THE TIDE OF COMMERCE AND INDUSTRY (1920–30)

CHAPTER V

THE POSTWAR WORLD

The United States emerged from its brief participation in the war by far the world's richest and most powerful Nation. Disillusioned with the chronic sickness of Europe and rejecting the power a world in chaos offered, America deliberately turned its back and set about building a national structure of self-sufficiency and plenty on the broad industrial base and the techniques of mass production it had acquired during the war. In the mid-1920's a social historian spoke simple truth when he said that "A dynamic history of the period might give a volume or two to the automobile and a foot-note to affairs of state." [1]

New industries born of the war were soon to make the Nation independent in nearly every manufactured necessity. The revolution in the coking industry and the confiscation of German patents upon our entrance into the war made possible the production of many of the dyes, medicines, and industrial solvents formerly obtained from Germany, and led to such important new industries as the making of synthetic plastics and fibers.[2] The new chemistry and advances in metallurgy joined with electric power to revolutionize the extraction and refining of copper and iron ores, the cracking of petroleum, and to make giants of the automobile, motion picture, radio, and telephone industries. With the introduction of the closed car at popular prices in 1922, the automobile by itself almost created a new industrial revolution through its mass consumption of steel, nickel, lead and other metals, plate glass, leather, textiles, rubber, gasoline, and oil, and its demand for roads and highways, gas stations, garages, and roadside accommodations.

Surpassing even the growth of the automobile and electrical industries in the decade after the war was the building and construction industry. Government construction of streets, highways, and public buildings alone are

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[1] Robert L. Duffus, "1900–1925," Century, 109, 488 (1925).

[2] Preston W. Slosson, The Great Crusade and After: 1914–1928 (New York: Macmillan, 1930), p. 18. The Trading-with-the-Enemy Act of Oct. 6, 1917 permitted the President to license the use of German patents by American firms, under the administration of the Federal Trade Commission. Frederic L. Paxson, American Democracy and the World War, II, 132.

said to have "used more capital and employed more men than in any single line of private enterprise."[3] At the same time, private construction, consuming vast quantities of brick, steel, stone, tile, cement, lumber, hardware, and plumbing supplies, changed metropolitan skylines and pushed up row houses and apartments along ever-lengthening radii out of the cities.

Technology and the plant facilities to make consumer products were far in advance of demand. "For every hundred people in American cities in 1920 there were only thirteen bathtubs and six telephones. One American in every thirteen had an automobile, but not one in ten thousand had a radio. Almost no farmhouses, and but one in every ten city homes, were wired for electricity; only in such homes, therefore, were there potential customers for washing machines, vacuum cleaners, refrigerators, floor lamps, incandescent bulbs, fans, and flatirons."[4] In city and suburb, technology thus stood ready to invade the home as the automobile, radio, telephone, bathroom plumbing, and kitchen appliances became essentials of the good life. Wages rose steadily, but not fast enough to sustain the buying power needed by the pace of mass production, and advertising and installment buying became giant adjuncts of industry to maintain mass consumption.[5] The promise of the decade appeared in the extraordinary boom that followed the end of wartime controls as industry, enriched by research and mechanization, sought to satisfy pent-up demands.[6] There was to be a severe postwar depression but it was delayed until late in 1920.

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[3] Thomas C. Cochran and William Miller, The Age of Enterprise: A Social History of Industrial America (New York: Macmillan, 1942), p. 298. Highway, road, and street construction expenditures, for example, rose from just over a half billion dollars in 1920 to a billion in 1921 and close to two billion by 1928. U.S. Bureau of the Census, Historical Statistics, p. 382.

[4] Ibid., p. 309. All these appliances, as well as air conditioners, electric ranges, water heaters, and garbage-disposal units, though some were yet crude and costly, were on the market before the end of the decade.

In the 28 million homes in the United States at the end of 1928, it was estimated that 19 million were wired for electricity, 17 million had an automobile outside the door, 13 million had a telephone, 13 million a phonograph, and 9 million had factory-built radio sets. Dellinger, "Radio," in A. B. Hart and W. M. Schuyler, eds., The American Year Book, 1929 (New York: Am. Year Book Corp., 1930), p. 460.

[5] Between 1900 and 1920 the volume of manufactured products went up 95 percent while population increased only 40 percent. Duffus, "1900–1925."

[6] In its haste to convert to peacetime production, industry often neglected new materials or sources developed during the war. Pointing specifically to the renewed but now unnecessary importation of German clays for glassmaking, Dr. Stratton deplored the "tendency on the part of manufacturers to revert to the old order of things just as soon as they could * * * [following] the path of least resistance and of the least financial risk." Letter, SWS to A. V. Bleininger, Feb. 3, 1919 (NBS Box 14, IR).

