latent Heats; Wave Lengths of Stronger Lines in Helium Spectrum; Relative Sensibility of Average Eye to Light of Different Colors and Some Practical Applications to Radiation Problems; Calculation of Constants of Planck's Radiation Equation; Extension of Theory of Least Squares; Luminous Radiation from Black Body and Mechanical Equivalent of Light; Experimental Study of Fahy Permeameter; Note on Electrical Conductors in Metals at Low Temperatures; Reflecting Power of Tungsten and Stellite.

The following new technologic papers were issued: Density and Thermal Expansion of American Petroleum Oils; Properties of Calcium Silicates and Calcium Aluminates Occurring in Normal Portland Cement; Properties of Some European Plastic Fire Clays; Constitution and Microstructure of Porcelain; Liquid-Measuring Pumps; Failure of Brass: 1, Microstructure and Initial Stresses in Wrought Brasses of the Type 60 Per Cent Copper and 40 Per

Cent Zinc; Failure of Brass: 2, Effect of Corrosion on Ductility and Strength of Brass; Failure of Brass: 3, Initial Stress Produced by the "Burning in" of Manganese Bronze; Manufacture and Properties of Sand-Lime Brick; Resistance of an Oil to Emulsification; Recovery of Paraffin and Paper Stock from Waste Paraffin Paper; Studies on Paper Pulp; Specific Gravity Balance for Gases; Structure of Coating on Tinned Sheet Copper in Relation to a Specific Case of Corrosion; Temperature Measurements in Bessemer and Open-Hearth Practice; Measurement and Specification of Physical Factors which Determine Saturation of Certain Tints of Yellow; Glasses for Protecting Eyes from Injurious Radiations; Effusion Method of Determining Gas Density; Durability of Cement Drain Tile and Concrete in Alkali Soils; Comparative Tests of Stitches and Seams.

The following new circulars were issued: Proposed National Electrical Safety Code; Standards for Electric Service; Electric Units and Standards; Specifications and Tolerances for Weights and Measures and Weighing and Measuring Devices; Specifications for and Methods of Testing Soaps; Specification of Transparency of Paper and Tracing Cloth; Rules and Regulations for Enforcement of Lime-Barrel Act; Gas Calorimeter Tables; Standard Samples for Thermometric Fixed Points.

The following miscellaneous publications were issued: Some Technical Methods of Testing Miscellaneous Supplies; Annual Report of the Director of the Bureau of Standards for the Fiscal Year ended June 30, 1916; Eleventh Annual Conference on Weights and Measures of the United States.

Technical Library.

The library contained at the close of the fiscal year 14,929 accessioned volumes, all of a scientific and technical character with the exception of a few law books. Two hundred and ninety-seven scientific and technical periodicals are currently received. This number does not include 94 (77 of which are German) not received on account of the war.

Personnel.

During the year the Bureau staff comprised 252 statutory appointees and about 265 engaged in researches and investigations specially authorized by Congress. The statutory positions included 149 scientific positions, 37 office assistants, 41 engaged in the operation of the plant, and 25 in construction work. There were 778 personnel changes during the year. These included 204 separations from the Bureau, of which 114 were resignations. There were 219 promotions and 338 appointments during the year.

Appropriation Statements.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1917, the disbursement during the year, the amount of unfilled and unpaid orders at the close of the year, and the unexpended balance remaining at the close of business June 30, 1917:

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$311,720.00	$277,357.70	$12,479.11	$21,883.19
Equipment	50,000.00	33,276.48	16,723.52	.....
General expenses	28,500.00	19,104.30	9,187.94	207.76
Repairs and alterations	5,000.00	1,379.21	3,387.03	233.76
Grounds	6,000.00	2,803.62	3,152.93	43.45
High-potential investigation	15,000.00	13,822.86	1,101.83	75.31
Refrigeration constants	15,000.00	14,394.70	575.95	29.35
Testing structural materials	100,000.00	90,034.04	9,815.03	150.93
Testing machines	30,000.00	25,254.75	4,547.03	198.22
Investigation of fire-resisting properties	25,000.00	18,355.12	6,644.88	.....
Public-utility standards	40,000.00	37,668.56	2,089.38	242.06
Railway materials	15,000.00	12,660.74	2,322.07	17.19
Testing miscellaneous materials	20,000.00	17,408.56	2,512.88	78.56
Radio research	[a] 14,459.71	12,511.20	1,644.81	303.70
Color standardization	10,000.00	6,661.30	3,324.08	14.62
Clay products	10,000.00	9,212.13	787.87	.....
Physical constants	5,000.00	2,932.50	1,694.08	373.42
Standardizing mechanical appliances	10,000.00	2,729.09	7,114.16	156.75
Testing railroad scales, etc	40,000.00	31,861.32	8,138.68	.....
Radio laboratory	50,000.00	1,334.76	733.80	47,931.44
Chemical laboratory	200,000.00	194,699.86	5,034.48	265.66
Equipping chemical laboratory	35,000.00	11,385.39	23,473.68	140.93
Total	1,035,679.71	836,848.19	126,485.22	72,346.30

