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

NATIONAL BUREAU OF STANDARDS

ITS FUNCTIONS AND ACTIVITIES

CIRCULAR OF THE BUREAU OF STANDARDS, No. 1

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"Let us raise a standard
to which the wise and
the honest can repair."
Washington.

FOREWORD

This circular* gives for the nontechnical reader an outline of the service which the Bureau of Standards renders. The technical character of the research and other laboratory work precludes any attempt to give details. The circular is intended merely to point out the purpose of the activities and some of their results. Examples are given in certain cases to illustrate the nature of the methods and results. For details on any phase of the work the reader may consult the publications referred to in the chapter on "Publications."

George K. Burgess,
Director.

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*Prepared by Henry D. Hubbard, of the bureau staff.

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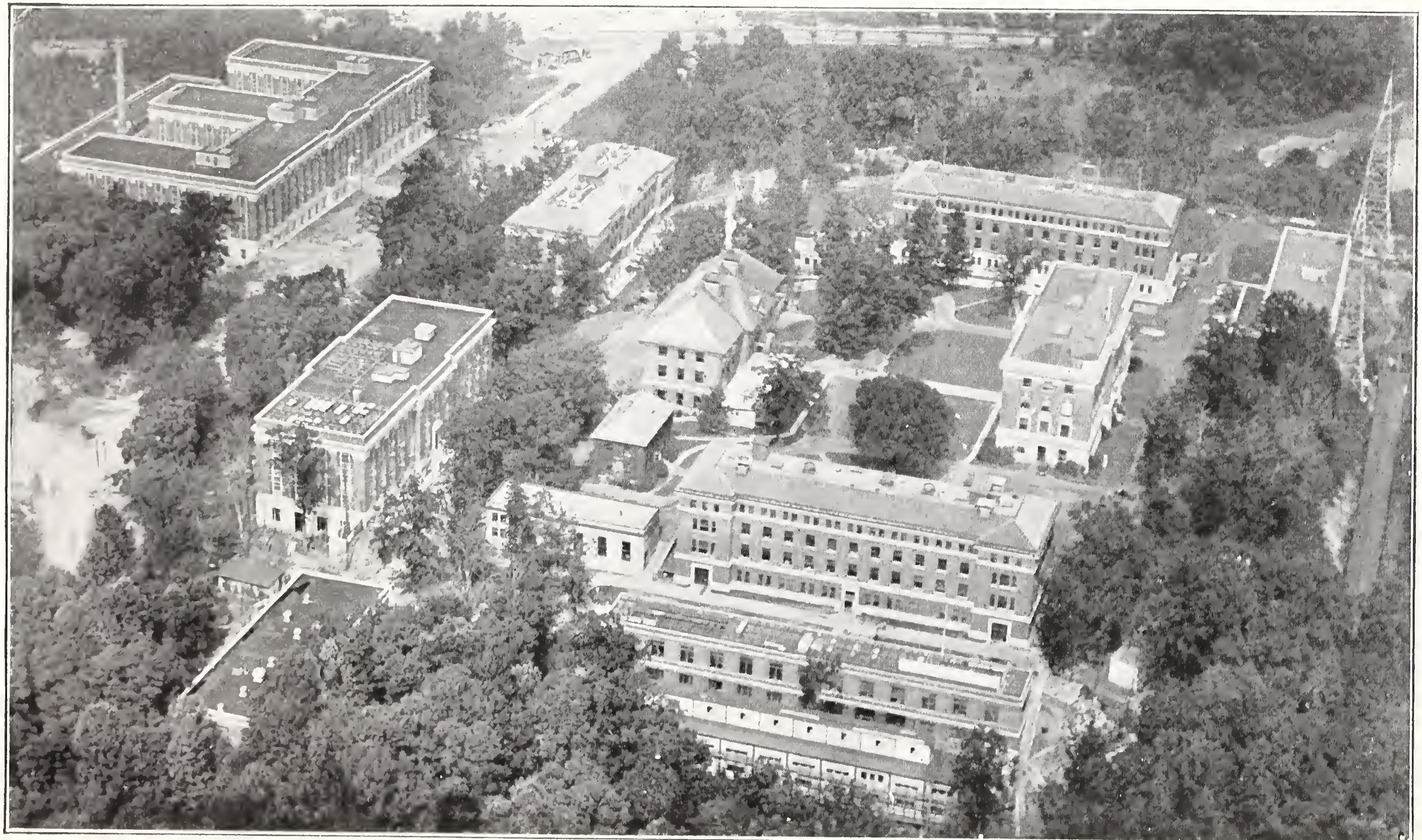

Fig. 1.—*Scientific and technical laboratories of the Bureau of Standards*

NATIONAL BUREAU OF STANDARDS

ITS FUNCTIONS AND ACTIVITIES

I. INTRODUCTION

1. PURPOSE

Bureau publications usually deal with specialized subjects. This circular is general. Its aim is to answer queries received in the daily mail and give the general reader a bird's-eye view of how the bureau serves the American people. Travelers from all parts of the country visit the bureau and carry away with them a new interest in the scientific work of our Government. This circular will give such visitors, and those who do not have that opportunity, a story of its varied, interesting, and important activities to be read at leisure.

To specialists who have a restricted contact, the circular will show the larger aspects and unity of its diverse activities. The illustrations are typical of the bureau's laboratories and facilities and are selected to give the general reader as well as the expert a clear idea of the work described in the text.

2. HOME OF THE NATION'S STANDARDS

Back of the thousand and one measures of industry and science are national standards on which they are based and to which they refer. As the home of the yard, pound, candle, ohm, volt, watt, and other measures, the bureau must, with all the resources of science, make and keep the national standards with an accuracy in advance of immediate needs. It must keep them acceptably constant. A standard may tend to shrink; the bureau should know how much and allow for change. It must devise methods—exact, convenient, efficient—by which local or industrial standards may be compared by the bureau and the accuracy certified. Basic standards for such measurements kept at the bureau are made available through such comparisons. This is an important bureau service to the Nation.

3. STANDARDIZATION

The bureau is a national agency for standardization and industrial research. It has no police power. Its conclusions are not mandatory, but its findings are accepted by all courts of justice. Its results have the authority which scientific data command. All this gives the bureau greater responsibility for improving all that affects the measured control of manufacture and utilization upon which modern efficiency and progress depend.

For a quarter of a century the Bureau of Standards has served the American people by fostering an interest in pure and applied measurements and has stimulated interest in higher precision in both science and industry.

Fig. 2.—*Central laboratories and administration building*

This group contains the South Building which houses the administrative units, the director's office, and the sections of the administrative office, finance, personnel, purchase, mail and files, publication, and information. The same building contains work of the optical and weights and measures divisions.

II. A TRIP THROUGH THE BUREAU

Most of us want to learn about new things, especially if they concern our daily life. When we read of some achievement of the Bureau of Standards and its resulting benefits to the public, this desire becomes acute. Again, an associate may have felt it his duty to tell us of his surprise at the really wonderful things Uncle Sam is doing with his corps of experts in Washington, and how a popular explanation and display of this work has given him a deeper appreciation and broader view of the way he is being benefited by his Government. We are, therefore, on our way to that institution, having made up our minds to take time to get acquainted with its extensive activities and how our tax money is returning to us values far in excess of our investment.

The following is characteristic of a visitor's experience: A pleasant ride along Connecticut Avenue north of Rock Creek Bridge takes you from the center of the city to Upton Street, the entrance to the bureau grounds. You are at once surprised to find an institution consisting of a group of laboratory buildings arranged like a university, situated on a natural hill amidst beautiful country surroundings. The glimpses of specimens of material under exposure tests alone give outward signs of the scientific work that is being carried on, much of it by night as well as by day.

You are directed to the administrative offices in the South Building. After a few minutes talk about the bureau and its functions you accompany one of the bureau's staff [1] on a general trip through the laboratories.

"This is an unusual location for a Government bureau, far from the business section of the city," you remark. "It would be, for most Government offices, but not for a plant of this kind," your guide replies. "We had to get away from electrical and mechanical disturbances, which seriously interfere with precise measurements. Also the ground we needed was easier to secure and cheaper than that in the built-up district. However, even now some of our precise work has to be performed at night when the elevators, street cars, and other heavy vehicles are not in operation."

"The bureau deals with five classes of standards," he continues, "standards of measurement, standard numerical constants, standards of performance, standards of quality, and standards of practice. In this vault on the first floor are kept the fundamental standards of

[1] The explanations and comments are such as H. G. Boutell or a member of his information section might tell any interested visitor during a trip through the bureau.

measurement—the meter and kilogram. These were supplied to our Government by the International Bureau of Weights and Measures at Paris. All measurement work is really referred back to these two basic standards and the standard unit of time."

"Is a material standard of length such as this absolutely constant?" you ask. "No; that is sometimes a difficulty. All such standards change with temperature and may change with time, even if only a very little—negligibly it may seem to most of us. But even a millionth of an inch can no longer be ignored. We hope eventually to adopt a certain wave length of light as our standard of length. Then, if all material standards of length were destroyed, we could easily carry on."

"Here in this adjoining room is a device set up to show you that a massive 5-inch steel bar supported at the ends bends measureably under the pressure of your finger. In the eyepiece here you see those rings enlarge as you press down. Those are shadow lines—interference bands—caused by the interfering light waves. By measuring their movement we can tell how much the bar is bent. You didn't believe you could bend a 5-inch bar? Well, you can see it bending under your touch if you have an instrument delicate enough to show the motion, perhaps a few millionths of an inch. Using light waves directly we have ruled here the most accurate scales in the world.

"In this other room we have a series of precision balances for comparing very accurate weights for precise weighings. We compare two weights of about 2 pounds each with an accuracy of one fifty-millionth of a pound. For such fine work the operator must stand at a distance from the balance so that the heat of his body may not affect the test. These rods are used to control the mechanism and the telescope to take the readings.

"In the basement of this building—the South Building, we call it—is a tile lined tunnel laboratory 165 feet long for comparing the base line measuring tapes for our national surveys and certifying other standard tapes in terms of our national standard of length.

"The West Building, which is one of the four that surround the 'campus' on the hill, houses several lines of work. On the top floor we have the polariscopic testing of sugar, on the other floors work in connection with heat and temperature measurements. These panels are specimens of typical wall constructions, and we are investigating the heat transfer through them. In other words, the bureau is finding out which style of construction keeps out the cold in winter and heat in summer to the greatest degree.

"This peculiar looking set-up in the basement is an apparatus for testing elevator interlocks. Over 75 per cent of the elevator accidents fatal to the public can be prevented by using a satisfactory interlock, and we are getting the necessary information to decide this matter."

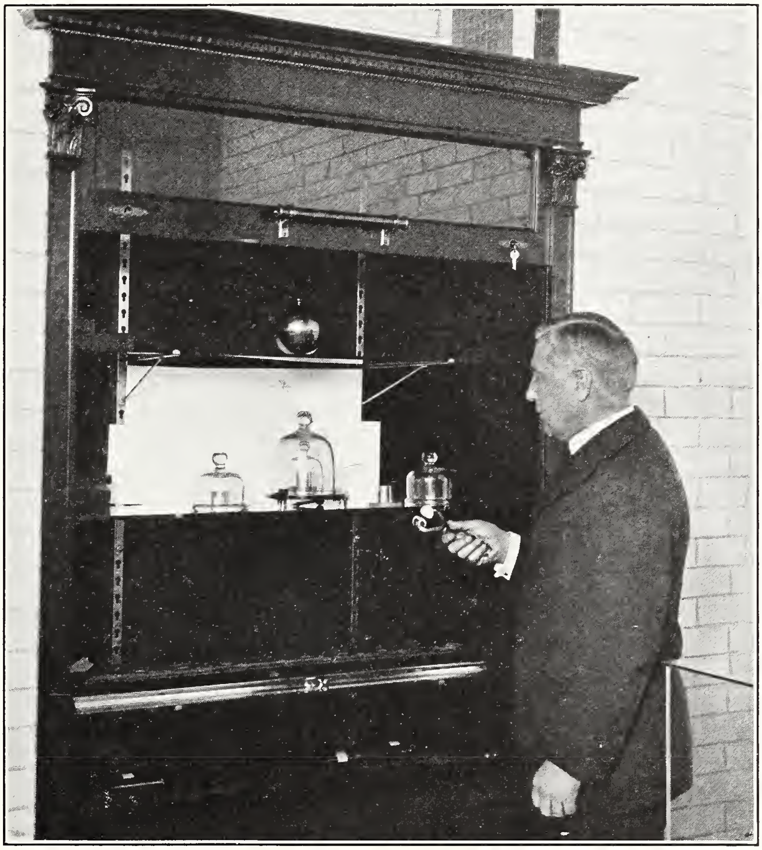

Fig. 3.—*Standards vault*

In the central bell jar is the National Prototype Kilogram—a cylinder of platinum-iridium resting on polished rock crystal. This is the standard of weight or mass. Below is the National Prototype Meter—the standard of length. All measurements of length and mass in the country are derived from these two standards.

"Is the bureau doing this work for any special industry or manufacturer?"

"No; of course, many industries will profit from it, but it is being carried out for the city of Baltimore in connection with their newly-adopted elevator safety code.

"We are now in the low-temperature building, another line of work carried out by the heat and power division. This large steam-driven compressor takes ordinary air and compresses it to about 3,000 pounds per square inch. It is then cooled and allowed to pass through a long coil of copper tubing. As it escapes from a valve at the bottom of the coil it expands, and in doing so it takes up heat from the coil. In other words, the air cools itself until some of it is cool enough to liquify."

"What is the temperature of the liquid?"

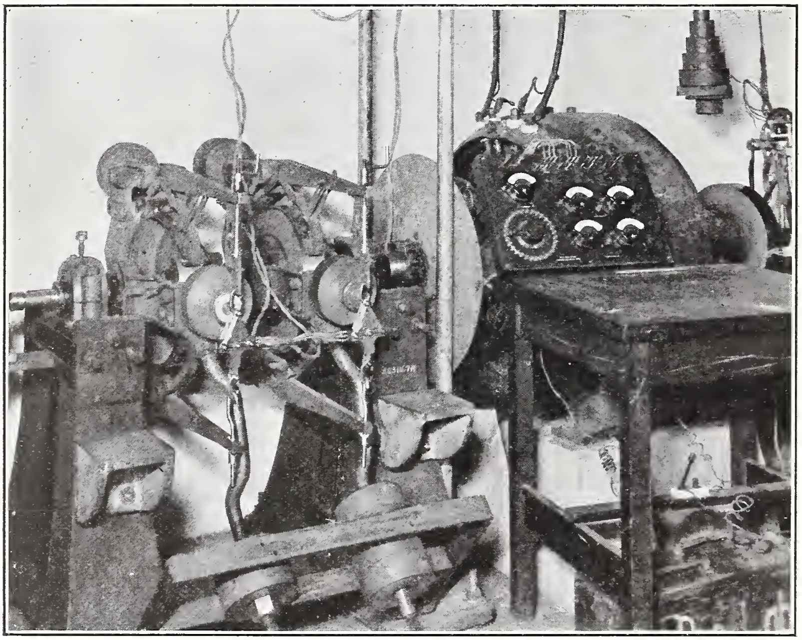

Fig. 4.—*Brake-lining test equipment*

Equipment mounted on a dynamometer for testing brake linings for automotive use; for the study of friction under varying conditions; and for comparative durability tests

"Three hundred and ten degrees below zero Fahrenheit. But we have produced liquid and solid hydrogen in this laboratory, at a temperature of 438° below zero, and we are now installing a plant to liquify helium, at a temperature only a few degrees above absolute zero.

"In this brick building and the smaller ones near it we carry out experiments on internal-combustion engines and appurtenances. We can mount an airplane engine in this concrete chamber and then by pumping out the exhaust gas and air we can lower the pressure to that corresponding with any desired altitude. We can also cool the air by a refrigerating plant, and in this way duplicate the conditions of an actual flight."

"What is that peculiar looking arrangement on that automobile?"

"That is a device for recording wind pressure and direction. As you will see, it is only part of a very elaborate arrangement for recording the entire performance of an automobile on the road. Through these tests we are learning just how much of the heat in the fuel is being converted into useful work, and as a consequence the efficiency of cars is being greatly improved.

"Here we are testing automobile brake linings. We developed this standard test several years ago. Similar apparatus has been installed by manufacturers, and the consequent improvement in brake linings is probably saving the public $15,000,000 a year.

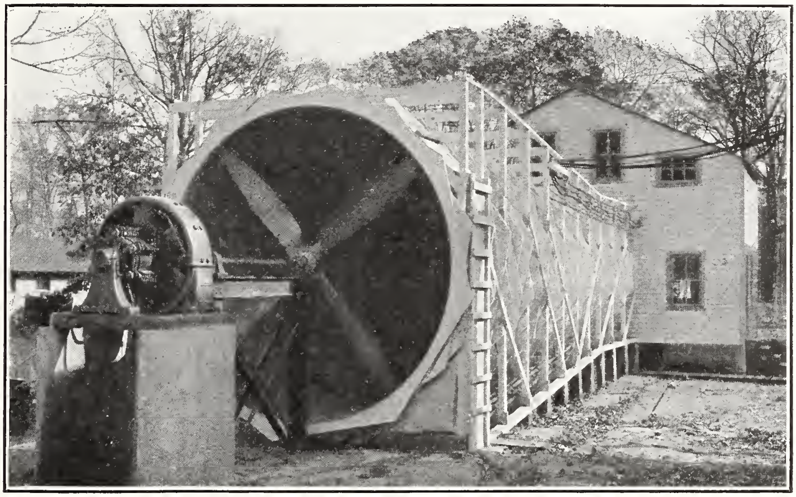

Fig. 5.—*Outdoor wind tunnel*

The 10-foot wind tunnel is used to test aircraft models, aircraft parts, bombs, roof ventilators, automobiles, and any other objects which encounter air streams or pass through the air. Such work is basic for the modern streamlining of such objects to secure effective profiles giving minimum air resistance.

"This small building we are now in houses our 54-inch wind tunnel, which was built during the World War, and in which many important military aeronautical problems have been solved. Wind tunnels are used to determine, by means of a model, the performance of any device designed to function in an air stream.

"The large outdoor tunnel which you see to the north is 10 feet in diameter and is used for testing large models, air pressure on buildings, bridge members, and other structural designs. The principle is simple, a large motor-driven fan blows an artificial wind of the desired speed (up to 75 miles an hour in the largest tunnel, and 180 miles an hour in our smaller one). A balance weighs or measures the forces on the model placed in the tunnel."

"So, if a man designs a new plane, you can test it as a model first, instead of his risking money and perhaps his life in a full-sized machine?" "Exactly; that is one of the objects of this work. Alexander Graham Bell's hydrodrome was tested here as a model, and the results aided him to perfect his design. Airship models are likewise tested.

"This large building (Northwest) houses our metallurgical work, our production and tests of high precision gauges, and other experimental work. You see we have a complete equipment of furnaces, a rolling mill, drawbench, forging press, and other metal producing and working equipment."

"Yes; it is really a small experimental metal-working plant, and I judge you can duplicate actual processes on a reduced scale." "That is the idea. You can not set standards for a big industry by sitting at a desk and theorizing; you must get down to brass tacks by actual experiments. We can study the actual mill procedure and show where improvements can be made by varying the constituents of a metal or alloy and methods of working it, and do it more quickly, cheaply, and more accurately than could possibly be expected in a full-sized commercial plant. That idea applies to quite a bit of our work, as you will see when we get to the Industrial Arts Building.

"We will now walk across the 'campus' to the East Building, to see the electrical work, and the radio laboratory—that long low building at the right. Let us go to the top floor of the Electrical Building. Here is the assembly room, where the staff members meet to discuss their work. Many scientific societies of the country meet here when they come to Washington."

"What a beautiful outlook!" "Yes; you can see the Capitol, the radio towers at Arlington, the new cathedral where the late President Wilson is buried, and the greater part of the city. An attractive quiet location is really an inspiration for the best results.

"In this room on the third floor we are testing, under measured conditions, the life of incandescent lamps purchased by the Government. Samples of all lamps the Government buys are tested by the bureau, so Uncle Sam is reasonably sure to get what he orders and pays for.

"Other work deals with tests of batteries, performance of electrical instruments, studies of telephone systems, and the maintenance of the electrical standards.

"Our work on safety codes is also carried out in this building. You have heard of the electrical safety code, the head and eye code for industrial workers, and the one now being formulated on aviation." "Yes; the electrical code was used by our city government in framing its present regulations."

"Here in the Radio Building we work on fundamental problems underlying radio. We also aid almost everyone who uses radio, and this means a large portion of our population, by sending out standard frequency signals, which anyone can use in testing his or her receiving set. Some time ago we got out designs and accompanying descriptions on several simple receiving and sending sets and these were largely used by radio fans." "Yes; Circular 120 was a household word in our family a short time ago."

Fig. 6.—*Radio Research Laboratory*

This laboratory provides space for the radio research of the bureau and of other departments of the Government. The standard frequencies are broadcast from here; the air is surveyed to secure constancy of frequency in broadcasting; and radio devices and instruments are standardized

"We will now walk down to the Industrial Arts Building to see the experimental plants for technical research in cement, stone, clay, glass, lime, plaster, paper, textiles, rubber, leather, sugar, and other structural and miscellaneous materials. In this central wing are located our big testing machines. The largest one, here on the left, has a crushing power of 10,000,000 pounds, and was recently used to confirm the strength of the Delaware River Bridge members." "Yes; I have seen pictures of that machine, and also the large Emery precision testing machine, which I notice in that room on the right. It is one of the most accurate testing machines in the world, is it not?" "Yes; that is correct."

"Across the areaway is the Kiln House, where optical glass research and other ceramics work is in progress. Prior to the war we began to develop the technique for making optical glass. The importance of optical glass in the making of lenses for photography and for the microscope, telescope, range finders, and all optical parts for technical uses, and for the making of a great variety of scientific equipment, has attracted nation-wide interest in this plant. Here, too, work is done on refractories, porcelains, and enameled metal ware, the latter material receiving renewed importance with the bureau's success in devising the method of avoiding flaking.

"In the woods here next to the Industrial Building may be seen experiments of many sorts; for example, on the hazard from shingles in roof construction from the high winds during conflagrations, on account of the blowing of embers. An artificial conflagration with a shingle roof built for the purpose was subjected to a strong wind from an airplane propeller, the wind speed being varied during the test. Provision was made for catching the embers during the course of the fire and studying the hazard under conflagration conditions.

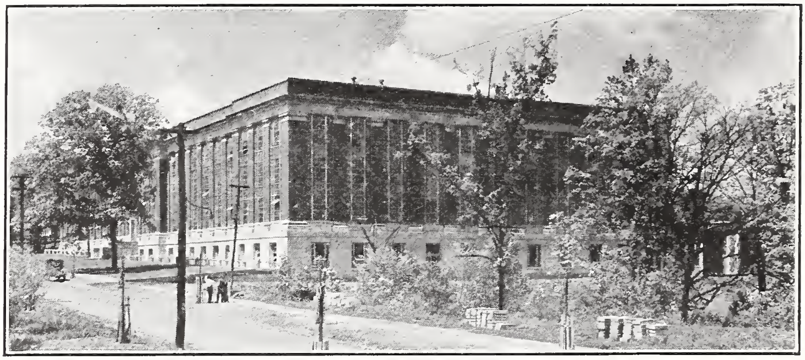

Fig. 7.—*Industrial Building*

Here research and testing are in progress on materials, such as cement, stone, metals; structural units; lime, gypsum, clay products, rubber, leather, paper, and textiles. In the rear is the kiln house in which are produced clay products, refractories, and optical glasses. The requirements for this class of work are quite different from those involving precise measurements, and this is reflected in the type of building.

"Returning to the Industrial Building, we have experimental plants for paper making, for spinning and weaving textiles, for manufacturing and testing rubber goods, for the production of sugar and many other materials of industry under controlled conditions. This photographic laboratory on the third floor won the highest award at the World's Fair in San Francisco for the quality of its photography. Here were developed the apparatus with which the sensitiveness of all types of photographic plates and films of American make were studied in great detail, adding a new chapter on the technical and practical side of photography. In another room was determined the relative utility of every part of a leather hide for making soles for shoes. This gave valuable data for the leather industry.

"These automobile tires are being run under experimental conditions to simulate road travel, and with means to measure the loss of power in the tires. We found an appreciable loss of power in transmission from the motor through the tires to the ground, varying with the design of the tires. In this laboratory specifications for tires were drafted, the details of rubber manufacture applied to specific problems, and various formulas tried out in making commercial rubber in the bureau's rubber mill." "I read that your work on tires had much to do with the abandonment of the fabric in favor of the cord tire."

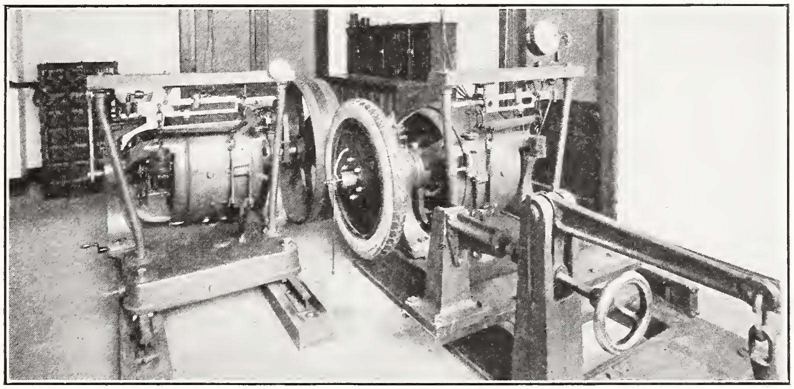

FIG. 8.—*Simulated road tests of tires*

This device literally runs the road past the wheel, with the wheel at rest, to measure how much power is lost in the tires. The design of the tire is found to affect such losses. The bureau ascertains which design causes least loss, thus permitting very large savings in the cost of operating automobiles.

"The cement laboratory is in this building. Research is in progress on important investigations, some of them going on for many years. These include the study of the effects of sea water on concrete structures to give data to engineers for making such structures endure where hitherto they had to be renewed every year or two; the effect of alkali waters on concrete tile used in irrigation projects; the effect of cement fineness on the strength of concrete; the microcrystallography of the constituents of cement; and many others affecting notably the technology of this important material. From here is administered the testing of Government cement—the cement used in the Panama Canal and other projects is tested by bureau experts and certified for use.

"The ceramics research on the technology of clay products ranges from brick to fine porcelain, including glazes and enamels. The bureau's fundamental work in this field paved the way for the scientific use of American clays by specifying the means of pretreatment, mixing, and chemical methods so that some of the finest foreign products could be equaled.

"Here we end our trip. The time allowed us has passed, and you have seen many of the things which would interest you most. I hope you enjoyed your visit." "I certainly have enjoyed the glimpses of your work; and to prove it I am going to tell my friends all about your bureau. We have many industrial plants in our town; I see that much of your work and the data you have obtained would be of great value to them. We are still in the dark on many technical aspects of our work. I shall ask your advice on several problems in my own plant."

"We shall try to help you, and will be glad to see you again at any time."

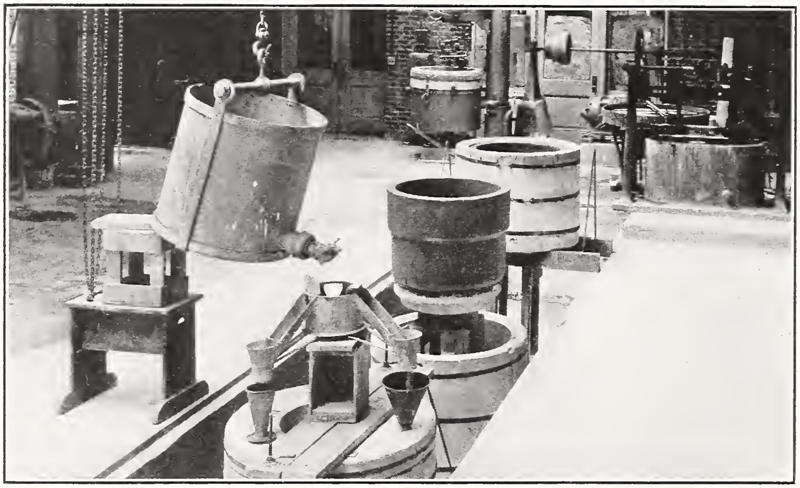

FIG. 9.—*Casting clay pots*

The development of the technique and actual production of glass pots of purity and quality essential in making the highest grades of optical glass were outstanding contributions of the Bureau of Standards to the establishment of the American optical glass industry.

"Thank you; on my next time I hope to spend at least a day here. It is one of the most interesting and instructive visits I have ever made."

Such a visit to the bureau and the appreciative reaction of the visitor are typical of hundreds of actual cases each year. Other parts of this circular give many more details of the bureau's work than could be told in the brief visit just described.

III. ORIGIN OF THE BUREAU

1. NATIONAL INTEREST IN STANDARDS

After this brief excursion let us at our leisure discuss some interesting things about the work of which we have seen glimpses. As is well known, Congress established the National Bureau of Standards in 1901. During these 24 years standardization has become the outstanding fact of industry. How well a machine acts depends upon how well the parts are designed and measured to fit. That automobile comfort and service are built to measure is obvious. It is less obvious that the purpose of all measurement is to increase human comfort, safety, and well-being. The bureau is the agency of the Department of Commerce to promote standardization—which is service set to measure. It fosters standardization by exact measures, many of them perfected in the laboratory and set to work in

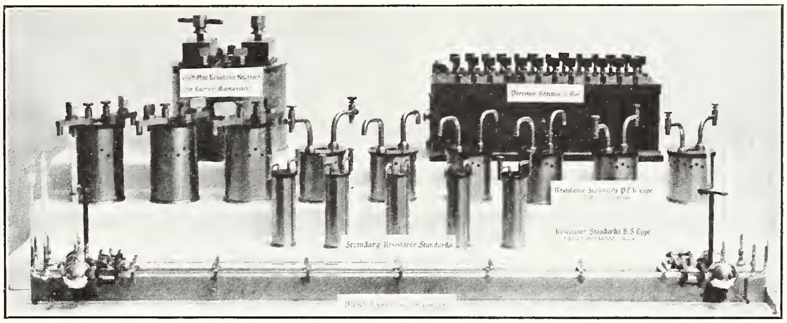

FIG. 10.—*Standards of electrical resistance*

These are typical of the elaborate nature of the newer standards. In the foreground is the so-called "mercury ohm," a column of mercury of specified purity and dimensions giving one unit (the ohm) of electrical resistance. The other standards are secondary standards of resistance.

the factory; by measuring whatever gives utility to things made for our use; and by specifications or standards defining their useful properties.

Measures are matters of national control, like the coinage. All nations so regard them. It was so in ancient Egypt no less than in old England, where the Magna Charta contains the decree of uniformity in the measures of the realm and prescribes them. The useful service of the Bureau of Standards had its origin in seven words of the Constitution which gave Congress power to "fix the standard of weights and measures." The writers could not have foreseen that measures would have to be provided for electricity, radium, light, and radio; yet to-day the watt, the curie, the candle, and radio-frequency or wave length are as needed in new fields as the yard, gallon, and pound in theirs. To-day scores of kinds of measures are used which were unknown in 1776.

2. EARLY HISTORY

The inside story of American weights and measures is a blend of biography of men like F. R. Hassler, to whom we owe our early achievements. His career is a record of persistence and genius such as a gifted chronicler might weave into a romance of measurement—constructing our national standards, affording industry effective linear measures, and creating the geodetic survey in which America has led the world.

The full story [2] of the standards is interesting history. Passing many details the bureau was built on old foundations, for the law creating it merely gave a new name to the old Office of Standard Weights and Measures. It was hardy stock on which the new enterprise was engrafted. The old office itself grew out of the complaints of business men that the standards in the customhouses differed intolerably.