At the National Bureau of Standards the boom seemed for a time more like disaster. With the war over, it expected the exodus of the scientists detailed from other Government agencies and those on leave from colleges and universities. But it found irreplaceable its loss of regular Bureau members to the siren call from industry for trained investigators. Attracted by salaries which in many instances were twice those available at the Bureau, over 78 percent of the total force of appointed staff members left in the 7 months following the armistice. Some positions had a succession of occupants; in others replacements simply could not be found.[7]

Subprofessionals (aids, apprentices, and mechanics) entered the Bureau at as little as $720 a year and could hope for no more than $2,740. Most, with any length of experience, were caught in the $1,140–$1,240 bracket. Professionals with degrees and experience came in at $1,440. Some among the key members were getting as little as $2,240, most were at $4,000, and only a few of the division chiefs had attained the maximum possible, $4,800.

This was at a time when a bookkeeper in downtown Washington could make $100 a month, "with meals." University salaries were sufficiently higher than those paid by the Government for Dr. E. W. Washburn to turn down the maximum of $4,000 that the Bureau had to offer. (He came 6 years later, in 1926, at the division chief level.) Industry paid close to twice the Bureau salary at every level of training and experience.[8]

The cost of living in 1920 was relatively high and left little for amenities. A Bureau apprentice making $65 a month before taxes could find room and breakfast within a mile of the laboratories for $20 a month. Not far away, a front room rented for $25, and meals were another $30. For a family, a four- or five-room furnished apartment with steam heat and electricity could be found on the way downtown for $110, or 2 miles north of the Bureau, in Chevy Chase, for $100.

Men's suits were fairly expensive, running from $25 to $85 for all wool and $15.50 to $25 for Palm Beach or mohair, with tropical worsteds in between. Hats were $4 to $8 and shoes $7 and up. Although probably 15 or 20 on the Bureau staff owned a car by 1920, it was seldom driven except on weekends and almost everyone still rode a bicycle to work or

[7] NBS Annual Report 1919, p. 279. For a list of the physicists who left the Bureau for industry in the 1920's, see letter, LJB to Secretary, American Institute of Physics, Feb. 24, 1936 (NBS Box 395, ID-Misc.).

[8] Interview with Dr. William Blum, Oct. 15, 1963. By the end of the decade, salaries at the Bureau had gone up by almost one-third. Living costs (a room with two meals a day was $45 to $55 a month) had risen only slightly. See NBS M94, "Scientific and technical positions in the NBS" (1929).

came by streetcar. Some of the prices for new automobiles that year read like Bureau salaries. While the Ford runabout was only $395, the sedan cost $795. The Dort "fourseason" sedan was $1,870, the Auburn sedan $2,775. Nor could used cars have been very popular when a 1919 Chevrolet cost $550 and an Overland $1,000. For the sporty youth on his own, however, there was that Stutz 6-cylinder roadster, vintage not given, going for $375.[9] Few below the scientific grades in the laboratories could afford any of them, just as few could afford to stay at the Bureau.

A loyal nucleus that included most of the key members of the staff remained, even though many of those in the lower grades who elected to stay were, Dr. Stratton said, being paid "less than a living wage." In its search for replacements, all that the Bureau had to offer was "a reasonably good entrance salary to young men just out of college." [10] With industry bidding for them, too, even recent graduates could not be found in any numbers and the Bureau staff fell from 1,150 members in July 1919 to 981 a year later, and 850 by 1921. Few eligibles appeared on the civil service registers and answers to advertising appeals grew meager. The Bureau turned to industry itself in an effort to restaff its laboratories.

Dr. Stratton some years earlier had warned that the schools were not turning out even a tenth of the scientific and technical men needed in industry, and as a consequence industry raided the Bureau in its search for trained men. In 1916, as industry expanded to feed the war machines in Europe and Bureau losses of skilled workmen went up, Stratton proposed to Congress that in order to relieve the pressure on his staff the Bureau make its facilities available to industrial specialists, technical experts, and researchers, and by setting them to work on problems in which both they and the Bureau were interested, "train them up for the industries." He cited as example a linoleum company which had recently asked to send a chemist to the Bureau who after 6 months' training would return and set up a laboratory in the plant where he worked. Without authorization or funds for this type of employment, the Bureau had to deny the request.[11]

