ELECTRICITY, RAILROADS, AND RADIO (1911–16)

CHAPTER III

STANDARDS FOR THE AGE OF ELECTRICITY

The first two decades of the 20th century witnessed a new industrial revolution, the electrification of American industry. In 1899 less than 5 percent of all power used in industry had been electric. By 1909, with the development of more efficient generators, better electric motors, and transmission lines of greater carrying capacity, it had risen to 25.4 percent, and by 1919 to 55 percent.[1] An age of electricity had arrived, its challenge to the long dominance of heavy industry, by promising lighter and more specialized products, as revolutionary in its impact on the lives of ordinary men as the present age of computers and automation.

Dr. Rosa was speaking of the electrical industry when he said: "It is largely to meet their needs [the electrical instrument-makers and manufacturers]—that the bureau was organized, and if by serving them the standard of excellence of American-made instruments and machinery is raised, the bureau will have served the public also." [2] Or as Dr. Stratton wrote to Secretary of Commerce and Labor Cortelyou, in a letter of 1904 describing the spheres of interest of the Visiting Committee: "The work of the bureau is perhaps more closely related to electrical interests than any other." [3]

Electric light and power companies, appliance manufacturers, communication and traction companies developed at a phenomenal rate throughout the period. So numerous were the demands of the electrical industry and of electrical research laboratories for basic measurements, instrumentation, tests and calibrations that almost half the new people coming into the Bureau went into Rosa's division. By 1910 the testing of materials for Government agencies, by its sheer volume, was in the ascendant, but Stratton reported that electrical research and testing was still, "next to structural

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[1] Samuel H. Schurr and Bruce C. Netschert, Energy in the American Economy, 1850–1935 (Baltimore: Johns Hopkins Press, 1960), p. 187.

[2] Rosa, "The organization and work of the Bureau of Standards," Science, 19, 949 (1904).

[3] Letter, SWS to Cortelyou, Dec. 10, 1904 (NBS Box 296, APV-Remsen).

materials * * * the largest division of the bureau's work."[4] As the world of electricity grew Rosa's division grew with it, extending its research in measurement into electrolysis and electrochemistry, into radio research and engineering, and radiology.

To satisfy the industry's need for better electrical standards and better measuring instruments, much of the early work of the Bureau was concentrated in fundamental electrical measurements. N. Ernest Dorsey of the electrical division reported some of the results:

> The progress that was made in the seven years 1903 to 1910 in the accuracy of [these] measurements was great. In 1903 it was generally believed that it was not possible to make absolute electrical measurements to a higher accuracy than one in one thousand; by 1910, such measurements had been made with an accuracy of a few parts in 100,000.
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> In 1903, manganin resistances were subject to large unexplained irregular variations; before 1910, these variations had been shown by [the] Bureau to be caused by the effect of varying humidity upon the insulation, and sealed coils largely eliminating that effect had been constructed.
>
> In 1903, the results obtained with the silver coulometer [i.e., voltameter] were distressingly variable; by 1910, the major cause of the variations had been discovered, and several types of coulometers yielding high reproducibility had been designed.
>
> [Finally,] much improvement had been made in the constancy and reproducibility of the standard cell.
>
> By the summer of 1910, the modern era of high accuracy in electrical measurements had begun.[5]

Most of the electrical values that were available to science and industry in 1903 were far from precise and tentative at best. The first application of electricity, to the telegraph, required few quantitative results other than resistance measurements. But by the 1880's, as electric energy was applied to light and power, the necessity for accurate measurements of other electrical quantities, of capacitance, inductance, electromotive force, and current, became acute. The Electrial Congress held in Paris in 1881, the first of many such international conferences, recommended that electric and magnetic quantities be measured in terms of absolute units, that is, the same units used to measure mechanical energy—the centimeter, gram, and second

[4] Hearings * * * 1912 (Dec. 2, 1910), p. 267.

[5] MS, N. Ernest Dorsey, "Some memories of the early days."

(CGS). But precise values for electrical units in relation to fundamental mechanical effects are difficult to establish, and electrical science and industry needed units that could be readily reproduced in their laboratories.

By 1903 general agreement on reproducible primary electrical standards had been reached. The international ohm was arbitrarily defined as the resistance of a specified column of mercury, the international ampere by its rate of deposition of silver, and the international volt as a specified fraction of the electromotive force of the Weston standard cell. Commerce and industry, assuming that the units defined by reproducible standards were indistinguishable from absolute units, were satisfied. But for the most precise work, science looked to the Bureau for an accurate statement of the small but very real difference between these reproducible units and fundamental (absolute) units.

Defining an electrical unit was one thing, determining its value relative to absolute units was quite another, and the standards set up in accordance with these definitions by the national laboratories here and abroad did not show the agreement that had been hoped for. Yet as Dorsey pointed out, between 1903 and 1910 the silver voltameter, standard resistors, standard cells, and instruments for comparing the standards were much improved.

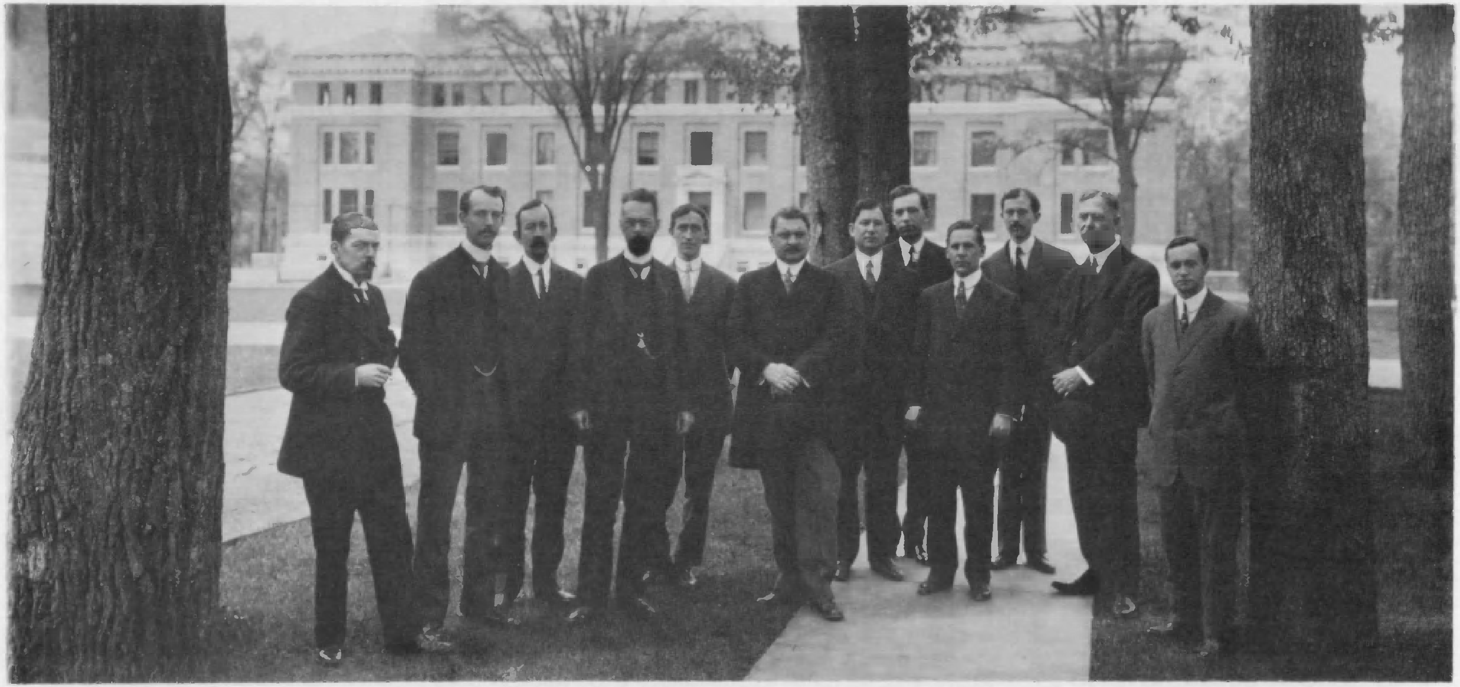
The work at the Bureau on the silver voltameter and standard cell, in terms of which current and voltage were measured, was to be of special importance in establishing more precise values for the volt. This was true of J. G. Coffin's construction and calculations of absolute standards of inductance, completed in 1906, a consequence of Rosa and Grover's extensive theoretical examination of inductance formulas. The work not only proved valuable for absolute measurement but of considerable service to the electrical industry in determining the inductance of circuit configurations.[6]

Earlier experience in the absolute measurement of current, the results of which were expressed in electromagnetic units, led to Rosa and Dorsey's painstaking experiment in 1907 which demonstrated that the measurement of a current in electromagnetic CGS units was related to its measurement in electrostatic CGS units by exactly the numerical value of the speed of light, accurate to within 0.03 percent.[7] An important confirmation of Maxwell's theory of light, the investigation otherwise had little immediate practical application, except as an immensely prestigious piece of work that paid dividends in recruiting young physicists for the Bureau.

[6] S9 and S10 (Rosa and Grover, 1903–5); S29 (Coffin, 1906).

NOTE.—S designates the Scientific Papers of the NBS, issued from 1904–28, as hereafter RP will represent a Research Paper in the Journal of Research of the NBS, 1928 to date, T designates the Technologic Papers of the NBS, 1910–28, and H the NBS series of Handbooks. For further information on these and other Bureau publications, see notes to app. I.

[7] S66 (Rosa and Dorsev. 1907).



Members and assistants of the International Technical Committee of 1910 gather on the lawn at the Bureau upon completion of the work to establish new values for the international ampere, ohm, and volt. From left to right: F. Laporte (France), Sir Frank Smith (England), Dr. Frank A. Wolff, Jr., Dr. W. Jaeger (Germany), M. P. Shoemaker, Dr. Stratton, Dr. Frank Wenner, Dr. A. S. McDaniel, G. E. Post, Dr. Frederick W. Grover, Dr. Rosa, and Dr. George W. Vinal.

Most of the early research in Rosa's division, however, was specifically concerned with electrical standards, and before long the work of the Bureau and that of the national laboratories abroad had sufficiently increased the possible accuracy of the values established for the primary electrical standards to call for a new international agreement. At the International Conference on Electrical Units and Standards held in London in 1908 a resolution was drawn up to adopt a new international ampere, ohm, and volt.

Two years later a technical committee representing the British, French, German, and American national laboratories, with Dr. Rosa as chairman, met at the Bureau in Washington to carry out the resolution of the Conference. In May 1910 the committee completed its work, reaching agreement on new values to be assigned to the ampere and ohm and from these deriving a new value for the international volt. Adoption of these values promised for the first time international uniformity to a high degree of precision in the electrical units. With high satisfaction, Rosa wrote: "There is reason to believe that the values adopted now will be satisfactory for a generation at least without change." [8]

The progress made by the committee had been reported in the Washington newspapers, and Congress was ready for Dr. Stratton when he appeared on Capitol Hill just prior to the announcement of worldwide adoption of the committee's work. In the Bureau budget before the Subcommittee on Appropriations was a request for a new electrical laboratory building, needed to regroup Rosa's division, now scattered all through North, South, and West buildings. Members of the subcommittee immediately challenged the need for the building. To Congress it seemed that the most pressing task of the electrical division of the Bureau was finished.

Dr. Stratton had to reassure Congress that the recent work of the international committee did not mean that electrical measurements were "all done." "The work in connection with these standards," said Stratton, "is going on all the time. Some of them must be continually produced. For instance, the standard of electromotive force must be produced from year to year. The work in connection with the standard [of] current is not nearly completed * * * . We must maintain continuously the standards of resistance, of current, of electromotive force, of inductance and capacity, and the magnetic standards. Every electrical problem goes back to these standards." [9]

Stratton's argument may only have heightened the mystery of electricity to the layman, but Congress was convinced. The electrical laboratory was

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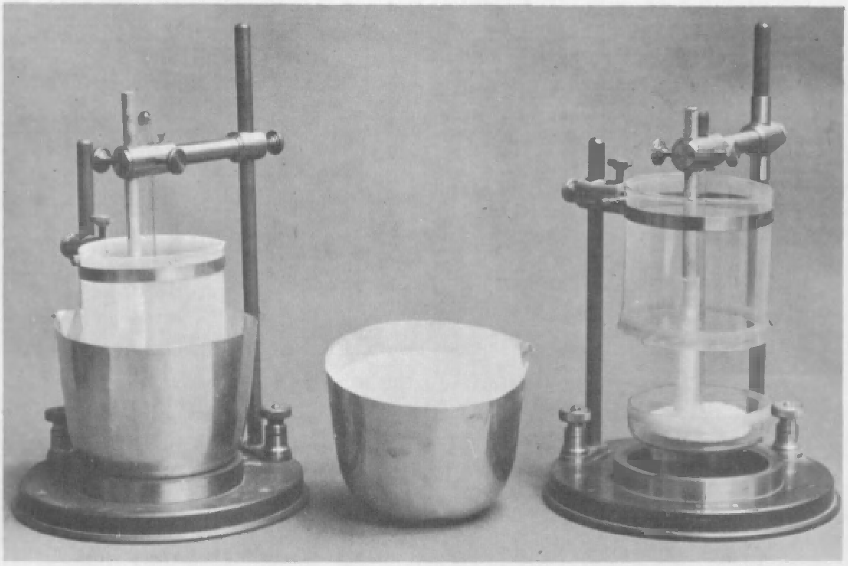
[8] Rosa in Science, 31, 601 (1910), and Engr. Mag. 39, 263 (1910); NBS C29, "Announcement of a change in the value of the international volt" (1911); correspondence of 1911 in NBS Box 8, IE; Annual Report, National Physical Laboratory, 1912, p. 7.

[9] Hearings * * * 1912 (Dec. 2, 1910), p. 267.



The silver voltameter used to determine a new value for the international ampere. The experiments at Washington in 1910 made it possible to assign mutually consistent values to the standard cells and standard resistors used in the respective national standardizing laboratories, in terms of the resistivity of mercury and the electrochemical equivalent of silver. The units thus established formed the basis for all electrical measurements throughout the world for the next 37 years.

approved and the sum of $175,000 appropriated for its construction. As East building, it completed the quadrangle on the hilltop, and Rosa and his division moved in during the spring of 1913.[10]

Useful and even necessary as the new international values were to electrical science and industry, they were, as Stratton had said, far from permanent. Continued research in instrumentation and procedures resulted in greater refinements of the values and the standard resistances and standard cells slowly began to drift. By 1925, serious discrepancies were evident among the standards maintained in the national laboratories here and abroad. Where measurements had been made with once satisfactory accuracies within a few parts in 100,000, certain of them could now be kept constant within a few parts in a million. There was need for agreement on the new values possible.

[10] The building was accepted in June 1913 but not actually completed until several months later, after members of the electrical division themselves installed the wiring. See correspondence in NBS Blue Folder Box 77. That wiring was still functioning satisfactorily when it was replaced with modern fireproof conduits in the 1950's (interview with Dr. F. B. Silsbee, Jan. 29, 1963).

In 1929 the International Committee of Weights and Measures at Sèvres, to which the establishment and conservation of electrical standards had been assigned in 1923, approved a resolution to replace the international system of electrical units by the absolute or CGS system originally proposed for them. The need for conveniently reproducible standards had diminished with the expansion of testing services in the national laboratories. Electrical methods of measurement, of increasing importance to science and engineering, demanded higher and higher degrees of precision that apparently only an absolute system of measurement could satisfy. Also the discovery of isotopes in 1913, with their hitherto unsuspected variation among different samples of silver and mercury reduced the certainty of international units defined by properties of these elements and favored absolute units independent of isotopic variations.