The law of 1799 gave general authority to study these standards. In 1830 Congress again authorized a general comparison of the weights and measures in use at the principal customhouses. The report of 1832 pointed out large discrepancies existing. Without awaiting authority from Congress a shop was equipped at Washington for making new standards for customs purposes, copies of which by act of Congress (1836) were sent to the States. The same office later supplied the governments of new States later created by Congress. Congress also directed (1866) that the States be supplied with sets of metric standards. From 1873 funds were separately specified for this office, which was named (1883) the Office of Construction of Standard Weights and Measures.

The splendid work of the old office in establishing American standards and comparing them interested men of science. The International Electrical Congress (1884) held a special session to consider a paper on "A National Bureau of Physical Standards"—the first call for such a bureau of science in America. The call was later echoed by the Secretary of the Treasury (1900) who proposed to Congress that such a bureau be established. "The enterprise," he stated, was "one of the most important branches of scientific work any Government was called upon to undertake" and that a scientific laboratory was called for "fitted for undertaking the most refined measurements known to modern science." The great technical and scientific societies joined the larger industries in support of the project. Congress, recognizing the rapid rise of applied science, established the bureau by act of March 3, 1901, giving the new bureau legal functions broad enough to meet modern ideals of standardization.

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[2] We may be excused for passing over its details here, since Dr. S. W. Stratton's addresses, L. A. Fischer's "History of the Standard Weights and Measures of the United States" (B. S. Misc. Pub. No. 64), and Dr. G. A. Weber's excellent monograph on the Bureau of Standards leave little to be added.

The early history of the bureau was closely associated with the Treasury Department. In 1903 the bureau was made part of the present Department of Commerce. The bureau then moved into its new quarters on Pierce Mill Road. This famous historical road is, at this writing, being legally closed. Building operations will soon make the neighborhood, once suburban, a part of built-up Washington.

The bureau has grown by steady development of its primary functions, and in part by the expansion during the war which caused many additions to staff and facilities, some of which were permanent. Its staff numbers about 750, its library receives more than 600 technical and scientific journals and contains 27,000 catalogued books. Its 11 scientific and technical divisions cover more than 60 specialties.

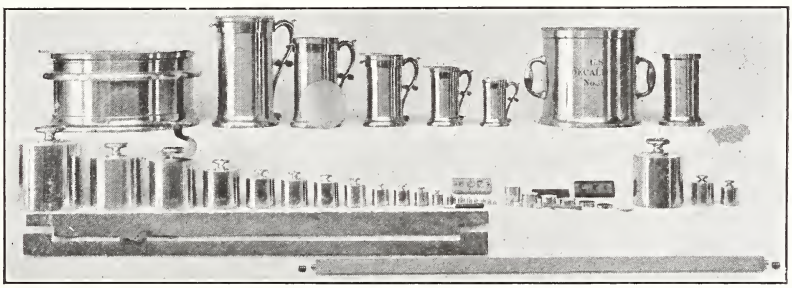

FIG. 11.—*Standards furnished the States*

The standards furnished to the States by action of Congress June 14, 1836 (customary standards), and July 27, 1866 (metric standards), comprised: 9 avoirdupois weights (1 to 50 pounds); 24 avoirdupois weights (0.0001 to 8 ounces); troy pound; 27 troy weights (0.0001 to 10 ounces); standard yard; 5 liquid capacity measures (½ pint to 1 gallon); half-bushel measure; line standard meter and end standard meter; liter, decaliter; 10-kilogram weight; ½ kilogram; 1 gram; set of metric weights (4 decigrams to 1 milligram).

3. SIMILAR BUREAUS ABROAD

America was the third nation to establish such a strictly national bureau. The treaty of May 20, 1875, resulted in the first governmental research laboratory—the International Bureau of Weights and Measures, now recognized as the world's highest tribunal on weights and measures. It is located at Sèvres, near Paris, and is claimed as the first "institution * * * created with the sole object of pursuing researches in science whose personnel was not at the same time attached to some great school." Its success inspired Germany to establish the Physikalisch-Technischen Reichsanstalt in 1887 at Charlottenburg. The valuable service of this institution to Germany and German industry led England to establish the National Physical Laboratory at Teddington, about 12 years later (1899). The institutions at Charlottenburg, Teddington, and Paris have made notable achievements in science and in the application

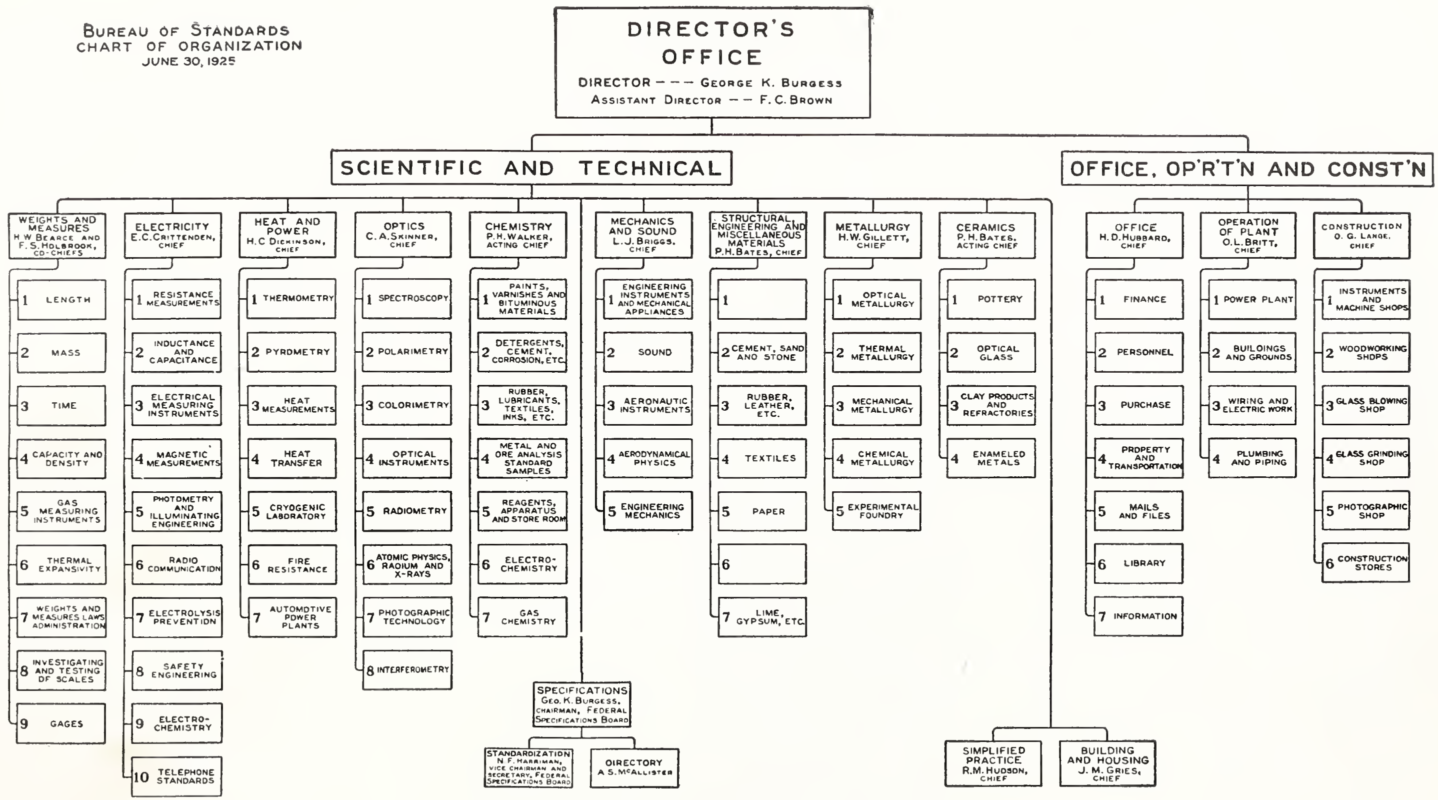

FIG. 12.—*Activities of the Bureau of Standards*

The section is the unit of specialization; a division is a group of related sections and is administered by a chief of full professional grade. A typical division conducts researches, tests, and investigations; prepares specifications for materials, devices, and practice; gives data and advice to the industries on units, standards, and measurements; prepares for publication articles on research results and other data within its specialty.

of precision to industry. It was natural that the United States should soon follow. When the National Bureau of Standards was established in Washington, Dr. Samuel W. Stratton was made its first director. Under his leadership the bureau expanded steadily into its present organization. He was succeeded in 1923 by Dr. George K. Burgess, of the bureau staff, who for many years had served in the fields of research and testing in high-temperature measurements, and in metallurgy as chief of the division.

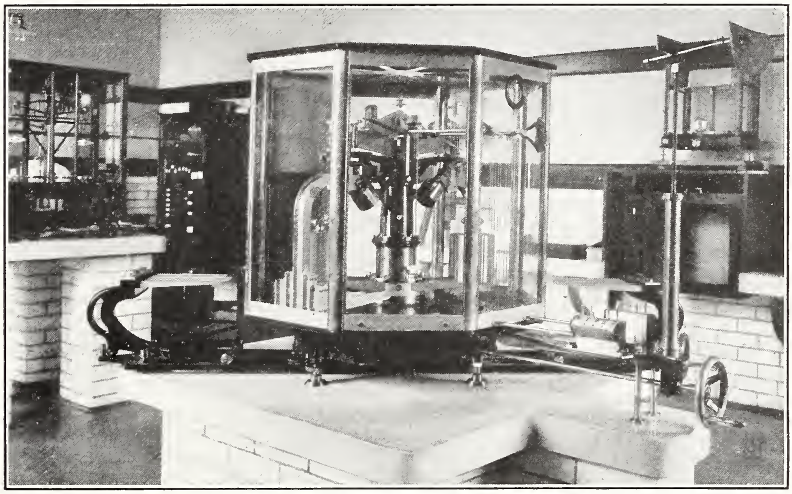

FIG. 13.—*Precision testing balance for large weights*

The bureau in its work of maintaining correct weights and measures throughout the United States is using a set of suitably precise balances for making mass measurements. The ingenious and efficient 25-kilogram balance shown above is typical of the several types of weighing equipments used in this service.

4. DIVISIONS OF THE BUREAU

The pioneer division is custodian of the yard, pound, and gallon of daily trade. Its standards control what the buyer gets, the length of ribbon or cloth, bulk of gas, weight of coal. Whether measured on the counter or in a staple package we buy by measure. Here are checked the cubic-foot standard for the maker of gas meters, the troy pound for the coinage, the inch of the factory, the gallon of the filling station. This division stands for correct measure, back of every quantity purchase through its active aid to local inspection. It is responsible for correct measures of length in the factory and mill through testing of gauges and measuring tools, especially serving the makers of such gauges and tools. Its work covers the measures of length, weight, volume, and time—the fundamental measures upon which all others are based.

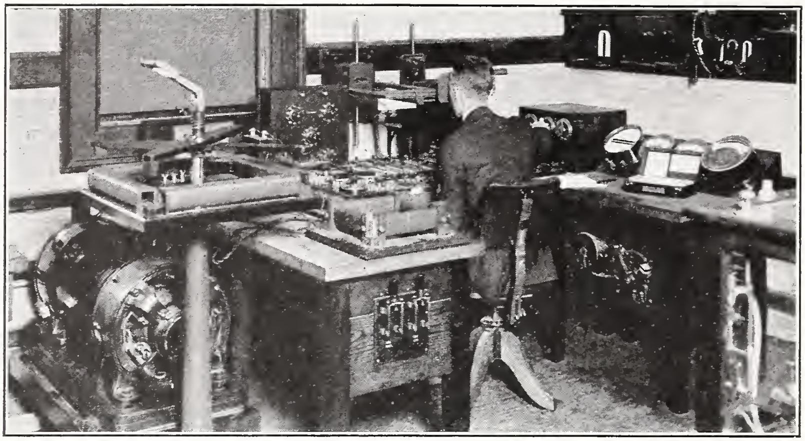

FIG. 14.—*Magnetic permeability testing laboratory*

The magnetic properties of materials often determine their utility in electrical appliances. Higher permeability may call for less of the material and make lighter construction possible. Progress has been made by using better methods of measuring permeability. The study of the magnetic properties of materials shows a close connection with their physical properties, which is proving useful in selecting materials free from flaws.

Electricity performs its modern miracles because of the measured control of voltage, conductivity, capacity, inductance, for which units and standards, methods of measurement, and tests are provided by the electrical division. To measure the pressure, flow, and behavior of electricity calls for experts and precise methods.

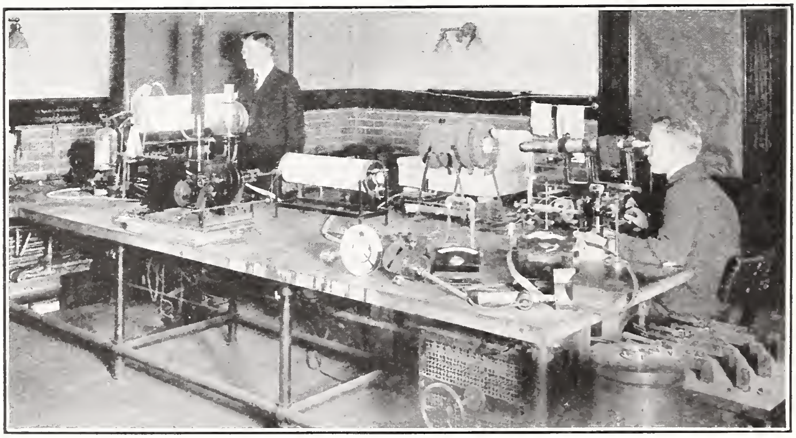

FIG. 15.—*High-temperature measuring equipment*

For measuring high temperatures the indispensable instruments (optical and radiation pyrometers) are shown in the foreground. The observer on the right is working with the primary standard optical pyrometer sighted into an electric (platinum wound) furnace. The pyrometer can also be used to measure the temperature of incandescent lamp filaments, arcs, distant objects, etc. The observer on the left is watching the operation of a new type of vacuum furnace for melting refractory metals, such as platinum and palladium.

The many measured factors which determine perfect radio transmission and reception are also subjects of test, research, and standardization in this division. Here, too, are administered the inspection of Government electric lamps at the factories, their life tests, and the steady perfectioning of the standards of performance of such lamps.

The mastery of heat and power in the service of man again depends upon measured control. The heat division answers the

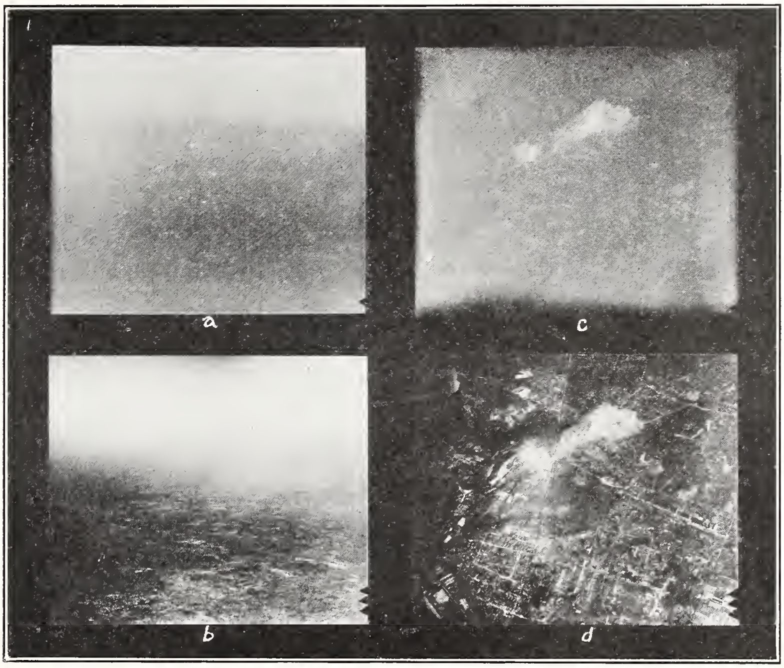

Fig. 16.—*Photographing through fog*

The pictures were taken in pairs at altitudes of 7,000 and 17,000 feet, respectively, through red filters by means of hypersensitized panchromatic plates. The pairs were exposed simultaneously in a multiple lens camera designed at the bureau. The exposure time was one-hundredth second. Several years of experimental work resulted in definite procedure for preparing photographic plates for special purposes. In the elimination of haze in landscape photography plates sensitive to the longer waves must be used and the bluish haze light cut out by filters.

questions: How hot? How cold? It fixes the zero, the degree, the calorie, and the temperature scale from frozen hydrogen to the vacuum furnace and beyond. Success in the heat and power industries depends upon the perfect use of the right degree of heat. This calls for measurements, exact, uniform, by means of instruments standardized at the bureau—pyrometers for the steel mill, thermometers for the bakery, the clinic, the chemical works. Enterprises interested in fire protection, power production, and the use of heat or cold cooperate with this division on experimental research. Automotive research is especially emphasized.

To measure light and color, how light is produced, and how it behaves when passing through materials is the work of the optics division. Light waves are measured with high precision. The science of optics calls for light sources of standard wave length. The division's measurements of wave lengths have been accepted for such uses. Atomic physics, radioactivity, and X rays are part of the work of this division. Devices using light are studied, tested, designed, and standardized—saccharimeters, colorimeters, radiometers, interferometers, and the optical parts of sextants, cameras,

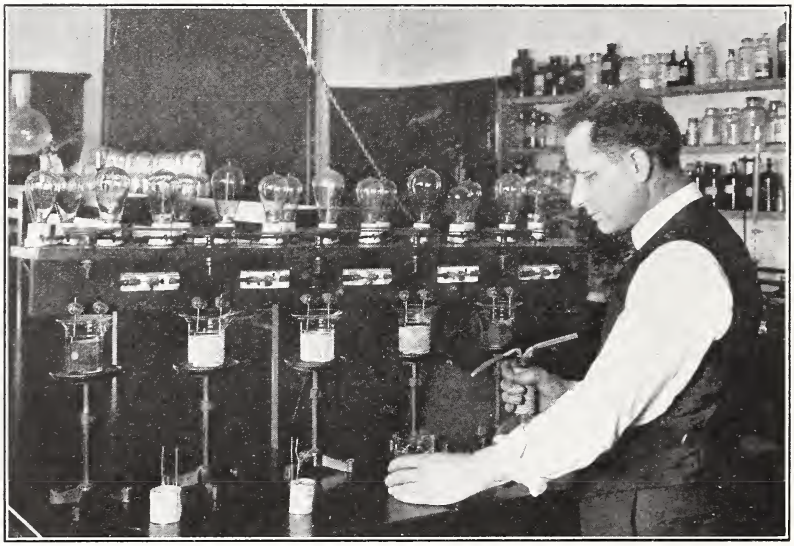

Fig. 17.—*Analysis of nonferrous materials*

Many nonferrous materials connected with purchases and with researches within Government departments are analyzed at the Bureau of Standards. The illustration shows one of the electrolytic determinations of elements, such as copper, lead, and nickel.

microscopes, and the like. Basic experimental research is conducted on how light is produced, its nature and properties, optics and optical instruments. The sugar laboratory is in this division since sugar is measured by its power to rotate a ray of light waves.

The chemist is essential to standardization. The composition of material so affects its properties that analysis is almost the first consideration. The chemistry division has distinctly chemical problems, but it works jointly with others for almost all research has a chemical aspect. The division touches all others. Standards of purity and composition and standard methods of analysis are important subjects of its activities. Its tests control quality, and add data useful in drafting specifications for materials.

Wind tunnels, a meter-rating tank, great testing machines, strain gauges, and other experimental testing equipment are the notable facilities of the division of mechanics and sound. Its experts study the mechanical properties of matter as affecting mechanisms and

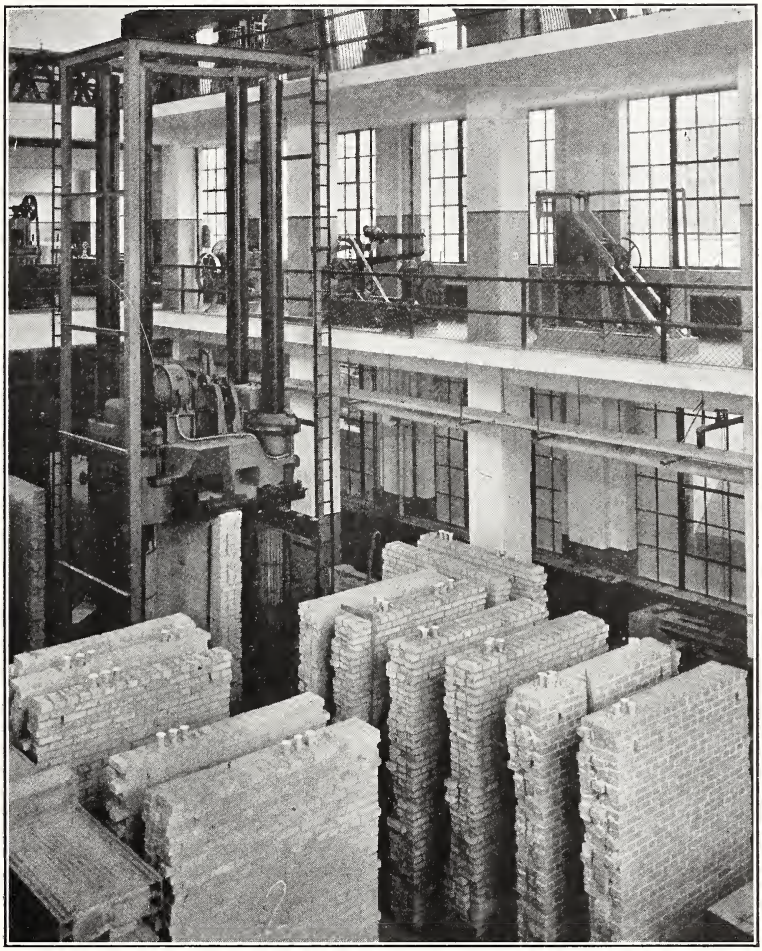

FIG. 18.—*Physical properties of sand-lime brick walls*

Experimental walls of known material and construction ready for test in the 10,000,000-pound vertical compression testing machine. The fundamental data developed in this research are of great value to engineers, architects, and the construction industry generally.

structures, how things behave in air streams, what profiles move through the air with least resistance, how structures behave under stress, how they bend and stretch, and how designs can be perfected for best service. The division perfects ingenious measuring instruments to guide the aviator in safe and speedy flight—the five senses of the airplane. This division has a wide range of activities, the theory of structures, gas flow, hydrodynamics, aerodynamics, mechanics, and the soundproofing of buildings and the improvement of the sound qualities of auditoria.

How useful materials are, why they are useful, and how they can be made more useful, are studied in the division of materials. What gives cloth unusual strength, what makes paper durable, how fast does sole leather wear out, how quickly does concrete set and what load can it bear, how to make metal glazes adhere, are the queries asked, and answered by measuring appliances which tell in units just how effective, strong, and durable the materials

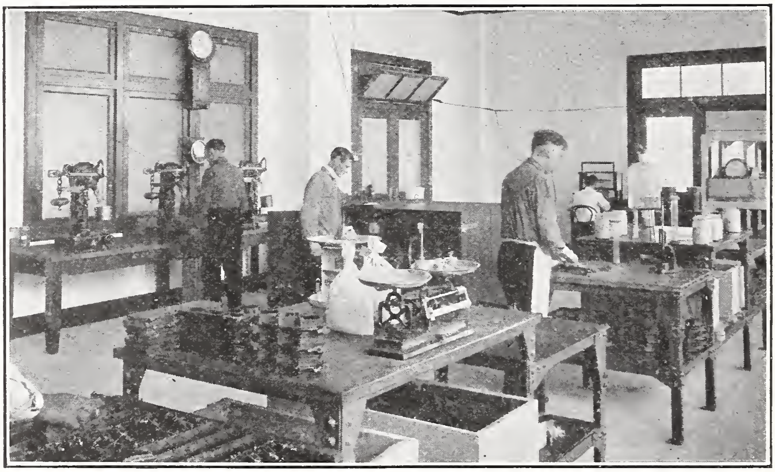

Fig. 19.—*Cement testing laboratory*

Left to right, foreground: Cleaning molds and glass plates with wire brushes and oiling them; samples as received in bags; balance for weighing samples; operator troweling surface of briquettes just molded (note glass mixing slab on table and glass plate under mold); jars contain samples weighed and ready for test; tanks for storage of test pieces under water; recording thermometer for water temperatures. Center: Measuring time of set with Gilmore needles; slate moisture cabinets for storage of specimens immediately after molding; weighing samples for fineness determination in sieves shown on right of operator. Background: Breaking briquettes to determine the tensile strength.

are. Science tells a more exact story of how materials behave and how they may be improved: Rubber, leather, paper, yarn, cordage, and fabrics; of glass, cement, lime, and stone. The division also works out better ways to test and specify the useful properties of materials and the better methods of making and using them.

Metals play a part in industry that calls for a special division. Its experts apply science to the preparation and use of metals and alloys to discover new ways to test their useful behavior, to purify metals, to mitigate corrosion, to compound alloys, and perfect their structure by heat treatment; in short, to make metals, already vital to industry, more useful and durable. Researches are undertaken in cooperation

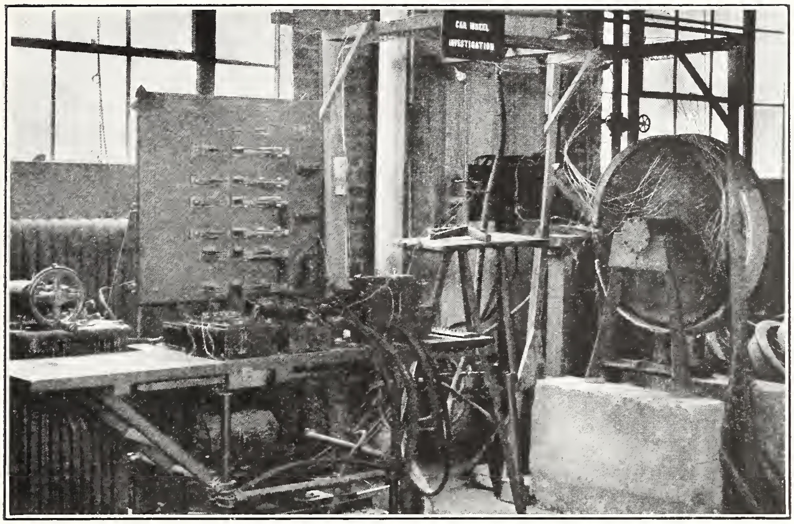

FIG. 20.—*Discovering why and how car wheels fail*

At the request of railroad experts Congress authorized a study of the failure of railroad materials. The view shows the apparatus used by the bureau in finding the cause of failure of car wheels. It was discovered that the unequal heating by brake friction produced stresses which cracked the wheels. The effect was duplicated experimentally in the laboratory.

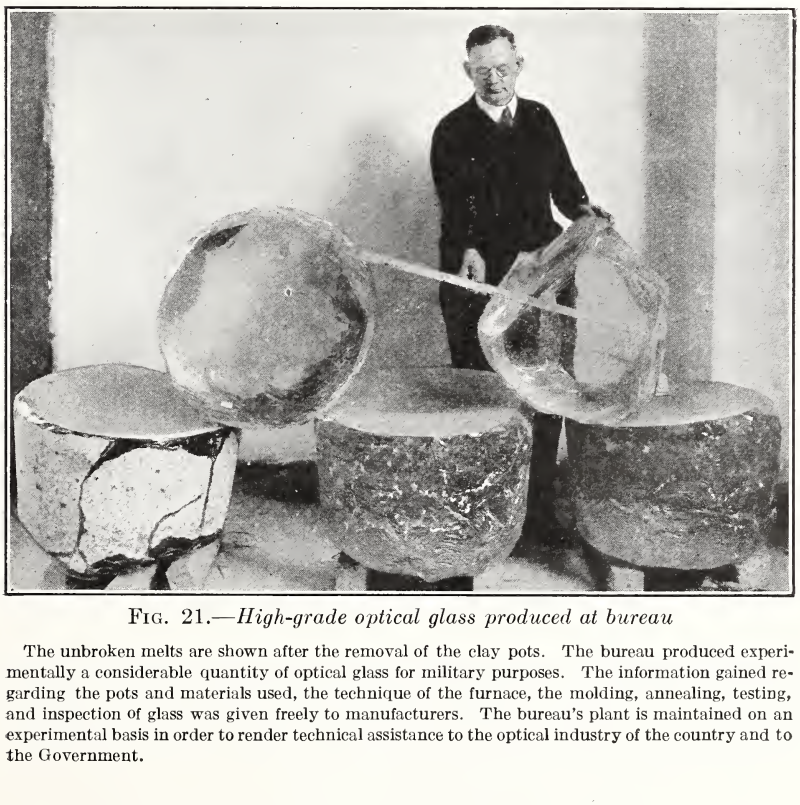

FIG. 21.—*High-grade optical glass produced at bureau*

The unbroken melts are shown after the removal of the clay pots. The bureau produced experimentally a considerable quantity of optical glass for military purposes. The information gained regarding the pots and materials used, the technique of the furnace, the molding, annealing, testing, and inspection of glass was given freely to manufacturers. The bureau's plant is maintained on an experimental basis in order to render technical assistance to the optical industry of the country and to the Government.

with the industries. Failures are studied, sometimes produced artificially; their causes are located and remedies suggested. New methods and appliances for the study of metals are developed.

American clays, thanks in part to researches of the ceramics division of the bureau, to-day produce clay products—chinaware, porcelain, brick, tile—of grades once attained only from foreign clays. This division has solved major problems in casting optical glass, aiding America to found an optical glass industry—a key industry, in war and peace. Investigations are made on raw materials, working processes, and burning conditions. The purpose is to develop tests and standards of quality and service. Actual manufacture is undertaken in the kiln house of this division. Optical glass pot making was developed here. The successful making of these pots was a critical problem in the establishment of the American industry.

To cooperate with American industries to eliminate waste, a special division was organized by the Secretary of Commerce. Its work, described elsewhere, actively promotes the voluntary elimination of needless sizes and varieties by a definite procedure based on sound business principles.

A division devoted to building and housing encourages construction by gathering and distributing data to builders and prospective home owners. Reports on prices, production, and market supplies are published to make more effective building and housing activities. An account of this work is given elsewhere in this circular.

The director of the Bureau of Standards is *ex officio* chairman of the Federal Specifications Board. The bureau has for many years drafted for the Government technical specifications for materials and appliances pertinent to its field of work. The enlarged scope includes the administration of the work of formulating and promulgating such specifications for any materials required for Government use. These are published and thus made available for use by States, municipalities, and corporations. The specifications, drafted by bureau experts and by interdepartmental technical committees, assisted in most cases by the experts of the bureau, adopted by the board are based upon research and test data obtained in bureau laboratories, as well as upon results of other laboratories and in service. A fuller account of the bureau's work on specifications is given elsewhere in this circular.

IV. RELATIONS

Since everything we make, buy, sell, or use is measured, everybody is concerned with the bureau's work. The bureau has intimate relations with the most varied groups on matters of measurement—governmental, industrial, scientific, and popular groups. The outlet of the bureau's work is through those who apply its results, through contacts which give the bureau important data and lead to active cooperation on research of mutual interest. This enables the bureau to serve as a clearing house, a most useful one, within its specialties. The links with all who aid or gain by its work are as interesting and varied as those of the diplomatic service.

1. INTERNATIONAL

Science is international, and foreign experts and laboratories abroad yield data of inestimable value to the bureau and through it to the American people. Its experts keep in touch with workers in related fields abroad.