Although he brought up the matter at hearings each year thereafter, Congress said no. By the summer of 1919 what Stratton had previously called "more or less a notion of mine" had become stark necessity, and he turned to the trade associations served by the Bureau, proposing that where they needed specific researches on important problems affecting their industry, they send qualified men to the Bureau to do this research. It was

[9] Advertisements in the "Washington Evening Star," April and October 1920.
[10] NBS Annual Report 1920, p. 279; Annual Report 1921, p. 272.
[11] Hearings * * * 1918 (Dec. 1, 1916), p. 483.

agreed that these "research associates" would be paid by industry, and since their work was for the industry at large, rather than for any single company. the results would be published by the Bureau and so made available to all.[12]

Two years later, in 1921, six associates in metallurgy were appointed by the Director. By 1923, 21 associates, representing 18 industries, were at the Bureau, and by 1925 a total of 61 associates, maintained by 36 organizations, were at work, most of them sponsored by trade associations but also among them a number from private research firms, science foundations, and Government agencies.[13]

At the heels of the staffing crisis came the brief but severe depression of 1920–21. Overnight at the end of the war, President Wilson's War Industries Board and other emergency regulatory agencies had been dissolved, ending nationwide Government control of the economy. For a time unfettered business boomed, but as prices soared out of sight, production and employment fell off and thousands of new companies, notably in the automobile industry, collapsed. Soon there was widespread criticism of the high cost of living, which since 1916 had seen the dollar reduced in purchasing value to 45 cents; of the new income tax and surtaxes, seriously felt for the first time since their imposition in 1913; and charges of inefficiency, extravagance, and overdevelopment throughout the Government.[14]

Reacting to "the avalanche of disapproval" aimed at the Wilson administration, Congress lashed out at "the army of clerks * * * and crocheting stenographers" said to be infesting every department of the Government, and at appropriations hearings hacked away funds, research and operating alike. The cuts that could not be compromised were annoying but not deep. The Bureau closed several of its branch offices and began saving its cinders to make cinder-concrete paths between the buildings. As Stratton

[12] Hearings * * * 1919 (Jan. 25, 1918), p. 984; letter, SWS to Managing Director, National Industrial Conference Board, June 26, 1919 (NBS Box 10, IG). Most responsive were industries which had small research laboratories or none at all, and had less to fear from patentable discoveries, as in dental materials, terra cotta, tile, and other building materials, pottery, textiles, and color research.

[13] NBS Annual Report 1921, p. 240; Annual Report 1923, pp. 4–5; NBS C296, "Research associates at the Bureau of Standards" (1925). The plan further solved staffing difficulties when a number of the research associates subsequently left industry and came to work for the Bureau, among them Dr. Paul D. Merica, Dr. John R. Cain, R. G. Waltenberg, Dr. I. G. Priest, N. S. Osborne, Dr. H. F. Stimson, N. D. Booth, J. A. Dickinson, Dr. Deane B. Judd, Dr. F. G. Brickwedde, T. S. Sligh, Jr., and Dr. A. V. Astin (see list of associates in C296).

[14] The top rate of tax on personal income, set at 7 percent in 1913, was slightly reduced during the 1920's. By 1932 it was up to 25 percent, and during the depression years it reached a high of 63 percent.

later reported to Congress, "In the program of economy adopted, some retrenchments were made." [15]

Stirred by the debates in Congress and the attacks in the press and periodical literature on Federal spending, Dr. Rosa, with Dr. Stratton's approval, cleared his desk and began work on a series of studies in the cost and efficiency of the Federal Government, in answer to the outcry. For their view of the question of science in Government, particularly as it affected the Bureau, some of Rosa's arguments in these papers are worth summarizing.

Pointing to the wartime exhaustion of raw and manufactured materials, the rising demand for consumer goods in short supply, inflation of currency and credit, and postwar profiteering as among the causes for continued rising prices, Rosa declared that more Government, not less, was necessary to protect the public. He warned of "economic and political disturbance or even disaster," asserting that the Government must again, as it had during the war, induce the Nation "to economize in the use of staple commodities and luxuries, reduce the waste of raw materials, make use of cheaper materials, increase the efficiency of men, of machines, and of processes, on a nationwide scale and at an early date." [16] By "more" Government Rosa made clear he did not mean reimposition of wartime controls but better education of the public in the cost of Government, more efficient operation of Government, and greater assistance to those Government agencies whose recognized function it was to work directly in the public interest.