The conference of 1929 agreed that the pursuit of "ideal" measurements must be resumed within the framework of the absolute system, and from the 1930's on this became the direction of fundamental electrical research. The same decade saw a marked acceleration in the work of extending the range of measurement of electrical quantities. Here, earlier pioneer work such as Dr. Herbert B. Brooks' development of the deflection potentiometer for measuring current and voltage in lamp testing came to full fruition. It was the first of many highly specialized potentiometers he subsequently designed.[11]

These lines of research continue to the present day at the Bureau and in the electrical standards laboratories abroad. Bureau research alone in the field of modern electrical measurement has been reported in almost 300 separate publications. The early work of Rosa, Wolff, Grover, Agnew, Wenner, Vinal, and Lloyd was continued in the 1920's and 1930's by Curtis, Brooks, and Silsbee, by Sanford, Snow, Thomas, and Moon, and from 1940 on by Curtis, Snow and others.[12]

In the early years of electrical research at the Bureau, something more than international agreement on standards of measurement, and provision of quantitative standards and instruments for the industry, was at stake. Out of its research, the Bureau also recommended to the industry equally important, if not equally welcome, standards of a quite different nature, those of service and safety.

[11] S33 (Brooks, 1906).

[12] Lyman J. Briggs, "Early work of the NBS," Sci. Mo. 73, 167 (1951); F. B. Silsbee, "Establishment and maintenance of the electrical units," NBS C475 (1949); F. B. Silsbee, "Extension and dissemination of the electrical and magnetic units by the NBS," NBS C531 (1952).

STANDARDS FOR PUBLIC UTILITIES

Still developing along the empirical lines evolved in the previous century, the electrical industry in the early century was as much in need of standards of quality, of performance, of safety, and of service as it was of standards of quantity. A contemporary historian's indictment of the gas industry, that owing to its monopoly in many cities it used fraudulent meters, supplied inferior gas, and collected excessive rates from helpless consumers, applied equally well, he said, to the electric lighting industry, street railways, and the telegraph and telephone companies.[13]

The Bureau was more charitable. Talking with utility company representatives, manufacturers, and industrial scientists, Stratton and Rosa found that many of the shortcomings of the industry were "not entirely [the fault] * * * of the manufacturer, but [resulted from] the lack of uniform standards and specifications."[14] So Stratton reported when in 1904 the Bureau threw out three-quarters of a shipment of electric light bulbs submitted for testing by a Government purchasing office. Not long after, the Bureau of Corporations, the new watchdog agency set over trusts in the Department of Commerce (and predecessor of the Federal Trade Commission, organized in 1915), asked the Bureau to investigate the relative illuminating power of a number of kerosene oils on the market. Their quality proved no less dubious than that of some of the gas and electric lamps already determined by the Bureau. Standards of illumination and uniform specifications for the lighting industry were manifestly needed. And because the Bureau's investigation began with the incandescent lamp, photometry or the scientific measurement of light became a function of Rosa's electrical division and remained so for 40 years before it was transferred to the optics division of the Bureau.

Before long the Bureau became involved with much more than gas, oil, and electric lamps. In the wake of Roosevelt's crackdown on the trusts, the public service monopolies came under fire. Many States and cities, goaded by the press, the muckraking periodicals, and reforming citizenry, instituted reforms of their own, first attempting to regulate the utilities by legislation and lawsuit and then setting up public service commissions and other local regulatory agencies. Beginning in 1907, city and interurban street railways, gas and water companies, electric light and power companies, the telegraph and telephone, and even the all-powerful railroads found their rates and services increasingly subject to a measure of regulation.

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[13] Harry T. Peck, Twenty Years of the Republic: 1885–1905 (New York: Dodd Mead, 1906), p. 315.

[14] Hearings * * * 1906 (Dec. 2, 1904), p. 232.

Very much aware of the weights and measures investigation of the Bureau and its assistance in setting up inspection systems in cities and States, the new public service commissions turned to the Bureau for help. The ensuing research that began with the measurement of lamp light was eventually extended to almost every aspect of public utility service.

One difficulty in establishing a uniform standard of light hinged on the use of the term "candlepower," based by tradition on a natural light source, the light value of an open flame measured by comparison with a sperm oil candle. By reason of the varying sizes and designs of the sperm candles used, the values originally derived from them differed considerably. Thus the "candles" of the electric lamp and illuminating gas industries bore little relation to one another, and even within the same industry the Bureau found the "candle" had little constancy.[15]

As working standards, some gas and electric companies referred to the English parliamentary candle. Most electric lamp manufacturers, however, had turned to the standard of light maintained by the Reichsanstalt, the Hefner amylacetate lamp, for their "candle" value. The flaws that Rosa's group found in the Hefner standard shortly after the establishment of the Bureau led him to propose as a new standard for the electric lamp industry the mean value of a number of 16-candlepower commercial lamps, and to make this applicable to gas light as well as to electric light.[16]

When the value of this new standard "candle" proved to be only slightly greater than the unit maintained by the national laboratories of England and France, the Bureau proposed an adjustment of its own value looking to an international candle. The proposal was accepted, and in 1909 the new value, based on a simple relationship between the British Hefner unit, the French bougie décimale, and the carbon-filament unit maintained in Washington, became the standard for all photometric measurements in this country.[17]

Interestingly enough, a year earlier, in 1908, Waidner and Burgess in the heat division of the Bureau attempted to construct an absolute standard

[15] NBS Annual Report 1909, p. 7.

[16] See letter, SWS to Edison Lamp Works of General Electric, Harrison, N.J., Apr. 30, 1904, and attached correspondence (NSB Box 8, IEL).

In July 1904 an instructor at Cornell, Eugene C. Crittenden, was brought to the Bureau to investigate flame standards in photometry. He remained for more than 50 years. Under his guidance the problems of a light standard were finally resolved by the international acceptance of a "new candle" in 1948, based on two accomplishments of the Bureau, the platinum black body standard of Wensel, Roeser, Barbrow, and Caldwell, and the determination of spectral luminosity factors by Gibson and Tyndall. See ch. V, p. 245, and ch. VI, p. 337.

[17] NBS C15, "The international unit of light" (1909; 3d ed., 1911). The Reichsanstalt's Hefner unit was assigned the value of 0.90 international candle.

of light, for use in pyrometrical measurement. For lack of suitable materials at that time, 20 years passed before the work was resumed and an absolute prototype standard was at last experimentally realized. With it the incandescent lamp standard, always difficult to maintain, was reduced to a working standard.

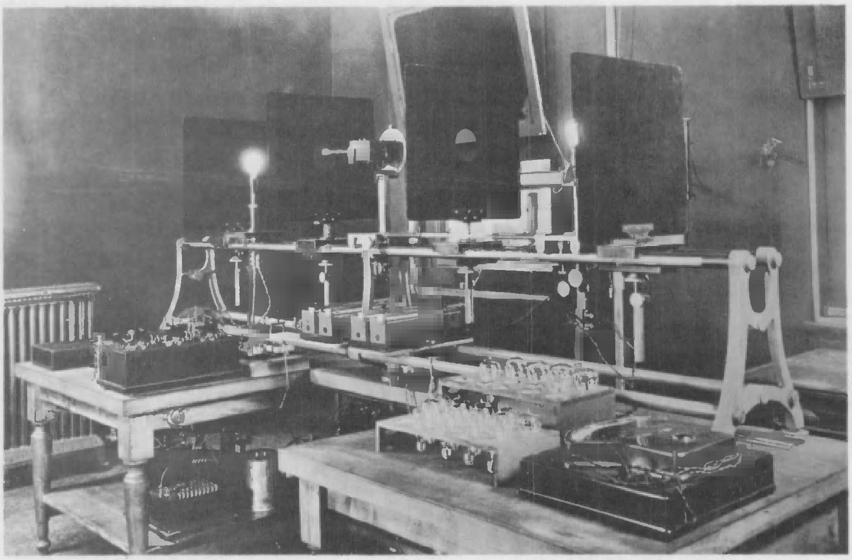
A uniform standard of light was not enough to assure acceptance of the lamps made by the electric industry, and 2 years before adoption of the international candle representatives of the lamp manufacturers in this country met with Government engineers at the Bureau to adopt standard specifications for electric lamps. Although the General Electric Co. had introduced its G.E. metalized (GEM) carbon-filament lamp in 1905, and in 1907 put its first tungsten-filament (Mazda) lamp on the market, the first specifications were based on the Edison carbon-filament lamp, then owned and manufactured by General Electric and its subsidiaries and the most widely used of electric lamps available.

It was agreed that the carbon-filament lamps sold to the Government must initially consume no more than 3.76 watts per mean spherical candle (the Bureau standard) and their "life," before decreasing to 80 percent of their original light value or burning out, must be 300 to 450 hours. Failure of 10 percent of the test lamps in any lot would automatically result in rejection of the entire lot. The details of these specifications were published in NBS Circular 13 (1907) and revised editions of the circular appeared with the adoption of the international candle and as each of the new types of electric lamps came into general use.[18]

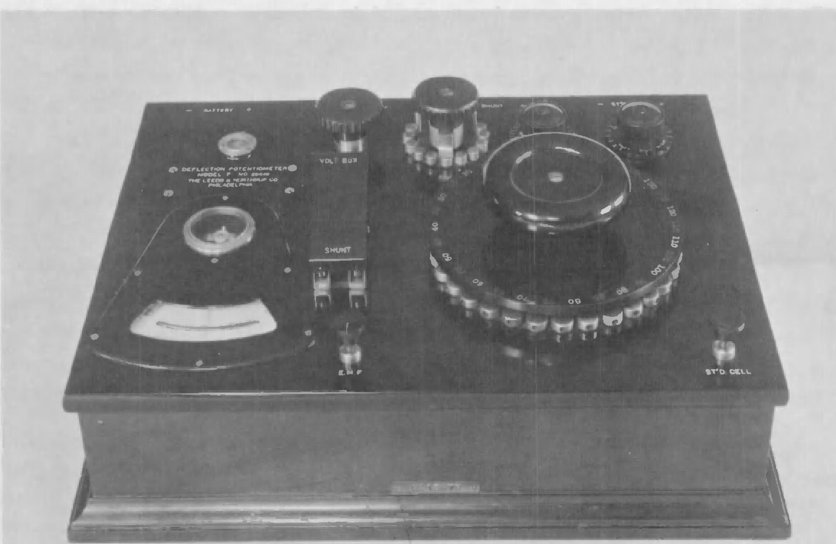
Although Bureau testing of incandescent lamps was the entering wedge, it was not by electric light but by old-fashioned gas light that the Bureau prepared its first proposals for the regulation of a public utility. For years the illuminating gas and oil industry had referred to Hefner and pentane lamps for its photometric standards. How unreliable these standards were the Bureau learned in 1906 when some 40 kerosene oils were submitted to it for tests of their composition and illuminating power.[19]

Preliminary studies revealed the necessity of a thorough investigation of gas and oil illuminants, and in 1908 the Bureau requested and received from Congress a special 2-year appropriation to work on this problem, in cooperation with the American Gas Institute. Russell S. McBride, a bright young graduate in chemistry from the University of Wisconsin, was brought into Rosa's electrical division, sent to school for courses in gas engineering, and put in charge of the investigation.[20]

[18] The last edition of C13, "Standard specifications for incandescent electric lamps," was the 10th, in 1923, after which the Federal Specifications Board, recently established in the Bureau of the Budget, took over the function of promulgating lamp specifications.
[19] Hearings * * * 1907 (Feb. 23, 1906), p. 653.
[20] See Hearings * * * 1915 (Feb. 26, 1914), p. 910.



Laboratory setup for testing the candlepower of incandescent lamps about 1910. This was the brightness test, using a horizontal bar photometer.



Dr. Brook's deflection potentiometer permitted the measurement of direct current and voltage more precisely than with any former laboratory indicating instrument. The potentiometer has come into wide use in the manufacture and rapid checking of precise indicating instruments with direct reference to a standard cell.

The work that McBride and his group did between 1909 and 1911 resulted in new methods for calibrating pentane lamps in terms of the Bureau candle and laid the basis for establishing standards of gas service, both illuminating and heating. The results were furnished to State and municipal authorities that had requested Bureau assistance in drafting gas service regulations.

The Bureau urged that the quality of gas be determined by its heating value rather than its candlepower, as was then the practice in most cities, and that it be sold on the basis of the British thermal unit (Btu), not by the cubic foot. Gas company engineers argued that the consumer was not concerned with heating value, certainly not in gas lamps; but statistical studies by the Bureau showed that the usefulness of gas to the consumer was almost exactly proportional to its heating value, whether used in heating appliances or in gas-mantle lamps, and successfully refuted the claims of some of the companies that the amount of gas used by consumers was not increased when the heating value was reduced. So long as gas was sold by the cubic foot, the gas companies had little incentive to purify their product, and it permitted them to sell excessive and useless quantities of nitrogen and sulfur compounds in their gas, introduced during the manufacturing process.[21]

The Bureau circular putting standards of gas service into the hands of public service commissions recognized the hostility of the utilities to the regulations it recommended. It reassured the industry that the Bureau "in no way concerned itself with the financial regulation of gas companies * * * [or with their] works management." It carefully stressed that "the attitude of the Bureau is entirely advisory, and its intention is only to place in the hands of the technical and general public an impartial and, as nearly as may be, accurate summary of the facts which must be considered in connection with the inspection and testing of the quality and distribution of * * * gas." The circular also pointed out that the utilities stood in need of public confidence and would therefore gain much from the passage of local laws and ordinances regulating their services.[22] But a decade passed before the in-

[21] Elmer R. Weaver, MS, "History of the gas chemistry section, NBS, 1910–1957" (October 1964), pp. 2, 6 (NBS Historical File).

[22] NBS C32 (1912), pp. 5–6. "Drastic" was the word Henry L. Doherty used to describe some of the Bureau's proposed regulations. A self-made gas utilities magnate, whose Cities Service holding company was to take over 53 independent operating companies in 1913 alone, Doherty spoke for the industry when he wrote to the Bureau: "I certainly do not want to see any burdens placed on the gas companies that will be hard for them to meet." Confidential letters, Doherty to NBS, Mar. 9 and Apr. 2, 1912 (NBS Box 7, IGC).

The original and somewhat intimidating title of C32, "State and municipal regulations for the quality, distribution and testing of illuminating gas," was changed to "Standard dustry accepted the findings of the Bureau and agreed to sell gas on the basis of its heating value.

One of the early investigations of the Bureau's gas engineering group led to modifications in the street gas lamps in the District of Columbia that increased street illumination by 50 percent, with no rise in the cost of service.[23] The gas industry was further aided, against its will, by later Bureau investigations of gas appliances, gas stoves, and gas furnaces. The results led to notable increases in gas efficiency and safety, as well as in sales.[24]

Dr. Rosa's division continued its research in gas photometry and gas engineering until the early 1920's when the work was transferred to a section in the chemistry division under Elmer R. Weaver, and gas instruments research became the province of the weights and measures division. By then the electric light had begun to replace gaslight almost everywhere and gas appliances were rapidly making wood and coal stoves obsolete. For lack of a satisfactory Btu meter, gas continued to be measured in cubic feet, as it is to this day, but in more and more States it was gas monitored by State laboratories equipped with chemical and calorimetric test equipment.

Four years passed before the Bureau undertook to establish standards of service for the electrical utilities as it had for gas. Meanwhile, the electrical industry continued to seek Bureau help with its measuring instruments, in particular the ammeters, voltmeters, wattmeters, and watthour meters by which its power production and consumer rates were measured. For almost 40 years, beginning with his arrival at the Bureau in 1903, Dr. Herbert B. Brooks dominated this section of the electrical division, devising a long series of ingenious new instruments for more accurate and rapid measurement of current and voltage. And the Bureau aided in other ways. As electric power consumption rose, not only Federal agencies, but business firms, and the public reacted to what they considered excessively high electric bills and called on the Bureau for meter tests. The meters were not at fault. The tests proved them to be much more reliable than generally supposed, and if neglected they actually tended to favor the consumer.[25] The Bureau was swamped as company meters poured in for calibration.

As long-distance power transmission developed out on the Pacific coast, Dr. Paul G. Agnew began his pioneer studies in the analysis and testing of current transformers for high-voltage power stations. Out of the work came the insulating materials (dielectrics) program of the Bureau, begun

regulations for manufactured gas and gas service" in the second edition, 1913, and to "Standards for gas service" in the third edition, 1915. A fourth edition came out in 1920, and in 1934 was superseded by C405.

[23] NBS Annual Report 1911, pp. 8–9.

[24] See ch. V pp. 263–265.