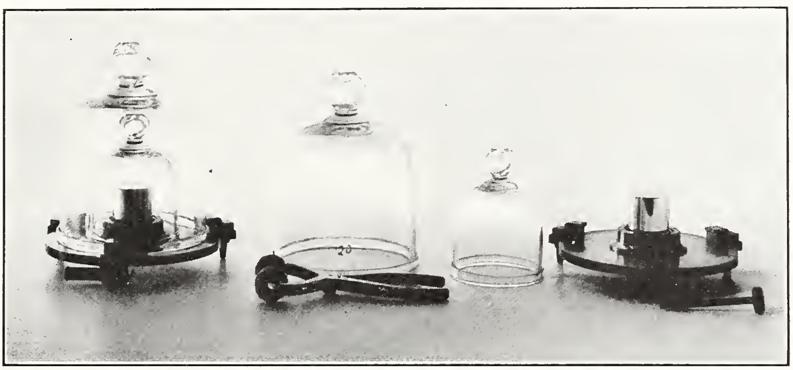

Fig. 22.—*The Standard Prototype Kilogram furnished by the International Bureau of Weights and Measures at Paris in pursuance of the metric treaty of 1875*

By treaty the United States, with 27 other nations, maintains the International Bureau of Weights and Measures at Paris on neutral territory in the historic Parc du St. Cloud at Sèvres. An international committee and commission, on which America is represented, supervise the work and together form the highest tribunal on standards. The bureau at Sèvres is official custodian of the international standards of length and mass, the meter and kilogram. The bureau, of course, keeps in touch with similar institutions, exchanges publications and data on common problems, promotes cooperation in fundamental research on standards. The bureau, for example, arranged with the four leading scientific nations to send their leading experts to join in an experimental determination of the unit of electric current—a research at the basis of electrical measurements.

Pan American standardization of industrial products is an enterprise intrusted to a group of which a Bureau of Standards expert is chairman. The trail of most standardizing enterprises leads abroad—the National Screw Thread Commission, for example. The work of the American Engineering Standards Committee is another example. Standard Greenwich time and longitude and latitude measurements are examples of international measurements on a universal basis.

The bureau is at present in close touch with international groups in order to secure international agreement on electrical standards, radio standards, sugar standards, X-ray standards and technique, units of light, the temperature scale, and the ratio of the yard to the meter. The last is a puzzling problem arising from the difference between the American and the British yard. These are all problems of mutual interest to all nations and their solution will benefit them all.

2. FEDERAL

Measures have a vital place in Government. Coinage is based on weights derived from and checked by the troy pound of the Bureau of Standards. The standard of length, the meter, controls the invar steel tapes by which the master surveys are made and National and State boundaries fixed. The bureau's researches aid navigation and broadcasting and the regulation of both. For the customs service the bureau expert was assigned to modernize the sugar-testing methods at the ports and to place them upon a scientific basis. Duplicate samples of all sugar cargoes are now tested at the bureau to control port analyses. The bureau standardizes the water current meters to measure stream flow in forecasting water supply and flood and drought in the national stream gauging service. For all departments of the Government the bureau performs standardizing service for research apparatus, measuring appliances and supplies, and conducts joint researches. A special law enables the bureau to take up researches in which a given department is concerned, a transfer of funds being made upon approval of the heads of the two departments concerned. The advice of the bureau is sought by congressional committees, national committees and commissions, the General Supply Committee, the Bureau of the Budget, and almost all departments and independent establishments.

3. STATES

The bureau aids the States to secure for their citizens full measure in shops and markets, adequate and safe public utility service of electricity and gas, and efficient specifications for State supplies. The States depend upon the bureau for standards of measurement, for testing them at intervals to keep them true to the national standard. State officials confer at the bureau in a national conference on weights and measures held each year to discuss the technical details of local inspection, model laws, ordinances, and tolerances. The

FIG. 23.—*Testing imported sugars*

Sugar imported into the United States is subject to a duty, determined by optical test. This test tells the amount of sugar in the sample. Sugar causes a light beam to rotate through an angle which measures the percentage of sugar in the solution. The picture shows the preparation of sugar samples for examination by the polarimeter. Sugar cargoes are sampled and tested both at the ports and at the bureau. The bureau acts as control and referee in supervising the analysis at the various ports of entry. The bureau standardizes the methods and instruments used by the sugar industry in testing sugars.

bureau's nation-wide survey awakened the States to the serious short measure prevalent in daily trade from defective measures, faulty measurements, or even fraud. The inspectors cooperated. Every household was concerned. Only two States had then adequate inspection. State legislatures and governors of States were apprised of the situation and took effective action. To-day most of the States have efficient inspection based upon the model State law first drafted at the bureau and upon the manual of inspection practice prepared by the bureau.

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A four-billion-dollar freight bill is paid by the citizens of the States on products on their way to the people. The bureau's test cars traverse the various States on their nation-wide mission of accuracy, testing the master railroad track scales for the States. These, in turn, insure accuracy in such weighings on devices which have shown notable improvement since this work was initiated.

Fig. 24.—*Track scale test car equipment*

This unique type of test equipment, two of which are in service, is a special design of box car with electric crane, motor-driven truck of known weight upon which standard weights may be loaded, and a dynamo driven by gas engine to supply current for crane and motor. 10,000-pound weights, 2,500-pound weights, and 50-pound weights (105,000 pounds in all) are carried in each car. The equipment is used in the test and adjustment of railroad scales and master scales for checking other test-weight cars.

The State purchasing officials requested the Department of Commerce to aid in the use of standard specifications for the purchase of materials and equipment. The National Directory of Commodity Specifications, compiled and published by the Bureau of Standards with the cooperation of the Bureau of Foreign and Domestic Commerce, is for the joint benefit of State and Federal purchasing agencies.

Technical conferences of State utility commission engineers are held each year to promote cooperation of experts, State and national, in this field. Standardization problems are of vital concern in all regulation of public utilities.

The bureau is by law permitted to extend free testing service to State governments. This service covers weights, measures, measuring instruments, and materials, and is most useful. On request of the States of Pennsylvania and New Jersey, the bureau tested full-sized members of the Philadelphia-Camden bridge, using its 10,000,000-pound compression testing machine, the largest of its kind in the world. The public was thus assured of the safety of the new bridge, for the test showed a strength double that of the expected service load, confirming the accuracy of both design and construction.

4. MUNICIPALITIES

The bureau aids cities by expert advice on utilities, such as gas, electricity, or on technical inspection services, such as elevators, fire hazards, gas-using appliances, lightning protection, and building codes. The bureau developed a system of survey of the damage possible from stray electricity which destroys underground metal structures. Its remedial measures were completely worked out by the bureau and applied to a number of cities with its experts cooperat-

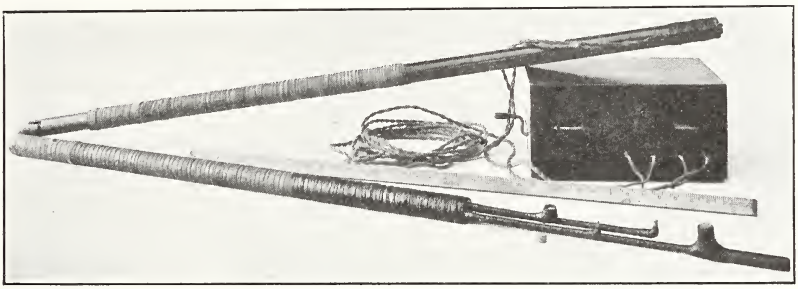

Fig. 25.—*Earth current meter at the bureau*

This was devised at the bureau especially for the study of damaging stray currents of electricity in cities or where underground structures are exposed to these hazards. A system of survey of such conditions has been developed for cities interested in the control of such electrolysis hazards.

ing. The bureau's manual of weights and measures inspection gives the city inspectors their standard reference and instruction book—the Manual of Inspection and Information for Weights and Measures Officials. This is compact with useful data drawn from the nation-wide experience of bureau specialists and is the inspector's most useful guide in his training and daily work.

The bureau aids city traffic management in several ways. It has devised automobile brake-testing methods, including a new decelerometer for measuring the rate of stopping. The methods have been demonstrated in testing campaigns in Washington. The bureau has tested and adjusted automobile headlight lamps, with excellent results to the car owners and road illumination. A publication giving the best lighting practice has just been issued and is being made the basis of city regulation.

The Zoning Primer explains the modern districting of cities. Housing publications on construction and on plumbing, and other subjects described elsewhere, are aiding city governments in the intelligent promotion and regulation of city housing enterprises.

The bureau has encouraged and aided the establishment of municipal testing laboratories. Its service to the local government of the National Capital would form an interesting chapter touching on river pollution, water power, bridge testing by strain gauges, inspection of causes of fires and of building accidents, street lighting, theater curtains, testing of supplies, expert investigations in criminal cases, check tests of gas and electric meters, and the technical phases of traffic regulation and other distinctly city problems.

5. EXPERTS

Most direct, however, is the bureau's contact with the expert groups who apply its discoveries, its standards, its specifications, and its tests. These experts write or visit the bureau in great numbers, bringing their problems. A helpful interchange of ideas follows and they carry away with them data and advice. The contacts thus made effectively diffuse the results of the bureau's activities.

More systematic are the bureau's relations with the national engineering, industrial, and scientific societies. Bureau members belong to these, serving on committees which keep in intimate touch with the bureau's work and advise on its programs of research. The long list of such societies suggests many interesting and useful services to the Nation through their contact committees.

The committees on units, standards, terminology, and research programs cooperate with the bureau and, in turn, the bureau is able to serve such committees by tests and researches on key problems of the expert. The bureau is officially represented on the standards committee of the electrical engineers, whose standard terms and usages have been translated for use abroad. The bureau also aided in translating and publishing the Standards of the American Society for Testing Materials. The department is represented on the American Engineering Standards Committee by several of the bureau staff. The close relations with the Society of Automotive Engineers is an excellent example of joint programs of research. The optics division cooperates with the International Astronomical Union for which its scientists have measured with high precision the standard wave lengths of light used by the astronomer. The expert advisers to the bureau number more than 900, and the cooperating committees are numerous. In general, the technical work and the results are for the expert who after all must apply them to industry and engineering practice.

Such experts are of all kinds and degrees of skill, for the bureau is of interest and concern to workers of all occupations involving measurements, tests, and inspections. These comprise inspectors of trade weights and measures; experts on meters for gas, water, and electricity; measurers of wood and coal; official weighers of mine products at the mines; land surveyors; hydrographers whose data are needed for navigation; observers who measure the weather; engineers who measure grading and construction; factory and mill artisans who dimension and condition products; astronomers who measure the positions and movements of the stars and planets; shopkeepers who vend by measure of weight, length, area, or volume; in fact, practically every group of measurers. Each has its problems of units, definitions, standards, appliances, methods, and tolerances

Fig. 26.—*Group of bureau workers measuring the errors of clinical thermometers*

At the left the mercury is being centrifuged back into the thermometer bulbs, in the center the thermometers, after immersion in heated water, are being read, and at the right the records are being entered.

since perfect measurements are not humanly possible. The bureau aims to aid all such workers who may apply for information, advice, or test. The daily mail contains numerous letters from experts in these groups. This service of information is a real correspondence school in applied measurements.

6. INDUSTRIES

The bureau aids industry by applying science. It was founded largely upon insistent request of the industries. For them the gains have exceeded all exceptations. The rapid advance of science during this century has given many opportunities for applied science. Two things were essential—exact science and facilities to apply it. The sciences of physics and chemistry are now available for improving industrial methods or devising new methods. Leaders of industry now appreciate how valuable are the researches which make such applications possible.

To cite an example, the bureau's work on clays comprises the preheating, chemical treatment, blending, working, burning, and the glazes used. Measured controls were worked out, published, discussed, applied in actual work in plants, and in some cases schools were conducted for manufacturers. A Member of Congress reported that the bureau's technical research and advice on clays was worth to his State alone more than the entire cost of the bureau from the beginning. The bureau uses the science of physics to solve problems of interest to a whole craft. Almost every industry submits problems, many of them critical: How to make the large clay

Fig. 27.—*Sample clay products made of American clays at the Bureau of Standards by methods perfected in the bureau laboratories*

pots in which to melt optical glass; how to assure sound rails; why cast car wheels break; why plaster pops; how to anneal glass thermometers; how to photograph the inside of a rifle barrel; how to detect and identify traces of impurities in tin; how to prevent enamel flaking; how to test durability of brake linings; how to cut pearl buttons without breakage; how to measure the sugar content of molasses; how to crystallize sugar from artichokes—these and thousands of others were answered only by intensive research, experimental and theoretical.

Success may depend jointly upon applied science and practical craftsmanship. In such cases the industry may offer men and facilities in their plants for the service tests involved and the advice of their experts on methods, the bureau furnishing the scientific staff and laboratory facilities.

The research associate system permits industrial groups to maintain technical research men at the bureau for research of mutual concern. The bureau furnishes supervision and advice, and the research associate works under the staff rules. The contact thus established brings the industries and the bureau into close and cordial working relations. The men are trained in research methods, attend the staff meetings, and have stimulating association with expert groups. The research results are, by terms of the agreement, made available to the entire industry. There are now 62 research associates. One of these conducts technical schools for the laundrymen, whose associations he represents, and he has published a working manual of modern methods for the industry. Another has aided in the standardization of hosiery boxes and cases described elsewhere. Research associates, in general, bring to the bureau practical problems and knowledge of the industry. In turn, they take back into the industry the investigative spirit of the bureau. They link in a most practical way the research laboratory of the Government with the planning departments of the industries.

7. PUBLIC

Directly or indirectly every American benefits by the bureau's work. The individual is the ultimate beneficiary of all its achievements. His clothes are made to measure by a yardstick derived from the bureau's standard, his glasses, furniture, house, and all the things he buys are made to measure and are acceptable because of suitable sizes or measured quality. Modern life is so fully based upon staple services and goods, measured for effectiveness, that the gains from standardized measures are promptly felt by the public. Thousands of measurements, for example, contribute to the comfort, effectiveness, and speed of an automobile—definite strengths, elasticities, dimensions, and the like. These are built into the car. The same principle determines the service of all products of industry.

The bureau's part is to diffuse precise values of all units of measurement on which such measured service is based. Standardization insures that the measures for effectiveness are, through exact measuring devices, realized in the factory. The bureau does more. Within its special field, its researches determine the effective magnitudes for economy and high utility in the products which Congress has assigned to the bureau for technical study: Metals, cement, stone, plaster, glass, clay products, textiles, leather, paper, rubber, sugar, as well as devices connected with utilizing heat, light, electricity, and power. The general public is served through correspondence, publications, personal visits, researches, tests, and indirectly through the bureau's aid to the compilers of reference books. The bureau cooperates also with technicians and expert groups in perfecting their vocabularies and with dictionary makers and handbook compilers in correcting definitions and equivalents affecting standards or measurements.

The bureau aids the public in many ways, few of which can be cited here. Its circular giving the legal bushel weights of all States is a basic reference work for farm or mill products. At the request of the Bureau of Markets, the Bureau of Standards for several months successfully demonstrated a system for radio broadcasting market news and other reports. With popular circulars on homemade radio sets, it is now possible for any family to keep in touch with time signals, weather reports, market and crop reports, and many forms of entertainment and instruction through broadcasting. The home-made radio set which a novice could build at home was described in a circular of which many thousands were sold. It was also filmed and exhibited widely and reprinted by the newspapers, and gave a nation-wide impetus to household interest in radio.

The bureau aids by publications on lightning protection for houses, farm structures, and livestock. These were based on original researches and investigations and have been in useful circulation for years. A lightning code is now in preparation. The remedies suggested have reduced the loss of life and property, especially in the case of domestic animals to whom ungrounded wire fencing was a serious menace. Of special interest in irrigation districts is the bureau's large scale field experiments on drain tile. The loss of tools and machines by rusting is in large measure preventable by proper care. The bureau's publication on "Slushing Oils" is a valuable treatise on avoiding such losses. Other researches on corrosion and its prevention have been made. The automotive researches are of general interest. The work of the entire bureau, in fact, directly or indirectly affects the public, since everything is built or sold by measure.

The bureau aids the household in the measured control of the construction and facilities of the home. A bird's-eye view of the ways in which the bureau has aided the household in the technology of the home will illustrate.

Its nation-wide campaign for honest weights and measures saves buyers millions of dollars formerly lost through short measure from defective devices. State laws and local inspection services are now general and the household is freer from preventable injustice. As we expect to pay the last cent due in a payment, so the last ounce due should be equally assured in a purchase. The latter is less easy. Here the bureau acts for the buyer by adjusting the State standards which check the inspectors' measures, by aiding the inspector on the technique of his work, by stimulating an interest in full measure.

The code of gas practice has given basic data to local governments for the effective and safe control of gas service. The bureau has made experimental and field studies of gas hazards and the efficiency of gas appliances. In household practice the bureau's circular on "How to Get Better Service With Less Natural Gas in Domestic Gas Appliances" showed that two-thirds of the natural gas used in the home could be saved by using the type of burner devised and recommended by the bureau for the purpose. The burner was found to have an efficiency four times that of the type in common use. The estimated possible saving (at replacement value) is now conservatively estimated as $250,000 a day, if the bureau's suggestions are adopted. A forthcoming publication shows the effect of change in the heating value of gas furnished to the home.

The bureau's researches and tests have aided in improving home building materials; for example, through quality standards for cement, brick, tile, lime and lime plaster, stucco, paint, roofing, tiling, lightning rods, fabric wall boards, and the like. An extensive publication "Materials for the Household" covers many others. Researches, some of them elaborate, in all of these lines, have yielded results of value to the manufacturers of such materials and the household shares the improved quality.

The practice of plastering, stucco application, painting, and the installation of plumbing, gas service, electric service, and house construction have received careful experimental study and the results have been published. The bureau's publications on "Measurements for the Household," "Safety for the Household," and "Protection of Life and Property from Lightning," give much valuable information to home makers. "Buying Commodities by Weight and Measure" helps the household in buying with due regard to quantity measures.

"How to Own Your Own Home," "Minimum Requirements for Small Dwelling Construction," "Recommended Minimum Requirements for Plumbing in Dwellings and Other Similar Buildings," and "Minimum Live Loads Allowable in the Design of Buildings" are publications of the housing division which deal with fundamental problems affecting the construction, ownership, and equipment of the home.

The bureau's kitchen card for the household gives tables of weights and measures, equivalents of the measures used in cooking, and the standard heights and weights of children at each age. A bureau expert in linear measures designed a new and effective type of "baby board" for the accurate measurement of babies. Both ends of the board can be adjusted exactly and a week's growth readily measured. This was devised and used in the national campaign for baby measurements in the prompt detection of rickets and other deficiency diseases. The simplified practice division aided the household by simplifying sizes and varieties of beds, springs, mattresses, and bed blankets. Here only the more acceptable sizes (as reflected in the sales) were retained on the manufacturers' schedules. The bureau's electric work on lamps, batteries, and on the standardization of quality of soaps, paints, chinaware, hardware, and many other household articles will benefit the home both as to economy and service efficiency.

A glance at the titles of the bureau's 1,200 publications shows how general and fundamental are its relations to the welfare of the general public.

V. DETERMINING STANDARD CONSTANTS

1. WHAT ARE PHYSICAL CONSTANTS?

How fast light travels, how much heat a fuel gives, how much silver a unit of electricity deposits, how much work a unit of heat can perform, at what temperature tin melts—all such questions as these may seem remote from standards; yet such data and thousands of others are the basis of standards and measurements. Congress gave the bureau the task of measuring these numerical constants, fixed points or data which underlie science and industry. They inhere in the nature of things. They describe the behavior of materials and of energy. Research is always in progress on such constants. The bureau determines those which it must use in its work or those of unusual value to technology.

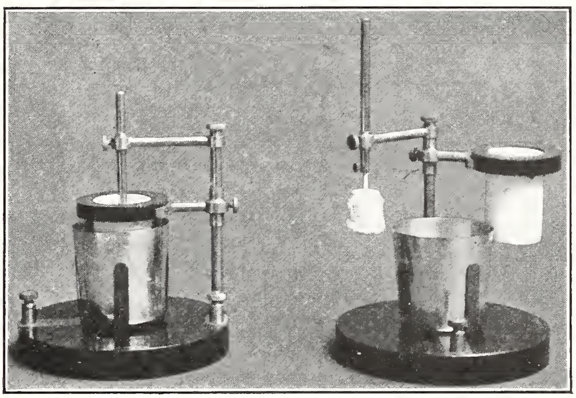

Fig. 28.—*Standard of electrical quantity*

The silver voltameter is the standard for measuring the international ampere, the unit of electrical current. Silver is electrolytically deposited upon a platinum cup. The amount of pure silver deposited is a true measure of the current.

Experimental research is often required in reproducing the unit from the constant. One such constant, the weight of silver which a unit of electricity deposits (0.00111800 gram per second), was accurately determined by the bureau. This measures the standard unit of electric current. The ohm is an example; the unit of electrical resistance is a natural constant. The value of the ohm is based on the resistance of pure mercury to the flow of electricity. Years were spent at the bureau improving apparatus and methods to reproduce the "ohm" from its definition. It is in daily use in fundamental work of the bureau.

How such constants are used in measurements for units and standards may be illustrated. The earth furnished three units—the unit of *length*, the meter, was derived and once defined as one ten-millionth of the earth's quadrant; the unit of *time*, the second, is based upon one turn of the earth on its axis; standard *gravity* is the acceleration of a falling body produced by the earth's attraction. Water furnished four units of measurement—the unit of *volume*, liter, is the volume of a kilogram of water (unit *mass*, the kilogram, was originally defined as the mass of a cubic decimeter of water); the unit of *temperature*, the degree, is one one-hundredth of the interval between ice and steam points of water; the unit of *heat*, the calorie, will raise the temperature of a gram of water 1°. Water also is unity in expressing density. These values are basic standards. So far as they determine units of measure, a knowledge of their measured value is as essential as a yardstick in measuring length.

Such constants numbering many thousands are recognized by the bureau as indispensable to success in science and industry. Each is a permanent service element in industry, playing its part no less than the tool or machine. Accurate values are naturally more effective than erroneous. In science physical constants are the foundation and framework of research.

2. A TYPICAL CONSTANT

The density (heaviness) of materials is a type of physical constant of practical utility. The bureau certifies devices to measure density. Density is of concern in many ways. It determines the floating and water line of a vessel, the rise of slag in a steel melt, the flight levels of airships, the flow of cream from milk in a centrifugal separator, the stratification of gases in the air, the effectiveness of storage batteries, and many other phenomena.

For the dairy industry the bureau determined the density of milk and cream at various temperatures. In Pasteurizing milk it is necessary to know how much to pour, when the milk is hot, to fill a certain volume at some standard temperature. The bureau's tables and graphs permit such facts to be ascertained easily and accurately.

One density test illustrates an unusual utility. The bureau certified the density of samples of river water from a Gulf port. High precision was asked. River water differs in density at surface and at keel, and it varies with the season. A ship's water line rises and falls with changes in density with the same cargo. The bureau certified the densities of water samples from keel, surface, and mid level, to within one hundredth of a per cent—an unusual accuracy. Inquiry disclosed that the reported densities were used to calculate the maximum fresh-water cargo which would become safe when it reaches the more buoyant sea water. The correct loading based upon the bureau's data was reported to be worth thousands of dollars to the shippers.

Density is a basis for the manufacture, sale, and use of petroleum oils. Official density tables were computed and are published in Bureau Circular No. 154, National Petroleum Oil Tables. These were computed at the bureau from the scale agreed upon by the Government and the American Petroleum Institute. The basic laboratory densities were also determined at the bureau. The conflicting scales in use were confusing. The new tables are now the national standard of densities for the control of the production and marketing of petroleum oils.

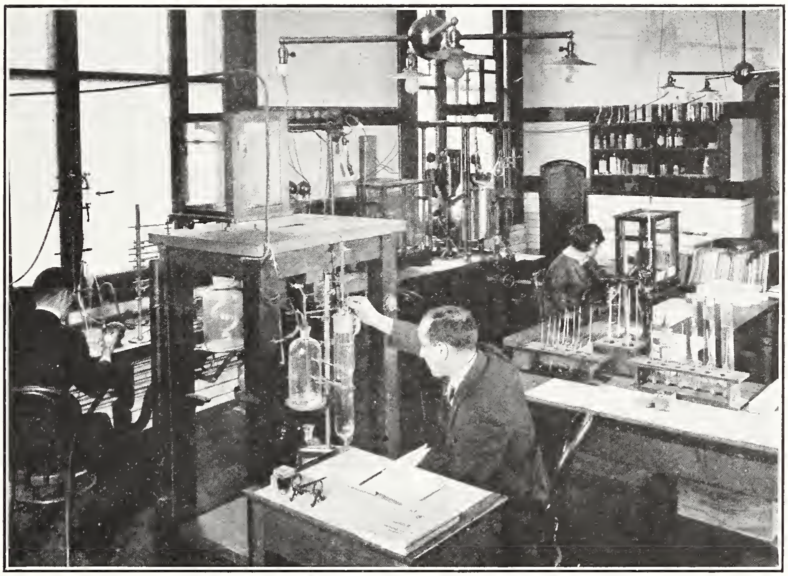

FIG. 29.—*Testing density measuring devices*

This shows a test of hydrometers used to measure the density of liquids, such as spirits, gasoline, battery acids, sugar solutions, and the like. The density is read directly on the vertical scale of the float at the water line, the hydrometer sinking deeper in the lighter liquids.

3. VARIETY AND USES

The constants are unlimited in number. The bureau's field covers the phases of matter and energy in their many forms. New kinds of material or forms of energy are found, and these add to the work. As science and industry demand enhanced accuracy, new determinations are made with better methods and instruments. The nature of constants is such that their sole merit is their accuracy.

When the basis of atomic weights in chemistry was changed from hydrogen (H=1) to oxygen (O=16), a bureau chemist determined the relative atomic weights of these two important elements. The use of atomic weight in chemical analysis concerns technology, since composition is one effective control of quality of materials.

At this writing a bureau physicist is measuring the force of gravitation with which any two objects in the universe attract one another. This is a universal constant. It is measured by timing the swings of a horizontal pendulum of two gold balls hung by fine tungsten wire as affected by known masses. The constant is expressed as the attraction between two unit masses at unit distance (two 1-gram masses 1 centimeter apart). It is used to compute and predict the motions and positions of the sun, moon, and planets on which the nautical almanac is based for the guidance of the mariner. It permits forecasting the time and height of tides for years in advance. With it the earth can be weighed. It controls the motions of all bodies. It is a fundamental fact of nature—a universal constant. A quarter of a century ago it was determined with fair precision, excellent for the time. The bureau aims to increase the accuracy tenfold.

When the two units of electricity (magnetic and static) are compared, their ratio is a number equal to the velocity of light. This universal constant is so useful in electrical measurements and calculations that the bureau determined it with high precision in a laboratory research occupying months. Here the accuracy was ten times that previously attained, 1 part in 10,000, the corresponding velocity of light being 29,986,000,000 centimeters per second.

Modern uses of electricity depend upon conductivity. The bureau determined the standard conductivity of samples of copper from the most varied sources and for aluminum, which, weight for weight, is even more conducting. The conductivity fixes the choice of wire thickness for transmitting power with low loss from resistance. The bureau published standard copper tables for the use of scientists, electrical engineers, and others, and they were based on the international value which the bureau aided in establishing. The tables have entered engineering practice involving the resistivity of copper. The design of transmission lines and conducting elements of devices is more effective the more reliable the data used.

The bureau makes fundamental determinations of the heat conducting power of materials, so that experts may wisely select materials to retard heat flow. It measures, by new methods, how much walls and floors conduct sound, giving the structural engineer data for designing soundproof structures. The bureau measured the transmission of some 60 kinds of special glasses, both for visible and invisible rays, so that the makers of eye-protective glasses can now select glasses opaque to harmful rays, or which transmit or absorb any special colors or rays as desired.

4. CONSTANTS AT WORK

In commerce the properties of materials are, of course, the real values bought, sold, and used. Heat energy release in fuel burning is the useful commodity in power production or indoor heating. The bureau measures heat of combustion, an important constant of

FIG. 30.—*Standards of composition, temperature, fineness, and acidimetry*

These furnish a known standard and certified magnitude of the constant or composition. They are made and distributed by the bureau for standardization of apparatus and methods of analysis. Similar standards are available for polarimetry and calorimetry.

fuel and food. It standardizes the units, the instruments, and methods by which the energy is measured. Motors and the human body burn the food or fuel they consume and the bureau serves specialists in fuels and foods, the energy of which is measured by combustion in an explosion-proof bomb—a heat meter called the "calorimeter." The bureau tests and certifies thermometers and calorimeters for such measurements and also furnishes highly pure material certified to give a standard number of calories (units of heat) on combustion. These include certified standard samples of high purity sucrose, dextrose, naphthalene, benzoic acid, standards of combustion which enable industrial experts to standardize their own calorimeters in terms of the bureau's determination. The sucrose is believed to be the purest yet produced and the benzoic acid shows no detectable impurities. Heat measurements are the basis of automotive research, food research, and heating engineering. In all three, accurately determined constants are of the utmost practical use.

Constants must be known precisely in planning processes in industry. The linear dimensions are important, but in recent years the measurement of the properties of materials is often equally important and, in many cases, more exacting than the control of size. Such physical constants are as essential to the functioning of a process as the size and form of a key to the opening of a lock. Melting points are such constants. The melting point of a metal fixes the correct temperature of a furnace for a successful melt and decides how refractory the fire-brick lining must be. The freezing point of pure tin (231.9° C.) safeguards steam boilers by means of the well-known tin boiler plugs which when overheated melt and release the steam. A bureau research illustrates the intimate relation between physical constants and effectiveness. A boiler of the steamship *Jefferson* had exploded, causing loss of life and damage to the vessel. The bureau was asked to find the cause and, if possible, a means of preventing a recurrence. The bureau's research disclosed traces of lead and zinc as avoidable causes of such oxidation which vitiated the safety function of the plug by raising its melting point more than 1,300° above that of pure tin. A new specification was suggested for the purity and for testing. An optical method of detecting impurities was devised. (See Research.) Here a physical constant, the freezing point of tin, safeguards life and property and is itself stabilized by bureau research.

Freezing points are physical constants which fix the standard temperature scale; for example, those of pure metals with certified freezing points (zinc, which melts at 419.4° C.; aluminum, 658.9° C.; copper, 1,083° C.; lead, 327.3° C.). By research the purity needed to give a definite standard freezing (or melting) point was attained. These are furnished to give fixed points on the temperature scale by which industrial pyrometers may be verified by the users.

The "production of cold" has become a great industry, which the bureau effectively served by determining the basic constants or data of refrigeration materials—ammonia, brine, water, and so on—with high accuracy. These researches are classic. They yield data unexcelled by any branch of engineering for an industry whose success depends upon accurate data as much as upon skill in design. Such data permit the theoretical maxima of production of cold to be computed for rating actual performance of refrigerating devices or processes. The properties of ammonia were then plotted graphically and published as a chart from which numerical values might be read off at a glance which would otherwise require long computation. It would be difficult to overestimate the value of such data. As the basis of refrigerating design and operation they are a beautiful example of physical constants at work in the industries.

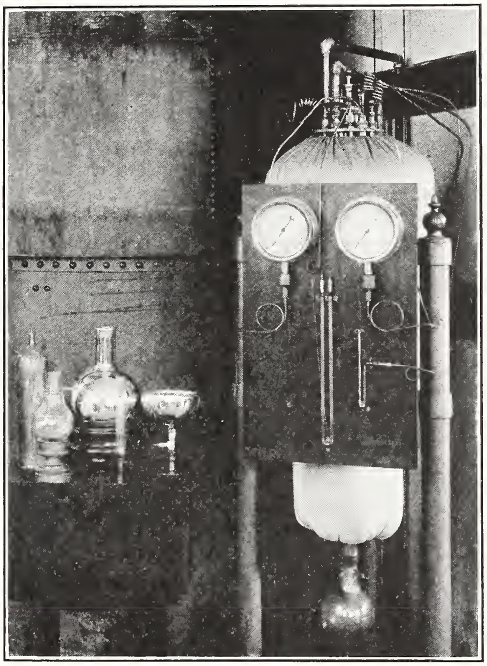

Fig. 31.—*Hydrogen liquefaction apparatus*

The device at the right is for producing liquid hydrogen. After being highly compressed the hydrogen is cooled with liquid air, then allowed to expand. The liquefied hydrogen collects in the vacuum-walled vessel at the bottom at a temperature of −253° C. (423° F.) or 36° F. above absolute zero. Several such vessels are shown at the left. In the background is one of the gas holders. Liquid hydrogen is furnished for experimental research purposes.