Answering the charge of extravagance in Federal spending, Rosa showed that in the budget for 1920 interest on the national debt as a result of past wars consumed 67.8 percent of Federal income, the military services received 25 percent, the cost of running the Government came to 3.2 percent, public works 3 percent, and research, education, and development 1 percent.[17]

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[15] Hearings * * * 1922 (Dec. 20, 1920). p. 1235; Hearings * * * 1923 (Feb. 1, 1922), pp. 424, 425, 452.

In a letter in March 1920 to a former Bureau member who had gone into industry, Stratton discussed the coming economy wave: "I personally know most of the leaders of the party in control and the chairman of the committees directly interested in our work." They had initiated the economy program and intended to push it, said Stratton, and there were no exceptions. Nevertheless, he was "working with the Senate committee and hoped to persuade it to restore some of the more important funds" (Letter, SWS to F. C. Clarke, Mar. 17, 1920, NBS Box 10, IG).

[16] Rosa, "The economic importance of the scientific work of the Government," J. Wash. Acad. Sci. 10, 342 (1920).

[17] J. Wash. Acad. Sci., pp. 346–349. The percentages were based on total revenues of approximately $5.68 billion. (Between 1914 and 1921, the national debt rose from $1,188 million to $23,976 million.)

In his final study, "Expenditures and revenues of the Federal Government," Ann. Am. Acad. Pol. Soc. Sci. 95, 1–113 (1921), Rosa included revenue and expenditure data for

He rivetted attention on that 1 percent, representing little more than 50 cents out of the approximately $50 per capita [18] collected by the Government from all sources, for it was the key to industrial recovery and to reduction in the high cost of living. Out of that 50 cents, agriculture received 62 percent; education, public health, and labor bureaus received 25.6 percent; the Bureau of Mines and Geological Survey 5 percent; and the Bureau of Foreign and Domestic Commerce, Bureau of Standards, Bureau of Fisheries, and Coast and Geodetic Survey together 10.5 percent or little more than 5 cents per capita. Considering these facts, said Rosa, the distribution of Government income left little room for extravagance.

The charge of inefficiency in Government, on the other hand, was more valid, largely because Government pay, based as it was on a statutory salary scale established prior to 1914, failed to attract and hold experienced and competent people. Federal employees from scientists and administrators to clerks and laborers shared the same scale proportionately. As the Secretary of Commerce was to point out to Congress, leading physicists in universities and industrial laboratories were getting between $8,000 and $25,000 a year, while top physicists at the Bureau of Standards could make no more than $4,800.[19] The consequence was an inordinate turnover of personnel at every level.[20] The remedy was revision of the civil service system and its wage scale, to make Government employment more attractive; and establishment of a budget bureau that would plan and coordinate the work of the Government and its agencies, to assure the best use of its employees.[21]

Returning to the subject of Federal research, Rosa pointed out that where the expenses of the Department of Agriculture amounted to about $1.50 for every $1,000 of the national value of agricultural and animal products, those of the Bureau of Standards came to $0.15 for every $1,000 worth of manufactured products, and less than half that amount was spent by the Bureau for the development of manufactures. Agriculture might still be "the most important industry in the Nation," but revival of the economy depended on the recovery of manufactures, by more efficient utilization of raw materials and labor and expansion of production.[22]

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the years 1910–19. His adjusted figures for 1920 did not materially change the validity of his conclusions and the earlier figures are therefore used here.

[18] Based on a 1920 population of approximately 110 million.

[19] Hearings * * * 1923 (Feb. 1, 1922), p. 14.

[20] Address by Rosa before ASME, "The scientific and engineering work of the Government," Dec. 2, 1920, p. 20 (NBS Historical File). It required at least a year to train a laboratory assistant at the Bureau, yet almost everyone hired in the postwar period left for better positions after 1 to 3 months. NBS Annual Report 1920, p. 30.

[21] Ann. Am. Acad. Pol. Soc. Sci., pp. 73, 88, 90, 94.

[22] J. Wash. Acad. Sci., pp. 342, 350–352.

Unlike agriculture, industry spent generous sums of money on research, but only for its own commercial advantage. Bureau research, on the other hand, reverted to the advantage of the public, for it led directly to decreased costs of commodities, improved service, better quality and performance, and reduced misrepresentation and exaggeration, all "constructive and wealth-producing contributions to the economy." Rosa declared that raising the per capita share of the Bureau appropriation by a single cent would yield returns a hundredfold, and raising it fivefold "would accomplish wonders." [23]

Among the many studies at the time in the causes and cures for the depression, Rosa's analysis was one of the most thorough and was widely studied.[24] The Bureau of the Budget which he urged and which had been under discussion for almost a decade was formally established in June 1921. Much-needed civil service reform, including a slight upward adjustment of salaries, came in July 1924. And Rosa's "wonders" in the national economy were to be accomplished, but in ways and to a degree he could not have foreseen.