[25] Letter, Rosa to Secretary of Commerce and Labor, Dec. 2, 1910 (NBS Box 9, IEP).

about 1912, and 2 years later the first high-voltage studies.[26] Other investigations in Rosa's enterprising electrical division in that decade included preparation over several years of a complete set of copper wire tables, for the American Institute of Electrical Engineers; preliminary studies in color photometry, a development of the gas flame standards work, later transferred to the optics division; and photometric measurement of locomotive headlights, carried out at the request of several States preparing new regulations for the railroads.[27]

Another kind of railroad problem came to the Bureau when the Interstate Commerce Commission, aroused by mounting complaints, requested that a study be made of railroad, elevator, grain-hopper, and other large-capacity scales used in determining freight charges in interstate shipments. Few States inspected scales, the Bureau found, and many railroads maintained such scanty supervision over their freight scales that some were little more than "guessing machines." As a result, railroad freight scales, upon which more than $2 billion annually in revenues were determined, had long been a source of bitter complaint and litigation. So high had feeling run against the railroads, Dr. Stratton reported, that they were more than willing to cooperate with the Bureau in order to "get right" with the public again.[28]

In 1913, with an appropriation from Congress of $25,000 for the investigation, the Bureau had a special railway scale test car built, hitched it to a series of slow freights headed north, and began testing railroad scales in the States of New Jersey, New York, Connecticut, and Vermont. The results matched the earlier experience with market weights and measures. Allowing a fair tolerance for such scales, between 75 and 80 percent of the track scales tested were candidates for outright rejection, some weighing short by as much as 1,349 pounds with a load of 35,000 pounds and 2,459 pounds with loads of 70,000 pounds. Acquiring another test car, the Bureau extended its investigation of scales into the Midwest and the South.[29]

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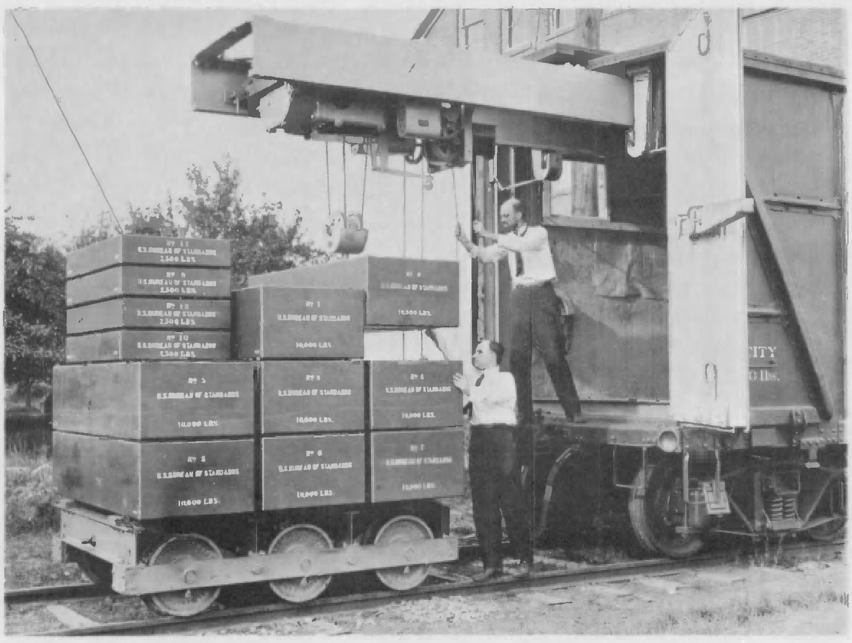
[26] The first high-voltage work began in a room in North building in 1911, when the Bureau acquired 3 voltage transformers, none with a maximum voltage exceeding 2,300 volts. The Bureau's high-tension laboratory, adjoining East building and housing two 100,000-volt transformers, was completed in July 1914. Present-day surge generators at the Bureau deliver 2 million volts. (See correspondence in NBS Blue Folder Box 80, and interviews with Dr. Silsbee.)

[27] NBS Annual Report 1909, pp. 5, 7; Annual Report 1911, p. 8. For the extensive correspondence on the copper wire tables program, 1910-14, see NBS Box 9, IER. Rosa's range of interests is displayed in his article, "The work of the electrical division of the Bureau of Standards," Science, 35, 8 (1912).

[28] Hearings * * * 1914 (Nov. 26, 1912), pp. 305-306.

[29] NBS Annual Report 1912, p. 14, et seq.; Science, 37, 937 (1913) ; NBS C83, "Specifications for * * * railroad track scales" (1920; revised as C333, 1927). For correspondence on the investigation, 1912-20, see NBS Box 20, IWS.



The first NBS railway scale test car for the standardization of railroad track and master scales.

Its equipment consisted of eight 10,000-pound weights, four 2,500-pound weights, 10,000 pounds of 50-pound weights, and the truck itself, a 5,000-pound weight which carried the test load on the rails.

Together with small auxiliary weights, the total testing equipment made it possible to determine weights between one-ten thousandth pound and 105,000 pounds or over 50 tons.

The crane for handling the weights was powered by an electrical generator driven by a gasoline engine. The equipment, mounted in a standard boxcar, was constructed for the Bureau by the A. H. Emery Co. of Connecticut, which built many of the Bureau's heavy test machines.

As the railroads, as well as manufacturing concerns and State agencies, set up inspection procedures under Bureau direction and large-capacity scales began to register more nearly true (i.e., with a tolerable error of 200 pounds in 100,000 pounds gross weight), the Bureau test cars with their master scales still continued their rounds, adjusting track scales and calibrating the scale cars that were acquired by the railroads. At a standstill during the war, the Bureau cars resumed their travels across the Nation into the 1930's, when the depression curtailed all but a fraction of this work.[30]

Yet another railroad investigation was prompted by a series of alarming statistics that appeared in the Interstate Commerce Commission annual report for 1912. Legislation enacted 2 years previously had for the first time required monthly reports of railroad accidents, and the returns, disclosing deaths and injuries resulting from collisions and derailments alone at the rate of almost 13,000 a year, shocked the Commission into further study. Going back into records for the years 1902 to 1912, the ICC came up with a total of 41,578 derailments caused by broken rails, broken wheels, flanges, and axles. Faulty maintenance, inferior iron and steel, severe service, and excessive wheel loads were suspected. The Secretary of Commerce urged the Bureau to make a thorough study of the cause of railroad accidents and related problems.[31]

Specimens of failed parts, sent to the Bureau by the ICC and the railroads, were subjected to chemical, microscopic, and mechanical tests. In every instance of rail failure, hidden defects or splits, identified as transverse fissures, were found in the interior of the rails. In track inspections made by the Bureau in the field, as many as four or five of these fissures or points of internal stress were found in a single mile of track.[32]

With the cooperation of the big steel companies, the recently organized metallurgical division at the Bureau and the engineering and chemical divisions began an investigation of the constitutents of railroad iron and steel, of heat stress and heat treatment and related problems in the manufacturing process. Here seemed to be the source of failed rails and wheels. The steel industry, behind Europe in this technology, had insuffi-

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[30] See track scale testing appropriations, NBS Annual Report 1934, p. 76.

In 1917 Bureau scale testing was extended to the scales used in weighing coal at mines (NBS Annual Report 1918, pp. 28–30), and in 1936 to vehicle or truck scales (NBS Annual Report 1937, pp. 61–62). As the programs began, the relative gross errors in the scales on which miners' wages were based and those on which safe operation on the highway depended matched or even exceeded those found earlier in railroad scales.

[31] ICC Annual Report Dec. 16, 1912, pp. 53, 63; letter, Secretary of Commerce Redfield to SWS, July 1, 1913, and attached correspondence, 1913–15 (NBS Box 11, IM).

[32] "Report on the formation of transverse fissures in steel parts * * *" (ICC Report by James E. Howard, NBS engineer physicist, 1923) L/C: TF258.U6.

cient knowledge of rail and wheel characteristics, the Bureau metallurgists reported, and had not established uniform practices in their manufacture.[33]

The Bureau investigation of railway materials, begun with special funds appropriated by Congress in 1912, continued until 1923 when the program was absorbed in the statutory research work of the metallurgical division. Answers were slow in coming, and during the war years railroad accidents hit an alltime peak. But from 1921 to 1930, as better steel through better technology went into rails and rolling stock, the rate of accidents from these causes fell by more than two-thirds.[34]

When the Bureau began its "high iron" investigation, it was already deeply involved in another rail problem, this one concerning city street cars. Of all its public service investigations, few defied the concerted efforts of Bureau physicists, utility company engineers, and municipalities as did the problem of electrolytic corrosion. The trouble began in the year 1887 when Frank J. Sprague laid out the first commercially successful trolley system in this country, 12 miles of track in the streets of Richmond, Va. In the next decade more than 2,000 miles of trolley track were put down in cities and towns and out into their suburbs. By 1917, over 40,000 miles of street and interurban railways spidered the Nation. New York City alone contained almost 700 miles of trolley track, and it was actually possible to ride from Brooklyn, up the length of Manhattan, out through Westchester to Bridgeport, on to New Haven and Providence, all the way to Boston by street car, paying a total of 48 five-cent fares for the trip.[35]

The majority of the trolleys operated on Sprague's overhead wire system, with the electric current flowing into the rails through the car wheels after passing through the car motor. In theory, the current then flowed back to the generating station by way of the tracks and earth, completing the electrical circuit. In fact, much of the current strayed on its return, following paths of least resistance through underground pipes, cables, and metal structures.

The first signs of trouble turned up in Boston in 1902 when, excavating to repair a break, the water mains under Boylston Street were found badly corroded. The moisture and ordinary salts in the earth

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[33] Hearings * * * 1913 (Feb. 10, 1912), pp. 761–762; Hearings * * * 1915 (Jan. 27, 1914), p. 677.

[34] From an annual average of 13,000 collisions and derailments in the period 1902–12, they rose to 25,000 in 1918 and 1919, to more than 36,000 in 1920, and then began a steady decline. By 1930 the total had dropped to 12,313. See Annual Table No. 61 in ICC Accident Bulletin Nos. 70 (1918), 74 (1919), 78 (1920), 99 (1930). L/C: HE1780.A2.

[35] Robert A. Futterman, The Future of Our Cities (New York: Doubleday, 1961), pp. 52–53.

made soil a fine conductor of electricity, and current straying from the trolley tracks into nearby water pipes and gas mains ate away the metal by electrolytic action as the current flowed out again.

The same condition was found elsewhere in the lead sheathing around telephone and telegraph wires that had been put underground after the series of city conflagrations around the turn of the century. When electrolytic pitting and corrosion was also discovered on underground light and power cables, at the foot of bridge structures, and in the reinforced concrete supports of piers and buildings, the press, the utilities, and construction people raised cries of alarm. Losses were estimated in the millions of dollars as a result of leakage from gas and water mains, the necessity of repairs and replacement, and devaluation of capital investment, to say nothing of the fire hazard traceable to electrolysis and the losses due to interruption of service.

In 1910 Stratton reported to a Senate committee that the problem had become nationwide, and the Bureau was granted a special 3-year appropriation to investigate earth electrolysis and find ways to mitigate its effects. Dr. Rosa's first move was to bring in Burton McCollum and Kirk H. Logan, two talented young electrical engineers then teaching in the Midwest, to head the investigation.

Working with municipal authorities and engineers in St. Louis, Chicago, Philadelphia, in Elyria, Ohio, and Springfield, Mass., McCollum and Logan identified the nature of the problem, developed procedures to enable utility engineers to make their own electrolysis surveys, and as the congressional appropriations came to an end, had devised an insulated feeder system as one way of mitigating electrolytic corrosion. The street railways, confronted with litigation brought by the utilities and hoping for a more economical solution than insulation, pressed the Bureau to continue its research. Aware that the problem was yet far from solution, the Bureau resumed the investigation under its regular funds.

With the organization in 1919 of the American Committee on Electrolysis, representing the principal national associations of utility companies, a research subcommittee was appointed to work with the Bureau. Of considerable importance was the development by the Bureau of an earth-current meter in 1921. In maintenance testing of pipe systems that the utilities established, it accurately measured the currents directly responsible for electrolytic corrosion and hence the rate of corrosion. Although electrolysis seemed impossible to eliminate entirely, almost 20 methods of mitigating it were devised by Bureau and utility engineers.[36]

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[36] NBS Annual Reports 1911, et seq.; NBS C401, "Abstracts * * * of NBS publications on stray-current electrolysis" (Shepard, 1933).

One phase of the electrolysis problem, the study of the corrosive action of soil itself on metals, without the agency of stray currents, continued. Urged by the utilities, particularly the gas companies transporting and distributing natural and manufactured gas via pipelines cross country and in the cities, the Bureau set up its Corrosion Laboratory in 1922. After more than two decades of research in corrosive-resistant materials and protective coatings, a new approach through cathodic protection came to seem most promising. Its principle was well known, going back to early 19th-century experiments made by Sir Humphrey Davy. As applied to soil corrosion, it involved the use of replaceable zinc anodes attached to the underground structure to be protected, making the structure cathodic or resistant almost indefinitely to the adjacent soil.[37]

If electrolysis wrought great damage to property but posed little life hazard, almost every other manifestation of electricity, from its generation to its consumption, threatened both. The mining industry that produced the coal for electricity was among the first to electrify many of its operations. But electric sparks often proved disastrous in the mines, and in 1909 the American Mining Congress called on the Bureau for assistance in setting up standards of electrical practice in mines and mining practices.[38]

The Bureau investigation for mines led to other studies of life and property hazards in the generation of electricity, both in its distribution at high voltages and in its industrial and domestic uses. These in turn prompted studies of lightning hazards, particularly as they affected the power industry.[39] In 1914, assembling the data amassed, the Bureau published a comprehensive set of safety rules for the electrical industry. A year later it prepared the first nationwide electrical safety code.[40]

Like the standards proposed for the gas industry earlier, the electrical safety code met strong resistance for a number of years. The very formulation of a safety code, protested the industry, gave undue publicity to the hazards of electricity. Its recommendations, and above all its origin in a Federal

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[37] NBS C450, "Underground corrosion" (Logan, 1945), superseded by NBS C579 (1957); RP1876 (Dension and Romanoff, 1948).

[38] NBS C23, "Standardization of electrical practice in mines" (1910). Although the Bureau of Mines for a time protested the NBS investigation, it later acknowledged that its own interest was in "improving mining practices," not standardizing them. Letter, SWS to Director, Bureau of Mines, Oct. 14, 1914, and attached correspondence (NBS Box 9, IES). With the NBS circular as guide, the Bureau of Mines assumed responsibility for electrical safety in mining operations. Letter, SWS to Congressman William B. McKinley, May 28, 1920 (NBS Box 10, IG).

[39] T56, "Protection of life and property against lightning" (Peters, 1915), superseded by M95 (1929) and H13 (1929); M92, "Code for protection against lightning" (1929), superseded by H12 (1929), H17 (1934), H21 (1937), H40 (1945).

[40] NBS C49, "Safety rules * * * in the operation and maintenance of electrical equipment and lines" (1914); NBS C54, "Proposed national electrical safety code" (1915).

agency, seemed an infringement of management and a threat to the independence of the industry.[41] Not a few city and State commissions, persuaded by the industry that the Bureau was setting intolerable standards, took up the proposed code only to let it languish.

The Bureau, with no authority but the congressional appropriation for the work, found it necessary to issue a special circular explaining the code and its scope, "to give [it] more publicity * * * and gain wider acceptance of it." Driving home its point, the circular included accounts of 100 typical electrical accidents, most of them fatal, taken from the newspapers of 1913, as representative of what was happening daily throughout the United States. Yet up to 1920 less than half the States had adopted the code or any part of it.[42]

But the years of unregulated operation of public utilities were running out. The State of Wisconsin had set up the first public service commission in 1907. Less than a decade later some 30 States and twice as many cities had established similar commissions or enacted regulating ordinances. Confronted with often hastily drawn and confusing rules and regulations by State and city authorities, the utilities in time came to welcome the Bureau's efforts to apply scientific and uniform principles to their services.