Expansivity measures are useful in many ways. The cracking of marble in the Lincoln Memorial was found by the bureau to be caused by the difference in the expansivity of adjacent stones. In the search for noncracking plaster, stucco, or concrete the measure of expansion, as affected by humidity, temperature, and so on, must play a major rôle. In developing more perfect methods, expansion is often a factor; for example, in aviation the cracking of spark plugs in aviation motors restricted the consecutive flying time. Expansion was the vital problem—ideal spark plug materials would expand alike—and the bureau took a step in that direction by developing a new formula for spark plug porcelain to match the metal expansion and not crack with the rapid and intense temperature changes to which a spark plug is exposed. The new formula and samples of bureau-made porcelain were furnished the industry and added useful life to the spark plugs. A program of research on dental materials is under way. In this research, dimensional changes are measured and studied as vital problems in mouth comfort and dental efficiency. The results are announced in the dental journals.

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VI. A. SCIENTIFIC RESEARCH

1. NECESSITY FOR PURE RESEARCH

"Research * * * on problems arising in connection with standards" is, by act of Congress, a primary work of the bureau. Progress demands new kinds of measurements, new standards, and ever increasing accuracy. They must be made more automatic, and the standards must be everywhere and always alike—constant, available, convenient. All these with their far-reaching details demand research at every point. Research is essentially pioneer work. Pure research in science is the fabled goose that lays golden

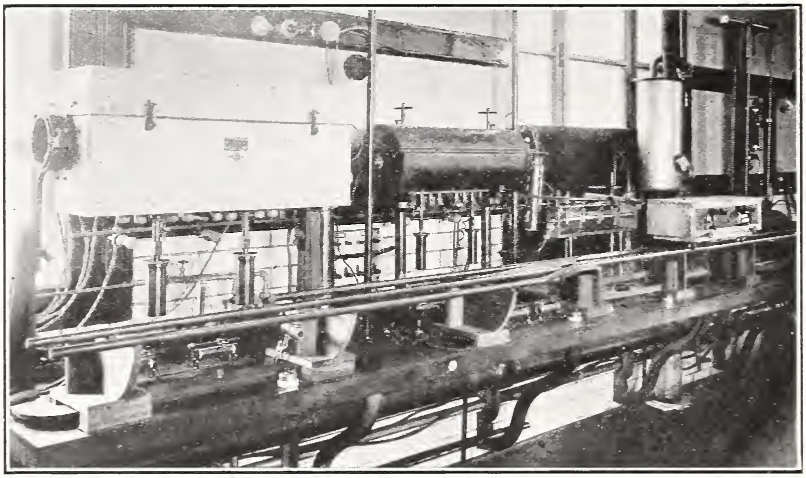

Fig. 32.—*Thermal expansion laboratory*

This is the most accurate thermal expansion measuring apparatus in the world. Temperatures are measured by electrically-balanced thermocouples. Length changes are measured directly by special micrometer microscopes. The increments measured are the actual expansions of the specimen under test and not values superposed on, or related to, some secondary material. The temperature range, −150 to +1,000° C. (−280 to +1,832° F.) is covered by this equipment. Standard values have been secured for the iron, copper, and aluminum alloys; for enamels, glass, quartz, porcelain, and numerous other materials. The results are of importance to designing and consulting engineers and to manufacturers in many industries where expansion plays an important rôle.

eggs. Its gains are best when new knowledge is the aim, unharassed by pressure for instant use. The bureau has kept alive its pure research in science side by side with its industrial research. Many uses follow easily and quickly once the science itself is mastered. Pure science may be compared to planting fruit trees; applied science, to picking the fruit. The bureau must do both. Many uses are usually found promptly for new research results, in fact so many uses that the bureau must leave to others the full application. Hundreds of researches are in progress, ranging from a few days to a year or more. Originality, expert knowledge, and skill are shown in almost every case.

2. FROM PURE TO APPLIED SCIENCE: USES OF LIGHT WAVES

Unexpected as it may seem, the precise measurement of waves of light led to revolutionary achievements in the construction of length standards in the bureau's laboratories. Its experts had measured tens of thousands of light waves of the rays characteristic of the chemical elements, waves of the order of one fifty-thousandth inch. The precision was notable, the error being less than 1/254,000,000,000 inch (one thousandth Ångstrom unit). The pure science of the interference of such waves was applied to making and testing gauges, making master screws, and ruling linear scales unsurpassed in point of accuracy. The master screw and the best gauges and linear scales were true to within a millionth of an inch. Two other results followed: The data became priceless for the new science of atomic structure, for every different wave length tells something of the

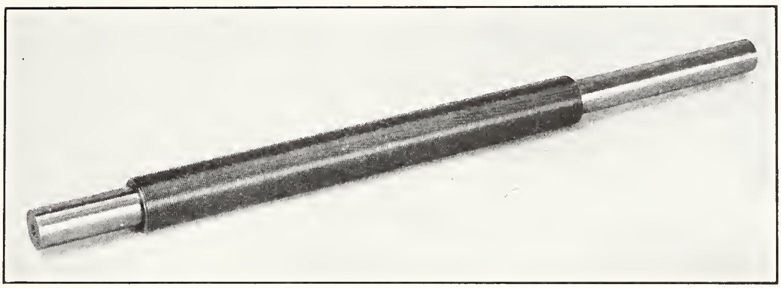

Fig. 33.—*Master precision screw*

This screw, constructed by methods devised at the Bureau of Standards, has an accuracy of the highest order. Researches have been completed or are in progress on the factors essential to highest precision in screw cutting.

structure of the atom which produced it; the same data were used in devising a new method of quantitative analysis of materials to detect the minutest trace of impurities—a method given successful application in controlling the purity of steam boiler plugs whose perfect functioning depends upon high purity. The road from light waves to the machine shop and steam boiler protection was an open road when the underlying science and data were mastered by the laboratory expert.

The line standards referred to were twelve 6-inch scales ruled by the bureau directly from light waves with a precision never before equaled. The work was done for a manufacturer of gauges and measuring tools. The scales were to be the foundation of his length measurements. The company stated "The accuracy with which they were done has obviated the continual series of calculations that are always in evidence when there are variations in the graduations" and describes the work as "a method that will help all industry that has occasion to get practically perfect master standards." The use of light waves makes it possible to reproduce units of length without a material standard, more accurately than was previously possible with line or end standards.

Again, another expert measured the energy of light waves. Radiation and reflection of radiant energy were known to vary with the wave length and kind of material. Just how they varied was the subject of many of his researches and publications. An inquiry from Army headquarters asking how the sun's heat might be kept out of Army tents met with prompt answer. His pure science gave him the solution, and a simple test verified it. White canvas as the outer surface of the tent, aluminum paint inside, would keep out 80 per cent of the sun's heat which would otherwise enter. Other uses created a sensation among technical experts. He found that metal paint would reduce the heat penetration in an ice wagon to one-half. Attics may be kept cooler in summer and warmer in winter by painting the roof with asbestos or white paint and painting inside the roof with aluminum paint, for the heat is thus restrained from entering through the roof in summer or leaving it in winter. Uses worth millions of dollars were promptly disclosed—an example of a change direct from pure science to the most practical problem of human comfort, saving money as a by-product.

3. MEASURING RADIATION USED TO KILL BACTERIA

An important research for the Department of Agriculture disclosed that exposure to ultra-violet light would kill a colony of bacteria coli communis in one second, with a 110-volt 320-watt mercury-in-quartz arc lamp, using wave lengths between 170 and 280 millimicrons at a distance of 6 inches. The lethal dose was found to have a total energy per bacterium killed equal to five trillionths of a gram calorie. The effect of wave length, time of exposure, intensity, and other items were carefully measured. This research is typical of the trend toward precise measurements in biology.

4. EARTH INDUCTOR COMPASS

Experts of the bureau invented a new type of compass consisting of a coil rotating in the earth's magnetic field. It is an excellent example of direct use of pure scientific research, requiring an intimate knowledge of the physics involved. The compass was successfully applied in the round-the-world flight by American aviators. A recent sea test showed that it was free from roll and pitch error, remaining steady under conditions which caused the ship's compass to move several degrees. The indicating part is unaffected by the ship's magnetism and can be placed at any convenient point.

5. EXPLORING THE ATOM

Research in a new field is illustrated by the work on atomic physics—the measurement of the energy required to displace an electron in an atom or remove it entirely from the atom. It is now known that the structure of the atoms can be learned and the frequency of radiation computed from a measurement of the energy referred to. Sound bases are being laid for uses which are certain to result from the mastery of this subject. It is too soon to appreciate the full possibilities and value of the new knowledge, but careful measurements are a sure road to the mastery of atomic behavior. Bureau experts have published many researches, including "The Origin of Spectra" and "Critical Potentials," fundamental texts in this field. Further experiments are in daily progress.

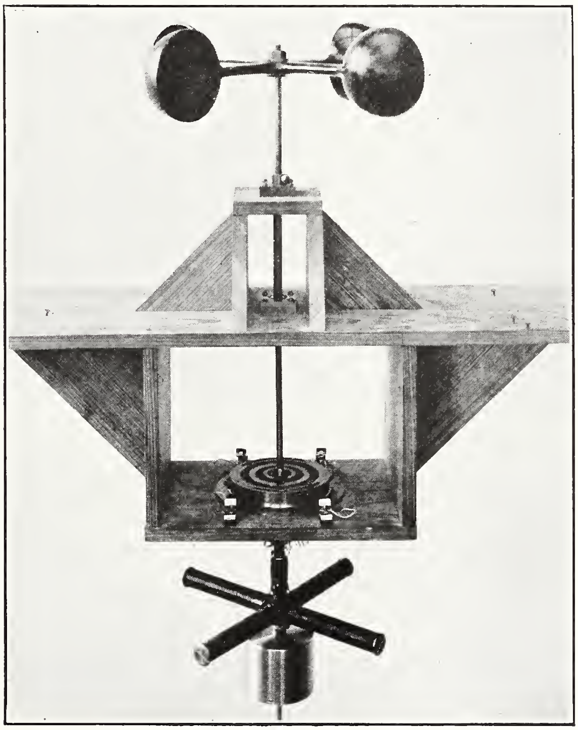

Fig. 34.—*Earth inductor compass*

6. ONE-BILLIONTH OF AN INCH

High sensitivity in length measures was attained in an improved ultramicrometer. Two plates, one fixed, the other movable, form an electric condenser in parallel with an adjusted inductance, giving, with a suitable current source, waves of radio-frequency. A second fixed source of radio-frequency waves is tuned so that the two wave trains "beat" audibly, a musical beat note being heard. When the movable plate of the first condenser described is moved by an amount as small as one-billionth of an inch, there is a decided change of pitch in the musical note. This apparatus is far too sensitive for any known use, but its principle is being successfully used for gauge testing to a millionth of an inch.

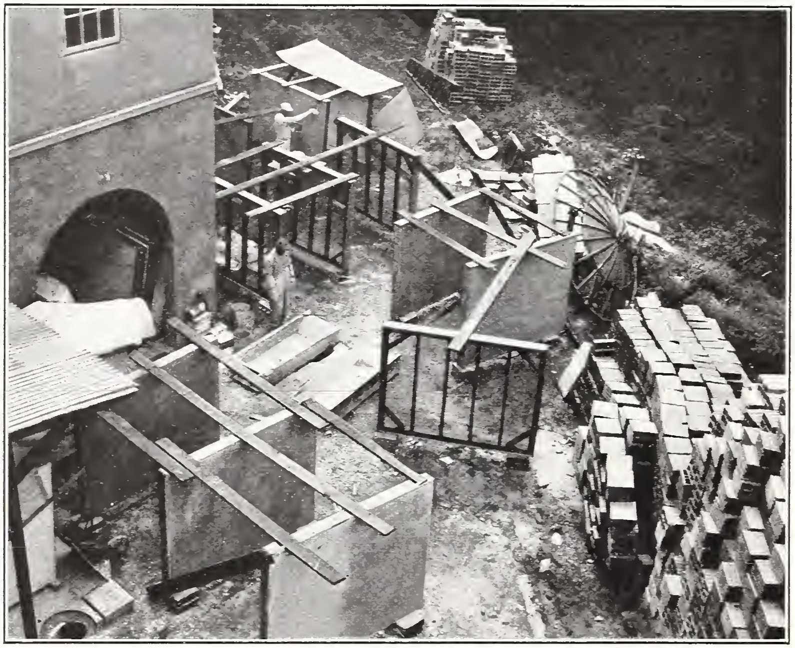

FIG. 35.—*Sound transmission research*

At the left is the sound laboratory; at the right panels are being constructed for tests of sound transmitting quality of walls of various types. A "standard noise" in one room is passed through a test wall carefully sealed in place, and the transmitted sound intensity is measured in comparison with the intensity of the standard source.

7. SOUND QUALITY OF FEDERAL AUDITORIA

By request, the bureau expert in sound studied a Government court room having an excessive reverberation time for sounds. A sound could be heard 3.85 seconds after the source had ceased to sound. Since one second is considered satisfactory, the expert recommended an increase in the sound absorbing units to improve the reverberation time from 26 to 87 per cent satisfactory. Costly auditoria are often unduly reverberant through faulty design.

8. DECIPHERING COMPLETELY CHARRED GOVERNMENT RECORDS

A research may end in discovering new methods or processes; for example, completely charred Government records, burned crisp, were deciphered by the bureau expert, when all other methods failed, by a new method devised in the photographic laboratory. Direct contact prints were made on two negatives at once, without a lens, without a camera, and without light, using several weeks exposure. Legible prints of both sides of the burnt records were thus obtained.

9. NEW MEASURING DEVICES

From the outset it was realized that the design or invention of new apparatus must be a vital part of the bureau's work. The bureau is continually designing needed instruments, or improving them with respect to ease, accuracy, or automaticity. Measuring appliances embody theory and practice; they link the science of measurement and its uses. A line-and-end standard comparator permitted a direct intercomparison of line and end standards of length. A recording photometer eliminated computing delays. A new absolute electrometer will give facilities for tests at 250,000 volts. An optical

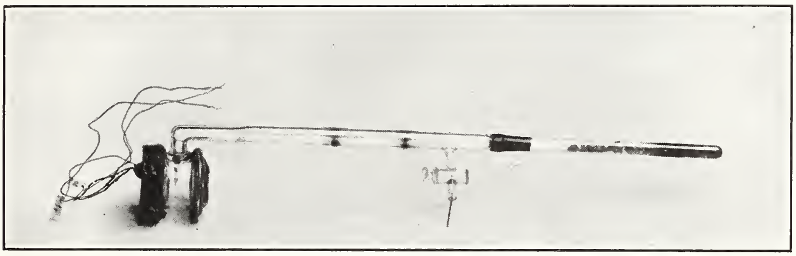

Fig. 36.—*Device to record the heat of the stars and other radiation*

This device was perfected in the radiation laboratory of the bureau and was found to be of almost incredible sensitiveness. It was used in measuring the heat of the stars, and especially in studying the temperature conditions on the planet Mars.

strain gauge gives, to 1/250,000 inch, the change of form under stress. A hydrophone-radio relay gives ship-to-shore distance. A target-practice camera records the shots and shows the distance from the target. A tautness meter shows accurately the tension of balloon fabric.

These measuring appliances are often of high precision or of great ingenuity. For an unusual psychological research a bureau expert devised and made an instrument to measure the heat evolved by a nerve carrying an impulse. Another, for a research on bees entering a hive, perfected an electrical doorstep to register homing bees with due precision. Minute traces of metal too small for melting-point measurements, as usually made, can be studied by a new type of pyrometer—a micropyrometer developed by the bureau's expert in metals and pyrometry. The bureau's radiation expert devised a highly sensitive radiometer responsive to the heat of a candle a hundred miles away. This was increased in sensitiveness 70 per cent by placing it in a vacuum. With this he has measured the heat of a hundred stars and of the planets Venus, Mars, and Jupiter. An electric device was made to measure the saltiness of the sea by comparing the electrical conductivity of samples of local sea water with that of known standard samples. The device permits work at sea, is rapid, and avoids storing samples for shore work. Such tests of deep-sea samples may indicate the promixity of icebergs, because the fresh

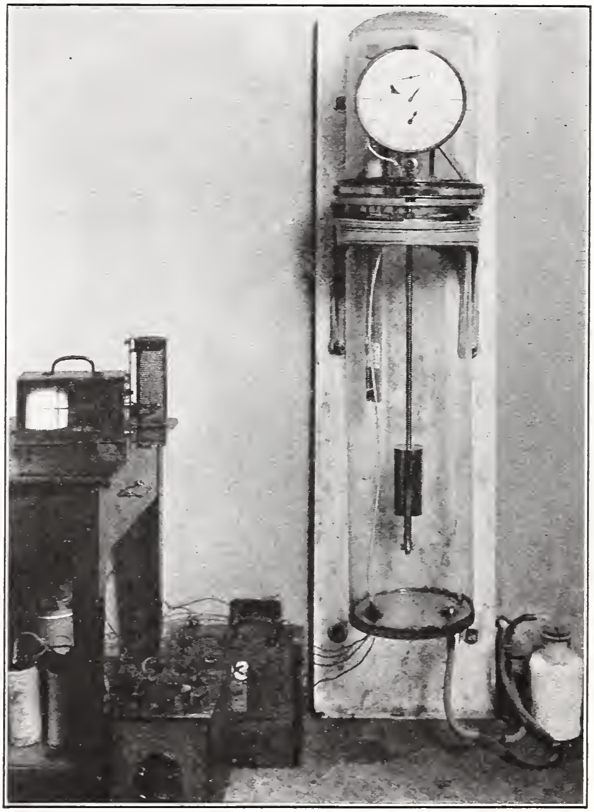

Fig. 37.—*High precision standard clock*

This master standard keeps time to within one-fifth second per month. It is verified by time signals from star observations at the national observatory. Its pendulum of invar steel runs in a vacuum case and may be retarded by admitting air or accelerated slightly by removing air. The clock is equipped to send an electric impulse by wire to any laboratory each second for the precision time service required in many researches.

water from a melting berg is colder and spreads as it sinks to the bottom. Devices are often capable of direct use for practical purposes. This work was done for the international iceberg patrol.

10. KEEPING THE STANDARDS CONSTANT

Researches to maintain constancy in the standards may disclose serious errors from unexpected sources; for example, the standards of electrical resistance and capacity, and of mass.

Humidity was found to alter the electrical resistance of fine wire used in standards. The shellac coating absorbed moisture, stretched the wire, made it thinner and longer, and thus increased its resistance. The varying air humidity thus changed the resistances unaccountably until they were inclosed, when the variation ceased.

So, too, the electrical capacity of mica condensers varied so much as to unfit them for use as standards. The cause was found in our variable atmospheric pressure. When kept free of such changes the condensers showed constancy.

Fig. 38.—*Standards of capacity*

The two flask standards (right) were designed and constructed at the bureau for the rapid verification of glass measuring apparatus. They are working standards standardized for precision tests.

The bureau's researches on the constancy of standards would fill a volume and the results are in daily use in almost every division of the bureau.

After measuring the volume of a standard of mass by immersion in water, errors may arise from absorbed moisture in the metal, a reduction in the mass continuing for months as the absorbed moisture evaporates. The United States Mint weights were changing two years after being made. Weights may change from impurities, oxidation, occluded gases, magnetic ingredients, wear, loss of lacquer, and so on. Changes occur even in weights kept with great care. They must be retested at frequent intervals. Continual care and accurate records are, therefore, essential in the use of secondary standards of mass.

11. PREPARING NEW STANDARDS

When the Bureau of Standards was created it was in possession only of standards of length and mass. To-day it has standards, either primary or secondary, for almost every type of physical measure-

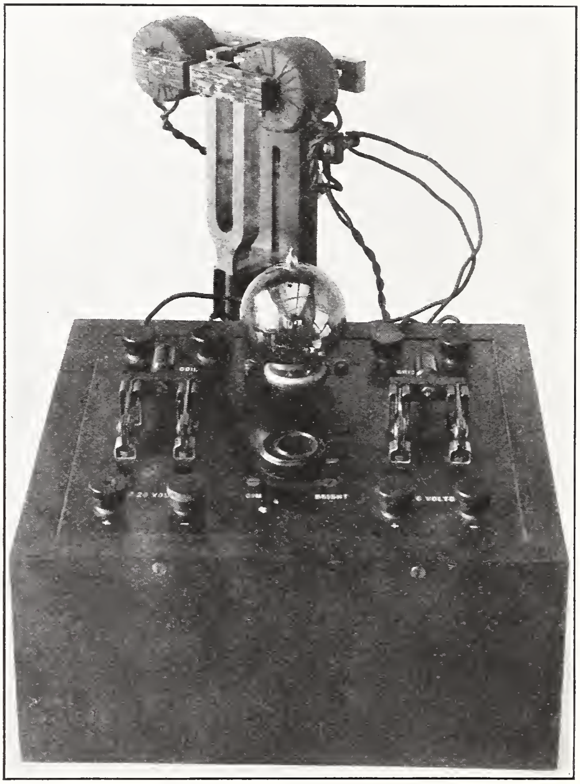

Fig. 39.—*Standard tuning-fork drive*

The electromagnetic drive was devised at the bureau to maintain standard and constant vibration frequency rate. Inversely the device may be used to measure small intervals of time in researches by recording such intervals as graphic traces and comparing them with the recorded curves of the sound waves.

ment. Many of these were designed and made at the bureau after special researches. The construction of standards is one of the primary legal functions assigned to the bureau by act of Congress. Among those prepared by the bureau are standards of length, mass, capacity radiation, melting point, combustion, heat, light, fineness, acidimetry, oxidimetry, composition, polarizing power, color, permeability, electrical resistance, voltage, and current.

12. PRESERVING THE STANDARDS

The custody of the standards, a bureau function of the utmost importance, is far more than the mere safe deposit of a mass of metal in a vault. It is often a research problem of almost continuous activity. The standard cells from which the unit of electromotive

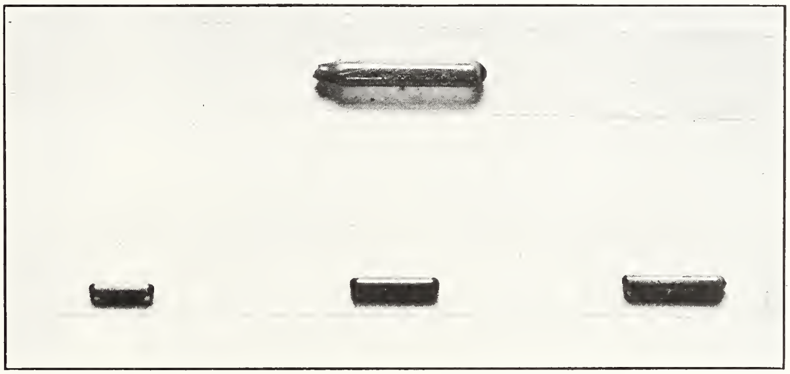

FIG. 40.—*Standards of radioactivity of the Bureau of Standards*

These tubes (actual size shown) contain radioactive salts of radium of known and certified amount. Upon the basis of these the radium bought and sold in this country is standardized and certified.

force, the "volt," is derived, are kept in a bath of oil. By stirring and thermostatic control, their temperature is kept always constant to within a hundredth of a degree. The voltage of each cell is known and recorded from the time it was made, and defective cells are promptly removed. Whatever is needed to preserve the constancy

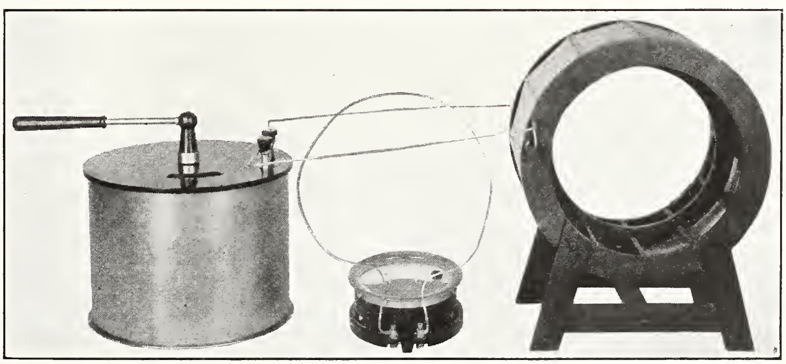

FIG. 41.—*Standard radio wave-length circuit*

The wave-length standard consists of standard circuits made up of the standard condensers and inductance coils. The circuit includes a pair of leads; the inductance coil is considered to include these when its value is determined.

of the unit which a standard represents must be done. In the standards vault of the South Building are preserved the national meter and kilogram standards. In an underground vault in partial vacuum is the famous Riefler clock, the standard for rating timepieces. It runs true to within a fraction of a second per month. Some standards require special control. Secondary color standards must be protected from light. Standard certified materials are safeguarded from moisture. Standards of magnetic permeability must be protected from mechanical shock which would alter their permeability. A standard may involve hazard, radium for example. The bureau's standards of radioactivity, tiny tubes of radium salts, are therefore kept in heavy lead cases preserved in thick-walled iron safes. When in use they are heavily shielded with lead blocks. For each standard the conditions needed for preservation are determined by research. How well this is done determines how perfectly the basis of national measurements is maintained.

B. INDUSTRIAL RESEARCH

Scientific methods are often far too complex or theoretical for direct application. Much of the bureau's research is therefore directed to perfecting means to apply science to industry. This phase of the bureau's work, involving precise measurement and fundamental science, is naturally one of great attractiveness. Its results are more obvious and of striking magnitudes. A research may within a single year return many times its cost. The bureau aims to apply at once to the industries it serves, the latest results of science. This requires exacting researches, some of which have an unusual economic value, not always obvious.

1. MONEY VALUE TO PUBLIC

It is credibly estimated that the bureau returns to the people much more than one hundred times its cost. Its annual cost is a little over a cent per capita. Individual research projects are known to have produced a permanent yearly gain to the country many times in excess of the bureau budget. Less direct gains are inestimable but of a very high order, producing something more than money income—added safety in industry and greater efficiency—and helping to lay foundations for the highly productive scientifically planned industries of to-morrow.

As investments the bureau appropriations have been likened to seed bearing a hundredfold the outlay. Its laboratories are a national asset and its appropriations are measures of national economy as well as development.

2. GAINS FROM AUTOMOTIVE RESEARCH

Several cases will illustrate the gains from the bureau's researches on automobile fuel oil, tires, and brakes. These three alone show a saving to the public of more than $155,000,000 a year as estimated by the industries.

An investigation at the bureau at the request of the petroleum and automobile industries and the recommendations based on the experimental results have made it possible to produce additional gasoline from crude oil to the value of $100,000,000 annually. On the initiative of the bureau the industries cooperated in a laboratory research, the results of which have effectively caused the abandonment of fabric tires. The saving in gasoline from the greater effectiveness of cord tires is estimated as worth $40,000,000 annually. A laboratory research on brake linings conducted by the bureau on request and with the cooperation of the Motor Transport Corps resulted in the development of testing apparatus for brake linings. As a result of this research, makers have improved their product fourfold and the way to further improvement was pointed out. A public saving of $15,000,000 and a greater safety of life and property have directly resulted.

3. SIMPLIFICATION SAVES A MILLION DOLLARS A DAY

Leaders in the industries concerned estimate savings from seven completed simplification projects amounting annually to $1,000,000 for brick, $2,400,000 for sheet steel, $5,000,000 for warehouse forms, $5,500,000 for range boilers, $10,000,000 for builders' hardware, $15,000,000 for inquiry, purchase, order and invoice forms, and $250,000,000 for lumber. The latter simplification meant a 60 per cent reduction in sizes of finished yard lumber.

4. SPEEDING UP THE HARDENING OF CONCRETE

An industrial research may be an experimental survey of means to accelerate a process. The bureau's systematic search and trial showed that 4 per cent of calcium chloride accelerated the hardening of concrete several hundred per cent. The great gain of time once lost in waiting for concrete work to harden now earns daily dividends in the building industry. The idea is now part of standard concrete engineering practice. The first research cost a few hundred dollars. It is reported to have saved $500 daily on the project for which it was devised. The total present annual value of the method is, of course, inestimable, but exceeds thousands of dollars daily.

5. ENAMELED METAL WARE

An example of the economic necessity for industrial research is offered by the bureau's successful solution of the "fish scaling," or flaking of the enamel from metal enameled ware. The industry itself was threatened. Its national organization asked the bureau for aid. Experimental researches on the relative expansion of the materials, on the composition of the enamels, the cleaning of the metal, and the temperature of the firing were made. By elaborate experimental research the cause and cure were found, and the bureau enabled the industry to improve its product and avert actual closing down of plants. The increased life and safety of such ware to the consumer were appreciable.

6. LOCATING SURVEY SHIPS BY HYDROPHONE

Another research, developed for the Coast and Geodetic Survey, is a system of measuring the shore distance of a survey ship at any

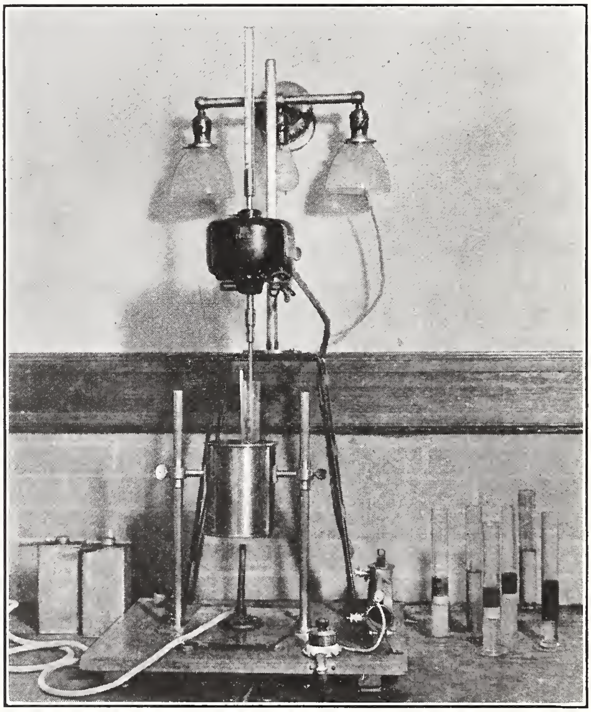

FIG. 42.—*Emulsifier used in oil tests*

Oils for use in steam turbines and for similar purposes must separate readily from water with which they become mixed in service. The test sample is stirred with water for five minutes in the apparatus shown, at a temperature of 55° C. (131° F.), and at 1,500 revolutions per minute. The result of the test is expressed by a single value, in cubic centimeters per hour, expressing the rate of separation of the oil from the mixture after being stirred. The demulsibility test developed at the bureau is now part of standard oil test methods.

time even during fog or night. The sound of an explosion from the ship travels through the water to two shore hydrophones which relay radio signals back to the ship. The number of seconds elapsed multiplied by the speed of sound in sea water (1,492 meters per second at 13° C.) gives the ship's distance from shore. So well was this applied by the surveying experts that the ship's shore distance may now be measured as accurately in the fog or at night by the radio-hydrophone system as by the usual survey methods made on a clear day. In this case a deep-sea sounding party of the Coast and Geodetic Survey was enabled to do continuous work where fog had previously prevented 25 days each month. This speeding of the work fivefold resulted in a saving of thousands of dollars per month. This research adds a new method to the art of the surveyor, capable of important applications.