A new and fabulous era in the Nation's history was about to begin. The early years of President Wilson's administration had seen a continuation of Federal efforts, begun under Roosevelt and Taft, to curb corporate monopolies and give a measure of Government back to the people. That reform impulse had ended with the war, and the disillusionment of the postwar period, climaxed by the severe depression, led to a massive rejection of the age of idealism, of political experimentation, that swept the President and all his policies off the scene.

The period of Republican ascendancy that followed, it has been said, represented not the high tide of laissez faire but of Hamiltonianism, the deliberate pursuit by Government of policies favorable to large business interests.[25] The trusts of the early century were to rise again in the mergers of the twenties, and the soaring wealth of the Nation reflected kiting of values as often as it did new capital investment. The consolidation of industries and utilities, moreover, exercised measurable control over prices and production, so that the cost of living, after a slight decline from its awful peak in 1920, was to hold steady to the end of the decade.[26] Salaries in the middle-

[23] J. Wash. Acad. Sci., pp. 373–374; Ann. Am. Acad. Pol. Soc. Sci., p. 107.

[24] See "New York Times," May 30, 1920, sec. VII, p. 4. John F. Sinclair, in the "Washington Evening Star," Mar. 19, 1924, p. 6, called Rosa's reports "the most comprehensive and most intelligent survey from the plain citizen's viewpoint of Government finances which was ever undertaken."

[25] Leuchtenburg, The Perils of Prosperity, 1914–1932, p. 103.

[26] The cost of living index, based on 1913=100, had by 1920 reached 286. By 1926 it had subsided to 241 and remained at that approximate level to the end of the decade. Historical Statistics, p. 127.

income bracket went up, and installment buying and liberal credit terms became new measures of personal wealth. But the farmer, the professional man, and the laboring man, unless he was in the automobile or radio industry, had small share in the new wealth.

If the aura of prosperity of the golden twenties resulted principally, as management was to claim, from increased mechanization of industry, greater efficiency through scientific management, industrial research, and the rising output of workers, no Federal Government ever before provided more assistance to industry or a happier climate for free enterprise. Economies in Government spending, a balanced budget, lower taxes, a high protective tariff, and a supremely able and energetic Department of Commerce all acted to accelerate the tide of commerce and industry.

HERBERT HOOVER AND THE BUREAU OF STANDARDS

The most capable man that came in with the Harding administration was the new Secretary of Commerce, Herbert Clark Hoover. Considered by many for a time the best man for the Presidency itself and tentatively claimed by both parties, Hoover, by his efficient handling of the wartime Food Administration and of Belgian relief had made his name a household word. His enginering background and knowledge of industry were needed as the Nation slid into depression. But by nature autocratic, often dogmatic, and almost wholly apolitical, he was not the man party leaders sought.

When he subsequently accepted the Cabinet post it was with reluctance and only on his own terms. His friend Oscar Straus, Commerce and Labor Secretary from 1907 to 1909 under Theodore Roosevelt, once told him that the office required only a couple of hours of work a day and "no other qualification than to be able to put the fish to bed at night and turn on the lights around the coast." [27] Hoover thought otherwise. He was quoted in the press as saying that the department, composed of uncorrelated scientific and semiscientific bureaus, had too long "been a Department of Commerce in name only." [28] With Harding's promise to stand behind him, he intended to expand foreign commerce through organized cooperation with industry, aiming at lower production costs; and to assist domestic commerce in im-

[27] Eugene Lyons, Our Unknown Ex-President (New York: Doubleday, 1948), p. 219. Cf. The Memoirs of Herbert Hoover: the Cabinet and the Presidency, 1920–1933 (New York: Macmillan, 1952), p. 42. (Hereafter designated as vol. II of the Memoirs.)
[28] "New York Times," Feb. 25, 1921, p. 1.

Herbert Hoover as Secretary of Commerce, it was predicted, would make his department "second only to that of the Secretary of State." He did just that, and by making all interests of commerce and industry the province of the Bureau, further expanded its scope of activities and range of research.

proving its industrial processes, abolishing waste, establishing better labor relations, and better business methods. With his knowledge, experience, and driving power, the "New York Times" editorialized, Hoover seemed destined to make his office in the Cabinet "second only to that of the Secretary of State." [29] The "Times" may have overestimated the position but it underestimated the man.