In 1913 Dr. Rosa reported that the Bureau, in cooperation with the Interstate Commerce Commission or with State commissions, was engaged in almost a score of investigations involving engineering problems and standards relating to the natural monopolies. All in one way or another looked to the resolution of "the mutual distrust and mutual misunderstand-

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[41] The utilities misunderstood Bureau recommendations and for years complained that by its appropriations Congress was "extending the field of regulation and control by the Bureau of Standards over the public utilities of the country." Letter, Acting Secretary of Commerce to Congressman Carl Hayden, May 26, 1919, and other correspondence in NBS Box 2, AG.

[42] NBS C72, "Scope and application of the national electrical safety code" (1918). Letter, Rosa to Prof. A. C. Lanier, University of Missouri, Feb. 26, 1918 (NBS Box 9, IES), recounted Bureau efforts to promulgate the code.

NBS C72 (3d ed., 1920), also issued as a handbook, H3, said the code had been approved by the American Engineering Standards Committee and adopted by administrative authorities in nearly half the States. The revised fourth edition in 1926 (issued as H4 in 1928) said this revision "more nearly meets the views of the various interests involved, some of which are to a certain extent conflicting."

For many years the able assistant of Dr. Lloyd in negotiations on the electrical safety code was Dr. J. Franklin Meyer, who represented the Bureau on the AESC electrical committee. Much of the success in establishing a national code was through his efforts, and the series of handbooks on safety rules in the operation of electrical stations and electrical equipment that appeared between 1920 and 1944 were the joint work of Lloyd and Meyer.

ing existing between the leaders of the financial and industrial world, on the one hand, and the great body of the American people, on the other." [43]

Dr. Stratton, however, did not feel that these scattered investigations by the Bureau in a few of the public utilities were enough. Standards of service and safety applied to all the utilities, he told Redfield, the new Secretary of Commerce, and could best be provided by making the Bureau the central "place of reference and * * * clearing house for scientific and technical matters pertaining to the public utilities." [44]

The Secretary agreed, and with his support Stratton proposed to Congress a large-scale study covering the public interest in all utilities, including gas, water, light and power, telephone, and street railways. It would include "the study of public relations questions, the preparation of specifications regarding the quality of service, methods of testing and inspection employed by municipalities and commissions, safety rules for use by the utility companies to safeguard their employees and the public, and the collection and distribution of information by published papers and through correspondence." [45]

With little debate, Congress in 1914 appropriated a special fund of $25,000 for the investigation of public utility standards. (By 1920 the annual appropriation exceeded $100,000 and continued at that level into the 1930's.) To allay the misapprehensions and continuing hostility of the utilities, the Bureau in articles, talks, and through friendly editors assured industry that its work was "not inquisitorial * * * but is thoroughly scientific, being handled by impartial engineers concerned only in the study of economic problems." [46]

With its congressional appropriation and, by inference, the directive to proceed, the Bureau began the preparation of a circular (4 years after that for the gas industry) on uniform standards for electric service. Thirty-three States and the District of Columbia, in many cases with the help of the Bureau, had already enacted laws regulating electrical service to some degree or another; evidence, said the Bureau circular, that "it is now generally recognized that the supply of electrical service is a natural monopoly and should be regulated." The standards proposed, the circular

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[43] Senator Root, quoted in Rosa's article, "The function of research in the regulation of natural monopolies," Science, 37, 579 (1913).

[44] See letter, SWS to Director, Department of Public Works, Philadelphia, Dec. 9, 1913 (NBS Box 4, AGC).

[45] NBS Annual Report 1915, p. 60; SWS letter of Mar. 10, 1914, inserted in Hearings * * * 1915 (Jan. 27, 1914), pp. 977–980.

[46] Herbert T. Wade, "The NBS and standards for public utilities," Eng. Mag. 49, 240 (1915). Wade was science and technology editor for the New International Encyclopedia and author of many books and articles on weights and measures, the metric system, electricity, and popular science.

explained, were principally to unify existing laws and regulations, to ensure the adequacy and safety of electrical service, and to establish procedures for inspection laboratories set up by the State commissions.[47]

Still educating the public and the utilities, another circular issued in 1917 described the scope of Bureau investigations on behalf of the utilities, its gas and electric work, gas analysis studies, the progress made in gaining acceptance of the national electrical safety code, its work on electrolysis, and its railroad investigations. All these were to continue and be extended as new problems arose, while in the planning stage were a gas safety code and circulars on street lighting and on telephone service and apparatus.[48]

The Bureau was well on the way to becoming the clearinghouse Dr. Stratton intended, its investigations springing from the need of the utilities to avoid long-drawn out or expensive litigation, or unfair and inconsistent regulation by local authority. As a spokesman for the Bureau said, it assembled facts in field and laboratory studies and reduced them to standard practices, "which may be adopted or not as those concerned may elect, and the published record of which will be available to all." [49] Held temporarily in check by the war, by 1920 special appropriations to the Bureau for public utility standards were exceeded only by those for industrial research, the testing of structural materials, and the testing of Government materials.

TESTING GOVERNMENT MATERIALS

While electrical, optical, pyrometrical and other fundamental measurement work at the Bureau grew steadily in the years prior to the war, structural and miscellaneous materials research and testing and calibration soared. In the period 1911–17 the volume of testing work at the Bureau almost tripled, with engineering, structural and miscellaneous materials tests alone rising from 38 percent to 84 percent of the total.[50] The establishment of a General Supply Committee in the Treasury Department in 1910, encouraging purchase by specification and standardization of miscellaneous supplies bought for the

[47] NBS C56, "Standards for electric service" (1916, 2d ed., 1923).

[48] NBS C68, "Public utility service standards of quality and safety" (1917). Of the circulars projected, only that on standards of telephone service later appeared in a new publication, as NBS C112 (1921).

[49] Wade, "The NBS and standards for public utilities."

[50] In the fiscal year 1910–11, approximately 62 percent of the 80,100 tests and calibrations carried out in the Bureau laboratories were in weights and measures, temperature, optics, photometry, and chemistry, the remaining 38 percent in engineering, structural, and miscellaneous materials. By 1916, less than 16 percent of the year's total of 217,400 tests and calibrations were in basic measurements; all else comprised physical and mechanical tests of materials. In 1917, as the Bureau shifted to wartime research, the number declined to 155,800, still almost 80 percent in materials. See NBS Annual Reports 1911–17.

Government, sharply increased Bureau testing. The transfer to the Bureau of the Geological Survey materials program occurred less than a month later. The two events coincided with a Government building boom just getting under way, and Dr. Stratton with his enormous interest in the artifacts of commerce saw for the Bureau an opportunity for research in the widest sense, in the instruments, materials, and products of American industry.

The principal structural materials that the Bureau began testing were cement, clays, lime, structural iron and steel, and protective coatings. Miscellaneous materials included Government housekeeping items ranging from rubberbands and rubber belting to paper, ink, paints, textiles, and cordage. Initially limited to the determination of their physical, chemical, and mechanical properties, the tests soon raised problems of their manufacture and performance, requiring full scale investigations. What began as simple testing solely for the information of Government agencies in many instances became programs of product research, necessitating close cooperation with the industries and trade associations involved.

While not entirely representative of the development in each of the materials investigated, a brief account of the Bureau's work on cement is illustrative.

In 1911 the cement laboratories of the Bureau tested over 23,900 samples, representing almost 2½ million barrels of cement purchased for Government construction projects. The sampling required 521,000 physical tests, for fineness, specific gravity, tensile strength, and time of setting. These tests did little more than determine whether the samples met current Government specifications. In many instances the specifications were far from clear or consistent, and nowhere did the Bureau find any two Government agencies purchasing cement upon the same specifications.

Early in 1912 the Bureau called manufacturers and Federal engineers to the first Portland Cement Conference, in order to consider preparation of a single standard specification. As a result, a Presidental Executive order was issued on April 30, 1912, declaring that all portland cement purchased by the Government was to conform to the specification agreed upon. Four years passed before final concurrence was reached and an acceptable specification was adopted by the principals, the American Society for Testing Materials and the American Society of Civil Engineers.[51]

Even the most elementary of physical and chemical tests of cement disclosed the inadequacy or imprecision of many procedures and instruments in common use in the industry, and the test sections and the engineering group at the Bureau set to work developing better test methods and

[51] NBS C33, "U.S. Government specifications for portland cement" (1912); letter, Secretary of Commerce to Engineer Commissioner, Washington, D.C., Dec. 26, 1916 (NBS Box 15, IRC).

equipment. Under Stratton, the lines of research at the Bureau were far from rigid, and he worked hard to keep them from becoming so. Afternoons he toured the laboratories inquiring about the work in each, beginning his tour the next day where he had left off the previous afternoon. In this way he carried ideas and problems from one division to another. Thus it was that Dr. Wilmer Souder, in the weights and measures division, hearing of the extreme difficulty with cement sieve measurements, became interested and devised new 100- and 200-line ruled scales for testing and certifying the sieves used by the cement industry.[52]

Improved test procedures and instruments disclosed the need for better understanding of the constitution and characteristics of cement materials, and as testing became routine, the Bureau extended its investigations. A petrographic laboratory set up at Pittsburgh studied the raw materials of cement, and an experimental cement plant with grinding apparatus and rotary kilns made it possible to determine changes in cement properties by various methods of manufacture. Next, Bureau staff members developed a granulometric analyzer and separator, to study fine grinding of cement. Before long the test principles and equipment developed for cement were being applied to other building materials, to sands and silica cements, concretes and concrete aggregates, mortars and plasters, stucco, marls, stones, and paving blocks.

Meanwhile, engineers at the Bureau subjected blocks of concrete and full-scale concrete columns to compression and tensile strength tests. The group at Atlantic City, investigating the action of sea water on cements, mortars, and concretes, established a second exposure station at Charleston, S.C. At Pittsburgh and Washington studies were made of the effect of alkali salts on cement, of temperature on its hardening, of the permeability of cement to water, and its resistance to heat, moisture, and pressure. The steady stream of reports announcing the results of these investigations brought inquiries from architects, engineers, contractors, and builders for still other tests and investigations that they were not equipped to make, and from the general public, for help with cement problems in and around the home.

Much the same pattern of development, from simple testing of Government purchases to devising test procedures, new instrumentation, and finally to the establishment of a full-fledged technological research program in the product, occurred in other materials used in large quantities by Government agencies—in clays and clay products including brick, building tile, porcelain, terra cotta, fire clay, glass, and white-ware china; in lime, lime mortar, and gypsum; protective coatings such as asphalt, felt, paints, oils,

[52] NBS C39, "Specifications for and measurement of standard sieves" (1912); correspondence in NBS Box 19, IWL; interview with Dr. Souder, Jan. 16, 1961.

and varnishes; lubricating oils; rubber and rubber materials, papers of all kinds, textiles and fibers, rope and cordage, and leather and leather goods.[53]

Gradually a procedure evolved to bring the Bureau's testing program into closer association with the industries making these materials. At an early stage in each investigation, manufacturers' representatives, laboratory personnel, and industrial engineers were invited to the Bureau to discuss their problems. To assure as wide cooperation as possible, the Bureau held conferences with industrial associations, technical societies, and educational institutions concerned with the materials investigated by the Bureau. And research that started with establishment of a specification before long enabled the Bureau to suggest better materials or methods in the manufacture of the product, improved quality control, new uses for the product, and even utilization of waste materials.

The Government testing program that began with a batch of incandescent lamps in 1904 achieved its main outlines by World War I. Almost three-quarters of the work of the chemical division was in materials testing and research. Dr. Stratton, in addition to heading the optical group, had taken over the new engineering research division, to supervise personally the construction of special test apparatus and to study and test instruments, devices, or machinery of interest to the Bureau but outside the province of its scientific divisions.[54] And out of the testing of structural iron and steel came another new division, for research in metallurgy, under Dr. George K. Burgess.

In charge of high temperature investigations since 1903, Dr. Burgess had done notable work in optical pyrometry, high temperature platinum resistance thermometry, determination of melting points of pure metals, and with Dr. Waidner, chief of the heat division, had proposed a theoretical absolute standard of brightness that was destined to be realized experimentally two decades later. Meanwhile, the testing of engineering instruments, metals, and metal materials—from alloy wire and flexible copper hose to car couplers, boilers, and girders—to see that they met Government specifications, had led the Bureau into the chemistry of metals, into studies of their electrical, magnetic, and mechanical properties, and into the field of stress measurement. Frequently consulted on these tests, Burgess became especially interested in the properties of metals at high temperatures and in the working of metals in foundry processes. Despite the fact that iron and steel was the industrial giant of America and its metallurgical processes were carried out with great technological virtuosity, Burgess found a distressing lack of application of scientific principles.[55]

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[53] See NBS C45, "The testing of materials" (1913).

[54] NBS Annual Report 1914, p. 15

[55] Burgess, "Metallography and metallurgy at the Bureau of Standards," Met. & Chem. Eng. 10, 1 (1912).

In 1911, at the suggestion of Henry M. Howe, professor of metallurgy at Columbia University and a recently appointed member of the Visiting Committee to the Bureau, Burgess undertook the determination of the critical points on their heating and cooling curves of a number of special steels. As the investigation continued, Burgess won Dr. Stratton to his proposed plan for a long-range investigation of basic physical metallurgy. In 1913, as the investigation of rail and wheel failures for the Nation's railroads began, his metallurgy section in the heat division was raised to divisional status.[56]

An allied field even more empirically operated at that time than metallurgy was that of electrodeposition, the deposition by electrolysis of metallic coatings on a variety of materials. As electrotyping, it was widely used to produce facsimile plates of metal type from a wax impression. Electroforming was employed in the phonograph industry to make master plates and molds to produce recording discs. Electroplating coated metals to improve their appearance and protect them against corrosion.

In 1913 the Government Printing Office asked the Bureau for help with their electrotyping baths. A young man in the chemistry division, Dr. William Blum, who had been preparing standard samples since his arrival at the Bureau in 1909, was sent to see what he could do. The GPO, he found, had no method for controlling the composition of the bath, and there was little or nothing in print on the subject. His calculations for restoring the sulfuric acid content of the solution as it was used up in the plating process solved the difficulty, and Blum's career in electrodeposition began.[57]

Blum's work on the structure of electrodeposits, on current distribution and throwing power in solutions, on pH control of the baths, and on alloy deposition was among the first scientific studies in this country to supplant the hit-or-miss information upon which the industry rested. His introduction in 1921 of electrolytic reproduction of plates used in printing currency at the Bureau of Engraving and Printing replaced the hand method of rolling into case-hardened soft steel, which was capable of approximately 70,000 impressions at best, while electrolytic plates with a chromium surface that could be recoated permitted as many as a million impressions. He directed electrodeposition research at the Bureau for over 30 years.

Not all Bureau work with metals was to be as rewarding as that in Burgess's division or in Blum's section. One such instance was the ingenious instrument developed during the early work on metals, a new type of permeameter, devised in 1909 by Dr. Charles W. Burrows of the magnetic

[56] Bureau Announcement No. 28, July 1, 1913 (NBS Box 3, AG).

[57] NBS C52, "Regulation of electrotyping solutions" (1915, 2d ed., 1916); Hearings * * * 1918 (Dec. 1, 1916), p. 483; interview with Dr. Blum, Oct. 15, 1963.

section, from an idea supplied by Rosa. For several years Burrows' permeameter became the standard instrument for determining the magetic properties of irons and steels, and was used in the preparation of magnetic standard bars which the Bureau sold as standard samples to manufacturers of electrical equipment.[58]

Elated by early results with the permeameter, Burrows became convinced that a close correlation existed between the magnetic and mechanical properties of materials and went on to develop magnetic test equipment which he was certain had great promise. The iron and steel industry had long sought a simple and effective means for detecting flaws produced in metal during the manufacturing process, as in rifle barrels and prison bars, in steel beams and track rails, to avoid the slow and costly destruction tests otherwise necessary.

During the Bureau investigation of railroad materials involved in derailments and wrecks, Burrows and his group worked to develop a magnetic method for quick determination of such flaws as the mysterious transverse fissures found in steel rails. So promising did the first tests appear that the Bureau reported the method might "possibly become commercially feasible." [59] In 1918, with special apparatus he constructed incorporating his permeameter, Burrows left the Bureau to set up a magnetic analysis firm to do this kind of testing.