7. WHAT MAKES GOOD ENGINE OIL

A research to determine a suitable test of lubricating oil for engines disclosed that the quality of such oil depended upon its demulsibility. The oil becomes mixed with steam or water during the engine operation. The result is an emulsion, the utility of which is slight. It is therefore necessary that the oil separate readily from the water or

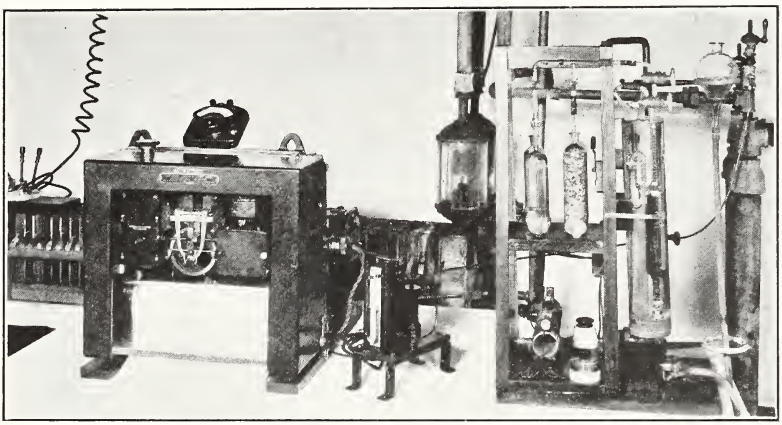

Fig. 43.—*Automatic self-recording gas analyzer*

The bureau has developed devices for the automatic analysis of gases, of which an example is shown here. Other examples include apparatus for testing leaks from balloons, for recording sulphur dioxide in sulphuric acid plants, for determining ammonia in hydrogen mixtures, for measuring the purity of electrolytic oxygen and hydrogen, for detecting carbon monoxide released from gas burning appliances and for many other purposes.

steam leaving the oil clear as at the outset. The instrument and method of test developed by the bureau's expert are now the basis of the Government's oil specifications and are part of engineering practice throughout the country, having been found to be a satisfactory gauge of quality.

8. AUTOMATIC ANALYZER OF FLUE GASES

In another research the bureau devised an automatic device for the continuous analysis of flue gases from boiler plants. Knowing the ingredients, any change in their ratio alters the heat conductivity by an amount easily detected. The change in electrical conductivity of a wire thus measures the changes in the proportions of the constituents of the fuel feed for maximum efficiency.

9. MEASURING SOUNDPROOFING OF WALLS

In order to measure the sound-transmitting and sound-absorbing properties of building materials and full-size built-up walls, a new method was devised at the bureau for determining the intensity of sound, covering an intensity range of 1 to 1,000,000. In this the current output of an electro-mechanical receiver is rectified by a crystal and the current is measured by a galvanometer. A series of full-size walls was studied and the sound absorption measured to acquire data for designing soundproof walls.

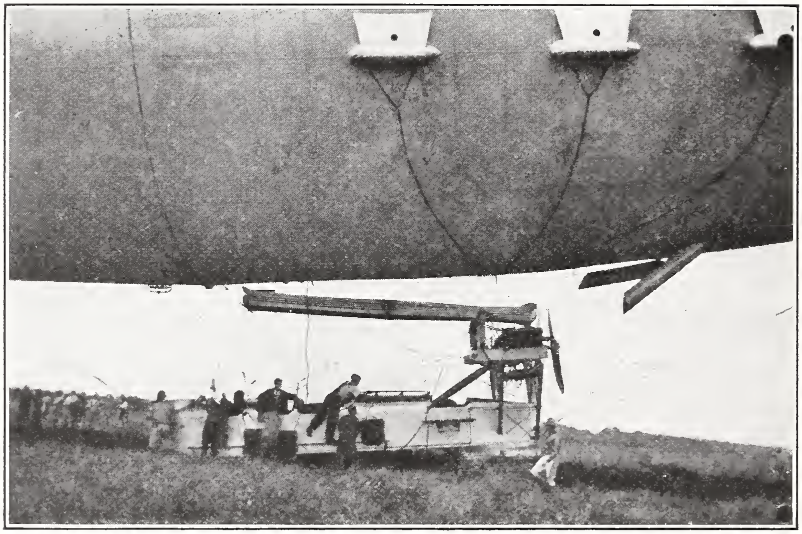

FIG. 44.—*Airship ballast recovery device*

An airship loses weight equal to that of the fuel burned. The water produced by the combustion weighs more than the gasoline consumed since the hydrogen in the fuel combines with eight times its weight of oxygen from the air. By cooling and condensing a large part of the water vapor produced the loss of fuel weight can be completely compensated.

10. TAKING AIRSHIP BALLAST FROM THE AIR

Airships lose weight by burning gasoline and passing the exhaust into the air. In the case of helium airships, in order to compensate for the increased buoyancy the valuable helium had to be thrown away equal in weight to the gasoline burned. On request of the Army Air Service the bureau made it possible to save this loss. A device was constructed for condensing the moisture from the exhaust, thus recovering more than a pound of water for each pound of gasoline consumed. Burning with oxygen taken up from the air produces water which actually weighs more than the gasoline consumed. The economic saving by this device is more than $1,000 per cruising hour for each such airship. This saves the waste of large quantities of lifting gas (hydrogen or helium) which formerly had to be released to maintain static equilibrium.

11. MEASURING AIR FLOW AROUND OBJECTS

A knowledge of air flow around objects is important in many fields of design and operation. Either the object or the air may be in motion; the result is the same, and in the wind tunnel the air resistance of an automobile at high speeds is readily determined by keeping the model at rest and moving the air. A model of an automobile tested in the bureau's wind tunnel showed that at 60 miles an hour the air resistance alone used up 30 horsepower in service. Air-resistance effects are applied to the study of the air flow around falling bombs in order to design them according to effective "streamline" profiles. The results of such researches will be useful in improving the future design of all craft or structures—airplanes, airships, automobiles, towers, buildings, and the like—which must encounter air flow with speed, precision, or efficiency.

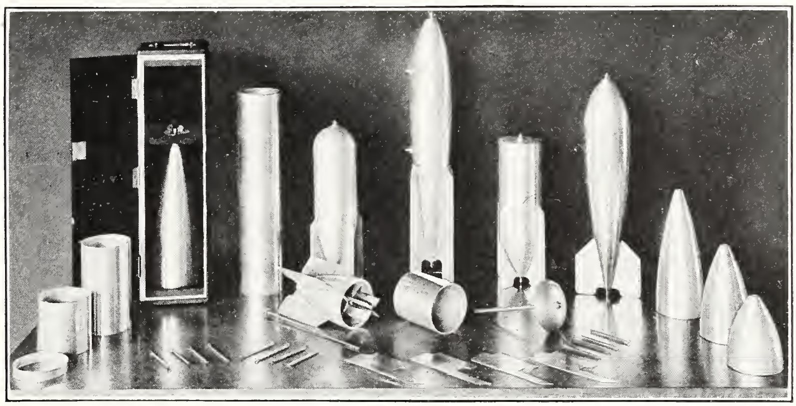

FIG. 45.—*Types of projectiles tested in the wind tunnel laboratories*

12. IMPROVING INDUSTRIAL TECHNIQUE

The new technical problems submitted to the bureau are most varied. The following examples will illustrate the wide variety of research results on such problems. The waste from breakage in the cutting of pearl buttons from river pearl shells was greatly reduced by methods suggested by the bureau at the request of the industry. The paper experts developed under measured control, manila paper 50 per cent stronger than previous papers. The textile section worked out the make-up and construction of cotton fabric with the properties of linen. The stone experts demonstrated that certain stones could be strengthened if dipped into melted sulphur. The lime section developed a plastic gypsum and, in cooperation with the lime association, a quick-setting lime block. The latter, usable within 20 minutes, could be sawed or nailed like wood. Elaborate

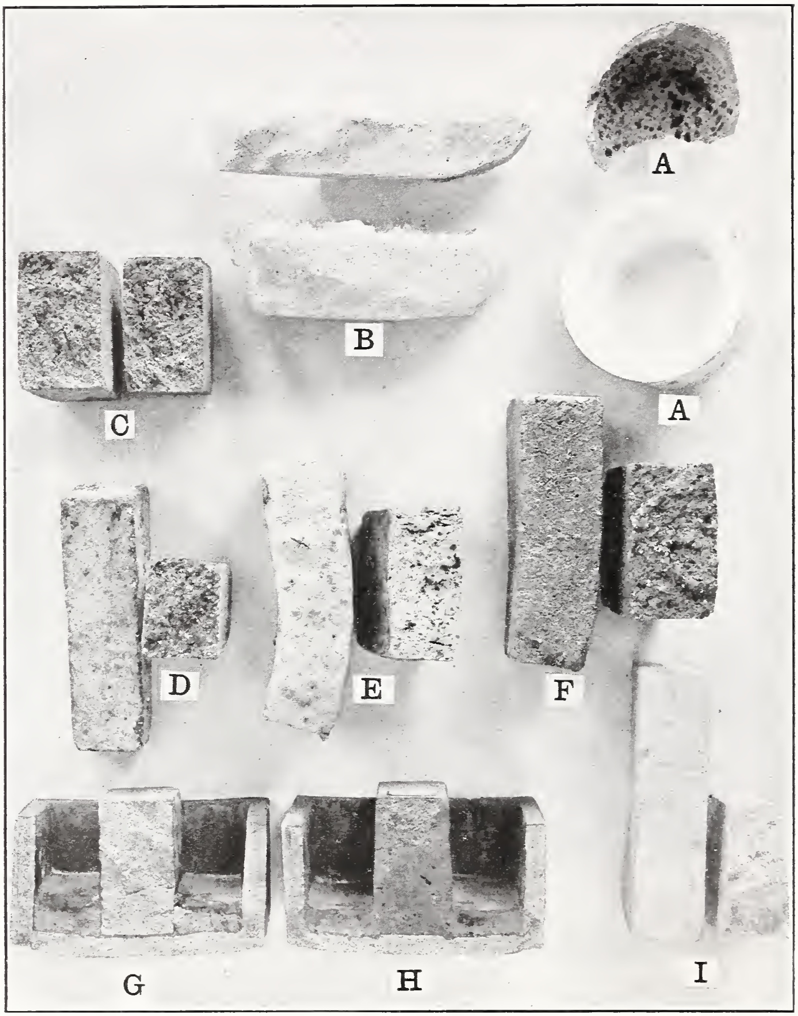

Fig. 46.—*Refractory materials investigated experimentally at the Bureau of Standards*

A, Experimental glass pot of the porcelain type made at the bureau;

A′, Fragment of pot (shown at *A*) which has been tested, showing corrosion from glass attack;

B, Fragments of porcelain glass pots (1,000 pounds capacity) made by the bureau's casting process. Fracture shows practically no glass attack;

C, Sections of fire-clay brick, handmade;

D, High grade fire-clay brick containing diaspore, after heating at 1,450° C. for 72 hours;

E, Low grade fire-clay brick after heating at 1,450° C. for 72 hours. Fracture shows extensive slagging of inherent ferruginous impurities and structure is vesicular;

F, Medium grade fire-clay brick after heating at 1,450° C. for 72 hours. Fracture shows incipient vitrification and appreciable uniformly distributed iron discoloration;

G and *H*, Fire-clay bricks ubjected to slagging action of fused ash. *G* is unaffected while *H* shows considerable penetration;

I, Silica brick, containing from 96 to 98 per cent SiO_2.

tests were made in producing effective metal enamels and porcelain glazes. The ceramics division also produced from American clays fine specimens of pyrometry tubing such as had been imported on account of the lack of technical data and experience relating to the manufacture of such articles.

13. ELEVATOR INTERLOCKS

Elevator interlocking devices were experimentally studied by the bureau in an accelerated service test to formulate specifications, including the cycle of operations involved in operation with change of

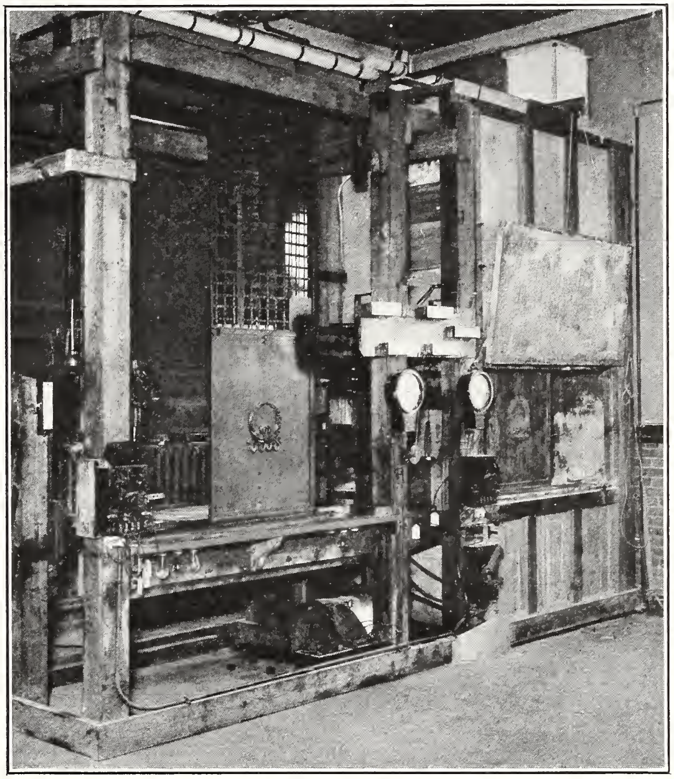

FIG. 47.—*Elevator interlock research apparatus*

To prevent elevator accidents the city of Baltimore requested the bureau to make experimental studies of the factors which make for perfect performance of interlocks.

alignment of platform landing and door, endurance tests in normal service, and operation in corrosive or dusty atmosphere. The results formulated became a basis for municipal codes. The work was undertaken when the bureau's investigation disclosed that 75 per cent of the fatal accidents in elevator service were preventable. Recent tests at the bureau make it possible for practically all manufacturers greatly to improve their product. There is good ground for believing that the annual insurance costs on elevators will be reduced over $500,000 by this work.

14. SOUNDNESS OF METALS

Congress authorized the bureau to study the production of sound rails, axles, and other railway materials. The metal experts found causes of unsoundness and failure. They tried out ways of improving the quality, some of which involved new mill practice. Nondestructive tests were also devised for testing steel. Materials destroyed in test can not be used for production, while untested materials are hazardous. Its magnetic test when developed permitted the bureau to grade the wearing durability of a set of drills used for boring metal at the navy yard. The drills, passed through coils carrying electric current, registered their magnetic property and thus enabled the bureau expert to select the best three and poorest three. The correctness of the choice was confirmed by service-to-destruction tests at the navy yard.

What can be done for drills may be possible for other tools and metal products; for example, rails may be run through coils to register their structural integrity—density, hardness, and flaws. When fully interpreted and developed, a new standard practice will be available for testing and grading metal products. Research is in progress on means to test long cables in place, as it is desirable to test the cables under actual service conditions.

15. IMPROVING PAPER-MONEY PRINTING PLATES

To lengthen the useful life of engraved plates two or three times that previously attained is a recent achievement of the electrochemical laboratory of the bureau. A new process takes an electrolytic reproduction of the original, adds alternate layers of copper and nickel to a thickness about 0.07 inch. This is sweated to a steel plate, and the face coated electrolytically with chromium to a thickness of about 0.0002 inch. No details are lost and the impressions are better than the original for the method deepens the channels in the plate. A thousand plates were made for full service trial at the Bureau of Engraving and Printing and, after five months of use, none are yet worn out. The chromium surface without retouching appears as if it had been highly polished. It can not be scratched by the hardest steel. When the surface wears out, it can be replaced at trifling expense.

16. NEW PROCESSES IN SUGAR MAKING

Under measured control the bureau devised methods of crystallizing-out rare sugars. In its researches on sugar technology the bureau has produced sugars from widely varied sources—fucose from seaweed, levulose from artichokes, mannose from ivory nuts, and so on. Process control is gained by research to ascertain the favoring conditions. In its laboratory the bureau solved the measured control for crystallizing dextrose commercially. The dextrose industry established on the basis of the bureau's work now represents an investment of millions of dollars. The full-scale demonstration of the commercial production of crystallized levulose is now under

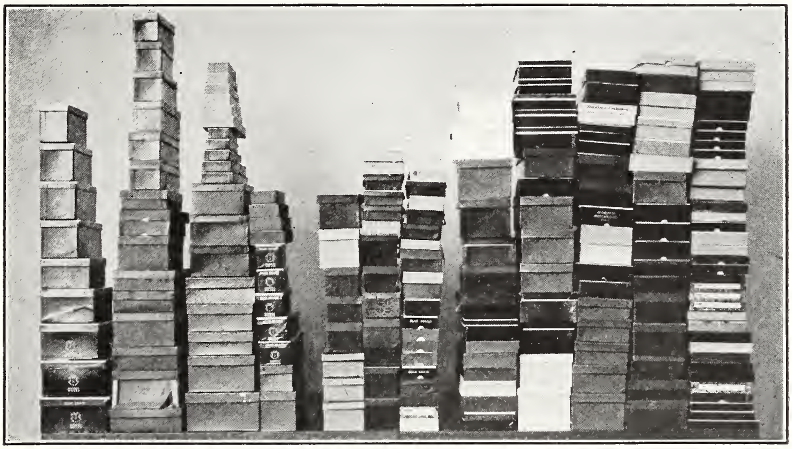

FIG. 48.—*Variety of hosiery boxes before standardization*

The four piles at the left contain boxes for children's hosiery; the central three piles are for men's hosiery; the five piles at the right, for women's hosiery.

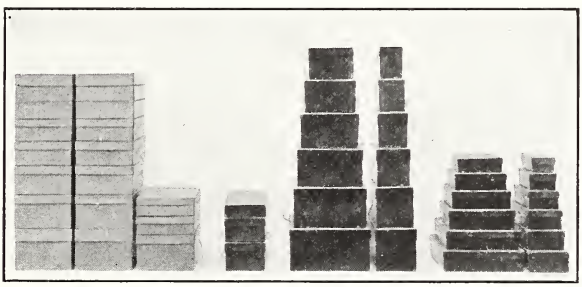

FIG. 49.—*Variety of hosiery boxes as standardized*

A reduction to one quarter of the number of sizes shown was recommended, with a possible further saving, aggregating in all 83 per cent. A saving of 5,000 tons of box board and cover paper is estimated. A large saving of waste space unoccupied and a reduction in the sizes of shipping cases will result. The undue breakage by crushing unoccupied parts of the boxes will be avoided, quantity production will be facilitated, and the proposed standard boxes will permit the hosiery to be pressed slightly by the box thus ensuring a more compact package.

way at the bureau under new methods, likewise devised by its experts and proven successful in the laboratory. Such researches are fundamental for the sugar industry.

17. STANDARDIZATION FOR HOSIERY INDUSTRY

The industry reports a permanent saving as a result of the standardization of hosiery box dimensions. The saving is expected to amount to $3,000,000 per year, chiefly resulting from saving the waste of material and storage space, reduction of breakage and crushing, and reduced cost of production. The total savings from hosiery standardization research, at the bureau are estimated at $28,000,000 by the officers of the national association of the industry.

The 450 boxes from 21 of the largest plants showed 50 different widths, 55 different lengths, 39 different heights. The variety and confusion presented a serious problem to the retailer in arranging the boxes on his shelves.

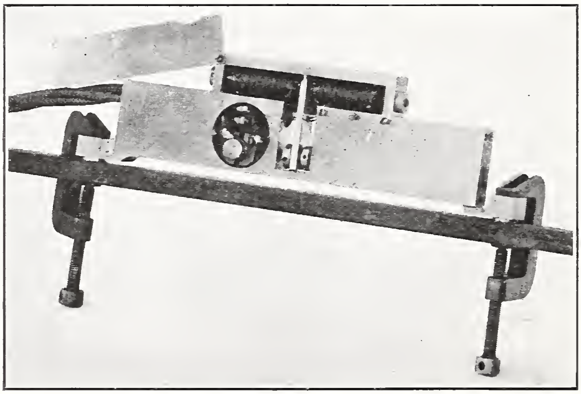

FIG. 50.—*Electric telemeter*

This device permits simultaneous records of measurements of strains, forces, and pressures occurring at widely separated points, photorecording even rapidly varying values in true proportions. The instrument was designed at the bureau and applied to measuring stresses in airplane stay cables during flight, testing structural members of airships and bridges, measuring live load stresses in steel bridges.

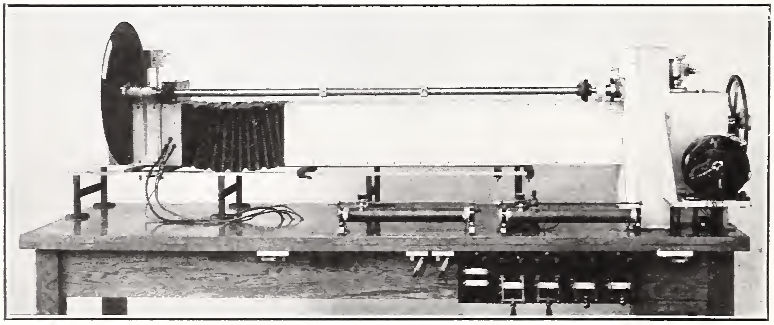

FIG. 51.—*Photographic sensitometer*

In measuring the sensitivity of photographic materials this sensitometer was designed and constructed at the bureau for both research and testing. It is a sector wheel in which the complete exposure is made during one revolution. The sector wheel may be run at speeds ranging from 0.0586 revolutions per minute to 480, covered by steps varying by powers of two. The purpose of the sensitometer is to expose the photographic emulsion to an accurately known intensity of light for a precise interval of time.

18. MEASURING APPLIANCES

Research often results in new measuring devices useful to industry. Actual cases include such devices as the walking machine for testing the wearing quality of sole leather, an automobile-tire testing equipment which simulates road conditions, a tautness gauge, a stretch-strain recorder showing the ratio of stretch of cloth in terms of deforming force, a complete recording device for testing road performance of automobiles, a plasticimeter to measure plasticity and

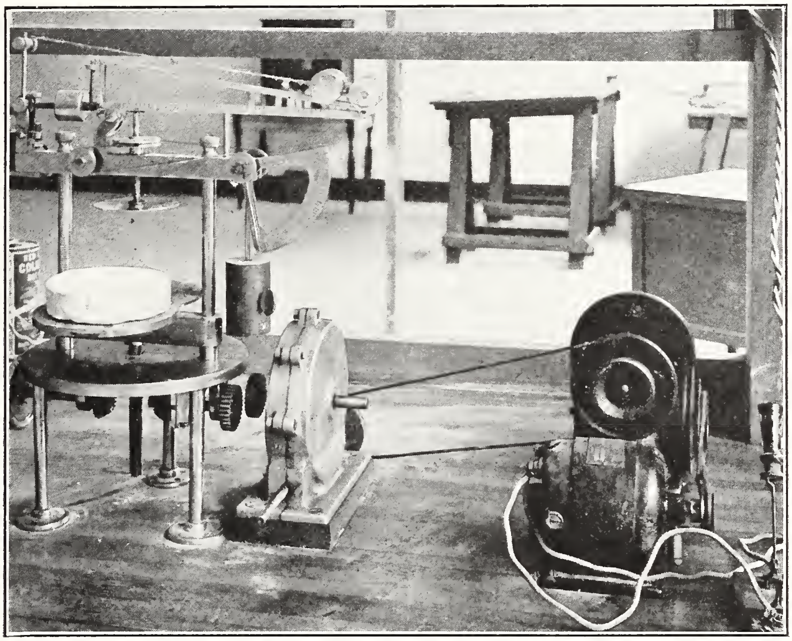

Fig. 52.—*Plasticimeter for measuring the plasticity of lime and other mortars*

The plasticimeter is useful in giving a quantitative measure of that property of lime mortars and other plastic materials which enables them to be spread upon the structural surfaces. The plasticity of the mortar and plaster greatly influence the cost of plaster work in building construction. The bureau has standardized the specification for plasticity and has designed the instrument pictured above for such measurement.

rate this useful property of lime, clay, and plaster. The latter measurement is now a factor in national specifications for these materials and in their production, purchase, test, and use. Bureau experts developed an electric telemeter for remote recording of slight strains. Its uses are many—for measuring impact stresses on highway bridges, measuring the strains in rigid airships during flight, and for measuring changes in all kinds of structures subject to stress. Photographic records of such stresses can be made at 12 separate points in the bridge at once, the records being 12 inches by 100 feet long. Such devices permit new kinds of researches upon the net effectiveness and characteristics of materials, structural parts, and assembled structures in service.

Researches often call for the prompt solution of some problem or the development of a new instrument. A projected airship flight called for the prompt development of a photographic sextant which would not require visual observation to ascertain the position of the sun with respect to the zenith, even when the horizon is obscured. The problem was quickly and effectively solved and the altitude of the sun which guides navigation can now be determined automatically to about five minutes of arc.

The few cited are typical of many others. The bureau conducts research on special problems of more general concern. Its unusual plant and staff uniquely fit it to focus the specialized groups on each research.

VII. TESTING

1. PURPOSE OF TESTING

In one year more than a million and a half lamps are inspected for Government use at the factories. The cement for national construction projects was inspected at the mills. Upwards of 170,000 separate tests were made in the bureau laboratories. Each test carries with it some standardized measurement to make industry more exact and better meet the user's needs. Nearly half of the bureau's activities are devoted to the maintenance of test standards and facilities, research on test methods and actual testing. In comparison with the volume of Government purchases and the value of such tests, the cost is moderate.

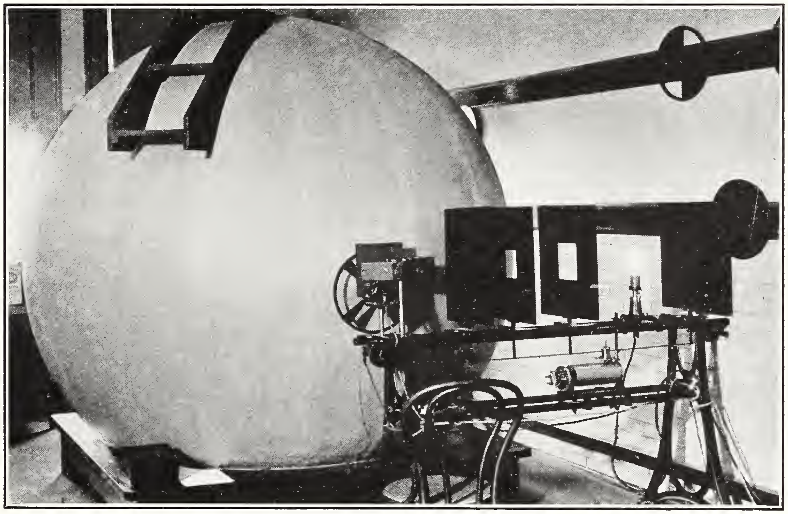

FIG. 53.—*Hollow sphere photometer*

To measure the total light output or spherical candlepower of a light source an Ulbricht hollow sphere is used. Its inner surface, painted white, reflects the light from a contained source so uniformly that the brightness of the inner surface may be used as a measure of the total light emitted by the source in all directions.

Testing includes all comparisons by which the national standards are made of use to the public through certificates. Testing is a primary service of the bureau, to meet demands which private testing laboratories can not meet. It aids those establishing local testing laboratories by certifying their standards and by advice as to methods, appliances, and procedure. Bureau tests are made with a suitable degree of precision in each case. Short-cut methods are developed for speed and accuracy, sometimes automatic or self-recording. Test certificates and reports serve as evidence of accuracy or quality, as a basis of competitive award or acceptance of deliveries. These assure maker and user of the acceptable quality of several hundred million dollars worth of materials which the Government buys each year.

Testing admits a device or material to active service or turns it back as unfit. The maker does the same with the raw material he buys for his mill production. It is to his interest that his material fail in test rather than in service. The bureau, however, cooperates with the industries in control by measurements and by the use of measured constants upon which high quality may depend.

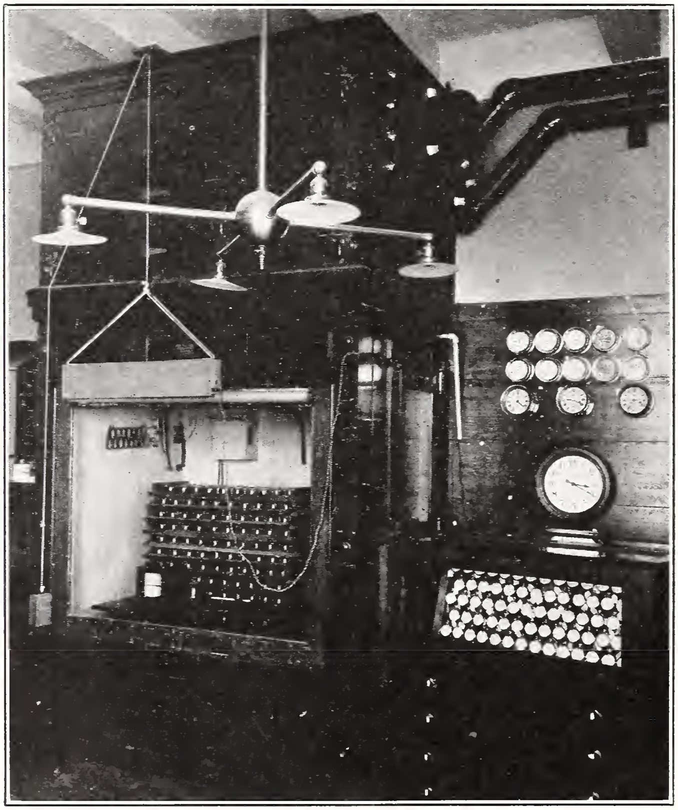

Fig. 54.—*Timepiece testing cabinet*

Here chronometers and watches are being tested for Government use under conditions of temperature and position of stem and face which are encountered in service.

A measuring instrument may be very accurate or too unreliable to use; a buyer has no means of knowing which. A test alone will tell. He may apply the certified corrections and thus obtain precise measurements with an inexact device. A steel tape of known error may be used if the correction is allowed for. Assay weights are tested by the bureau so that the assayer may apply to each weight the certified corrections to perfect the accuracy of his weighings. The same holds true for many appliances.

2. VARIETY OF TESTS

The articles tested number thousands. Even major classes are numerous. The weights and measures division, one of nine scientific and technical divisions which test articles, has published schedules for major classes of tests, as follows:

Reference standards of length.
Working standards of length.
Commercial standards of length.
High precision gauge blocks.
Precise capacity standards.
Ordinary capacity standards.
Metal measuring tapes.
Level rods.
Contact standards.
Precision screws and calipers.
Area measuring appliances.
Standard sieves and sieve cloth.
Timepieces.
Volumetric apparatus.
Gas measuring standards and instruments.
Weights and balances.
Track and mine scales.
Hydrometers and thermohydrometers.

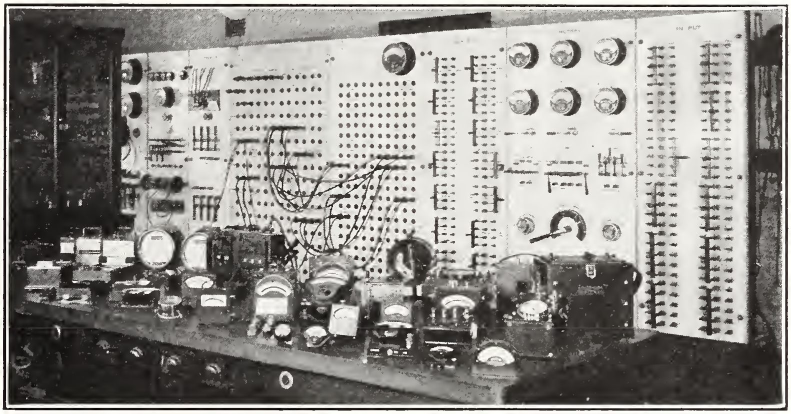

FIG. 55.—*Types of electrical instruments tested*

The bureau is called on by the electrical industry, the Government, and scientific institutions to standardize and calibrate their electrical measuring instruments. These include reference standards and precision instruments used in calibrating instruments for commercial needs, development of specifications, and research work. Above are shown some of the more important types of electrical measuring instruments studied and compared with the fundamental electrical standards of the bureau.