[a] Includes reimbursement of $4,459.71.

The following statement shows the condition of the appropriations for the two preceding fiscal years at the close of business June 30, 1917:

FISCAL YEAR 1915.

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$293,500.00	$278,379.16	.....	$15,120.84
Equipment	[a] 57,311.33	55,198.58	$1,127.07	985.68
General expenses	27,000.00	25,965.04	364.00	670.96
Repairs and alterations	2,000.00	1,998.52	.....	1.48
Grounds	6,000.00	5,998.74	.....	1.26
High-potential investigation	15,000.00	14,984.96	.....	15.04
Refrigeration constants	15,000.00	14,997.89	.....	2.11
Testing structural materials	100,000.00	99,759.68	53.95	186.37
Testing machines	30,000.00	29,853.15	117.02	29.83
Investigation of fire-resisting properties	25,000.00	24,650.37	.....	349.63
Public-utility standards	25,000.00	23,230.31	1,410.33	359.36
Railway materials	15,000.00	14,839.06	110.00	50.94
Testing miscellaneous materials	20,000.00	19,920.64	.....	79.36
Testing railroad scales, etc	40,000.00	39,821.07	100.08	78.85
Total	670,811.33	649,597.17	3,282.45	17,931.71

[a] Includes reimbursement of $7,311.33.

FISCAL YEAR 1916.

Salaries	$298,780.00	$283,079.84	.....	$15,700.16
Equipment	50,000.00	47,723.70	$1,666.24	610.06
General expenses	27,000.00	26,656.01	263.20	80.79
Repairs and alterations	2,000.00	1,985.88	.....	14.12
Grounds	6,000.00	5,901.11	1.58	97.31
High-potential investigation	15,000.00	14,799.92	152.00	48.08
Refrigeration constants	15,000.00	14,923.23	.....	76.77
Testing structural materials	100,000.00	99,437.16	250.37	312.47
Testing machines	30,000.00	27,634.65	2,264.51	100.84
Investigation of fire-resisting properties	25,000.00	24,879.78	82.00	38.22
Public-utility standards	25,000.00	24,756.29	3.00	240.71
Railway materials	15,000.00	14,427.15	292.51	280.34
Testing miscellaneous materials	20,000.00	19,999.96	.....	.04
Current-meter testing tank	3,000.00	2,998.34	.....	1.66
Heating system, north laboratory	3,000.00	2,520.54	.....	479.46
Radio research	[a] 12,308.74	12,140.49	.....	168.25
Testing railroad scales, etc	40,000.00	27,728.78	12,271.22	.....
Total	687,088.74	651,592.83	17,246.63	18,249.28

[a] Includes reimbursement of $2,308.74.

Summary of Tests.

The work of the Bureau involves, among other things, a large amount of testing of standards, measuring instruments, and materials. It involves primarily the investigation of the scientific principles underlying the tests, the studying of existing methods, and the development of new standard tests of determinate accuracy. For each test a reasonable fee is charged, except when made for the National or State Governments.

During the fiscal year 1917 the Bureau made 155,848 tests and inspected 1,782,044 incandescent lamps at various factories for other departments of the Government. Of the total tests, 145,939 were for the Government and 9,909 for the public. The testing was distributed as follows, according to the nature of the tests: Length measures, 387; mass, 3,746; capacity, 1,189; temperature, 15,763; hydrometry, 926; miscellaneous, 23; optical, 1,365; time, 69; electrical, 1,290; photometry, 2,864; chemical, 13,170; engineering (miscellaneous), 511; engineering (instruments), 482; structural materials, 107,078; paper and textiles, 5,583; metallurgical, 1,402. The estimated fees amounted to $194,778.14, of which $17,765.47 were collected on account of tests for the public. The fees noted for Government tests are included merely for comparison purposes, as no charge is made for tests performed for the National or State Governments.