Subsequently, other workers at the Bureau found that magnetic and mechanical properties in metals showed little true correlation, and as a result the Bureau abandoned its magnetic standard sample work. For almost a decade the Bureau continued its efforts to develop magnetic tests for proving metals. Except in the case of soft steel and small metal objects the tests in most instances were inconclusive. So, to his disappointment, were Burrows' private efforts, and his firm folded with his death in 1925. Continuing research at the Bureau indicated that with the permeameter it was "not possible to realize any units of magnetic quantity in concrete form," and that it was "only by the greatest care in the selection of test specimens and manipulation of testing apparatus that an accuracy of 1 percent can be attained." [60]

Although this early work on the magnetic properties of metals—a phase of Bureau research in the physical constants—led to largely negative results, some of the most successful work on the determination of physical constants was soon after to be done in the temperature laboratories of the

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[58] NBS C17, "Magnetic testing" (1909).

[59] NBS Annual Report 1915, p. 50; Annual Report 1917, pp. 52–54; Hearings * * * 1920 (Dec. 12, 1918), p. 955.

[60] NBS C17 (4th ed., 1926), p.. 22, and repeated in its sucessors, C415 (1937), and C456 (1946).

Bureau, particularly that on the temperature scale and on refrigeration constants.

In 1909 the American Society of Refrigerating Engineers, in search of physical data for more efficient refrigeration, asked the Bureau to determine the specific heats of several calcium chloride brines. Upon completion of the work several years passed while the heat division which had made the study went on with investigations in the constants of gases for the use of gas engineers, in heats of combustion, its preparation of standard combustion samples, and its experiments preliminary to establishing new fixed points on the standard temperature scale maintained by the Bureau.

Then in 1913, at the request of the refrigeration industry, Congress appropriated the sum of $15,000 for an investigation of the physical constants involved in the construction and operation of large-scale refrigeration machinery, such as that used in meat-packing and other cold storage plants and in refrigerated cars. Under Dr. Hobart C. Dickinson, D. R. Harper 3d, and N. S. Osborne, studies were made of such fundamental constants as the specific heat of ice, the specific and latent heats of the liquids and vapors used in refrigeration, and their density and pressure-temperature relations. Engineering aspects of the investigation included the study of insulating and other materials used in the construction of large-scale refrigeration structures. It was, Stratton reported to Congress, "a splendid piece of work" and a distinct contribution in the field of physical constants.[61] By 1918, when most of the original staff was diverted to military research, the basic investigation had been completed and the accumulated data were reported to the industry. The chemistry division took over certain portions of the work as a long-term project.

A year after the study of refrigeration constants began, Congress authorized an appropriation for another special investigation, a study of fire-resistant properties of building materials. Fires were claiming thousands of lives annually in this country, with property losses exceeding $250 million—10 times the rate of any country in Europe. Particularly baffling to many, in the series of disastrous fires that struck American cities around the turn of the century, was the fact that skyscrapers and lesser structures purported to be fireproof often burned out as completely as the older buildings. It was an investigation long overdue.

Upon surveying city building regulations, Bureau engineers found them "full of the most absurd data regulating the properties of materials." [62]

[61] Hearings * * * 1919 (Jan. 25, 1918), p. 979; letter, SWS to Secretary of Commerce, May 31, 1922 (NBS Box 17, ITH).

[62] [Senate] Hearings * * * 1913 (May 22, 1912), p. 236. Stratton also noted that "The greatest [fire] losses are in the cities having fire laws and regulations" (Hearings * * * 1913, Feb. 10, 1912, p. 759).

In many of the codes it was assumed that brick, mortar, plaster, cement, and metals were uniformly fire resistant. No distinction was made between the various kinds and compositions of bricks, cements, metals, and other materials. Rules for their use had been set up without any real knowledge of their melting points or their behavior at high temperatures, without any real knowledge of the stress and support limits of common building materials under attack by fire.

In a joint undertaking with the National Fire Protection Association and the Underwriters' Laboratories, the Bureau aimed at a thorough study of the behavior and safety of building materials in various types of construction under all possible fire conditions. The study would furnish architects, builders, State and city building bureaus, and insurance interests with fundamental engineering data long needed but nowhere available. In nominal charge of the program was Simon H. Ingberg, born in Norway and trained in structural engineering in this country, who was with a midwestern construction company when the Bureau brought him to Washington to plan the investigation. Less than a year later a fire-resistance section was established in the heat division, with Ingberg in charge.

But so broad became the scope of the investigation that it soon involved almost every one of the scientific and engineering laboratories of the Bureau. It included high-temperature measurements, fire tests, and thermal conductivity studies by the heat division; solution of composition and construction problems by the chemistry and structural materials divisions; electrical wiring and safety code studies by the electrical division; and the behavior of structural materials under heat as a special study in the weights and measures division.[63]

Besides data furnished city and State authorities on the fire-resistant and heat-insulating properties of common building materials and those used in fire-resistive construction, on fire tests of building columns, wood and metal frame partitions and walls, the Bureau evolved a standard time-temperature curve which specified the furnace temperatures to which the elements of a structure became subject in any period of time up to 8 hours. Building materials and construction design were classified by their hours of ultimate fire resistance, making it possible to set up regulations that would insure building into any structure a reasonable degree of fire resistance.[64]

As the program developed, panel-testing furnaces were constructed and partial buildings, steel and concrete columns and numerous other structures were erected and destroyed in endless controlled tests. For years Bureau members in the project made hurried trips out of Washington to probe

[63] NBS Annual Report 1914, pp. 29–30.

[64] See BH14, "Recommended minimum requirements for fire resistance in buildings" (J. S. Taylor, 1931), summarizing more than a decade of research.

Fire-severity tests of buildings, deliberately made on abandoned structures in downtown Washington the 1920's. In the picture at left, the walls of a non-fire-resistive building began to bulge after 40 minutes. In the picture at right, a five-story and adjacent two-story structure, near the old Post Office Buildings, that were soon to be razed were loaded with typical office furniture, along with 30 types of office safes. Besides determining the progressive temperatures of the fire, observations were made on the destruction of the buildings and the effects of the fire on the structure and contents of the safes. The fire threatened to get out of control and local fire officials never again permitted such Bureau tests in a congested area.

in the debris of large city fires for additional data for their studies. Research and technological papers, handbooks and circulars recorded the results of the long-term investigation, and were reduced to rules and specifications in new and revised building and fire codes issued by city and State authorities and by fire insurance associations. Fire research continues in the building research division of the Bureau to the present day.

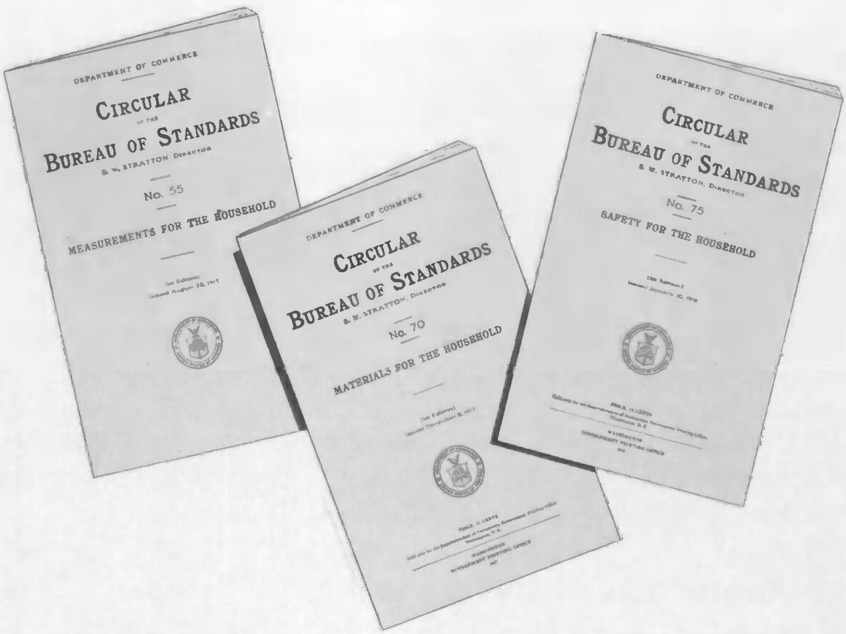
Bureau records suggest that in its second decade, despite more than a score of other research projects going on, three investigations were paramount, certainly in the eyes of the public, and of great interest to their Congressman at budget time. These were the weights and measures, public utility standards, and structural and miscellaneous materials programs. And it was the results of these investigations that were levied on for a remarkable series of circulars that came out just before the war, designed not for Federal or State agencies or for industry, but for the ordinary citizen, the ultimate consumer.

STANDARDS FOR THE CONSUMER

The publication of lamp specifications in Circular 13 in 1907—the first of its kind—raised a problem that long plagued the Bureau. The circular, available to the public for 10 cents, was a technical report, as were later circulars on textiles, inks, soaps, paper, paint, varnish, and other materials. It was filled with complex data and it made no mention of brand names. How then was the ordinary consumer to identify the lamps or other products tested by the Bureau without the laboratory apparatus described in the circular?

In England, the National Physical Laboratory, governed by the Royal Society, was largely supported by private funds, with only meager assistance from the British Government. It was therefore relatively independent, and free if it chose to make open recommendations of products it tested. The National Bureau of Standards, on the other hand, was an agency of the Federal Government. It had come into being at a time when business and industrial interests were synonymous with the national interest. Without power to enforce adoption of standards or specifications, the Bureau could only offer its technical findings to Government purchasing agencies and by making them public suggest that their adoption was in the best interests of industry.

Dr. Stratton insisted from the start that the Bureau must be free to make test results public, but in doing so the Bureau must show no bias. All products and materials tested had therefore to remain anonymous. Yet in hearings before Congress, Stratton made much of the fact that the test and



So great was the success of the first of the NBS "household" circulars with the American public that Secretary of Commerce Redfield wrote to Stratton: "I think the time is peculiarly fit now for the immediate publication of the book 'Materials in the Household.' I hope nothing will be allowed to delay it longer and that you may be able to tell me that it will appear within a very short time. It seems to me that it is wanted at this time more than ever before and at least as much as it will be wanted in the future." Letter, Aug. 22, 1917, NARG 40, Box 118, 67009/5.

research work of the Bureau for the Government was of equal service and value to the public. Through publication of the specifications of a Bureau standard, he said, "the public can see what should be allowed * * * and what should not." [65]

That the "public" he referred to was industry rather than the ordinary householder, and in some cases only the industry for whom the specifications were established, was evident from the nature of the Bureau reports. The circular on incandescent lamps, for example, specifically stated that "only those thoroughly instructed in the art of lamp manufacture and in the science of photometry should undertake to determine upon the acceptability of lamps under the terms of the specification." While of considerable use to organizations with laboratories possessing the apparatus and skills for

[65] Hearings * * * 1912 (Dec. 2, 1910), p. 261; Hearings * * * 1917 (Feb. 2, 1916), p. 974; Hearings * * * 1917 (Dec. 1, 1916), p 478.

making the same tests, the data of the circulars were of little use to the general public. [66]

Long concerned with this apparent impasse, the Bureau found a way around through a series of circulars specifically written for the general consumer. The first, Circular 55, on "Measurements for the household," appeared in 1915. The 149-page guide, based on data gathered during the weights and measures investigation, during the electric lamp and gas and electric service and appliance studies of the Bureau, was widely publicized in Edward Bok's Ladies' Home Journal and other publications and became the first best-seller among Bureau publications.[67]

Up to that time 200 to 300 copies of a Bureau publication was customary and few had exceeded 5,000 copies. Within 3 months 10,000 copies of Circular 55, at 45 cents each, were distributed, the Government Printing Office had in press a second, cheap paper edition of 8,000 copies, to sell at 15 cents, and the Bureau requested a third printing of another 10,000. With a further printing of 5,000 copies early in 1917, a total of 33,000 copies of Circular 55 were sold.[68]

It was the first work of its kind issued by a national laboratory, or indeed by any scientific agency, and it caused an immense stir. One British publication called it "a treatise on domestic science," the first to demonstrate "the place of science in practical affairs." [69] In simple language the circular described the operation of common household measuring appliances: scales and balances, gas, water, and electric meters, the thermometer, barometer, hydrometer, hygrometer, cooking measures, and household clocks.[70] The

[66] In testing for the Government, Stratton told Congress on another occasion, "we are compelled to establish standards of quality, methods of testing and proper specifications * * * which are given freely to the public and to industries, and that is worth tenfold what we save the Government in the purchase of materials" (Hearings * * * 1913, Feb. 10, 1912, p. 755). The ambiguity in the words "public" and "industries" are resolved if Stratton meant that as industry improved the products it sold to the Government, the public also received a better product.

[67] The most common household weights and measures in C55 were also reprinted on a "kitchen card" and issued as M39 in 1919. Requests for the card reached the half million mark within a year, but Bureau funds restricted the supply to a tenth of that number (NBS Annual Report 1920, p. 51). New editions of the card in 1920 and 1926 included a meter-inch conversion rule and a table of heights and weights of children.

[68] Memo, Director of Publications, Department of Commerce, for Secretary of Commerce, Feb. 16, 1916 (NARG 40, Office of the Secretary of Commere, File 67009/48); Director of Publications, Annual Reports, 1916–17.

[69] Editorial, "The American state and household science," Nature, Feb. 17, 1916. See also Herbert T. Wade, "Efficiency in the household," Sci. Am. 113, 448 (1915).

[70] C55 seems to have assumed that every household had a hydrometer and hygrometer, or ought to have, but it is not likely that even the hydrometer became a kitchen staple until the rise of home brewing during Prohibition.

succeeding chapters explained how to use these in household operations and in planning and buying for the house.

Although no firm names, no trademarks or brand names appeared in the circular, in many instances the Bureau left little doubt of the product involved. A notable example appeared in the section on causes of high bills for electricity wherein the Bureau questioned the quality of some of the electrical lamps then on the market. There was reason to raise the question.

It had come as no surprise to the Bureau when in 1911 General Electric and 33 other companies manufacturing and marketing lamps under GE patents were accused in a Federal antitrust suit of price fixing. The Federal courts ordered General Electric's National Electric Lamp Association (NELA) dissolved, but were less successful in restraining General Electric from "bringing pressure to bear in order to market types of lamps lacking any legitimate demand." This referred particularly to the GE-metalized (GEM) lamp which General Electric, supplying both the lamp and, indirectly, its electric power, continued to manufacture profitably by the millions.[71] The Bureau circular on lamp specifications had drawn attention to the inferiority of this old-fashioned carbon-filament lamp over tungsten, especially after Coolidge's development of ductile tungsten in 1911 and Langmuir's use of a gas-filled bulb in 1913 resulted in lamps with 14 times the efficiency and 13 times the light per watt of the early carbon lamps.

Though the name "GEM" did not appear in "Measurements for the household," what this particular lamp meant to the consumer was clearly spelled out: "The tungsten lamp has been improved in quality and reduced in price to such an extent that no customer can afford to use carbon lamps, even if he were paid a bonus on each lamp for so doing. Many householders cling to the use of carbon lamps because they are usually supplied free." [72] It was true. Anyone could get GEM lamps for nothing, and for a good reason: the GEM lamp used almost three times as much electric current as the tungsten Mazda lamp for equal light values.

As Rosa explained, when tungsten lamps were first introduced, the electric power companies, fearing loss of revenue, began the practice of giving away or exchanging burned out GEM carbon lamps and even tungsten lamps of 100 watts or more in order to maintain high power consumption. The public gladly accepted them. Neither Federal frowns nor Bureau exposure of these lamps won the public away from them or reduced their high rate of manufacture. As late as 1917, Secretary of Commerce Redfield told Dr.

[71] John W. Hammond, Men and Volts: The Story of General Electric (New York: Lippincott, 1941), pp. 335-336, 342, 388-389.

[72] NBS C55, p. 84. The warning was repeated in NBS C56, "Standards for electric service" (1916), p. 157.

Stratton that when he moved into his new home he had to replace 74 GEM lamps with Mazdas.[73]

The second Bureau publication designed "to make scientific results available for those with little or no technical training" was Circular 70, a heavy 259-page manual on "Materials for the household," of which 15,000 copies were sold in 1917, the year it came out. It was an excellent summary in simple terms of Bureau testing results in engineering, structural, and miscellaneous materials, with chapters on structural materials in the home, flexible materials (rubber, leather, etc.), stationery, cleansing agents and preservatives, fuels, illuminants, and lubricants, and a final chapter on "Quantity in purchase and use of materials."