Some of these cover many individual appliances, too diverse to list here. The list is typical of equally numerous major classes tested by the other eight testing divisions, with their 60 or more specialties; for example, there are about 20 schedules of electrical tests. Bureau circulars give schedules for this great variety of tests which the bureau is prepared to make. The range doubtless exceeds that of any other national testing institution. Gauges and watches have accuracy as their one aim. They must be correct. Materials must have useful properties. A paint film must cover or hide the surface, harden in a set time, develop a certain elasticity and strength if it is to serve acceptably. Cement must harden in a stated time and attain a definite strength within a certain setting period.

The bureau is called upon to check the accuracy of blood count apparatus, the durability of an automobile tire, the hardness of a steel, the softness of a fabric, the accuracy of a thermometer, the sugar content of a molasses, the uniformity of weave of a fine sieve, the life of an electric lamp, the strength of a cable, the crushing resistance of motor-truck wheels, and similar tests of the utmost variety. Testing sugar and molasses, cloth and paper, rubber and leather, stone and cement, clays and glass, and their thousands of products is the daily task of the testing laboratories. To measure all these things in so many ways calls for almost every branch of physics and chemistry. The making of measuring appliances forms a great group of industries.

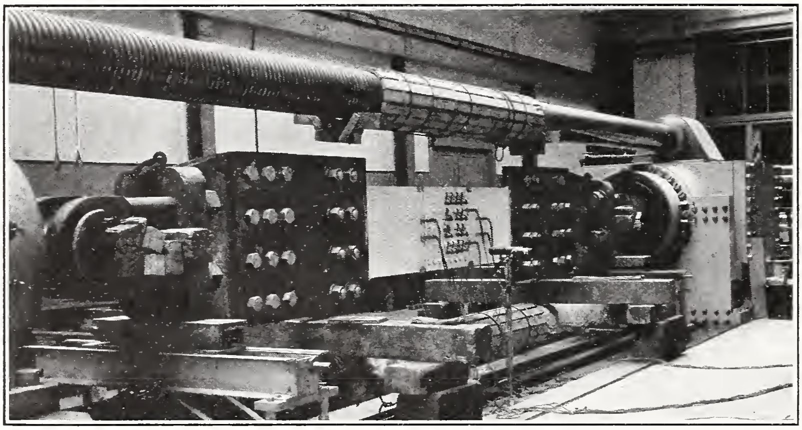

Fig. 56.—*Testing riveted ship joints*

In this test the joint is subjected to tensile stress in the 2,300,000-pound Emery testing machine. The stresses in the different portions of the plates are recorded by a special electric strain gauge or "telemeter" designed and built by the bureau. Investigations promote stronger and more economical construction.

Requests for tests are too numerous for the facilities and staff. Preference is given tests for which the bureau is uniquely equipped. A test is not usually taken which would delay work of greater importance. In general, the bureau does not make tests for which private testing laboratories are equipped. Nor does it test secret processes; inadequately described materials, devices, or processes; ores or compounds by methods already standard; or material already well studied; nor make tests where advertising is the primary object.

Fundamental tests are those of standards for industry or science. For this the bureau is the only laboratory having direct access to the fundamental national standards, and its facilities for such tests are unique.

Routine tests of measures, devices, and materials are the more numerous class. About two-thirds of such work is for the Government. Such tests are made for the public only when they do not compete with private agencies.

Referee tests are rare. When the parties to a dispute agree to abide by the decision, the bureau in important or key cases, serves as referee. Investigative tests of molasses and renewable fuses are examples. The results of the latter are published with the experimental data of the bureau's findings in the case.

Cooperative tests are made where the results are of mutual concern. The results are open to the public. When done for a manufacturer concerned with improving his product a nominal fee may be charged.

3. COMPARISONS WITH STANDARDS

Manufacturers may send master standards to the bureau to be verified and their corrections certified in terms of the national standard. Schedules for such work are published in bureau circulars.

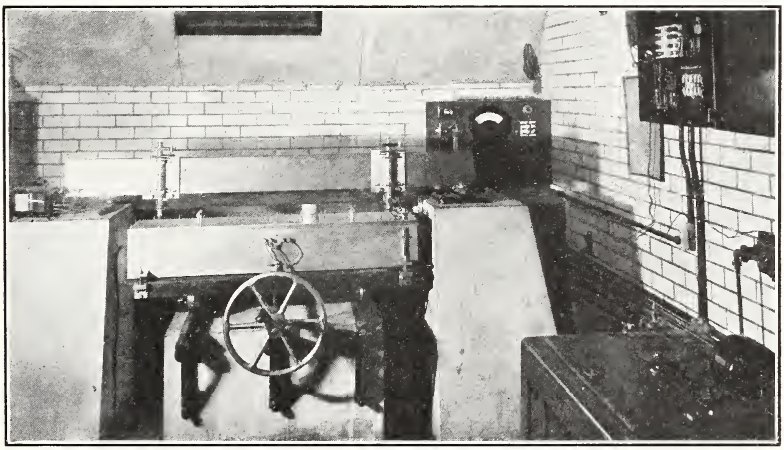

FIG. 57.—*Length standard comparator*

Two microscopes are adjusted to position over the lines defining the length interval of the reference bar. This bar and the bar to be compared are in a constant temperature bath. The second bar is substituted in similar position by moving the carriage. Differences are read by micrometer screw on the microscopes. The cross bar is of "invar" steel. Such tests are the basis of precision in industry.

This national service of accuracy carries definite working units into active service in field and factory. Makers of measuring appliances must first of all have their own master measures compared with the national standards to insure accuracy in the factory where measuring tools are made. These master standards in turn gauge the shop standards which build accuracy into measuring appliances.

While the bureau prepares in advance for such work, any standard may present new problems of design, condition, or use. These are studied by experts who know what affects accuracy. The underlying science must be mastered. Several observations by independent experts are rechecked to insure accuracy, and the order of precision itself is measured and rated. No known error may be neglected where the highest precision is involved. When the certified result reaches the standards room in the factory it is used to correct all measurements made with the shop's master standard, which is, naturally in error by a slight amount.

4. SCIENTIFIC METHODS OF TEST

Science must blaze the way to dependable testing. The items to be measured must be analyzed and separately studied. A simple

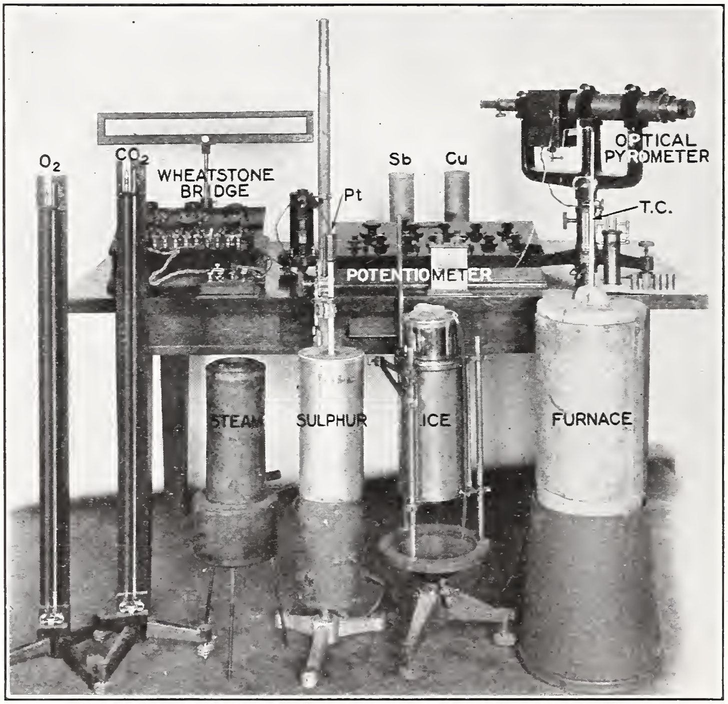

Fig. 58.—*Apparatus for reproducing the standard temperature scale*

The platinum resistance thermometer *Pt*, used to reproduce the standard interval −195 to +450° C., is calibrated at the boiling point of oxygen (−183° C.), the sublimation temperature of CO_2 (−78°.5 C.), the melting point of ice (0° C.), the boiling point of water (100° C.), the boiling point of sulphur (444°.6) all under normal atmospheric pressure. The thermocouple *TC*, used to reproduce the standard scale from 400 to 1,100° C., is calibrated at the freezing point of zinc (419°.4 in furnace), antimony (630°), and copper (1,083° C.). The standard scale above 1,100° is reproduced by means of the optical pyrometer which is standardized at the freezing points of pure metals (gold, palladium, etc.) which are melted in the small crucibles shown. In the cut the pure materials are indicated: Sb, antimony; Cu, copper; Pt, platinum; O_2, oxygen.

test may require elaborate research to perfect the measuring devices and to insure accurate methods. The perfected system of testing clinical thermometers is an excellent model of controlled testing, rapid, convenient, and of just the accuracy required. The procedure for precision thermometers, however, demands greater accuracy, and provides for reference to the fundamental temperature scale. The aim is to make the speed and accuracy sought conform to the need in each case. Science must control each test throughout.

Special facilities are planned and provided for the various tests as needed. For example, air-speed meters, used under low atmospheric pressures encountered in high air flights, are studied as to their performance in reduced pressure (partial vacuum) and in wind streams.

The proper test of aircraft engines requires elaborate measuring appliances, a special air-tight room in which air speed, pressure, and

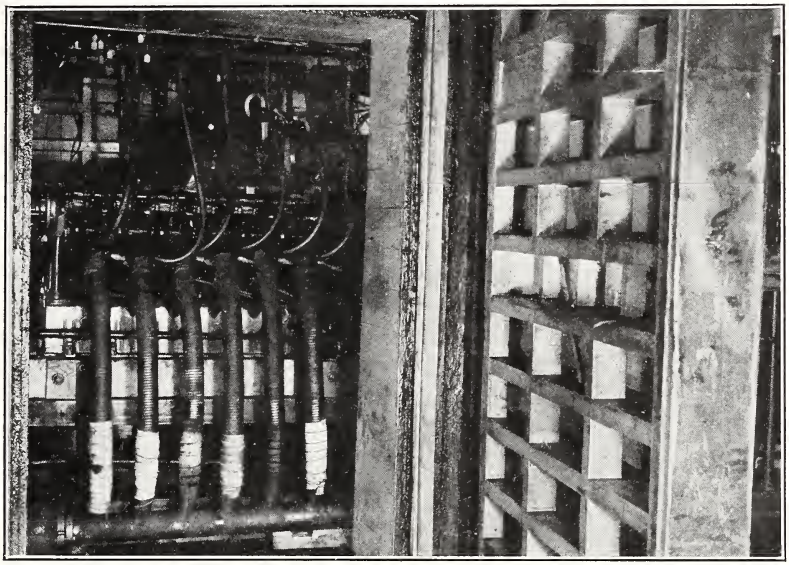

Fig. 59.—*Airplane engine under test in altitude laboratory*

Aircraft engines can not be properly tested in an ordinary laboratory because they are used at altitudes where air pressure and temperature are much lower than at ground level. The engine shown is under test in the bureau's airtight altitude laboratory where pressure and temperature are reduced to those encountered in flight by means of a vacuum pump and refrigerating plant, and the power produced is measured by an electric dynamo meter. A full battery of measuring instruments give accurate knowledge of all pertinent conditions in the engine and the laboratory.

temperature may be varied at will, and a plant for producing such extreme atmospheric variations under measured control. To test the streamline efficiency of an automobile, or the wind pressure on a house, requires small-scale models, a wind tunnel with large motor-driven propeller, and weighing mechanisms of unique kinds. Where constant voltage is required as in the life tests of lamps, storage batteries a special generator may be used, governing to constant output voltage. To test structural materials crushing and tensile forces are available up to thousands of tons.

5. A SIMPLE TEST

A single typical example will illustrate. Although length is one of the simplest kinds of measurement, even so simple a test as that of a steel tape calls for carefully planned procedure and elaborate equipment. Metal measuring tapes are used by the surveyor, engineer, and builder to measure the land, the grading, the construction. For perfect work accurate tapes are essential. Errors in the tapes cause disputes or blunders. Hundreds of tapes are, therefore,

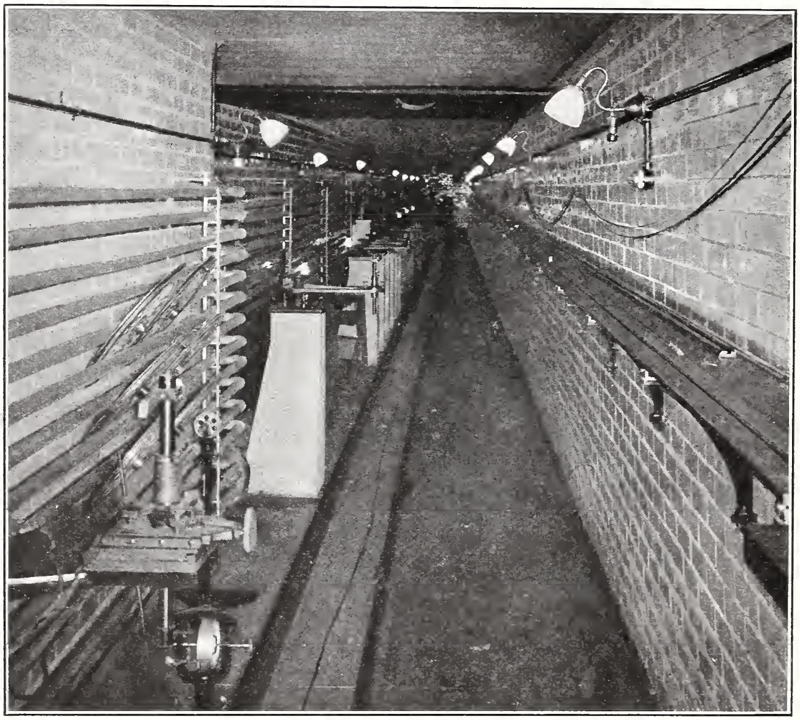

Fig. 60.—*Tunnel laboratory for length comparison of steel tapes*

The steel bench standard at the right is used to compare metal measuring tapes. The geodetic tape comparator at the left is used for calibrating base line tapes for precise geodetic surveys. Pipes on the wall carry brine or steam so that comparisons at widely differing temperatures may be made to determine the expansion with temperature.

submitted to the bureau for test and certification. A tape-testing tunnel 165 feet long, with means to cool or heat it to duplicate the range of temperatures at which tapes are used, is equipped with a set of thermometers, microscopes, tension balances, and micrometers. In the tunnel runs a track carrying a truck of melting ice holding the standard of length which is true length only at the freezing point of water. The distances between a series of piers are marked by a hair line in a microscope on each pier. These hair lines are adjusted so that they are 1 meter apart and the truck is moved to permit 1-meter intervals to be laid off to give an interval of 5 meters, and this interval is repeated to produce a total interval of 50 meters (165 feet). Geodetic tapes are compared directly with this interval. A standard procedure is followed for verifying the steel bench standard used for comparing other tape and computing their corrections.

Surveyors' tapes expand with heat, hence the correction determined by the bureau is useful only if the thermometer is accurate. The length of the tape is specified for a certain pull on the ends of the tape as measured by a standard spring balance. The corrections are again futile unless the balance is correct. Both balance and thermometer are, therefore, certified and the corrections to each used when the corrections to the tape are applied for the best work.

6. SERVICE AND ACCELERATED TESTS

Service tests are the best measure of quality. The bureau's stucco-test building, made of some 50 brands of stucco, stands exposed

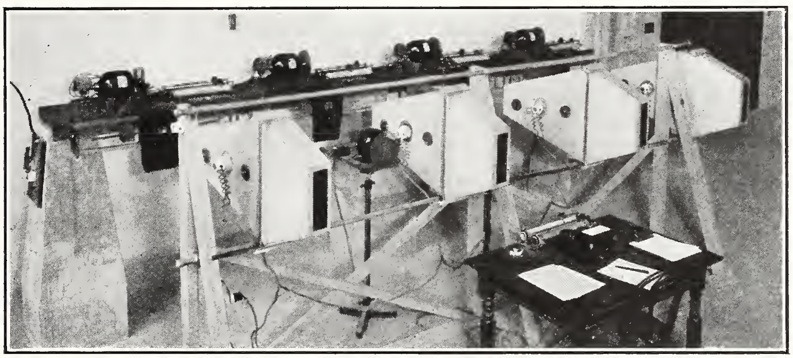

Fig. 61.—*Fatigue tests of sheet metals*

The samples are vibrated back and forth by a small electric motor, which subjects them to a reversal of bending stress. The amplitude of the vibrations is indicated by optical means, the path of a spot of light on a ground glass showing the amount of bending of the specimen.

to the weather on the bureau grounds. The fittest stuccos survive. Service takes note of all factors at once. The bureau metal-spray expert sprayed zinc on exposed metal parts of naval destroyers, and months of service failed to show corrosion and erosion which had been a serious cause of failure of submerged metals.

If actual service tests cost too much in time or money, or if itemized measures are to be taken, the bureau simulates service conditions. Tires are run against studded wheels to imitate road bumps, tumblers are dipped alternately in hot and cold water to simulate heat changes in dishwashing, cloth is abraded by rotating blades to give a wear similar to rubbing a garment. It can do the same for each item of endurance or effectiveness, keeping the conditions under measured control, varying one at a time. Structural materials—for example, stone and concrete—are made to endure many alternations of moisture and dryness, heat and cold, to duplicate climatic variations or stress encountered in use. The bureau reproduces in the laboratory under such measured control those service conditions which affect the utility, accuracy, economy, or durability of the thing tested. Impact tests are made on street-car rails, giving results far more quickly than service exposure would give. Paper is also folded rapidly back and forth automatically to measure folding endurance, duplicating in a few minutes the service wear of months. Duralumin sheets for airship use, in bureau tests, survived 200,000,000 bending cycles, equal to 40 years' normal service. A watch is tested hot and cold; with stem up, down, side; with face up and down, to duplicate the positions encountered in service.

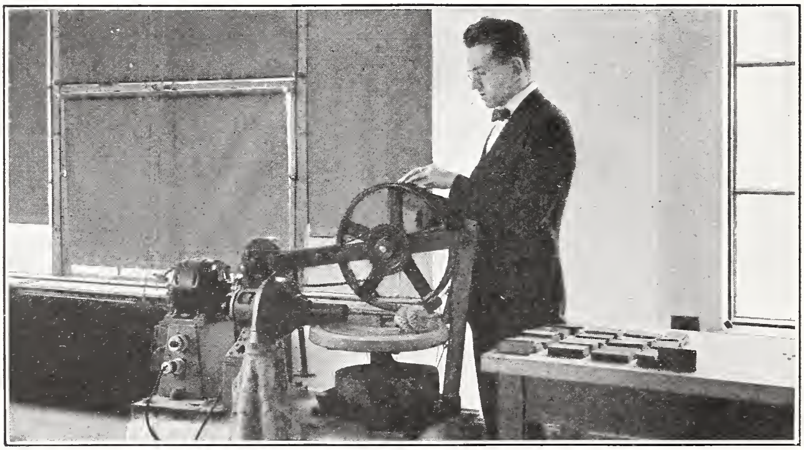

Fig. 62.—*Sole leather testing machine*

This imitates the abrasive friction to which sole leather is subjected in service. It permits accelerated test, the equivalent of several months of actual wear of shoes is obtained in 24 hours operation of the machine. Various kinds of sole leather have thus been studied and their comparative wearing qualities determined. The wear of leather from 75 parts of the hide has been compared. Leather substitutes are similarly tested.

Accelerated tests are devised to ascertain quickly the quality of the material or effectiveness of the device. In using accelerated tests, the bureau must find how actual service may be learned from accelerated test results, what correction to apply to give a true gauge of useful life. Dyes and inks are faded under ultra-violet rays more intense than those encountered in service, so that the test may be used in advance as a basis of purchase and use. In the life test of electric lamps, run at "forced voltage," a known correction factor increases the rating to the true measure of useful life. Laboratory tests simulate walking wear for sole leather in an automatic device which speeds up the wear measured by the volume of leather lost. A few hours' testing duplicates the actual shoe wear of months. Sole leather tests in the "walking machine" were compared with service durability by volunteers who wore shoes with soles made of the leather to be tested. Police, postmen, soldiers, and others thus aided the bureau in interpreting laboratory test results in terms of actual service. The testing laboratory must predict the utility in advance of use. Accelerated tests are, therefore, universally used wherever they can be thus interpreted to foretell the behavior or useful life in service.

FIG. 63.—*Automatic life tests of dry batteries*

Life tests of dry batteries are made at constant temperature until their voltage output drops to a certain percentage of the initial voltage. The machine on the table turns the battery circuits on and off, giving an intermittent test. It is controlled by the clock.

7. SELF-RECORDING TESTS

Some test devices write their own reports (a curve or a number), self-explaining at a glance. Autographic cooling curves are plotted to note rates and changes of rate of cooling and to study critical temperature points which tell of changes of molecular arrangements in the metals and the quality which they represent. The bureau has aided notably in making cooling curves a research method of great power. A photometer was also designed and built by the bureau to record without computing the candlepower of each lamp tested, as a point on a chart. So, too, the strain and yield of materials under stress are recorded as graphic curves which may be interpreted at leisure. Time signals and watch tests are also recorded on a

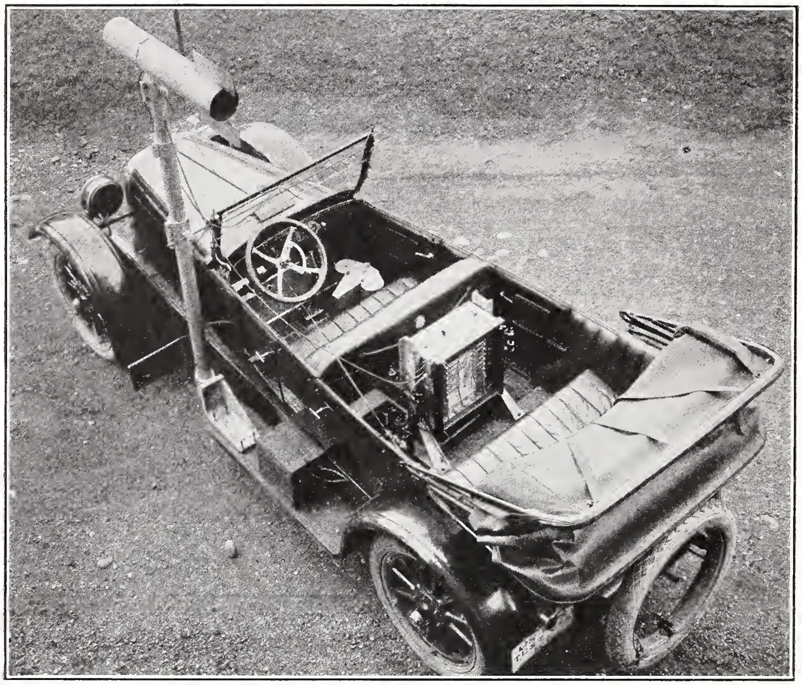

Fig. 64.—*Autographic recorder of automobile performance*

This car is equipped with the bureau's device which autographically records car speed, acceleration, wind speed and direction, manifold pressure, temperature of water outlet, oil, carbureter, air, transmission, lubricant, differential lubricant, fuel, and also weight of air used by engine. It may be used under all the usual road conditions, and gives a very complete record of the performance of an automobile in service.

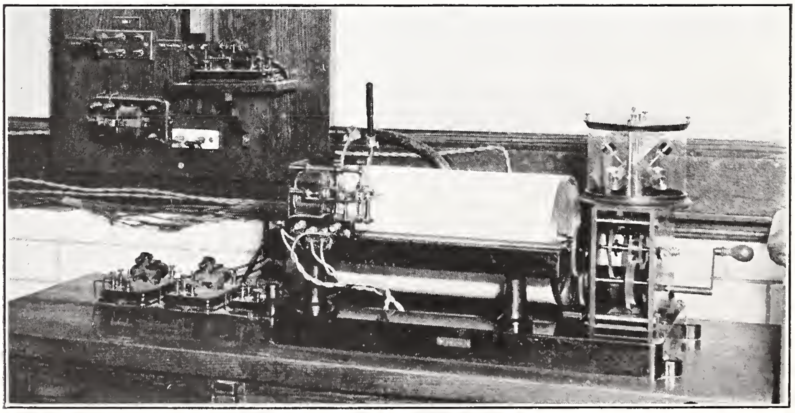

Fig. 65.—*Automatic time recording*

A pen traces a line as the drum rotates. An electric impulse causes a notch in the inked line. By measuring the distance between two notches the time interval is given. Two notches, for example, may be the noon signals from the Naval Observatory and the bureau's standard clock. The distance between the two would give any difference or correction to the bureau's precision clock.

chronograph, time being translated into length on a pen-traced line. In testing dry cells an intermittent testing machine provides automatically both for periodic contacts with the cells under test and for the recording of the output voltage, providing for multiple automatic tests with the same equipment. Such examples of self-recording devices drawn from actual work of the bureau might be multiplied almost indefinitely.

Many instruments are photorecording, frequently by light reflected from mirrors, the turn of which measures the quantity under test. The soundness or faults of metals are recorded magnetically as

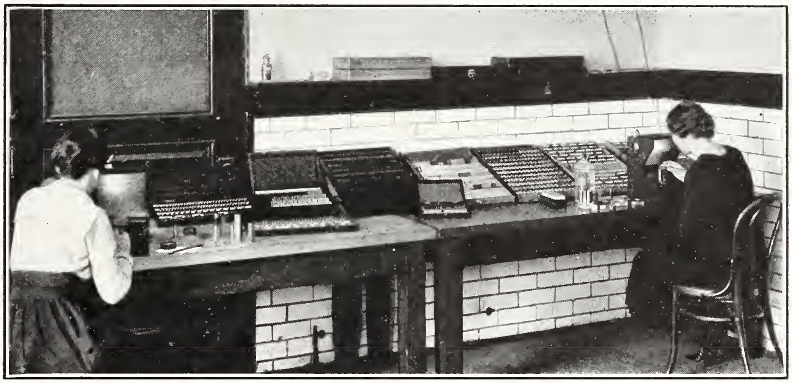

FIG. 66.—*Standardizing precision gauge blocks*

The gauge blocks are of steel and have opposite faces plane, parallel, and are of accurate specified thickness. They are used in inspecting tools and gauges in machine shops and as reference standards for checking micrometers. Light waves are used in testing these blocks by methods devised at the bureau. The results are accurate to a few millionths of an inch. The light waves have been determined to one part in 15,000,000 in terms of the international meter.

curves on a photographic film. For many tests autographic methods alone are available; for example, oscillographs for measuring the wave form of high-frequency alternating electric waves, the variation of pressures in guns during firing, or the receipt of sound waves for locating enemy batteries. Bureau publications contain many examples of the value of the camera as a recorder of test results. Photography plays a most important part in testing, recording the appearance of columns, girders, truck wheels, and so on, before, during, and after test, showing the structure of a fracture or microstructure of failed parts. The camera records test effects not as yet measureable, but useful in judging a material. Spectrographs are now almost the only means used to study wave lengths of characteristic radiations of elements and compounds, the methods used to find the components of materials.

8. MAKING TESTS SIMPLER AND MORE PRECISE

The bureau aims to make methods of testing simple and as nearly automatic as possible. It devises new methods which actually tell the story at a glance; for example, light waves of a single color show at a glance any deviation in the thickness of the cover glasses for blood-count apparatus. A glance shows the observer to within a hundred-thousandth of an inch whether the surface is true flat. High-precision gauge tests are almost equally simple.

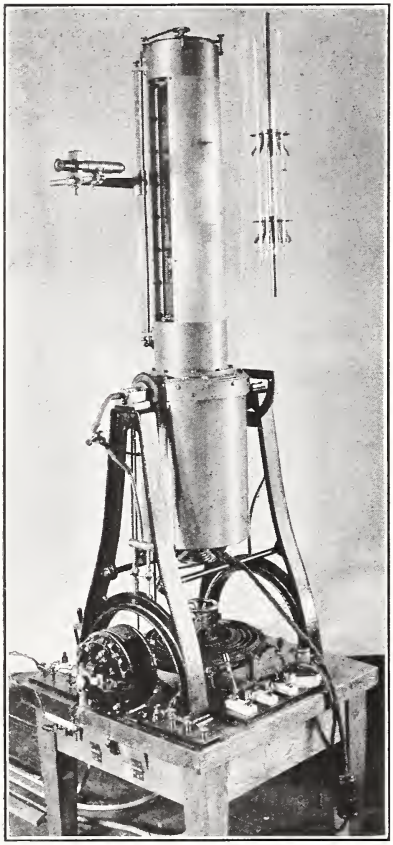

Fig. 67.—*Apparatus used in the testing and calibration of precise thermometers*

Equipment designed and built at bureau to meet demand of manufacturers and scientific workers for a standard of temperature measurement. The comparator shown can be cooled by ice water or heated by electric current. There is a motor which keeps the water in the bath circulating; the thermometers to be tested are placed on a spool and immersed in the bath. They can be turned around on the inside of the comparator and read one after the other, as well as the standard thermometers which are also immersed with those being tested.

For all routine tests the bureau must devise methods for quick and exact measurements. Many tests once laborious are now semiautomatic. The first 1-inch gauge disk required many hours of fine micrometer measurements. To-day by methods developed at the bureau a much higher accuracy is attained almost at a glance, using the interference fringes of light rays. The purity of platinum ware is now tested by the loss of weight by evaporation when heated. Tool steel is tested by passing it through a magnetizing coil. Hundreds of ingenious, simple, and automatic methods of test have been applied. A rapid method of precise test of volume measuring flasks was developed as a substitute for the weighing method once used. The contained water was formerly weighed and tables gave the volume. The new method uses a standard pipette delivery system with automatic overflow and set times of drainage, every detail being experimentally determined in a research covering many months.

A simple, rapid, and accurate means was devised to measure the fine phosphor-bronze sieves used to measure the percentage of the fine "flour" of Portland cement, fineness being a great factor in the strength. The first bureau test of such a standard sieve demanded days of painstaking measuring of the wire mesh with microscope and micrometer. The new method permits the test to be made almost at a glance. A glass ruled with 200 lines per inch is laid on the sieve or the sieve cloth, and illuminated from below. Instantly each wire in excess of the standard 200 per inch (or in defect) forms a dark band to be counted. The cloth itself may be thus inspected. This insures in advance that the completed sieves will be of accurate mesh. Both user and maker are thus alike benefited by an ingeniously simple and rapid method of test devised in the bureau laboratories.

9. PROGRESS THROUGH TESTING

An important result of testing is the improvement of the products of industry. The test is a challenge to prevent defective materials getting into service. Testing assures fitness for use. When made for the maker of a product it helps him maintain the quality of a brand which alone can make and hold a deserved reputation. The bureau does more. It advises with respect to the essential points of fitness. By telling the truth about products, testing promotes better factory inspection before delivery to avoid rejections. In turn, factory inspection promotes better measured control of production process to insure uniformly high quality. The final result is standardized process, the output of which is of predictable quality. Such standardized process requires such complete analysis of the parts of the process that the automatic machine suggests itself and follows as a matter of course. Factory inspections of output are already made in all well-regulated factories. Much of the bureau's testing is to provide certified standards and measuring instruments for this purpose. Testing, which begins with police duty, ends by stimulating and guiding the process of making and establishing standards of process.