NUMBER AND VALUE OF TESTS COMPLETED, FISCAL YEAR ENDED JUNE 30, 1917.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length	197	$491.80	190	$427.95	387	$919.75
Mass	2,309	27,554.85	1,437	606.00	3,746	28,160.85
Capacity	900	455.25	289	278.05	1,189	733.30
Optical	1,327	1,980.50	38	173.00	1,365	2,153.50
Hydrometry	650	681.15	276	377.60	926	1,058.75
Miscellaneous	16	60.00	7	8.50	23	68.50
Time	1	100.00	68	322.50	69	422.50
Temperature	12,850	2,475.07	2,913	3,124.10	15,763	5,599.17
Electrical	736	3,684.77	554	3,387.37	1,290	7,072.14
Photometry [a]	2,568	9,411.50	296	625.50	2,864	10,037.00
Chemical [b]	10,047	79,688.40	3,123	6,192.00	13,170	85,880.40
Physical and mechanical tests:						
Engineering, miscellaneous	481	1,773.00	30	65.50	511	1,838.50
Engineering instruments	421	2,150.50	61	400.00	482	2,550.50
Structural materials	106,627	31,281.50	451	1,359.90	107,078	32,641.40
Paper and textiles	5,417	10,880.00	166	313.50	5,583	11,193.50
Metallurgical	1,392	4,344.38	10	104.00	1,402	4,448.38
Total	145,939	177,012.67	9,909	17,765.47	155,848	194,778.14

[a] In addition, the Bureau inspected 1,782,044 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to $8,910.22 additional.
[b] Of these tests, 7,633, amounting to $64,331, were chemical tests made on structural materials.

Metric System.

The general use of the metric system in Europe and the need for supplies and equipment in the metric system has called for a greatly increased use by American manufacturers. Manufacturers and exporters in large numbers have appealed to the Bureau for assistance and information concerning the metric system and the equivalents.

A large number of charts and circulars have been distributed for this purpose.

In addition, the movement of the troops to Europe has brought forth an extended demand for information as to the metric system for the officers and men in both the Army and Navy. The battleships, cantonments, arsenals, and the various bureaus of the War Department have been supplied at their request with metric literature.

A very large distribution of metric system publications has gone to the public schools of the country at their request. This is especially large in the case of public schools located in manufacturing districts.

Exhibits of the Activities of the Bureau.

Frequent requests are received from various organizations for the Bureau to make exhibits of its activities at expositions or conventions. While it is recognized that such publicity as is thereby given increases the usefulness to the public of the Bureau work and publications, it has not been possible to comply with all of such requests owing to lack of funds and personnel available for such work. In fact, under present war conditions it will probably not be feasible to participate in any such exhibits. However, when normal conditions are restored, funds should be especially provided for the proper preparation and organization of exhibits typical of the activities of the Bureau, such work to be put on a sure and permanent basis. The excellent results obtained for past exhibits indicate that a reasonable expenditure will be fully justified.

Among the exhibits in which the Bureau has participated during the year are the following: Second Exposition of Chemical Industries, New York, N. Y., September 25 to 30, 1916; American Chamber of Commerce, Washington, D. C., January 30 to February 2, 1917; American Metric Association, New York, N. Y., December 26 to 28, 1916; Aeronautic Exposition, New York, N. Y., February 8 to 13, 1917; and the Industrial and Export Exposition, Springfield, Mass., June 23 to 30, 1917. The metric exhibit prepared for the American Metric Association has been permanently installed in the American Museum of Natural History.

IV. RECOMMENDATIONS.

Increase in Scientific Staff.

The demands upon the Bureau in connection with the scientific work of the country, the industries, and especially the military departments of the Government, have grown by leaps and bounds. The Bureau is not only neglecting much work that should be done, but has been compelled to do many things in a temporary and superficial manner. This has been true especially during the past three years; nevertheless, every effort has been made to utilize the resources of the Bureau to the greatest possible extent in assisting the public to meet these new conditions and in aiding the military departments in the application of science to their problems. The demand on the part of the industries for accurate and reliable scientific data, a rapidly increasing one, has never been as great nor as important as at present, and such data will be of particular value at the conclusion of the present war. A conservative estimate for the additional services needed has been prepared and will be submitted. This estimate has been based solely upon the most urgent and pressing needs of the Bureau. It is hoped that Congress will recognize the importance of this increase and provide accordingly.

Increases in Salaries.