In style and contents Circular 70 anticipated by many years the appearance of such publications as Consumer Reports and Consumer Bulletin, and had as in its declared purposes to stimulate intelligent interest in household materials, to explain the nature of their desirable properties, aid in their selection, and promote their effective use and preservation. The circular admitted that few standards of quality existed in the market as yet, and where possible it offered simple home tests of materials, such as the use of a spring balance to test the strength of thread. If home tests were not possible, the Bureau could only recommend that householders "buy of local reliable dealers, as learned from common repute or experience." Sounding very like the voice of Stratton himself, the circular noted that buying well-known brands "may not be an economy, but it is some safeguard as to stability of quality. There is no certainty, however, that the quality will improve with the art." [74]

Neither the circular on "measurements" nor that on "materials" seems to have been revised for a second edition, perhaps because of the size of the printing in the first instance and the transitory nature of the subject matter in the second. More enduring was the third publication, Circular 75, "Safety in the household," which came out in 1918 (10,000 copies), was revised in 1932, and again in 1948.[75] If the inspiration of the first two

[73] Letter, Redfield to SWS, Mar. 16, 1917, and letter, Rosa to Redfield, Mar. 27, 1917 (NBS Box 8, IEL). Edward Bok told Stratton that after reading "Measurements for the household," he found and replaced 140 GEM lamps in his home (letter, SWS to Redfield, Jan. 15, 1916, NBS Box 21, PA).

The lure of the GEM lamp seems comparable to a present-day continuing phenomenon, the futile efforts of the Food and Drug Administration to warn the public against costly and useless food diets, drugs, and nostrums. The warnings in FDA and medical publications apparently reach no greater public than did the NBS circulars.

[74] NBS C70, p. 11.

[75] NBS C75 was superseded by C397 (1932) and C463 (1948). A consolidated edition of the three circulars appeared as "Measurements, materials, and safety for the household" in 1918. For further note of these circulars, see letter, SWS to Secretary of Commerce Hoover, Jan. 25, 1922 (NBS Box 21, PP).

circulars may be traced in some degree to the muckraking and reform movements of the period, the "safety" circular, as the introduction said, was prompted by the increase in hazards "in modern times from the service of gas and electricity and the use of such dangerous articles as matches, volatile oils, poisons, and the like."

Drawing on the mass of safety code data gathered by the electrical, chemistry, engineering, and materials divisions of the Bureau, the 127-page handbook on safety in the home covered electrical hazards, lightning hazards, gas, fire, and chemical hazards, and in a final chapter covered falls, cuts, scalds, burns and other miscellaneous accidents in the home.

Nothing since the Bureau's weights and measures crusade made so great an impression on the public as did the publication of these circulars, and for years the Bureau was identified in the public mind with testing of household materials and appliances and besieged with correspondence requesting personal help with home problems. Reported for the most part in specialized publications and periodicals, the work of the Bureau in electricity, in thermometry, photometry, calorimetry, radiometry, polarimetry, and spectroscopy, in metallurgy and in chemistry, was known only in scientific and technical circles. It came as a shock to Dr. Stratton when late in 1915 the Secretary of Commerce told him that Thomas Edison, unaware of the fundamental research carried on at the Bureau, had suggested that the Government establish such a laboratory.[76]

Four years later, better acquainted with the Bureau, Edison wrote saying that its recent publication, The Principles Underlying Radio Communications, was "the greatest book on this subject that I have ever read * * *. Usually, books on radio communication are fairly bristling with mathematics, and I am at a loss in trying to read them." [77] The early radio work at the Bureau introduced a large public to the scientific research of which it was capable.

RADIO, RADIUM, AND X RAYS

In the autumn of 1904 a young man came to the Bureau with a new book and an assignment in a new field of physics, neither of which aroused more than passing interest at the time. He was Dr. Louis W. Austin, an assistant professor of physics at Wisconsin who had spent the past 2 years as a guest worker at the Reichsanstalt in Berlin. Returning home by way of

[76] Personal letter, Secretary of Commerce to Secretary of the Navy, Oct. 11, 1915 (NBS Box 3, AG).

[77] Letter, Edison to SWS, Apr. 25, 1919 (NBS Box 4, AGC). He referred to Radio Pamphlet 40, prepared by the Bureau and issued by the Signal Corps in March 1919.

Cambridge, he picked up a book just issued by the university press, Ernest Rutherford's Radioactivity.

Rutherford's book was the first summary account of the experimental work of Roentgen, Becquerel, Thompson, Mme. Curie, and Rutherford himself in the decade following the discovery of radium and X rays. A young man in Rosa's division, Llewelyn G. Hoxton, given the book to discuss at one of the weekly meetings of the Bureau staff, recalls that when he sat down, Dr. Rosa came over and said, "Let me see that book!" But little in the book except the chapter on methods of measurement, describing the crude "electrical method" as the best then available for the quantitative determination of radiation and emanation, seems to have interested Rosa, for he returned the book the next morning.[78]

A second edition of Radioactivity, enlarged by the avid research abroad from 382 to 558 pages, appeared a year later, and Rutherford himself, who won the 1908 Nobel prize in chemistry for his work on alpha particles, visited the Bureau to lecture on radium and radioactivity not long after.[79] Such was the Bureau's introduction to the coming age of nuclear physics.

Dr. Austin himself was not particularly interested in radioactivity but in another kind of emanation and a still newer phenomenon, that of radio telegraphy or wireless, as it was called. Radio as we know it today was as yet remote, although in 1901, the same year that Marconi received his wireless signals across the Atlantic, Reginald A. Fessenden, recently appointed head of electrical engineering at the University of Pittsburgh but still then with the U.S. Weather Bureau, heard at a distance of a mile the first faint voice by electromagnetic waves over his wireless apparatus.[80] Six years later Lee de Forest invented his audion detector or three-element tube and applied it to the long-distance telephone. When used in 1912 to amplify a feeble audio-frequency current, modern radio was born.

Although experimentation continued, much of it in secrecy and attended by barbaric litigation, voice radio remained primitive, found no application on the battlefields of World War I, and was not developed commercially until the 1920's. For the first two decades of the century

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[78] Interview with Dr. L. G. Hoxton, Charlottesville, Va., Nov. 27–28, 1961 (NBS Historical File). Austin's copy of Radioactivity is in the NBS library.

[79] Dr. Hoxton recalls Rutherford's visit to the Bureau. No record of the visit has been found, but in his biography of Rutherford (Cambridge University Press, 1939, p. 129), A. S. Eve says: "About 1905 the world caught fire and radium was the vogue. * * * A great number of Universities and Societies poured in appeals to Rutherford to come and lecture to them about radium. He did what he could."

[80] Helen M. Fessenden, Fesseden: Builder of Tomorrows (New York: Coward-McCann, 1940), p. 81.

the problems still posed by long distance radiotelegraphy were sufficient to keep scientists and electrical engineers fully engaged looking for useful solutions.

Austin came to the Bureau as a guest worker to investigate the practical application of radiotelegraphy for the Navy, and from 1908 to 1932 headed the U.S. Naval Radiotelegraphic Laboratory at the Bureau (in 1923 renamed the Laboratory for Special Radio Transmission Research). Shortly after Austin's arrival, the U.S. Army Signal Service also requested space in the Bureau's electrical division, where their engineer, E. C. Cramm, investigated military applications of wireless.[81]

Not until 1911 did the Bureau itself enter the wireless field, when an engineer in one of the new commercial "electric signaling" companies sent in a wavemeter (frequency meter) for calibration. To set up a standard for this instrument was a problem in inductance and capacity, and the wavemeter was turned over to J. Howard Dellinger, who had come to the Bureau in 1907 from Western Reserve where he had been a physics instructor. He was then taking courses locally for his doctorate in physics, had become interested in the high frequency phenomena associated with radiotelegraphy and as a result was the acknowledged wireless "expert" at the Bureau. Soon Dellinger headed a new section in the electrical division called radio measurements.

Earlier that year a draft of regulations on the use of wireless as a safety aid in navigation, prepared by Prof. A. G. Webster of Clark University for a forthcoming London Wireless Conference, was submitted to the Bureau for review. Dellinger studied the paper and among other suggestions proposed that the word "wireless" everywhere in the text be changed to "radio," in keeping with its connotation of radiation. And "radio" rather than "wireless" became the accepted name in this country.

Bureau research in radio began in earnest with an investigation by Dellinger of ammeters used to measure the high frequency current in transmitting apparatus. As determined then, ammeter measurements were subject to considerable margin of error, and Dellinger's study resulted in a much needed heavy-current standard for radio frequencies. The work earned him his Princeton doctoral degree in 1913.[82]

No conflict of work existed in the several radio laboratories that had been set up at the Bureau, for Austin and Cramm were working on

[81] Letter, Chief Signal Officer to Secretary of War, Oct. 18, 1909, and attached correspondence (NBS Box 10, IEW). Although Cramm's tenure at the Bureau is uncertain, Austin headed the Navy laboratory at the Bureau until his death in 1932, publishing much of his research on radio signal intensities, long-wave transmission phenomena, atmospheric disturbances, and long-wave radio receiving measurements in Bureau publications. See Science, 76, 137 (1932).

[82] S206, "High-frequency ammeters" (Dellinger, 1913).

various means of generating and detecting low frequency (long distance) radio waves, while Dellinger concentrated on higher frequency waves, those used by experimental broadcast stations. Considerably later his investigations moved into still higher frequency wave ranges, where they became the short waves of long-distance transmission, and after that into very high frequencies, where he first confronted the problems whose challenge continues to the present day, those found in communication via outer space.

It was also in 1911 that Frederick A. Kolster was brought to the Bureau by Dr. Rosa to investigate some of the difficulties in radio engineering coming into the electrical division from industry. A former assistant in Lee de Forest's laboratory in New York, Kolster proved to be one of the most inventive mechanical geniuses ever to work at the Bureau. As his first assignment, he went to the Wireless Conference in London as technical adviser to Professor Webster.

.On the night of April 14, 1912, 2 months before the Conference, the White Star liner *Titanic,* on its maiden voyage, struck an iceberg 800 miles off the coast of Nova Scotia. The disaster disclosed how much an innovation maritime wireless was at that time. The scarcity of trained telegraphers often put ships' wireless in the hands of inexperienced operators who found signals hard to catch, were hampered by the necessity of having to relay their messages, and to send frequent repeats before their messages—most of them for passengers beguiled by the novelty—made sense on shore.

Four ships were within 60 miles of the *Titanic* when it sent out its first call for help. All at various times that day had warned the *Titanic* of the ice fields in the vicinity. One, the *Californian,* was less than 10 miles away when the CQD went out. But its wireless operator, rebuffed earlier by the operator on the *Titanic* for interfering with private messages going ashore, had shut down for the night. Of the others, only the Cunard liner *Carpathia* 58 miles away, dared to chance the ice field in which the *Titanic* lay sinking. When it arrived a bare handful of lifeboats and rafts drifted in the area where the *Titanic* had foundered more than hour before.[83]

Shocked by the disaster but ignorant of the catalog of human errors that had caused it, the Wireless Conference meeting in London gave its attention to the technical aspects of radio it had met to resolve. Of the two wavelengths then used by international maritime wireless, the Conference agreed that the 600-meter wavelength be restricted to the use of ships at sea. It also agreed that in order to reduce interference from the spark transmitters on ocean liners, the decrement or rate of decay of the waves emitted by the transmitting antenna should not exceed the log 0.2.

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[83] Walter Lord, A Night to Remember (New York: Henry Holt, 1955), pp. 36–38, 171–172; Logan Marshall, Sinking of the Titanic . . . (New York: John C. Winston, 1912), p. 299.

The Conference ruling on interference became the second radio law enacted by the United States. (The first, in 1910, had called for installation of radio apparatus on all steamers, foreign and domestic, operating out of American ports.)[84] Congress, aroused to the importance of radio, also called for more efficient radiotelegraphic service, restriction on the free use of wavelengths, and the licensing of commercial and amateur radio stations. Commerce's Bureau of Navigation, made responsible for these matters, called on the Bureau of Standards to investigate the bases for establishing the laws asked for by Congress, including better radio equipment, test procedures, and standards.[85]

Congress turned over enforcement of the interference ruling to the Bureau of Navigation, and at its request Kolster was assigned to devise a portable measuring instrument for this purpose, to be used by ship radio inspectors. The decremeter he designed, measuring wavelength as well as decrement, was at once adopted by the Bureau of Navigation and by the War and Navy Departments.[86]

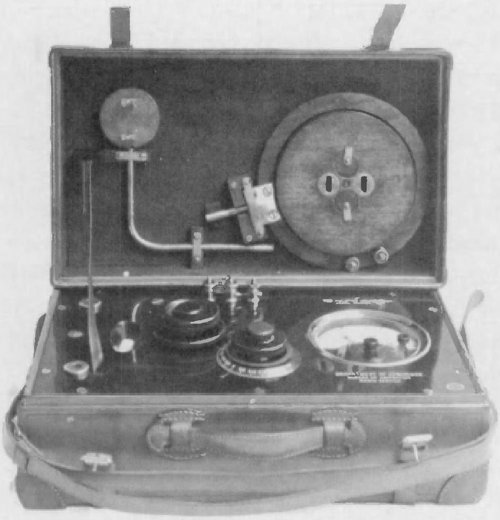
The Bureau of Navigation also called for a radio beacon system to aid ship navigation in fog and rough weather. Between 1913 and 1915 Kolster developed an improved radio direction finder or radio compass—the forerunner of modern aviation instrument landing systems—that enabled a ship to establish its position by determining with high accuracy the direction of sending station signals.[87] But it took more than twice as long to put the new direction finder into operation as to design it. The Bureau of Lighthouses proved reluctant to use scarce funds to install beacon stations along the shore until ships were equipped, and ship captains, traditionally conservative, refused to have all that machinery—and electrical, at that—cluttering up their ships.

[84] Commerce's Bureau of Navigation C211 (1910) announced that after July 1, 1911, by the Radio Act of June 24, 1910, it became unlawful for any ocean-going passenger steamers to sail without radio communication apparatus. After the *Titanic*, the Radio Act was amended to require two operators, instead of one, on constant watch; an auxiliary power source; and extended the act to include cargo ships. See correspondence with NBS and copy of the act in NBS Box 10, IEW; also Paul Schubert, The Electric Word: the Rise of Radio (New York: Macmillan, 1928), pp. 63–65.

[85] Earlier, in the summer of 1912, Waidner and Dickinson of the Bureau's heat division, aboard Navy patrol boats, investigated methods of detecting the proximity of icebergs. Most promising seemed temperature variations, but they proved as great far removed from icebergs as near them. NBS Annual Report 1914, p. 28, and S210 (1914). Later a salinity meter was developed for the International Ice Patrol to locate icebergs and reported in RP223 (Wenner, Smith, and Soule, 1930).

[86] NBS Annual Report 1914, p. 35; S235, "A direct-reading instrument for measuring * * * decrement" (Kolster, 1915); correspondence in NBS Box 10, IEW.

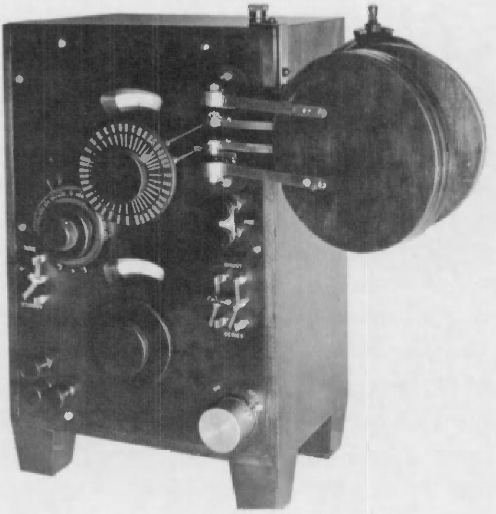
[87] NBS Annual Report 1916, p. 56; S428, "The radio direction finder * * *" (Kolster and Dunmore, 1922). The original direction finder was the invention of two Italians, Bellini and Tosi, in 1907. See Schubert, pp. 139, 154.