The Department of Commerce in 1921 comprised the Bureaus of Foreign and Domestic Commerce, Lighthouses, Navigation, the Coast and Geodetic Survey, the Bureaus of the Census, Standards, and Fisheries, and the Steamboat Inspection Service. In 1922 Congress was to add a Building and Housing Division to Commerce, and in 1925 Hoover secured by Executive order the transfer from Interior of the Bureau of Mines and the Patent

[29] "New York Times," Feb. 25, 1921, pp. 2, 10. The editorial spoke of Hoover's "dictatorial temper."

Office.[30] In 1926 a congressional act added an Aeronautics Division and in 1927 a Radio Division to Commerce.

On taking over the Department, Hoover seems to have been under the impression that "the Bureau of Standards had hitherto been devoted mostly to formal administration of weights and measures," and that, as he later said in his Memoirs, by greatly enlarging its research not only in "abstract knowledge but * * * [in] its application in industry," the Bureau under his direction became "one of the largest physics laboratories in the world."[31] In all fairness, the Bureau under Stratton had already achieved that eminence. It is true that in the period 1921-28 it expanded from 9 divisions with a total of 68 sections to 13 divisions with 85 sections, but staff and appropriations actually increased very little in those 7 years, from 850 to 889 members and from $2,209,000 in operating funds to $2,540,000.[32] As for any limitation on Bureau research interests, it was quite otherwise. Under Stratton and Rosa, little that was measurable in the home, in the market, in commerce, industry, science, or Government but had at one time or another become a subject of investigation at the Bureau, and as often as not a sustained investigation.[33]

By 1920, in addition to several score investigations and test programs conducted under statutory funds, the Bureau had some 16 other investigations going with special congressional appropriations. That year Stratton secured more special funds to begin another nine studies. Three were short-term investigations, in industrial safety standards, Government materials testing, and platinum and rare metals research. The other six, metallurgical research, high temperature studies, railroad scale testing, sound research, standardization of equipment, and a new huge industrial research

[30] The transfer of the Bureau of Mines to the Commerce Department concentrated the oil testing and ceramics work of Mines and Standards in the latter bureau, with a heavy clay products section located in Columbus, Ohio. The transfer added 52 employes to the Bureau staff. NBS Annual Report 1926, p. 44; Annual Report 1927, p. 2; NBS Blue Folder Box 3, file AG–138c.

[31] Memoirs of Herbert Hoover, II, 73.

[32] See apps. F and H. "In retrospect Hoover was proud of the fact that despite its increased activity the department grew little in size or cost under his charge." Dupree, Science in the Federal Government, p. 340.

[33] So reported a committee of electrical manufacturers appointed by Hoover in 1922 to advise the Bureau on electrical research. The committee, apparently piqued by some of the current public utility recommendations of the Bureau, called "attention to the fact that the Bureau's activities have been very widely extended into various fields not contemplated by the act creating the Bureau, through the medium of * * * special Congressional appropriations, and * * * we [are] not ready to accept this means of enlarging the Bureau's sphere of activities as a safe procedure, and especially since it is apparent that when an activity of this kind is initiated by such appropriation it is apparently considered a function of the Bureau from that time forward." Letter, Chairman, Electrical Manufacturers Council, Committee on the Bureau of Standards, to Secretary Hoover. Oct. 2, 1922 (NBS Box 2, AG).

program, were to continue for more than a decade before being merged in the regular work of the Bureau.[34]

The nine were among the last of the special appropriations made to the Bureau. Coming into office on an economy wave, Hoover in a public announcement declared: "This is no time to ask for appropriations to undertake new work. It is the time to search for economy and reorganization, for effective expenditure on essentials, the reduction of less essentials, and the elimination of duplication." [35] The same regimen held true for the general economy. Recalling the scene of widespread unrest and unemployment as he took office, Hoover was later to say: "There was no special outstanding industrial revolution in sight. We had to make one." His prescription for the recovery of industry "from [its] war deterioration" was through "elimination of waste and increasing the efficiency of our commercial and industrial system all along the line." [36]

To do this, Hoover divided the direction of his bureaus between two special assistants, "except Foreign and Domestic Commerce and Standards, which I took under my own wing." [37] These two bureaus represented ideal instruments for jogging a lagging economy and putting industry back on its feet. The "wing" actually proved to be Assistant Secretary J. Walter Drake, brought to Washington from the Detroit automobile industry. But Hoover himself was to give Bureau interests his wholehearted support, and in his annual encounters with Congress at the side of Dr. Stratton pled the Bureau's need for better salaries and for its research funds.