In 11 years of bureau testing of railroad track scales, the percentage passing the tests has risen from 38 to 62.5 per cent of those tested. Sugar tubes show similar progress, the percentage passing having risen from 13 to 73 per cent. Such percentages indicate the progress of industry, those passing the tests measure its success, those rejected measure its failures. The certificate gives the diagnosis of the trouble and points the way to cure. A testing laboratory is, therefore, a clinic. The research laboratory, which is vitally connected with the testing laboratory in the Bureau of Standards, is where much constructive work is done on the causes and cures for failure of products. In this work the industries gladly cooperate.

FIG. 68.—*Aeronautic instrument testing laboratory*

The service rendered by the bureau in the development and testing of instruments used by the aviator is of great value. This work is primarily undertaken for the air services of the Government. The view shows a portion of the laboratory and facilities, and the types of instruments studied.

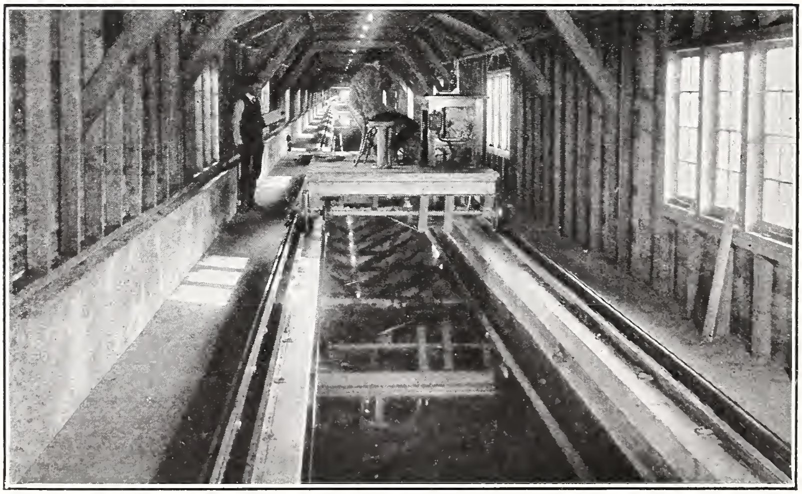

FIG. 69.—*Testing water-current meters*

Water-current meters, used to measure the velocity of flowing water in streams, open channels, and elsewhere, are tested by moving the meter at various uniform known speeds through still water. The tank is 400 feet long and the instruments are carried on a motor-driven car with a hydraulic gear for speed control. Records are made autographically by electrical means. Water-current meters are used in stream gauging and flood and drought forecasting.

VIII. STANDARDS AND SPECIFICATIONS

1. STANDARDS—THEIR NATURE AND PURPOSE

The work of the Bureau of Standards comprises the development, construction, custody, and maintenance of reference and working standards and their intercomparison, improvement, and application in science, engineering, industry, and commerce. They may be classified for convenience. The classes and the purposes of each are briefly summarized as follows:

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, and 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 for each the quantity, flux, intensity, density, etc.

Purpose.—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; and to Facilitate Precision in Science and Technologic Research through calibration of units, measures, and instruments involved.

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, electricity, and 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 equivalents and atomic weights; and many similar magnitudes determined experimentally with maximum precision and referred to fundamental standards of measure.

Purpose.—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, or in compiling tables for standards of quality and performance, and wherever such uniformity is desirable; and to Aid Laboratory Research by Reducing Errors and uncertainty caused by use of data of doubtful accuracy.

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 determines 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.

Purpose.—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; and to Promote Precision and Avoid Waste in science and industry by affording quality standards by which materials may be made, sold, and tested.

STANDARDS OF PERFORMANCE.

Specification of operative efficiency or action for machines and devices, known as 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.

Purpose.—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; and to Stimulate and Measure Mechanical Progress.

STANDARDS OF PRACTICE.

Codes and regulations impartially analyzed and formulated after study and experiment into Standards of Practice for technical regulation of construction, installation, and 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.

Purpose.—To Furnish for each utility a single Impersonal Standard of practice as a Basis for Agreement of all interests, clearly defined in measurable terms; to Insure Effective Design and Installation of utilities of all kinds; to Promote Safety, Efficiency, and Convenience in the Maintenance and Operation of such utilities; and to Secure Uniformity of Practice where such is practicable, and Effective Alternates in other cases.

2. STANDARDS OF QUALITY: SPECIFICATIONS

The bureau is headquarters for specifications. The Government's interdepartmental agency is the Federal Specifications Board. Under its auspices specifications for Government supplies are being rapidly standardized and promulgated. The Director of the Bureau of Standards is its chairman, and the bureau's specification expert is vice chairman and technical secretary. The bureau provides quarters, clerks, and supplies. All who can add useful data or who will be affected by the terms of the standards are consulted in their preparation. The success of the work is due to the full cooperation of experts in each line from all branches of the Government. Seventy-two technical committees of the board aid in perfecting the specifications. They draft the text and recommend adoption. Three hundred and sixteen such specifications have been formulated, approved, and promulgated by the board as "United States Government Master Specifications." Those which fall within the scope of the bureau are published as bureau circulars and sold by the Superintendent of Documents. For example, 32,000 copies of the specifications for window glass were sold in advance before the specification was in type, indicating the widespread interest of the general public.

Specifications tend to improve the quality and lower the price. Competitors aim to meet the new specification and doubtless many producers raise their quality to meet the new standard. Quality standards are thus the basis of manufacture as well as of purchase and sale. Such specified products are really made to order in the mill by mutual agreement. With such standards of quality all bidders may quote on the same standard quality, so that reasonableness of price measures business enterprise. In some cases a "good enough" quality is substituted for an unduly costly product without real loss of efficiency in service. The Director of the Bureau of the Budget reported:

> A commercial varnish costing $4.37 a gallon was in almost universal use by the Federal Government. A varnish prepared according to the standard specification of the Federal Specifications Board, costing $1.44 a gallon, has been found a most satisfactory and suitable substitute. The Navy Department estimates a saving of $90,000 annually by the use of this just-as-good varnish.

The bureau aids in connection with specifications in several ways; it studies the behavior of materials, their useful or harmful properties, and their utility in service; it helps to draft specifications, devises methods of tests; it tests Government deliveries of supplies, and investigates how to improve the materials or the standards of quality. Its researches may experimentally determine the best magnitudes of useful properties, the deviations allowable in the interest of economy, and how best to determine the suitable quality. To-day we measure suitability, economy, and durability, as well as dimension, so that standards of quality are set as scientifically as other standards.

The entire output of industry for every use is now in process of standardization, some of it by individuals or companies, others by technical organizations, and still others by the Government. The variety of qualities to be measured and for which standards of quality are to be set is without limit. The Government program of standards of quality or specifications must eventually include all articles used by the Government.

The testing and certification of papers used in Government publications were done by the bureau for years for the Government Printing Office. Standards of quality replace guesswork. Paper quality, once gauged by tearing, crushing, even chewing, is now specified in measurable terms by which it may be tested. A scientific standard of quality specifies by description, sample, or both; or fixes in measurable terms the property or group of properties which determine the quality. It furnishes a scientific basis for fair dealing to avoid disputes and settle differences; promotes truthful branding and advertising by prescribing quality measurably. Service experience reported back to the bureau may be incorporated in future standards of quality, when revised, so that the standard becomes a means to harvest service experience, and in agreement with the technical experts of industry advance the quality, step by step. Much experimental work must be done. As this helps the manufacturer to produce more suitable materials, standards of quality prepared in full cooperation with the industry accelerate industrial progress.

(a) A NATIONAL DIRECTORY

Jointly with the Bureau of Foreign and Domestic Commerce and with more than 500 public purchasing agencies, the bureau has compiled a "National Directory of Commodity Specifications," aptly called the "buyers' bible" by the Secretary of Commerce. This cites 27,000 technical commodity specifications. The work was done at the request of a national conference of representatives of the State governments, called to discuss active cooperation between the Federal and the State Government purchasing officers on specifications and tests. The National Association of State Purchasing Agents actively cooperates with the Department of Commerce through the Bureau of Standards in the enterprise. This was later enlarged to include municipal purchasing agents. The bureau has also been in touch with more than 500 technical societies and trade associations, and with the larger corporations cooperating, as purchasers through their organization, the National Association of Purchasing Agents, and as sellers through the National Association of Manufacturers. Besides the direct aid to Government purchasing, Federal, State, and municipal, the new directory will promote the general use of standard commodity specifications in place of purchasing merely by brand or past reputation, and will further promote the general movement for the unification of such specifications.

(b) BEGINNING OF BUREAU'S WORK

The bureau's work on systematic standardization of specifications began 18 years ago. The examples of electric lamps, volumetric glassware, and Portland cement will illustrate the bureau's direct work in this field. In 1903 and 1904 the Bureau of Standards prepared specifications for glass volumetric ware, covering all factors affecting the accuracy and serviceability. The specifications for glass measuring apparatus and regulations for testing the same were published by the Bureau of Standards November 1, 1904. Foreign practice was studied, and the recommendations of the committee of the American Chemical Society were taken into account. Both were modified where improvements were found possible after extensive researches at the bureau. The specifications were also approved by the American Chemical Society which had originally requested that the work be taken up. Manufacturers now advertise measuring glassware conforming to the bureau's specifications. A technical specification for Babcock milk-testing glassware was later drafted by the bureau, on the basis of bureau research, and was adopted by the Association of Official Agricultural Chemists and by the various dairy associations throughout the country.

After several years of experiments and tests the bureau published, in 1907, its first standard specifications for electric lamps. The unit of light measurement was not definite. The candlepower for gas light differed from that used for electric lamps, and both differed from those used abroad. They differed from factory to factory. The bureau's efforts secured uniformity in both industries as to the value of the candlepower. The bureau based its draft of the specifications upon a survey of Government needs; and a conference of Government users with the makers, dealers, and bureau experts was held in 1907, at which these first specifications were adopted simplifying the varieties used and establishing standard tests. Annual revisions based on experience and expert judgment of maker, seller, and user were made for a time, and at this date all Government lamps are efficiently purchased on uniform specifications which are of nation-wide application.

On the initiative of the Bureau of Standards a conference of Government engineers met in 1912 to adopt a standard specification for Portland cement used by the Government for construction work. The final specification based upon experimental tests and researches at the bureau and elsewhere was adopted February 13, 1912. The President, by Executive order dated April 30, 1912, made the specification mandatory for all Government purchases of Portland cement and authorized its modification by a similar departmental conference with the approval of the heads of the several departments. A series of laboratory and field researches on cement was conducted on the key problems—fineness, hydration, strength, and so on—affecting the details of specification and test.

(c) HARDWARE—A TYPICAL EXAMPLE

The national standardization of builder's hardware was completed largely by the efforts of the bureau staff as an outgrowth of the preparation of Federal specifications. Bureau tests and surveys led to the selection of items suitable for adoption. The first report eliminated 26 per cent of the items which had been staple in the industry in 1922. The establishment of standard types permits the user to select economical hardware on the basis of comparable service types. An outstanding achievement was the adoption of 25 standard finishes in place of about 100 nonstandard finishes previously in use. Standard samples of the adopted finishes were prepared for reference and are kept at the Bureau of Standards. The estimated saving on finishes alone is $10,000,000 per year. A chaotic and nonstandard nomenclature was replaced by clear technical terms which are used in the published description. Both the simplification and the standardization are of general nation-wide application, the experts of the industries and of the bureau having reached practically unanimous conclusions on all points. These are published as Simplified Practice Recommendation No. 18, and as United States Government Master Specification, Circular No. 275, of the Bureau of Standards.

3. STANDARDS OF PERFORMANCE

Specifications or standards of performance must be set also for devices. The bureau aids in such work. Actual bureau work also covers in part ships' watches, sextants, dry cells, postal scales, rubber tires, automobile brakes, elevator interlocks, signal glasses and lamps, chemical glassware, milk-test apparatus, electric transformers, electron tubes, radio sets, and so on. Specifications were drafted by the bureau, jointly with the experts concerned, for master track scales in cooperation with the weighing experts (see Bureau Circular 83) and for hopper-type scales (Circular 199). Perfected standards of performance with tolerances were drafted for gasoline vending pumps after a field and laboratory study of how they function. A national basis was thus given for local inspection.

To aid in drafting such specification, the bureau contributes research data from experiments at the bureau. These may include any or all of the following: (*a*) Listing the functions to be served, (*b*) measuring the elements which serve each item of use, (*c*) setting the 100 per cent efficient performance, (*d*) defining a commercially acceptable standard, (*e*) devising means to measure each factor pertinent to the service, (*f*) drafting specifications for performance, or (*g*) making such specifications available to industry and the public.

The items of acceptable performance are most varied—speed, economy, accuracy, efficiency, durability, and scores of others. The breakage and wear of a hacksaw depend on the steel and on the design of teeth and frame. To specify its useful life and cutting rate is to set a standard of performance. A performance may involve speed, for example, the photography of a flying bullet in a millionth of a second; an effective profile of a propeller or airplane wing. The performance standard may involve: Continuity, the first Liberty motor tested at the bureau made a nonstop run of 50 hours; uniformity of speed, as in a timepiece; efficiency, as in the gasoline motor; economy, as the luminous efficiency of the electric lamp; accuracy, as in a thermostat; and so on. If fixed in units or measurable terms, these are standards of performance. They require judgment based on experience and experiment, a knowledge of physical constants of materials and energy, and a correct use of the principles of physical science.

The bureau recognizes thus two distinct types of performance standards: (*a*) A scientifically ascertained theoretical maximum, and (*b*) a commercial standard of acceptable performance based on what can be reasonably expected of industry in the present state of the art. A perfect motor could not exceed a known theoretical maximum and the actual performance of motors is rated as a percentage of this. A most valuable aspect of such an ideal standard of performance is that it gives the goal—the ultimate limit. This is not attained in practice, but it stimulates progress; for example, the mechanical equivalent of light was ascertained by the bureau as about 50 candles per watt. An ideal standard of performance would then be an unattained conversion of electricity into light at the rate of, say, 1 watt input for 50 candles of light output. Industry produces about 2 candles per watt. Such absolute standards are determined by scientific research. They both stimulate and measure achievement, for they point to further progress theoretically possible by which the standards approach the attainable limit. Researches by the bureau add such data which become permanent working factors in industry. These have proven so productive that science and industry will doubtless encourage the complete formulation and use of standards of performance for all tools and devices used in science, industry, or other activities. Such standardization is under way in all industry. In this work the bureau may play an important rôle in view of the functions assigned to it by Congress.

4. STANDARDS OF PRACTICE

The modern trend toward standards since the bureau's work began notably affects process or practice. Its practice standards for gas and electric service, logging, aeronautics, protection of head and eyes, illustrate what service the bureau can render. As the bureau's standards of quality define the behavior of materials, so its standards of practice or process describe measurable factors which insure success and safety in the operations of science, industry, or commerce.

The bureau rarely develops a complete standard of practice, but aids on parts of the complete program within its legal functions. It may determine annealing times and temperatures for thermometers and optical glass, the best finishing temperature for steel rails, the best firing temperatures for metal enamels, or the best pouring temperatures for bronze castings. For gas service, the bureau may show the significance of a change in heating value; it does not advise as to price. Its work is on the essentials of good service, leaving questions of price to business men. Its field is the technical phase of practice standards.

The bureau's code for the protection of the head and eyes of industrial workers embodies research results gained in the laboratories of the Bureau of Standards.

The bureau's work on the electrolysis of underground metal work, for example, led to a standard electrolysis survey by which cities now safeguard underground property from damage by stray electric currents. In this research, laboratory and field experiments were the means of discovery and applied control. The bureau staff applied the system with success in a number of cities. The work of the bureau experts thus saves yearly many times the cost of the research.

The bureau experts in telephony study the measure of quantity and quality of telephone service. They find ways to measure each element of service, assist regulatory bodies, publish available data to all interested, help to standardize telephone terms by eliminating inexact, nondescriptive, or duplicate designations. The bureau's circular (No. 112) on "Telephone Service," an excellent introduction to the measurement of telephone service, naturally precedes the drafting of standards.

"Standards for Electric Service," prepared by the bureau in cooperation with a score of national organizations concerned with electric service, ranging from the financial and technical to the linemen and laborers and the general public. These sum up good technical electric practice, insure satisfactory service by a mutual understanding of what is acceptable service. These standards for electric service are used by regulatory bodies to rate the percentage efficiency of compliance with the complete service standards set up. The direct use of the code is, however, to furnish local regulatory bodies a model basis for their own rules. The result is gratifying. Twenty-two States have used these standards for electric service as the basis for regulations. As a result such regulations are practically uniform.

The bureau's first safety codes covered the more hazardous occupations. The more complex standards of practice prepared by the bureau are illustrated by the national codes for electricity, gas, aeronautics, lumbering, lightning protection, and elevator practice. These are well developed expert proposals and have authority only as embodied in rules of public utility commissions or local governments. The work of the Bureau of Standards on safety standards of practice is in effect a nation-wide, permanent life-saving service within the fields covered. Safe conditions are strictly made to measure: the thickness of a conducting wire or its insulation, the load capacity of a fuse; the stopping distance of an automobile brake; the voltage of a circuit; the pressure of a safety valve; the percentage of injurious gases allowable in household gas; the flash point of oils—these and thousands of others are made safe by safe limits set in units of measure.

Uniformity of practice is promoted when a single national standard is available as a model. Distressing differences of local rules for locomotive headlights vanish with the adoption of the national specification which the bureau aided in drafting for the nation-wide campaign of education.

In automobile headlight practice the illuminating engineers drafted specifications to define acceptable performance of automobile headlights. These were based on tests and researches over a series of years in cooperation with the Bureau of Standards. Approved by the American Engineering Standards Committee as tentative American standards, they sum up good road practice. They have authority only as put in local laws or rules. If applied they assure safety, comfort, and speed on streets and highways. With experience, the specifications will be revised under the practice of the approving committee.

The standard code for logging was prepared jointly with the Forest Service, State officials, employees, lumbermen, insurance companies, and the American Engineering Standards Committee. Bureau experts visited logging camps, sawmills, and locations for river driving to study conditions at first hand. The successful completion of this code means permanent provision for an open-air industry of a most hazardous character.

The rapid growth of aviation made the safety code for aeronautics one of extreme urgency and value, and the bureau's work on aerial hazards received the support of the Society of Automotive Engineers.

Bureau specialists collect reliable data on industrial safety to aid those preparing national safety codes. It collates existing rules, studies current practice, to combine the best elements in new model standards of practice. To formulate them is a difficult technical task. Topics studied thus far include walkway surfaces, paper and pulp mills, hot stamping and forging, mechanical refrigeration, industrial sanitation, and school lighting.

The trend is clearly toward a single national service standard for every distinctive use, exactly as we have a single national standard of length. The importance of a single standard of length has long been recognized; the importance of a single service standard for each material, device, or practice is beginning to be realized and made the basis of effective standardization.

When perfected the specification becomes a true standard of quality for a given use. It fixes in measurable terms the magnitudes of the qualities or properties pertinent to a given serviceability of materials. The specification is the common meeting ground of the maker, dealer, and user. It is the point where science is applied to the quality of the service or the measurement of such quality. The true specification embodies at once the users' needs and the maker's guarantee. As such, to the extent that it is effective, it becomes a controlling technical factor in regulating the processes of industry. Its position is therefore of supreme importance. The aim of the bureau is to promote and aid on the scientific side, in the development of such standards.

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IX. SIMPLIFIED PRACTICE

Hundreds of millions of dollars a year are being saved as a result of accomplished work of the division of simplified practice. Eliminating unnecessary sizes and varieties is now an accepted means of reducing waste in industry. The division of simplified practice was established by the Secretary of Commerce as the department's agency to secure the cooperation of producers, distributers, and users in a voluntary reduction of sizes and varieties, and the limitation of production to the more useful sizes and varieties. Over-diversification is a serious economic waste. Paving brick, the first commodity to be thus simplified, were reduced in the number of staple sizes from 66 to 4, eliminating 62 varieties.

This division grew out of the conservation work during the war. The simplification movement has the full cooperation of the United States Chamber of Commerce and the American Engineering Standards Committee, and numerous industries. According to general service program the division tells to trade groups the results gained and describes the plan, surveys present practice, confers to review and recommend, circularizes individual producers for acceptances, explains by mail or illustrated talks, publishes the results, and resurveys later for constructive revision.

The elimination of waste through simplification and standardization is demonstrated as an effective means for saving billions of dollars annually. A survey has already disclosed hundreds of opportunities for simplification. The division brings together producers, distributers, and users, and supports their united recommendations unanimously accepted on simplification programs. The services of the division are available for any producing, distributing, or using group for any proposed simplification.

Simplification serves to reduce to an effective minimum stocks, production costs, selling expenses, misunderstandings, and the initial, accessory, and maintenance costs to user. It at the same time constructively increases stock turnover, stability of employment, promptness of delivery, foreign commerce, quality of product, and profit to producer, distributer, and user.

Leaders in the industries concerned estimate annual savings resulting from completed simplification projects as follows: Paving brick, $1,000,000; sheet steel, $2,400,000; warehouse forms, $5,000,000; range boilers, $5,500,000; builders' hardware, $10,000,000; inquiry, purchase order, and invoice forms, $15,000,000; lumber, $250,000,000; metal lath, $2,000,000; reinforcing bars, $5,000,000.

Under the auspices of the division of simplified practice, the lengths of hospital beds were simplified from 33 to 1, widths from 34 to 3, and heights from 44 to 1; fixed wall blackboards from 90 to 3 slab heights; bedsteads, springs, and mattresses from 78 to 4; milk bottles from 49 to 9; bed blankets from 78 to 12; hotel chinaware from 700 to 160 varieties; range boilers and expansion tanks from 130 to 13; metal lath from 125 to 24.

FIG. 70.—*Hotel chinaware* (*simplified schedule*)

Under the auspices of the simplified practice division 700 varieties and sizes were reduced to 67 by makers, distributers, users, and other interested groups. Price discount of 15 per cent to users of schedule items is a direct saving resulting to consumers. With added items this is also the basis for cafeteria and hospital chinaware simplification in which 77 per cent elimination was effected.

The potential savings possible to the full simplification program may be judged from the results already accomplished. The magnitude of the possible savings may be further judged from the report on "Waste in Industry" published in 1921 by an expert group of engineers and economists. In six typical industries—the building trades, men's ready-made clothing, boots and shoes, printing, metal trades, and textile manufacturing—the waste preventable through standardization and simplification was found to range from 29 to 64 per cent, a total of $10,000,000,000 annually for these six industries.

The division's activities are not mandatory. It focuses attention upon the importance of the subject and the great opportunities for saving. It is a central agency around which the initiative of the industry can rally and upon which it can depend in the promulgation and revision of its simplifications. The publication "Simplified Practice: What It Is and What It Offers," summarizes the activities of the division and describes its services which are available to American industries. Recommendations are promulgated in a series of "bluebooks," each dealing with an accomplished simplification project. A typical publication gives the names of the organizations and personnel concerned, the names of the organizations accepting the recommendation, a brief history of the project, and the text of the recommendation signed by the director of the bureau and by the Secretary of Commerce.

X. BUILDING AND HOUSING

The bureau's work affects the household through tests and researches upon structural materials, building construction, and the utilities which serve the home. Nearly every division has work in progress of direct interest to the household, as described in the chapter on "Relations," under "Public." The division of building and housing was specially organized by the Secretary of Commerce to gather data useful in cheapening, improving, and encouraging the building of homes and other structures. Its surveys of seasonal operations and prices have a direct effect on the building industry. Constructive remedies were suggested for the serious seasonal irregularities in the building trades, caused more by custom than climate or necessity. The suggested remedies are being applied effectively.

Home financing is the subject of "How to Own Your Home," a widely circulated manual for the prospective home maker, prepared by the housing division. Cooperation is given to the "Better Homes in America" movement. In hundreds of places "demonstration homes" are exhibited to stimulate and educate popular interest. Technical phases of home making are given in publications dealing with plumbing requirements for dwellings, masonry walls, floor-load requirements, and so on. These were prepared by the Building Code Committee appointed by the Secretary of Commerce, and are based upon data acquired by expert experience and embody results also of bureau's researches and tests, as well as those of other laboratories.

The division of housing serves cities and towns with valuable technical information essential to city planning and to the efficient regulation of housing and building in the public interest. The data are furnished as building and plumbing codes and other publications. Its "Zoning Primer" describes the modern policy of establishing special districts restricted to certain types of construction and occupation. This simplifies regulation and prevents or mitigates the haphazard growth of cities and towns. The "Recommended Minimum Requirements for Small Dwelling Construction" was prepared through cooperation of the Government and the public, effected through the Building Code Committee of The Department of Commerce. This code was undertaken because of defects in existing laws. Its purpose is to save expense to millions of American home makers and exert for better housing a wholesome influence worth more than money. The "Recommended Minimum Requirements for Plumbing in Dwellings and Similar Building" were drafted frankly from the point of view of "the people whose health may be endangered by faulty plumbing or whose comfort will be increased by living in houses well supplied with means for using water and for disposing of liquid wastes." The points of view of the sanitarian, manufacturer, plumber, and inspector were necessarily considered. This code is proving helpful to the public and to cities and towns in simplifying and reducing the cost of plumbing installations, especially in dwellings. It affords a scientific basis upon which to plan State and local codes for small dwelling installations. It contains a comprehensive report, the first of its kind, on the physics of plumbing systems, giving data from experimental and theoretical investigations at the Bureau of Standards.

The division aids the building industry also through its collected data on prices of building materials in different cities, the volume of building construction, and data on building costs and building materials. In addition, numerous statistical and economic studies are made of specific problems of interest to the industry and the household. The division renders a service unique in its nation-wide scope and application by bringing together the economic, scientific, and industrial factors to meet a fundamental and universal need—housing.

XI. MILITARY WORK

The war was a "battle of the laboratories" and the bureau took a notable part in applying science to warfare through hundreds of researches and thousands of tests. The story is in part told in "War Work of the Bureau of Standards." Some of it is confidential, and

FIG. 71.—*Munitions gauge-testing laboratory*

This laboratory was established soon after war with Germany was declared to certify the large number of master gauges used in the construction of munitions of war. Altogether about 50,000 such gauges were tested in this laboratory during the war.

can not yet be told. Most of it is also of direct use in preparedness in peace times. Anticipating that America would enter the war, the bureau prepared to test gauges, a first requisite to the mass production of munitions. The creation of a central gauge laboratory promptly met the emergency and in it was developed a new system of gauge

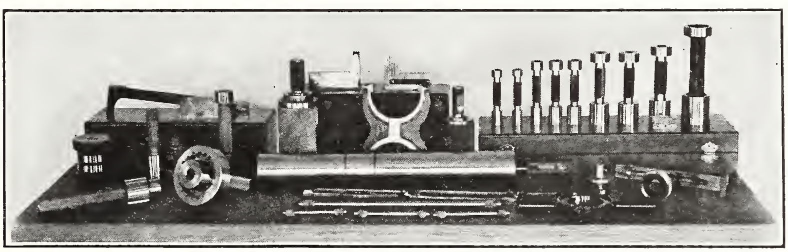

FIG. 72. *Types of munitions gauges*

The first essential for quantity production of war munitions is the system of gauges and tolerances which govern the dimensioning of such products. The types illustrate a few of the kinds of gauges which the bureau tested during the war. For this work new methods of high precision were required and these were developed at the bureau, the apparatus constructed, and the munitions plants were thus enabled to push the mass production of interchangeable parts essential in the crisis.

making and dimensioning of unequaled accuracy. Many bureau experts brought their specialized knowledge to bear upon war problems—communication, transportation, gun firing, aeronautics, radio communication, and so on.

1. RESEARCH IN PEACE TIMES

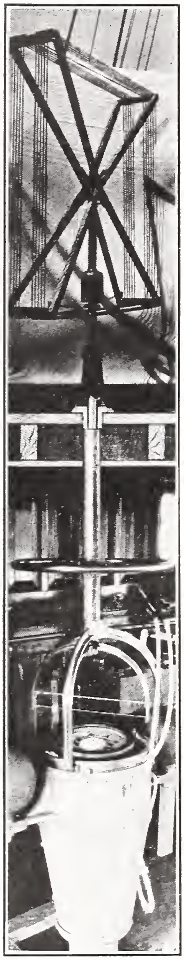

Fig. 73.—*Radio direction finder*

Invented at the Bureau of Standards. It consists of a few turns of wire wound around a wooden frame used for receiving radio waves and determining the direction from which they come. Experiments have developed most important uses in navigation in time of fog or heavy weather, or wherever knowledge of direction is required.

As war turned science to combat, it was turned back to peace uses. Many researches are the same in peace as in war. After the war the bureau's wind tunnels were used to test out a great number of factory roof ventilators, to measure wind pressures on models of tall buildings, and the air resistance of automobiles and aircraft parts. Aviation research turned to air mail craft and commercial aviation. Research on Army trucks led to studies on commercial trucks. Radio direction finding was applied to commercial navigation by sea and air in peace time. The brilliant researches affecting airship construction and operation turn naturally to useful application in the design and operation of gas-filled ships for peace uses.

2. TECHNICAL INFORMATION

The bureau's special war information service gave prompt telephone and mail answers to technical questions submitted by military experts. Technical news bulletins were issued by the bureau during the war for use of military experts and war material producers. Safety standards were drafted for the special hazards in military industrial establishments. Many technical reports were circulated on important military subjects, such as the strength of the new light alloys of aluminum, which the war brought into prominence; aeronautical instruments; power-plant researches; precise gauges and gauge tests. These were indispensable to the work at the arsenals and munitions plants. The reports were widely distributed to military experts, and played an important part in the war.

3. AIDS TO COMMUNICATION

The war work of the bureau aided communication by the design of the radio direction finder. This has had the most astonishing uses. Facilities were furnished one Army expert for the early wired wireless experiments conducted with a new type of high-frequency alternator. Two reference works prepared by the bureau gave Army and Navy officers authoritative data on the principles and instruments of radio, works which were and are still used for instruction and reference. An effective system of radio communication to and from submarines was developed and applied. Constructive advice was given on telephony at the National Capital during the war.

4. AIDS TO GUNFIRING

The bureau also aided the war by experimental research and developments of gunfiring problems. Means were devised to perfect the timing of airplane gunfire between the propeller blades during air combats. The air resistance of bombs at falling speeds was determined in the wind tunnels. Copper crusher gauges were experimented upon to standardize this means of studying pressure in guns.

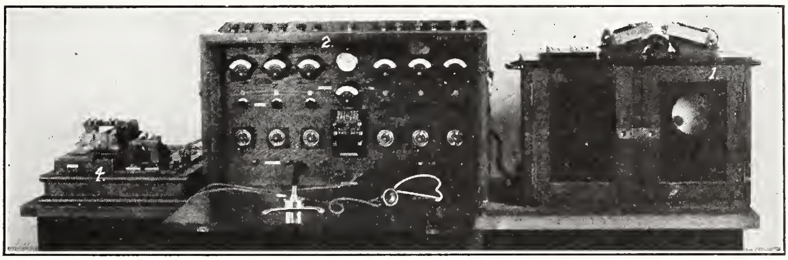

FIG. 74.—*General view of sound-ranging equipment*

In cooperation with American military authorities and the French Scientific Commission the bureau early in the war undertook a study of the fundamental principles and practical requirements of sound-ranging equipment for the location of enemy guns. Existing types of such equipment were studied and improvements suggested. An improved type of sound-ranging equipment designed and constructed at the bureau is shown

The bureau also developed and built a microphone for locating enemy batteries. This was made unresponsive to the "crack" of the firing but sensitive to the "muzzle wave," even though the crack of the bow wave might be many times greater. As finally perfected, the bureau's sound ranging was so accurate that enemy guns could be located within the length of a great gun several miles away. Many other gunfiring problems were handled.

Methods were devised to remove metal fouling from rifles. Magnetic analysis was applied to measuring the quality of rifle-barrel steel. The cause of erosion in machine guns was sought in the hope of avoiding the injury to allied soldiers from the scattering fire of their own protective barrages. The centrifugal gun was tried out and the subject of ballistics in general received much attention.