The Kolster decremeter for measuring wavelength and decrement was developed between 1912 and 1914 for the use of the Department of Commerce's Bureau of Navigation and for the armed services.

An early radio receiving set constructed by the Bureau, designed, along with a separate transmitter, for use on ships of the Lighthouse Service, Bureau of Navigation, and the Coast and Geodetic Survey.

It was a closed-circuit type of receiver using a variable condenser of the decremeter type and with a crystal detector connected across the condenser. This particular set served as a wavemeter and decremeter as well as radio receiver.



It was 1919 before the impasse was resolved and the direction finder was successfully demonstrated and officially approved. Soon after, Kolster left the Bureau to set up a company to manufacture his radio compasses. When success eluded him, he turned to the development of radio receiving sets. The radio boom was on, he was hired away by industry, and his inventive genius was exploited, but he got none of the millions made through his work or from the Kolster Radio Corp. set up to trade on his name. He died "a magnificent failure," as he called himself, in 1950.[88]

Until 1917 the electrical work of the Bureau centered around the power industry. There was almost no research in wire telephony or telegraphy, radio research was just beginning, and except for Kolster's radio direction finder, Bureau efforts were concentrated on more precise determinations of the laws and physical quantities involved in radio apparatus, in trying to maintain and improve measurements and standards, and supplying basic information.[89] Nevertheless, some tests and calibrations had been made of available radio apparatus, of circuit components, of various kinds of detectors (electrolytic, Fleming valve, audion), and of the new continuous-wave techniques that were coming in with radiotelephony, putting an end to damped-wave (spark) transmission. For use with Kolster's direction finder, the radio section had devised an automatic device that sent out a characteristic signal once every minute, to guide incoming ships in fog. Unable as yet to obtain specialized equipment from industry, the laboratories also built and installed a number of radiotelegraphic units on Coast Survey steamers and tenders of the Bureau of Lighthouses, enabling the latter to maintain communication between lighthouses and ships at sea.[90]

The Bureau received its first special appropriation for radio research from Congress, the sum of $10,000 "for the investigation and standardization of methods and instruments employed in radio communication," in 1915. A year later Congress appropriated $50,000 for the construction of a radio laboratory building, a two-story structure erected south of the electrical laboratory, with two 150-foot antenna towers adjacent to the laboratory. The ensuing pioneer work in radio at the Bureau was to prove its worth when war came.

Radio and radioactivity, as previously noted, arrived at the Bureau on the same day in 1911, but laboratory interest in radium and radiation, phenomena actually far removed from radio, did not begin until late in 1913. It may well have been the use of electrical methods for the measurement of radioactive quantities that made it seem logical to establish this work in Rosa's division. Or it may have been, as Dr. N. Ernest Dorsey said, that the disintegration hypothesis promulgated by Rutherford, together with his conjectures on the structure of the atom and the phenomena associated with radioactivity, were all "bound up with our ideas of electricity."[91]

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[88] Letter, Lloyd Espenschied, Bell Telephone Laboratories, to A. V. Astin, Feb. 18, 1954, and attached correspondence on early radio at NBS (NBS Historical File).

[89] George C. Southworth, Forty Years of Radio Research (New York: Gordon and Breach, 1962), p. 32.

[90] NBS Annual Report 1916, pp. 55–56.

[91] Dorsey, Physics of Radioactivity (Baltimore: Williams and Williams, 1921), p. 33.

Kolster's wireless laboratory in East building in 1916, showing models of the decremeter on the left, and in the center, an early radio receiving set. The overhead wiring was the beginning of the intricate webs that were spun with the passing of time in most of the electrical laboratories of East building.

That the two somehow seemed related is evident from Dr. Stratton's frequent use of the portmanteau phrase "radio telegraphy and radio activity." [92]

In Europe, where radium and radiation research had been carried on at fever pitch since the discoveries of Roentgen and Becquerel, a Congress of Radiology and Electricity met at Brussels in 1910 to survey recent progress and discuss the question of standards for radium research. A year later Mme. Curie prepared a carefully measured quantity of radium chloride sealed in a glass tube, based on the proportion of radium to the weight of the radium salts in the tube as measured by its gamma rays. This was accepted by the International Committee on Radium Standards, appointed by the Congress at Brussels, as the international standard and deposited in the International Bureau of Weights and Measures at Sèvres. Research in radium began at the Bureau of Standards in December 1913 when a phial containing 20.28 milligrams of pure radium arrived from abroad. A covering communication certified its equivalence to the International Radium Standard at Sèvres and described its comparison with another quantity of radium salts prepared at Vienna and accepted as a second standard.[93]

Dorsey, who came to the Bureau from Johns Hopkins in 1903 and for almost a decade worked under Rosa on electrical measurements, had followed with excitement the published accounts of radiation research. He became interested particularly in the applications of X rays and radium to medical diagnosis and treatment, then a craze sweeping the country and involving almost as many fakers as reputable physicians.

As early as 1896 Scientific American magazine described the construction of a fairly effective X-ray tube by connecting the carbon filaments of an incandescent lamp to an improvised high-voltage apparatus. These X-ray tubes, as well as fluoroscopic screens, soon became commercially available and doctors and technicians by the hundreds opened offices across the country to practice the new wonder on marveling patients. Pusey and Caldwell's The Practical Application of the Roentgen Rays in Therapeutics and Diagnosis (1903, reprinted in 1904) warned of certain radiation hazards to doctors and patients alike but the dangers were not yet clearly understood. As a result, efforts at protection from the rays tended to lapse after the first meager precautions.[94] X-ray and radium protection standards were not to come within the province of the Bureau until the late 1920's.

Learning of the international standard of radium in Washington, hospitals and physicians sent their radium salts to the Bureau for analysis, and

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[92] E.g., at Hearings * * * 1918 (Dec. 1, 1916), p. 465.

[93] Dorsey, Physics of Radioactivity, pp. 162–163.

[94] For the early history of medical radiology, see Percy Brown, American Martyrs to Science Through the Roentgen Rays (Springfield, Ill., and Baltimore, Md.: C. C. Thomas, 1936), pp. 144–145.

Dorsey became the radium specialist as he began making intercomparisons of sealed radium standards and started an investigation of the gamma-ray method of radium measurement. Soon Dorsey and his assistants were studying the properties of radioactive substances, the alpha-ray activity of powdered radium salts, of uranium mixtures, radium ores and radium emanations. In a few short months he, like all who were handling radium at that time, had burned the thumbs and the index and middle fingers on both his hands. By 1919, as a result of the amount of radium and luminescent materials containing radium handled during the war, he had developed typical "X-ray hands," characterized by ulcerative tissue, whitlows below the nails, pronounced lack of sensitivity of touch in the fingers, and extreme sensitivity to cold.[95]

Dr. Dorsey left the Bureau in 1920 and, away from radium, his hands though permanently scarred improved rapidly. His book, Physics of Radioactivity, based in part on a Bureau circular he began in 1915 and never completed, was prepared as a text for the medical profession and came out in 1921.[96] For almost a decade he practiced privately as a consultant physicist in radium. He returned to the Bureau in 1928 with independent status and until his retirement in 1943 carried out a number of research projects in physics and acted as advisory consultant to the radium and X-ray section of the optics division.[97]

"REVISING" THE ORGANIC ACT

The year 1913 was a milestone in the history of the Bureau, a time of reappraisal and redirection. Much of the testing of standards, measuring instruments, and materials was now "organized on an accurate routine basis and * * * handled with dispatch, through increased efficiency of appliances and methods of testing." [98] Fundamental research in the scientific divisions continued at a high level, but the principal energies of the Bureau were directed to investigations for the Federal and State governments, for in-

[95] Dorsey, Physics of Radioactivity, pp. 175–177.

[96] Announcements of the circular appeared in NBS Annual Reports 1915 and 1916.

[97] Dr. Dorsey, whose research for his book on "water substance" was conducted in that period, was the second of three workers given independent status at the Bureau, free from all administrative duties. The others were Dr. Edgar Buckingham, in 1923, to continue his work in theoretical thermodynamics, and Dr. Louis B. Tuckerman, in 1937, to carry out research in aeronautical mechanics. Memo, Hugh L. Dryden to Division N section chiefs, Dec. 20, 1937 (NBS Box 403, ID-Misc).

[98] NBS Annual Report 1913, p. 36.

dustry and the public utilities.[99] The Bureau had grown far beyond the confines of its organic act and in directions unforeseen.

Seemingly taking all knowledge for its province, the Bureau was currently engaged in over 200 different projects, its Baconian scope of research demanding an extraordinary spirit of cooperation. In his annual report that year Stratton said of this spirit that it alone "minimized the somewhat narrowing effects of a rigid division system. Each problem when studied in a broad scientific spirit leads into every specialty * * *." Cooperation had been "particularly notable in the development of standards for gas, in the researches upon metals, and the methods of testing the properties of materials, in the study of electrolysis experimentally in the field, in the structural materials investigation, and in many other cases where success depends upon many specialties." It had been most striking "in the gradual development of the public-service commission work of the Bureau. This is an outgrowth of the weights and measures activity of the Bureau, of the cooperation with the Interstate Commerce Commission, and with other regulative and inspection services, notably the wireless service, the regulation of navigation, municipal gas regulation, standardization of specifications for materials, and central-station power service * * * simply [applying] measurements and standards to new fields * * *. Such work is an extension of the general purpose of the Bureau as a whole, cooperation in all movements which have for their object increase in efficiency in all fields through measurements and standards." [100]

It was this "extension of the general purpose of the Bureau" that had resulted in its extraordinary growth. In a little more than a decade appropriations for the Bureau had risen from $32,000 to almost half a million dollars a year, with that much again appropriated in 1913 for a new electrical laboratory, additional land, and special test equipment. In addition to the field laboratory at Pittsburgh, three new divisions—engineering research, metallurgy, and structural and miscellaneous materials—had been added to the original five in Washington, and Bureau personnel had risen from 13 to more than 280, of whom at least 50 were high-grade physicists.

Congress sometimes worried about those physicists. Other agencies in the Government didn't seem to need them. "What is a physicist?" Mr. Leonidas F. Livingston of the House Appropriations Subcommittee asked. "I was asked on the floor of the House what in the name of common sense a physicist is, and I could not answer." [101] At a Senate hearing, Mr. Lee S.

[99] "The bureau is, to a certain extent, a clearing house for technical information * * * cooperating with all movements tending to improve conditions in which standards of quality or standards of measurement are involved." M18, "The National Bureau of Standards" (1911), p. 7.

[100] NBS Annual Report 1913, p. 3.

[101] Hearings * * * 1912 (Dec. 2, 1910), p. 263.

Overman of North Carolina wondered too: "You have here * * * [a request for] a physicist qualified in optics. I want to know what you do with that fellow. What is his business?" [102] Patiently, Dr. Stratton explained, and the physicists were his.

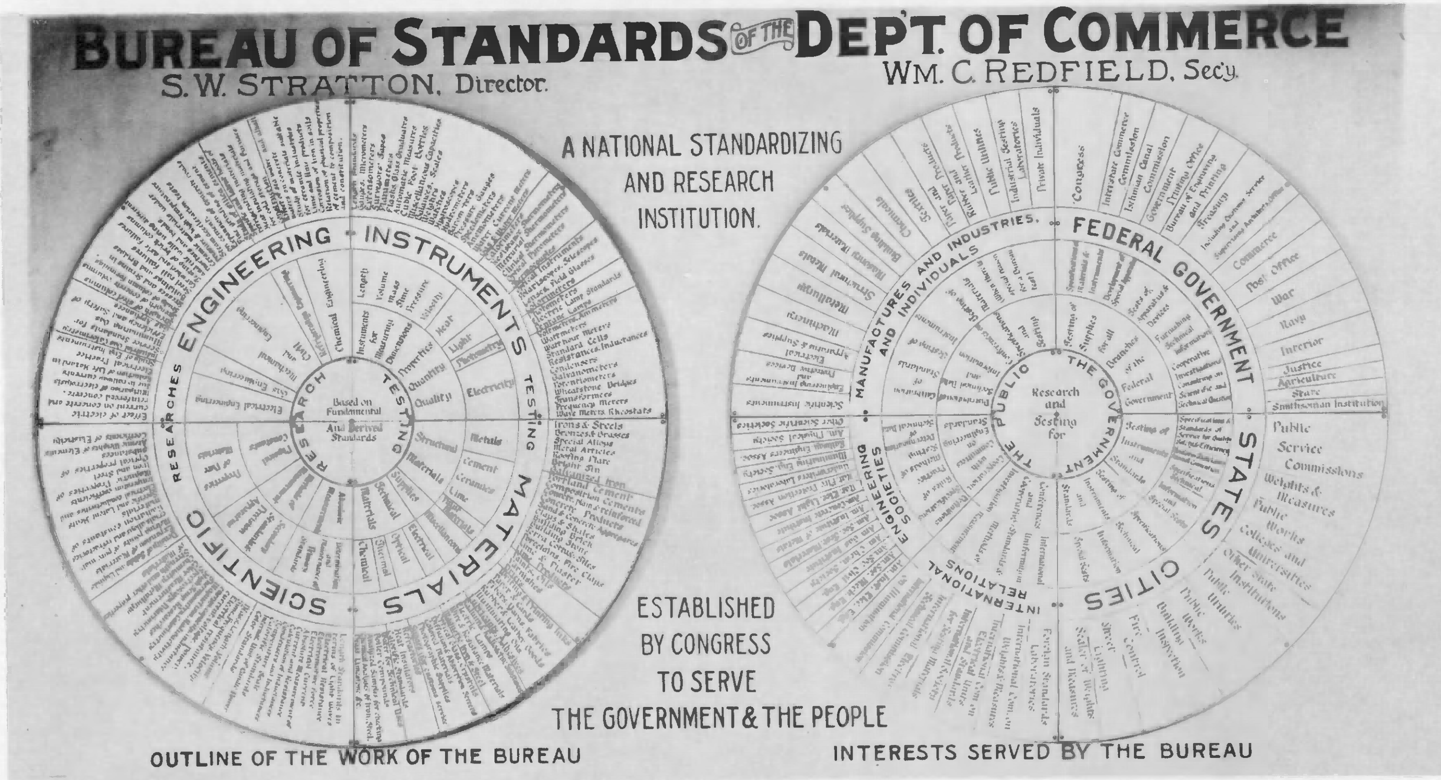
So well did Stratton get along with Congress that one of his admiring colleagues, sitting with him at the annual hearings, referred to him as "a scientific politician." Congressman Joseph T. Johnson of South Carolina marveled at Stratton's way with a committee, even when the subject was as minor as funds for grading the Bureau grounds. "Now, you have made a specially strong plea—in fact, you always make a strong plea and hypnotize this committee." [103]

Behind the pleas were results, and the kind that a business-minded Congress appreciated. Stratton poured out facts on the dollar-and-cents value of Government testing and the public benefits "from a financial standpoint" of Bureau research in public utility service. He had only to show that "we have never been able to keep up with 25 percent of the demands made on the Bureau," to say that never before had "the Bureau had so many demands for its cooperation in regard to industrial standards, in devising standard methods of measurement and test, and in researches involving precise measurement," for Congress to reach for its purse and add something more.[104]

The annual increases in Bureau staff, equipment, and funds were the envy of other research agencies in the Government. "As you know," Congressman Frank H. Gillett of the Appropriations Subcommittee once said to Stratton, "our liberality to this bureau is one of the things that is criticized somewhat, and [so] we should be glad to get * * * results." [105] And Stratton cited the weights and measures investigation and the testing of Government materials, now being done for almost 60 different bureaus representing every department of the Government, the success of which had led to the organization of the General Supply Committee and almost doubled the test work of the Bureau.