Where to commence jogging the economy was not difficult to see. Wholly inadequate as a result of the war and beset by excessive costs, home construction offered the most immediate means of reviving the greatest number of industries and providing work for the largest numbers of unemployed. Because its stimulation would depend upon personal organization and massive publicity, Hoover organized the division of building and housing in

[34] See app. G.

A member of Great Britain's National Physical Laboratory, visiting the Bureau in 1921, found it "very considerably larger" in every sense than the Teddington plant, its chemical, spectroscopic, and metallurgical work particularly on "a totally different scale than anything at NPL." Impressed by the ceramics, refractories, and optical glass work at the Bureau, the visitor reported that the effort at NPL in these fields, by comparison, "becomes almost insignificant." NPL Annual Report 1922, pp. 197–199. For a comparison of the Bureau with the German PTR in the 1930's, see ch. VI, p. 310.

Another comparison with NBS research, made by a member of the Bureau's National Hydraulic Laboratory after a year's study of hydraulic programs in the laboratories in Europe, appears in a report attached to letter, LJB to Martin A. Mason, June 28, 1939 (NBS Box 430, ID—Misc.)

[35] "New York Times," Mar. 11, 1921, p. 3.

[36] The Memoirs of Herbert Hoover, II, 61.

[37] Ibid., II, 42.

his own office. The necessary scientific, technical, and economical research, simplification and standardization of building materials, and revision of municipal and State building codes required by the program he made the responsibility of the Bureau of Standards, where a division similarly named was activated.

At the end of 1921, with the housing program well launched, Hoover established a division of simplified practice at the Bureau, on the model of Baruch's wartime Conservation Division, to work with and encourage the technical committees then operating in most trade and industrial associations to eliminate waste in industry. Like the former Conservation Division, simplified practice aimed at reduction of varieties and sizes in commodities and greater standardization of materials and products. Further extending these aims, two more units, a specifications division and a trade standards division, were set up at the Bureau to reinforce and promote the demand anticipated for standardized and simplified products.

The new divisions insured the fullest exploitation of Bureau plans for industrial research, but to Dr. Stratton's dismay, their direction was centered in the Commerce building downtown. Although the whole of the scientific and technical research required by the housing and standardization programs was to be financed out of Bureau appropriations, the administrative staffs of the four divisions were under Secretary Hoover's personal direction.[38] It may be guessed that the divided control and responsibility rankled.

Outwardly, relations between Dr. Stratton and Secretary Hoover were cordial and even close, as correspondence between them and Stratton's letters to members of Hoover's family make abundantly clear.[39] Although Hoover is said to have visited the Bureau rarely, he kept in close touch and consulted Stratton frequently on Department matters; and as the senior administrator in the Commerce Department, Stratton often spent afternoons downtown when the Secretary was out of the city, signing Department correspondence as Acting Secretary of Commerce.[40]

Just when Dr. Stratton first thought of leaving the Bureau is uncertain. It was doubtless an accumulation of events that occurred in that 20th year of the Bureau's founding. On the afternoon of May 17, 1921, Dr. Rosa, not quite 60, died suddenly at his desk in East building. Two months later Stratton's long-time chief of weights and measures, Mr. Fischer, died at his

[38] The roles of the divisions at Commerce and their counterparts at the Bureau are distinguished in memo, Secretary of Commerce Hoover for GKB, May 23, 1923 (NBS Box 40, AG).

[39] See correspondence in NBS Box 10, IEW–1922; letter, Mrs. Hoover to SWS, Sept. 1, 1922, and other correspondence in Stratton Papers at MIT. See also Dr. Stratton's speech at 25th Anniversary of the NBS, Dec. 4, 1926 (NBS Blue Box 3, APN–301c).

[40] Interview with Dr. Lyman J. Briggs, Nov. 1, 1961; communication to the author from the Hon. Herbert C. Hoover, Dec. 14, 1962 (NBS Historical File).

home, and 8 months after, Dr. Waidner, chief of the heat and thermometry division, was gone. The deaths of three of his division chiefs within less than a year affected him profoundly. They had been with the Bureau since its establishment, had been his most intimate associates, and understood his ways. Other division chiefs, coming later and without the bond of the early years, sometimes found Stratton's autocratic ways difficult and his concern with the minutiae of every laboratory and Bureau operation excessive. With the loss of his closest associates and amid a faint undercurrent of unrest, of which he could not be unaware, Dr. Stratton may have felt that the Bureau might never again be the same.[41]