Never has the demand for scientific and technically trained men been as great as at present. This has resulted in the loss of many well-trained men in the Bureau's staff. The time has come when some of the salaries paid such experts must be increased or their services dispensed with. This can not be done without a loss in quality and the deterioration of the high standard of the Bureau's work.

Additions in the Clerical, Operating, and Construction Staffs.

The clerical staff is entirely inadequate and should be increased to meet the present urgent needs, which have greatly multiplied on account of the new demands made upon it. This is true especially in the care of property, files, records, and correspondence.

The addition of the chemical building, finished a year ago, and two new buildings now in process of erection, to be completed before June 30, 1918, make it absolutely necessary to increase the operating force of the mechanical plant.

The testing and investigational work of the Bureau is greatly handicapped by the lack of sufficient instrument workers. Estimates will be submitted for additional assistance of this kind.

Increases in Special Funds.

Increases are urgently needed in several of the special funds under which the Bureau is carrying on important work. The structural material fund is barely sufficient to care for the testing work of the

Government service. It should be increased by at least 50 per cent in order that the Bureau may undertake more investigational work needed by the Government service and by the public. The importance of this work can hardly be overestimated, not only from the standpoint of economy and efficiency in the structural work of the Government, but from that of the efficient and economical use of these materials on the part of the public and the military services.

The Bureau's work in connection with public utilities has proven of the utmost importance. The fund available is insufficient to cover more than two or three problems. The present appropriation might well be increased several fold; it would meet with the hearty approval of all public-service and municipal bodies having to do with the regulation of public utilities. It would contribute greatly to better service on the part of public utilities, as well as to the conservation of life and property.

The enormous annual loss of property by fire emphasizes the great necessity for a better knowledge of the fire-resisting properties of materials and construction. To be of value such work must be carried on with specimens commensurate with those used in practice. The Bureau's work in this direction has been well organized and much of the apparatus constructed. However, funds are needed for additional equipment as well as materials upon which to work, which in such cases are necessarily expensive; therefore, this fund should be increased to at least threefold its present value.

An increase is needed in the fund for miscellaneous materials, due to the growing tendency on the part of the Government to buy such materials according to properly prepared specifications and tests.

During the past year the Bureau submitted an estimate to provide for the determination of physical constants, a part of which was approved by Congress. These constants are of the utmost value in scientific and industrial work. Their determination involves the most difficult work in physics and chemistry. The Bureau should ever be the source of accurate and authoritative values of this kind and ample provision should be made for their determination.

The funds available during the coming year for the investigation of mechanical appliances are insufficient to meet even the needs of the Government service alone. This is true especially of the large number of military appliances and devices that have been submitted to the Bureau by the military departments. Here again, as in the purchase of materials, the Government is purchasing machinery and all sorts of devices in accordance with carefully prepared specifications, and suitable tests are made before their acceptance. The standard of performance in such cases and the methods of measuring the same are equally important to the manufacturer and to the public. This fund should be increased to two or three times its present value.

In general, it has been thought best to submit only such estimates as are urgently needed to care for present work rather than to enter new fields. However, several exceedingly important cases have arisen for which estimates will be submitted. The work of the Bureau in connection with the investigation of optical glass has proven of the utmost importance, both in military and scientific work, and in view of the necessity for the development of important kinds of glass which have heretofore been imported, an increase in this special fund will be submitted.

Estimates will be submitted for work in connection with the following: Standard materials; textiles, paper, leather, and rubber; electrodeposition metals; research fellowship; metallurgical research; chemical reagents; illumination investigation; radio activity; magnetic analysis; insulating investigation; and sea-water concrete investigation. All of these investigations are urgently needed in connection with the scientific, industrial, and military development of the country; in most cases the results obtained will be applicable to all of these interests.

Buildings.

Attention is again directed to the urgent necessity of placing the structural material work of the Bureau in permanent quarters. An estimate for a suitable site, building, and additional equipment has several times been submitted and is again presented. It is earnestly hoped that favorable action will be taken during the coming year.

New Refrigerating Machine.

A new machine to produce the refrigeration needed in laboratories is essential. The present machine was installed in 1904 and was well suited to the conditions then existing. However, the growth of the Bureau's work and the addition of new buildings make an increase of capacity imperative, while these and other conditions indicate marked economy to be obtained from a motor-driven compression machine instead of the present absorption type.

S. W. STRATTON, *Director.*

Respectfully,

To Hon. WILLIAM C. REDFIELD,
Secretary of Commerce.

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