The proliferation of Bureau research interests under Stratton and Rosa had largely changed the mission of the Bureau envisioned in its organic act. Established to provide this country with a scientific basis for accurate measurements and a source of information regarding basic properties of materials determined by such measurements, the Bureau became involved almost at

[102] [Senate] Hearings * * * 1913 (May 22, 1912), p. 232.
[103] Hearings * * * 1916 (Nov. 28, 1914), p. 142.
[104] Hearings * * * 1912 (Dec. 2, 1910), p. 270; NBS Annual Report 1912, p. 3.
[105] Hearings * * * 1912, p. 262. On a later occasion, when asked by Congress how appropriated special funds were being spent, Stratton said that in most investigations from 75 to 80 percent went for staff, the remaining for materials and equipment (Hearings * * * 1921, Jan. 2, 1920, p. 1566).



The proliferation of Bureau interests, abetted by special congressional appropriations for investigations not covered in the Organic Act, inspired the wheeled chart of NBS activities. It was probably prepared for an appropriations hearing before Congress about 1915.

once in practical applications of these services to meet the needs of Government and industry. The resulting activities, nowhere referred to in the organic act, fell within the province of the Bureau only through broad interpretation of the clauses calling for "the solution of problems which arise in connection with standards" and "the determination of * * * properties of materials" (ignoring the qualifying clause in the latter case, "when such data are of great importance to scientific or manufacturing interests * * *").

The standards intended in the organic act were physical standards of measurement, but in the technological and engineering fields entered through Government testing, in the preparation of standard samples, and in structural and miscellaneous materials testing, "standards" had come to mean specifications of materials and codes of practice. Other research agencies in the Government began to question the broad interpretation of the Bureau act and its extended use of the term "standards," but not Congress, which found Bureau investigations highly productive of visible and tangible results.

The Bureau was further encouraged by the method adopted by Congress to expand Bureau activities—that is, by the appropriation of specific funds for special investigations.[106] This began in 1910 with the appropriations for the weights and measures crusade and the investigation of gas-light standards and continued thereafter, with special appropriations for one or more new projects almost annually, until 1936. By the thirties, grown to double the amount of direct appropriations by Congress, they had become administratively unwieldly. In 1936 all Bureau operations and activities funded by Congress were consolidated in four general categories: administration, testing, research and development, and standards for commerce.

With the first of the special appropriations the Bureau set up two categories of personnel, those engaged in fundamental research and routine work and paid from statutory funds, and those brought in for its special investigations and paid from specific appropriations. Although most of the special investigations went on for a decade or more, in some instances, as funds were withdrawn, those portions of the investigation that the Bureau thought ought to be permanent were transferred, with their staff, to the regular work of the Bureau. Thus the Bureau grew, but not without some friction.

It seems possible that it was criticism of certain of the Bureau research in this period that first alerted Stratton to a hazard in the latitude of research permitted in the wording of the organic act. In 1908 the Bureau of Chemistry in the Department of Agriculture had complained that the Bureau of Standards was duplicating work specifically delegated to Chemistry, including determination of the quality of volumetric apparatus, testing sugar

[106] The chart showing these special appropriations from 1910 to 1935 appears as app. G.

imports at the ports of entry, and chemical analysis of supplies furnished to Agriculture and other departments, in particular of paper and paper materials bought for the Government. Although Dr. Stratton pointed out that the Bureau's physical and chemical tests were to determine specifications of quality and design, improve the standards used in polariscopic work on sugar, and develop paper testing instruments and methods, while Chemistry's investigations were confined to the agricultural side of these problems, the Bureau of Chemistry continued to insist that "no part of the organic act establishing the National Bureau of Standards * * * warrants transfer of this kind of work * * * to the Bureau of Standards." [107]

As Bureau investigations expanded, so did the murmurs of Agriculture, that work "conducted by or projected by the Bureau" was duplicating that being done not only in its Bureau of Chemistry but in its Forestry Service, Bureau of Plant Industry, and Bureau of Animal Industry.[108] And when, at the request of the American Mining Congress, the Bureau made a study of standards for electrical machines and electrical practice in mines, Interior's Bureau of Mines saw it as an invasion of its domain, as it had the investigation of building stones and marls earlier. The Bureau acknowledged that "in spite of [its efforts] to avoid infringing upon the functions of other Bureaus * * * there has been a feeling in some quarters that the Bureau has enlarged its activities unduly." [109]

This problem of function was very much on Stratton's mind when late in 1912 the President's Commission on Economy and Efficiency sent out a questionnaire to all departments in the executive branch asking whether any changes in law pertaining to the organization and form of appropriations for their agencies were necessary for more efficient operation. Dr. Stratton expressed his entire satisfaction with the method of appropriations for the Bureau; his principal concern was over the continuing criticism:

> In view of the fact that the organic act establishing the Bureau has been somewhat misunderstood (generally by those bureaus claiming authority for the same class of work), I have sometimes

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[107] Letter, SWS to Secretary of Commerce and Labor, Feb. 15, 1908, and attached correspondence (NBS Box 4, AGA).

[108] Letter, Secretary of Agriculture to Secretary of Commerce, Apr. 28, 1913 (NARG 16, Records of Office of Secretary of Agriculture, sub: Duplication of work, 1913).

[109] Letter, Rosa to Secretary of Commerce, Oct. 2, 1913 (ibid.). The feeling possibly had some warrant, as is indicated later in a memo from P. H. Bates to Stratton, May 1, 1918 (NBS Box 2, AG): "With such active competition as we are now getting in the ceramic work from the Bureau of Mines, it is very essential that we be able to take up and actively push to completion all problems given to us."

thought that the organic act might be made more specific. On the other hand, this would be gained at the expense of flexibility.[110]

Unwilling to tamper with the basic act, Stratton suggested another way around the problem. Because of their national eminence and their connections, the Visiting Committee to the Bureau, then composed of Dr. Elihu Thomson, Dr. Robert S. Woodward, Prof. Henry M. Howe, Prof. Arthur G. Webster, and Prof. John F. Hayford, exerted considerable influence on behalf of the Bureau in high places, as well as on its operations. Stratton proposed to Secretary of Commerce and Labor Nagel that the Committee, presently made up largely of scientific men, be increased from 5 to 8 or 10, to include more representation for the new research interests of the Bureau: "It is highly desirable that the technological and industrial interests be also represented." [111]

Neither an increase in the Committee nor a change in the organic act proved necessary. What amounted to an amendment to the organic act was sufficient. On March 4, 1913 Congress passed an act (37 Stat. 945) that made the testing of industrial and commercial materials for the Government a specific function of the Bureau:

> Materials for fireproof buildings, other structural materials, and all materials, other than materials for paving and for fuel, purchased for and to be used by the government of the District of Columbia, when necessary in the judgment of the commissioners to be tested, shall be tested by the Bureau of Standards under the same condition as similar testing is required to be done for the United States Government.

In Dr. Stratton's view, this act for the benefit of the District of Columbia formally justified the materials testing and public service testing involving materials that the Bureau had been doing since 1904 for the Federal Government, its establishments in this country, in Panama, and in its oversea possessions.

That same month of 1913 the Wilson administration took office, the Department of Commerce and Labor was split in two, and William C. Redfield, soon to become a close friend of Dr. Stratton and one of the most ardent supporters the Bureau has ever had, was appointed the new Secretary of Commerce. Redfield at 55 had been in business and manufacturing most of his life, was vice president of an engineering firm, author of a recent book, The New Industrial Day (1912), and had been a Congressman for the past 2 years when he became Secretary. An intense man, with strong con-

[110] Letter, SWS to Secretary of Commerce and Labor, Nov. 14, 1912, and attached correspondence (NBS Box 3, AG).
[111] Ibid.

Secretary of Commerce William C. Redfield, a prince of industry and a splendid presence, who bought his first automobile in 1916 because the trip to the Bureau was too far by horse and carriage.

victions about what his Department should be, he left it in 1919 feeling he had failed it. His books and articles describing his years as Secretary were filled with passionate criticisms of Congress and Congressmen as venal, incompetent, and do-nothing. But of this sense of frustration there was little evidence at the time. He was a better Secretary than he knew.

He found good men everywhere in the "working" areas of the Government, as he called the executive branch, and nowhere so many as in the Bureau of Standards, which he particularly admired for what it was doing for industry, often against industry's will. As he said:

> Long industrial experience taught me what our work at the Bureau of Standards constantly justified, that on the whole American manufacturers failed to apply science to industry * * *.[112]

Dr. Stratton he came to admire for a talent he felt he lacked, the ability to get along with Congress, but he took no credit for his own efforts before Congress on behalf of the Bureau.

> One service, the Bureau of Standards, which deservedly had the confidence of Congress, was not only well housed but well equipped so far as the requirements of that time were concerned. Its need was for steady expansion to meet the growing demands of the Government itself and the increasing call for aid from industry.[113]

Soon after taking charge of his Department, Redfield visited the Bureau and before long began coming up in his horse and carriage every week,

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[112] Redfield, "Glimpses of our government," Saturday Evening Post, May 17, 1924, p. 44.
[113] Redfield, ibid., May 3, 1924, p. 81.

and sometimes twice a week.[114] Stratton would take him to the laboratories he himself had been recently touring and where investigations that would interest Redfield were in progress.

It was almost certainly as a result of Redfield's visits that in an effort to increase Bureau usefulness as well as to settle an old area of interdepartmental bickering, Redfield sought by agreement with the Secretary of Agriculture to transfer the miscellaneous testing laboratory in the Bureau of Chemistry to the Bureau of Standards. On July 1, 1914 that laboratory, with funds of $26,000 for the testing of textiles, paper, leather, rubber, oils, and paints, was officially transferred and within a week the new group, headed by Dr. Percy H. Walker and F. W. Smither, with eight assistant chemists and a clerk, was organized on the second floor of North building.[115]

Redfield seems to have been diligent in his search for ways to enhance the prestige of his Department, and to have made the Bureau a prime beneficiary of these efforts. By tradition, the executive departments of the Government hid their lights and good works, a fact he resented since it made "informing Congress of one's needs * * * very difficult." Soon after taking office he began making it a point to attend congressional committee hearings with his bureau chiefs and personally brought key people with him to explain their needs.[116] He took an active part in the proceedings, demonstrating a fine talent in the use of the first person plural. His intense personal identification with the Bureau was exhibited on one occasion when Stratton was seeking a new special appropriation by his remark, "I can only say that anything that Dr. Stratton wants I back up." [117]

It was almost certainly Redfield who authorized a major change in format of the annual reports of his bureaus the year he came in. The Bureau report for 1913, 38 pages in length, almost tripled in size to 99 pages in 1914 and continued to swell by nearly 50 percent each year thereafter.[118] Its

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[114] At Hearings * * * 1919 (Jan. 18, 1918), p. 893, Redfield said he finally bought an automobile in 1916, because the trip to the Bureau was too far by carriage.

[115] Letter, SWS to Redfield, June 5, 1914, and attached correspondence (NARG 16, Office of the Secretary of Agriculture, sub: Duplication of Work, Department of Commerce, 1914).

[116] Redfield, Saturday Evening Post, May 3, 1924, p. 78; ibid., May 10, 1924, p. 19. Results of these trips to the Hill were mixed. Stratton and his staff, Redfield found, explained their scientific problems in terms which laymen could understand. On the other hand, some like Dr. O. H. Tittmann, chief of the Coast Survey, unfortunately "resented the sharp questions that were often asked," an attitude that was reflected in meager appropriations (Redfield, ibid., May 3, 1924, p. 81).

[117] See Hearings * * * 1915 (Jan. 27, 1914), p. 664 et passim; [Senate] Hearings * * * on H.R. 15279 (Apr. 29, 1914), p. 61.

[118] The report of the Bureau of Corporations in Commerce expanded from 8 to 48 pages and all but three of the reports of the other nine bureaus of the Department showed considerable increases in size. No such sudden expansion occurred in other Department reports examined, i.e., Interior and Agriculture.

new table of contents drew attention to the fact that the 8 divisions of the Bureau were engaged in more than 225 separate investigations. Following notes on administration and statistical data on the year's work, the report for the first time appended a list of current Bureau needs, including a new building to house the structural materials work, a radio laboratory, additional ground, and more scientific assistance. And where 300 copies of the Bureau report had been printed the year before, a thousand copies of the 1914 report were distributed.

Most striking of all in the amplified annual report of 1914 was the restatement of the functions, aims, and purposes of the Bureau that appeared in the preface. Still concerned with the "extension of the general purposes of the Bureau," Dr. Stratton sought to clarify the new scope of work for which the Bureau had become responsible. The organic act was unchanged, he said, but a more "convenient" classification of functions as now authorized and exercised made the Bureau responsible for standards of measurement, standard values of constants, standards of quality, and standards of mechanical performance. In the report the next year Stratton amended this list to include a fifth function, standards of practice.[119]

Standards of measurement, he wrote in the annual report, included their custody, construction, and comparison, with methods of comparison presently available ranging from those "capable of measuring the thousandth part of a milligram to the large testing machines capable of measuring a load of thousands of tons." *Standard values of constants,* requiring accurate and authenticated determinations of the many fixed relations between physical quantities, ranged from the relation between heat and mechanical energy, required in designing steam engines and boilers, to the amount of heat required to turn liquid ammonia into vapor or to melt a pound of ice, as in the refrigeration industry.

Standards of quality, "confined almost exclusively to Government purchases," involved the physical and chemical investigation of materials to prepare methods of measurement and uniform specifications for their composition or manufacture. *Standards of performance,* whether of an engine, boiler, or pump, an electric generator or motor, a weighing device, or a telescope, involved the use of standards of measurement, standard values of constants, and standards of quality, and sought to arrive at specifications based on correct scientific and mechanical principles. A function only

[119] This classification may have evolved from Dr. Stratton's remarks at a congressional hearing several months before. In a discussion of the investigations in public utility services, the Bureau was, he said, concerned with standards of engineering, comprising standards of practice, standards of construction and operation, standards of service, and standard methods of testing, all of which involved standards of measurement and quality. Hearings * * * 1915 (Feb. 26, 1914), p. 980.

recently assumed by the Bureau, it too would relate almost entirely to Government purchases. *Standards of practice* looked principally to the enactment of laws in technical and scientific matters, to ordinances relating to the regulation of public utilities, and to the establishment of building and safety codes.[120]

The almost wholly pragmatic cast of these functions could not be missed, nor their overwhelming reference to Government testing and Government investigations. The source of the new look of the annual report was explained in a section entitled "The relation of the Bureau's work to the public." Yet not there but elsewhere in the report Dr. Stratton said: "Government purchases are not greatly different from those of the public," and all information and data obtained in this work by the Bureau "is given to the public in the form of suitable publications * * *. In other words, the needs of the public and the Government service are precisely the same as far as standards and specifications are concerned, whether it be standards of measurement, quality, or performance." And "the Government can do no greater service to the country than to place its own purchases on a basis which may be taken as a standard by the public at large." [121]

Two years later an elaborate chart of these "new" functions appeared in the annual report. Asked about it at a congressional hearing, Stratton replied: "There is not a single thing that the bureau does that I can think of * * * which does not fall within five classes of standards * * *. I think it [the chart] will clear up a great deal of uncertainty as to the scope of the work of the bureau." [122]

The new classification of functions and the elaborate reporting of Bureau research projects continued through the annual report of 1923, a tome running to an imposing 330 pages. Then a wave of conservation hit the Nation and the Bureau. The report of 1924, in the third year of Secretary of Commerce Hoover's tenure, totaled a scant 38 pages. The chart of functions and classes of standards that had appeared since 1916 was omitted and the splendid chart of the Bureau organization and map of the Bureau grounds that appeared in the 1923 report were gone. While standards were still pursued under five classes, they were not so listed, and in their place was the statement: "As a matter of convenience the organization of the Bureau is based not on classes of standards, but upon the nature of the work."

In a way, an era as well as a decade had ended.

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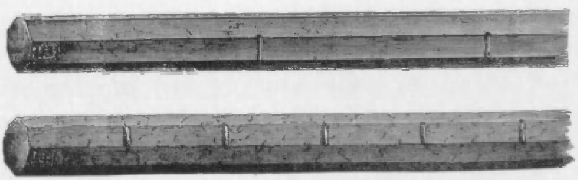
[120] NBS Annual Report 1914, pp. 9–12; Annual Report 1915, p. 14.
[121] NBS Annual Report 1914, p. 12.
[122] Hearings * * * 1918 (Dec. 1, 1916), p. 482.



The standard yard of Henry VII, showing sixteenths of yard and, below, the subdivisions of inches.