Continuing many investigations after the war, the bureau has kept in close touch with many problems of both Army and Navy. A stable zenith was devised for control of naval gunfiring and studies of the accuracy of such firing were made, a motion-picture camera being later devised for the purpose.

5. WAR MATERIALS

The miscellaneous war researches of the bureau were diverse and interesting. Substitutes (paper and cotton) for airplane linen were developed. Military uniform and blanket problems were studied, including dyestuff chemistry.

The bureau's metal expert visited the front to collate data on the metals used and their uses and failures—knowledge of the utmost value to the Allies through the American participation. The International Aircraft Materials Specifications were prepared by a board which met at the bureau and on which the bureau's chief metallurgist was the American representative. A technical report on toluol recovery was drafted and published as a guide in the expert problems involving the use of this important material for producing T.N.T. Radium paints were standardized, their variability and useful life studied, radioactive preparations tested for the military departments, and a special report on the subject drafted for military use.

There were many other problems of importance relating to military materials: Sole leather was investigated for Army shoes, waterproof materials being tested out; optical barium crown glass was first produced in America by the bureau for glass parts of optical military instruments; acetylene generators for field service, incandescent lamps, rockets and illuminating shells, and signaling lamps for daylight transmission of messages were developed. Chemical tests in great numbers were part of the bureau's war work to control the quality and effectiveness of war materials.

6. TRANSPORT

The bureau aided war transport by testing the Liberty and other motors for aviation, trucks, and truck motors and their structural design, and vehicle metals and tires, and supplies. Truck wheels were crushed in destructive tests, brakes tested by new methods and devices. Air and sea transport were facilitated by instrument design and research. Ship watches and sextants were investigated and tested. Strains in ships and concrete construction were actively studied experimentally by the bureau expert in this field. In the bureau's war work on searchlights all causes of light loss were charted and measured, and a searchlight photometer was built. Its experts measured the transmission of the various rays through the air under various weather conditions.

Photography was the subject of numerous successful researches. Mapping by cameras was helped by increasing their sensitivity to red by the use of dicyanin. Methods were developed for testing camera lenses and shutters. Airplane photography reached high effectiveness with hazelight filters. A photographic method for detecting camouflage was devised and tried out. Airplane landing was studied, and a system of safe landing in night or fog was devised.

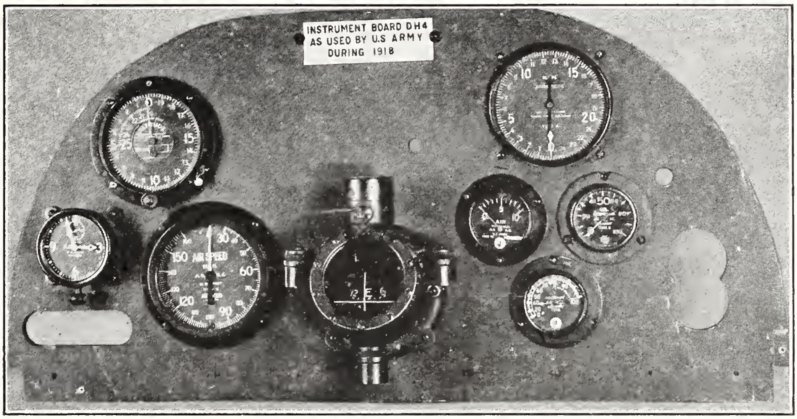

FIG. 75.—*Typical airplane instrument board used by aviators during the war*

These measuring instruments give the data essential to perfect flying. They are the five senses of the aviator. The bureau has tested and perfected about 40 of such types of instruments through extended series of researches in the laboratory and in the air.

7. THE BUREAU IN PEACE AND WAR

Continuing its work on strictly military technology, the bureau has developed instruments, aided in perfecting firing devices, studied experimentally the most diverse problems of direct military use, in close cooperation with the military departments. Altogether the manifold activities of the bureau proved most useful. Only the early peace prevented a notable demonstration of their full value in warfare.

The statement, often made, that any future war would demand new scientific principles and use new devices and systems emphasizes the importance of the bureau's many highly specialized laboratories as an investment in preparedness which pays its way in peace time by saving or increasing national wealth a hundredfold its cost.

XII. PERSONNEL, PLANT, AND PUBLICATIONS

1. PERSONNEL

(a) STAFF

An expert staff has been assembled at the bureau with an unusual and interesting variety of specialists—scientists, technicians, artisans skilled in laboratory arts, administrative officers, clerks, mechanics, laborers, and engineers.

The bureau's technical work usually requires employees who have had intensive training in pure sciences or in technology. Positions are filled through competitive civil service either by written examination or statements of the candidates' training and experience, together with corroborative evidence obtained by the Civil Service Commission. Notices of the details concerning such examinations are sent upon request to any interested persons.

The bureau staff now numbers 748 members, about 12 per cent of whom are women.

(b) OPPORTUNITIES AND ADVANTAGES

About 70 per cent of the personnel are in the professional and subprofessional service. While experimental testing usually forms the major part of the early work of new appointees, the opportunities for research are unexcelled. Experience in the bureau is admirable training in science, and its intimate connection with the industries makes it particularly valuable as a training in industrial research.

Members of the bureau have exceptional educational opportunities—the weekly meetings of the scientific staff, the journal meetings of its physics club, the cooperative study courses in physics, mathematics, etc., special lectures by visiting scientists, meetings of scientific societies, all afford valuable training. Several universities credit the study courses toward degrees. Many, who entered with only high-school training, have since taken their degrees at local universities where night courses are offered especially for Government day workers.

The bureau has a highly specialized scientific library and the many other scientific libraries in Washington and the Library of Congress are available for reference and study.

The attractiveness of work at the bureau has other aspects. The bureau's facilities make it probably the best equipped physical laboratory in the world. At the outset a site was selected on high ground in the most picturesque suburbs of the National Capital. Its location in the open suburbs is pleasant and healthful. Provision is made for the individual welfare. Voluntary first aid is rendered in all principal buildings, care is provided for those injured in line of duty, retirement allowances are paid, 30 working days annual leave and additional days for sick leave. There are tennis courts at the bureau, and Congress provides facilities for golf, tennis, bathing, baseball, polo, skating, and other sports in the public parks. The Potomac River is much used for canoeing, swimming, and its banks for camping and hiking. The Library of Congress, National Museum, Art Gallery, Zoological Park, and many other civic institutions peculiar to the National Capital afford unusual opportunities for culture and recreation.

(c) POSITIONS AND SALARIES

The classification act (effective July 1, 1924) classifies positions at the bureau as follows:

Class	Number of grades	Minimum salary	Maximum salary
Professional and scientific	7	$1,860	$7,500
Subprofessional	8	900	3,000
Clerical, administrative, and fiscal	14	1,140	7,500
Custodial	10	600	3,000
Clerical-mechanical	4	(1)	(1)

1 Paid by the hour.

Professional and scientific service (about 317 members) includes all who perform routine, advisory, administrative, or research work, which is based upon the established principles of a profession or science. This service requires professional, scientific, or technical training equivalent to that required for graduation from a college or university of recognized standing.

Subprofessional service (about 230 members) includes all who perform work incident, subordinate, or preparatory to that required of employees holding positions in the grades just described which requires or involves professional, scientific, or technical training of any degree less than that required for graduation from a college or university of recognized standing. The clerical, administrative, and fiscal service (about 127 members) includes all who perform clerical, administrative, or accounting work, or any other work commonly associated with office, business, or fiscal administration. The custodial service (about 68 members) includes all who perform manual work involved in the custody, maintenance, and protection of public buildings, premises, and equipment, the transportation of public officers, employees, or property, and the transmission of official papers.

Under a special law and a unique apprenticeship system in office, shop, and laboratory, the bureau may advance those who enter as apprentices, as experience qualifies them, to the top of the line which they enter—scientific, mechanical, clerical. The present director was assistant physicist; the chief of an important division entered as a laboratory assistant, and many minor assistants have become leading experts in their fields. All lines are open. The industries and scientific and educational institutions, recognizing the value of bureau training, draw many employees at increases in salary sometimes 50 per cent or even double that paid by the bureau. Reclassification has, however, recently advanced the average salary scale for scientific work by nearly 10 per cent. The turnover is ample evidence of the value of work at the bureau for personal advancement. Many employees, with a broad vision of possible usefulness, find the work at the bureau attractive on account of the exceptional opportunities to render a public service second to none in interest or importance.

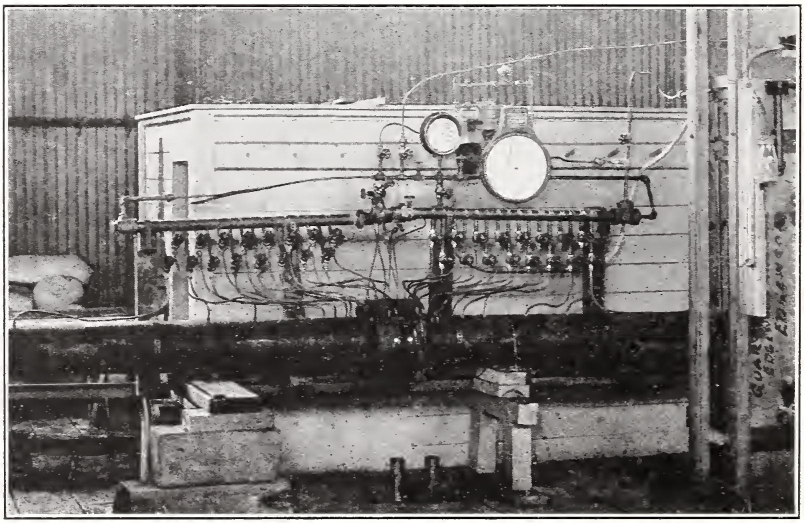

Fig. 76.—*Equipment for orifice meter research*

The accuracy of orifice meters used in the measurement of gas flow is of great importance to the gas industry and the public because of the increased demand for gas for industrial uses. The quantity to be measured may in a single case vary from hundreds to millions of cubic feet per hour. The above set-up is part of the general equipment being used by the bureau in a cooperative investigation of the factors affecting the accuracy and performance of these gas measuring instruments.

2. PLANT

(a) BUILDINGS AND FACILITIES

[See maps at end of circular]

Twenty buildings, half of them permanent, others housing temporary or experimental work, on a 43-acre site form the headquarters of the bureau's work. The site is on a natural hill in northwestern Washington 3½ miles from the White House, 350 feet above the Potomac River (lat. 38° 56′ 30″ N., long. 77° 04′ W.).

Intercommunicating tunnels serve as passageways for piping and wiring, for trucking supplies and for distributing gas, water, steam, exhaust, compressed air, electricity to the bureau laboratories

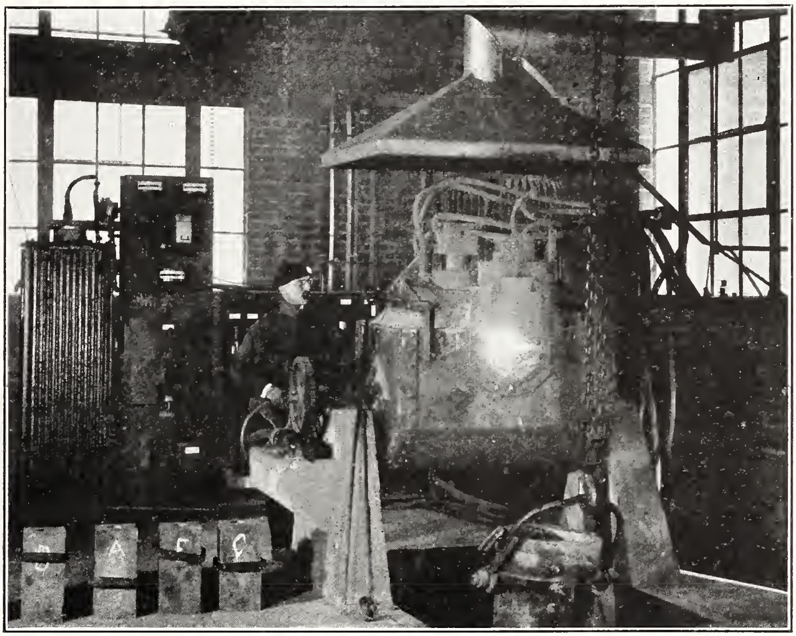

Fig. 77.—*Electric furnace*

The Heroult furnace here shown has a capacity for making 500 pounds of special alloy steels or cast iron in connection with the research work of the metallurgical division. The furnace is heated electrically through two carbon electrodes.

through service piping and wiring; freezing brine service; gas; hot, cool, and iced water; live and exhaust steam; compressed air and vacuum; electric current of wide ranges of voltage and amperage; and other services. For special uses, liquid air, liquid hydrogen, and other liquified and solidified gases are available. Thirteen refrigeration plants to supply local facilities for producing cold are provided for experimental purposes. Precision time service is wired to the laboratories for sounding true seconds and controlling time-measuring apparatus.

Dark rooms for exact weighings and optical work, constant humidity and constant temperature laboratories, altitude laboratories for pressure control, fire-test rooms for artificial conflagration research, high-voltage room, sound research laboratory, a 400-foot water tank for stream-speed meters, and a great variety of unusual facilities for special researches and tests are available.

(b) EXPERIMENTAL MILLS

For research on the conditions required to improve the quality of material products, the bureau operates small-scale mills. These produce, experimentally, various kinds of textiles; textile products;

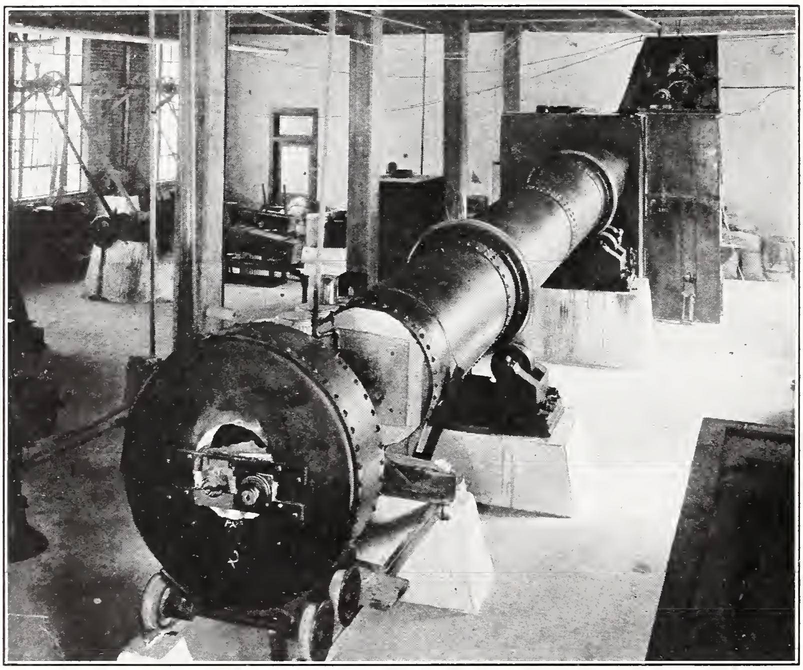

Fig. 78.—*Experimental rotary cement kiln*

In aid of industry researches are made on the things which affect the strength and durability of cement and concrete. This kiln is a type of experimental mill in which the quality factors are varied singly to test the effect upon the resulting quality. The measured control of the production permits reproducing any desired factors at any desired measured value. Such researches are the systematic method of improving quality.

pulps and papers; rubber and rubber goods; cement; plaster; clay products; leather; glass; enameled ware; sugars; chemicals; metals, including plates, rods, and other shapes. New processes are tried out. Each factor may be separately altered to find the effect of each change. In general, each mill may be controlled at every point, and its performance measured and compared with the quality of the product.

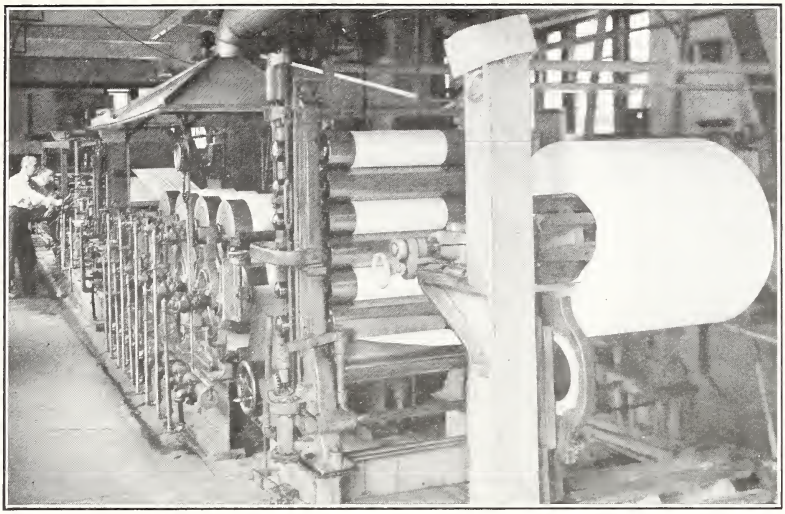

FIG. 79.—*Semicommercial paper-making machine*

This machine is a miniature of a commercial paper-making machine. In it is determined the practicability of using new materials, and also experiments are tried with standard materials under systematically varied conditions. The picture shows the machine in operation, the roll of paper at the right being the finished material. Briefly, the conditions which determine the quality of papers are studied experimentally.

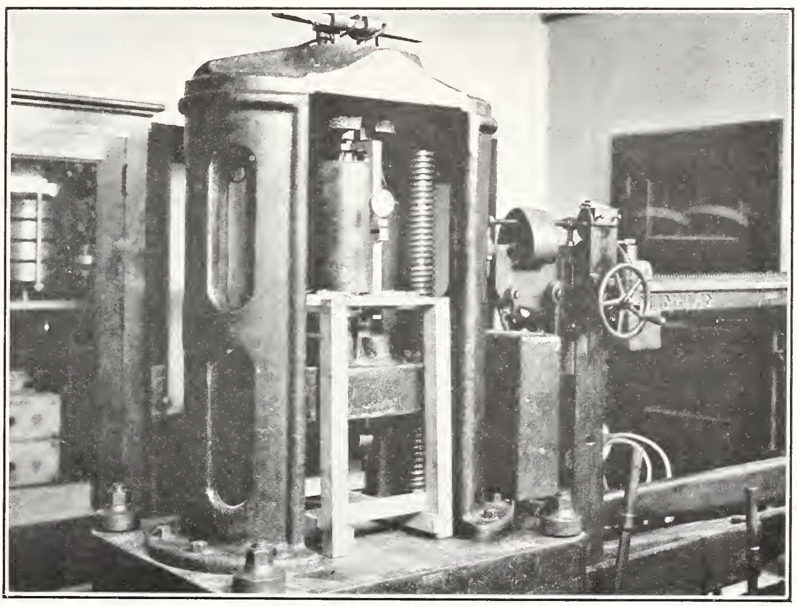

FIG. 80.—*Thermal test of metals under load*

Many metals, such as boiler plate, must withstand tensile or compressive stress while at a comparatively high temperature. In the special set-up here shown the metal is heated to the desired temperature electrically while the known stress is applied and indicated by the testing machine. Deformation is indicated by a strain gauge.

FIG. 81.—*Scientific instrument shop*

Here are constructed new apparatus designed at the bureau for research and testing. Varied skill is required, ingenuity and precision. The staff comprises highly trained instrument makers, machinists, toolmakers, pattern makers. The picture shows a room in the main shop. Seven branches are maintained at other points

FIG. 82.—*Glass-blowing shop*

Intricate forms of apparatus are blown of glass for use in the laboratories of chemistry and physics. Most of these are designed at the bureau for special researches. The work calls for the utmost in glass-blowing technique.

FIG. 83.—*Glass-working shop*

Here are produced lenses, prisms, flats, mirrors, and other precision surfaces and shapes, many of them of new types. These are usually parts of optical systems of scientific apparatus required in bureau researches or in testing. Surfaces have been produced without perceptible error. Much scientific research and testing depends for its success upon surfaces being accurately ground

FIG. 84.—*Typical products of the glass-grinding shop*

Prisms, lenses, blocks, flats, parallels, and mirrors are ground with high accuracy. Sample rough blocks of the different kinds of glass are shown. In the background is shown a pair of night binoculars designed and constructed at the bureau. The grinding tools are shown at the right in the foreground.

(c) TECHNICAL SHOPS

The instrument shop, glass-blowing shop, carpenter shop, glass-working shop for grinding optical glass parts for instruments, gauge shop, photographic shop, and the experimental foundry, rolling mill, and draw bench aid the scientific workers, providing facilities unusual in their ensemble even in experimental research laboratories. The instrument shops, for example, are well equipped with modern machinery, the most varied materials, and an expert construction staff. Facilities are available for melting the most refractory materials, such as thoria and other resistant substances. The foundry is useful for casting special metals and alloys experimentally. Here was conducted the practical work of determining the best pouring temperature for casting standard bronze.

3. PUBLICATIONS

New research results or discoveries are announced in printed bureau publications. Nearly 1,200 have been published to date. Releases to the daily press give briefly the outstanding news of the bureau's activities. Technical abstracts are prepared for dissemination to the technical journals. The diversity of the bureau's subjects calls for several series of publications. No sharp line divides them. New knowledge of general or pure science is published in *Scientific Papers.* Results of direct application in the industries are printed as *Technologic Papers.* These two series are bound in volumes of about 750 pages. About 18 volumes have been issued of each series. Compiled technical or administrative matter is issued as a *Circular;* for example, the standard gasoline tables, test schedules, tests, specifications, and the like. Codes and reference texts, for example, the codes of electrical, gas, and logging practice, which must be carried about by the expert in his daily work, are issued as *Handbooks.* This series is of pocket size.

The program for the simplification of commercial practice leads to definite recommendations, published in two forms: *Simplified Practice* and *Recognized Practice.* Charts, conference reports, and material not suitable for other series are published as *Miscellaneous Publications.*

The bureau's *Technical News Bulletin* is a monthly periodical giving items concerning pending or completed work of the bureau. At this date about a hundred issues of the *Technical News Bulletin* have been prepared and distributed. The bureau also prepares *Letter-Circulars* on specialized subjects for use as replies to inquiries by mail. The 169 letter circulars prepared to date cover a wide range of subjects and represent material not yet ready to be included in the printed series.

In addition to the Government publications, papers on subjects within the respective specialties are printed in outside journals. If funds permitted many of these should appear in the bureau's series. Outside journals, however, print promptly, reach specialized groups of readers, and usually print larger editions, all of which aid the bureau in reaching those for whom the bureau's work is done. Journalists visit the bureau to prepare articles of public interest on its work, and many articles on the bureau are published in the newspapers and special periodicals.

Bureau publications are sold by the Superintendent of Documents.[3] Subscriptions may be placed in advance for the *Scientific Papers* and for the *Technologic Papers*. The bureau issues a descriptive list (Circular 24) of its published work, with a comprehensive index of all published material. The list is brought up to date by the occasional issuance of a supplementary list giving descriptive abstracts of later publications. Announcement cards giving titles of all new publications are sent regularly on request to those concerned with the bureau's work. The general reader will be interested to know that by direction of Congress publications are sent to certain designated "Government depository libraries" in the several congressional districts on condition that they become available for reference use by the general public. In this manner, the bureau is enabled to refer readers to local files of its publications when the publication itself may be out of print.

WASHINGTON, June 24, 1925.

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[3] Address "Superintendent of Documents, Government Printing Office, Washington," who furnishes such publications at cost and reprints documents for which there is sufficient demand.

FIG. 85.—*Key to the plan of Bureau of Standards buildings (airplane view)*

In upper left is the Industrial Laboratory, which houses the work on industrial materials, such as metal structures, cement; stone; sand; gravel; lime; gypsum; clay products, including terra-cotta tile, brick, pottery, porcelain; refractory products and glass; textiles; paper; leather; and rubber.

In the left foreground is the low-lying Dynamometer Laboratory for Automotive Research, and beyond it the Metallurgical Laboratory building.

The Radio Laboratory is in the middle ground at the extreme right. At its left facing the reader is the East Building in which the Electrical, Photometric, and Radium Laboratories are located. The next building toward the reader is the administrative or South Building, in which also the optical and weights and measures divisions are housed.

Still nearer the foreground facing the reader is the four-story laboratory building (West Building) in which the offices and laboratories of the heat division and the division of mechanics and sound are located. The wind tunnel of the latter is a single story building at the left. Beyond it (with gable roof) is the Liquid Air or Cryogenic Laboratory. In the center of the picture is the North Building containing the power plant, the instrument shop, and central store rooms. At its far left is the Chemistry Laboratory.

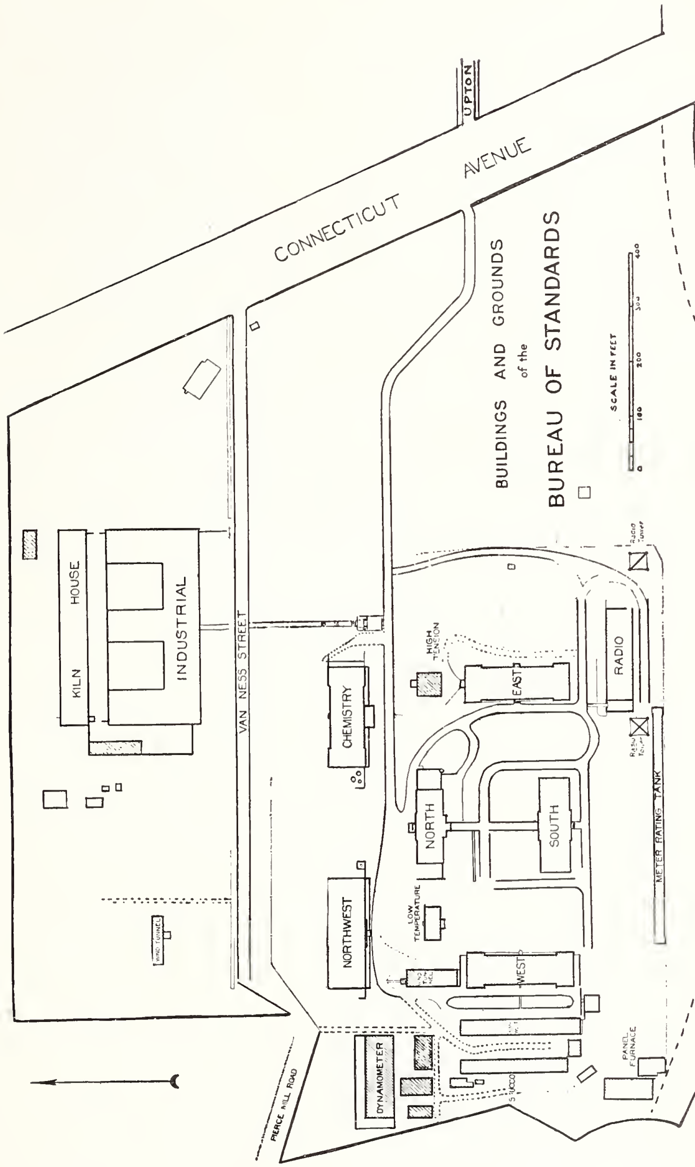

FIG. 86.—*Plan of site showing location of buildings of the Bureau of Standards.* (See key view on p. 112)

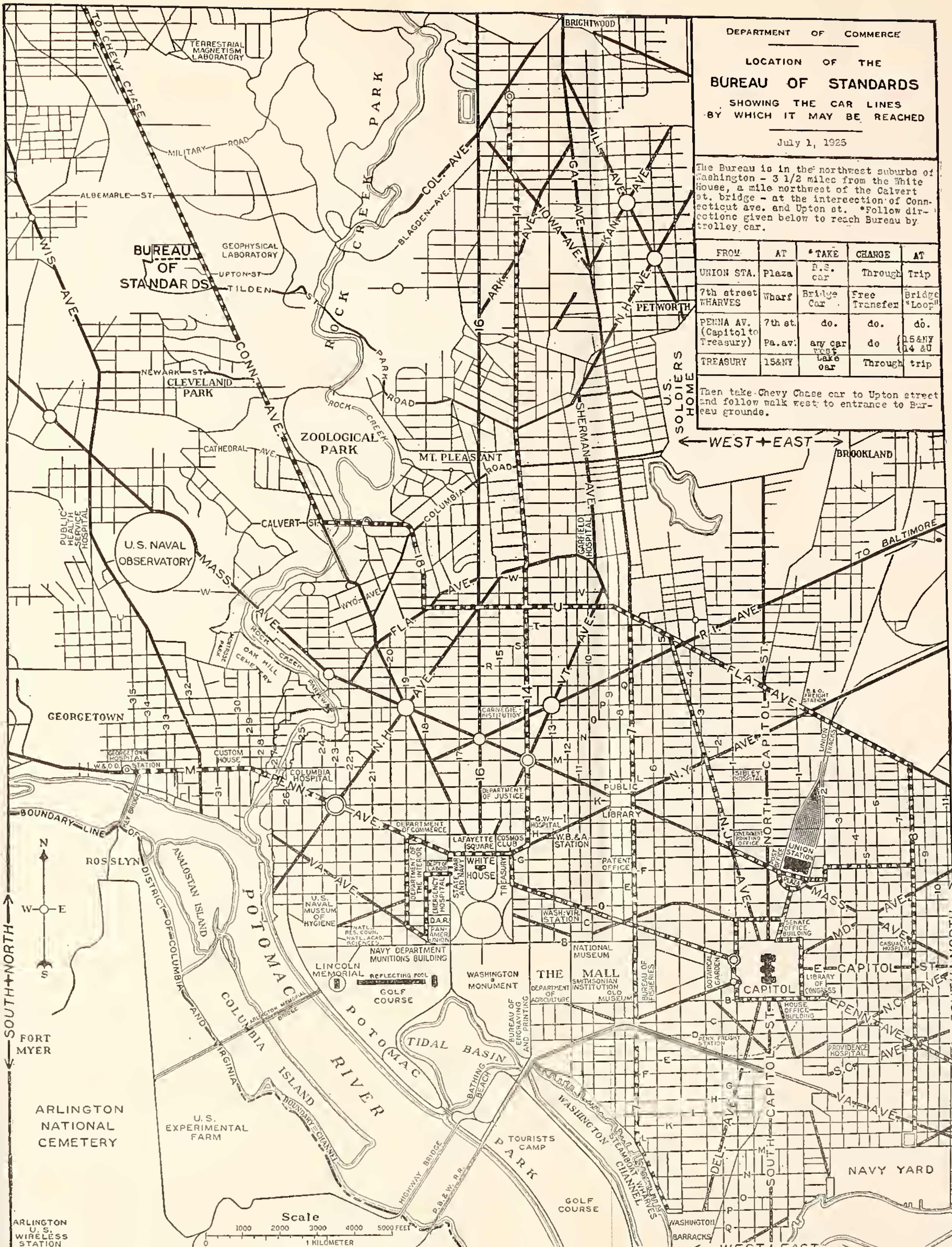

FIG. 87.—*Map showing location of the Bureau of Standards*

The bureau site is 3½ miles northwest of the White House in the suburban residential district of the National Capital. The car lines leading to the bureau are shown as broken lines. The location of other scientific laboratories and points of interest is also given.

Street cars marked as follows pass the Bureau of Standards:

"BUREAU OF STANDARDS" from Navy Yard, Library of Congress, House of Representatives, Capitol, Union Station, Rock Creek Bridge, Connecticut Avenue.

"CHEVY CHASE" bus from House of Representatives, Capitol, Union Station, downtown, Connecticut Avenue.

"CHEVY CHASE LAKE" from Potomac Park, War, Navy, Interior, State, and Treasury Department buildings, Fourteenth Street, Rock Creek Bridge, Connecticut Avenue.

"CHEVY CHASE" from Seventh Street Wharves, Rock Creek Bridge, Connecticut Avenue.

"KENSINGTON" same as "CHEVY CHASE LAKE."

53853°—25 (Follows p. 113.)