There were other considerations, too. In the 20 years that he had been Director, Dr. Stratton's salary had risen from $4,000 to $6,000, the maximum permitted for the position under civil service rules, even though the staff he directed had increased more than sixtyfold. As Secretary Hoover told an appropriations committee, it was a ridiculous sum by comparison with salaries paid outside the Government. The work and responsibilities of the position, said Hoover, were fully equivalent to those of a university president receiving $25,000.[42]

Although a bachelor, Dr. Stratton had heavy expenses. In an age more sedulously social than our own, he delighted in entertaining members of the staff and his circle of friends in Washington. His elaborate Christmas and summer parties for the children of the staff became festive traditions.[43] Entertainment of visiting scientists and businessmen and his colleagues from the national laboratories abroad he had long met out of his own pocket, as he had the expenses of membership in the social and scientific clubs required by his position.

Besides his lifelong interest in his private workshop at the Bureau, which entailed some personal expense, Stratton as a result of his frequent official trips to Europe developed a collector's interest in tapestries, fine crystal, polished glassware, instruments, and ingenious mechanical devices which he found in the shops abroad. The interest was constrained, for many of these things were far beyond his means and likely to continue so. He was in his 60th year, had no private income or other prospect but his

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[41] A brief rebellion of some of the staff several years earlier against certain Bureau administrative policies is recorded in letters from six Bureau members to Stratton, Mar. 29, 1917, and letters from 19 members to Secretary Redfield, Jan. 25 and Feb. 7, 1918, with attached correspondence (NARG 40, Secretary of Commerce file 76694). The Secretary recommended appointment of an assistant director at the Bureau to lighten the Director's administrative burden, and this was done (letter, Redfield to SWS, Mar. 19, 1918, and attached correspondence, NARG 40, file 67009/66).

[42] Hearings * * * 1923 (Feb. 1, 1922), p. 14.

[34] A good characterization of Stratton and of life at the Bureau at that time appears in G. K. Burgess, "Dr. Samuel Wesley Stratton," Tech. Eng. News (MIT) 3, 146 (1922).

meager retirement pay. Nor, in 1922, did it seem likely that Congress would remedy the salary scale anytime in the foreseeable future.

Dr. Stratton may well have voiced these feelings to his friends at the Department of Commerce, and when Secretary Hoover told him that the Massachusetts Institute of Technology at Cambridge, which had been without a President for more than 2 years, had approached him to recommend a candidate, Dr. Stratton consented to the recommendation.[44]

Stratton had had similar offers before, but he had been building the Bureau then and could not be tempted. In 1913 the Russian Imperial College at St. Petersburg had sought him for an executive post at a large salary and under his own conditions. And in 1916 he was offered an administrative position at Columbia University at $10,000 a year. He had turned both down.[45] This time he accepted the invitation, and on September 19, 1922, the Executive Committee of MIT appointed Dr. Stratton as its ninth president. He took office on January 1, 1923.

In his notice to the press of Dr. Stratton's departure, Secretary Hoover sounded a recurring complaint of Government department heads:

> While the Massachusetts Institute of Technology is to be congratulated on securing Dr. Stratton, one cannot overlook the fact that the desperately poor pay which our Government gives to great experts makes it impossible for us to retain men capable of performing the great responsibilities which are placed upon them. The Massachusetts Institute of Technology, an educational institution, finds no difficulty in paying a man of Dr. Stratton's calibre three times the salary the Government is able to pay him.
>
> Dr. Stratton has repeatedly refused large offers before, but the inability of the scientific men in the Government to properly support themselves and their families under the living conditions in Washington, and to make any provision for old age makes it impossible for any responsible department head to secure such men for public service at Government salaries.[46]

The severance was softened by Secretary Hoover's appointment of Dr. Stratton to the Visiting Committee to the Bureau, succeeding Dr. Joseph S.

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[44] Communication from the Hon. Herbert C. Hoover, Dec. 14, 1962.

On the death of President McLaurin of MIT in 1920, Hoover himself was sought for the position. See "New York Times," Feb. 1, 1920 (letter to editor), sec. III, p. 1, and May 27, 1920, p. 2.

[45] The Imperial College offer is referred to in a pencil notation on letter, Frederic A. Delano, Smithsonian Institution, to SWS, Jan. 10, 1928 (offering Stratton the secretaryship of the Smithsonian); and the Columbia offer is in letter, Treasurer, Columbia University, to SWS, May 5, 1916, both letters in Stratton Papers at MIT.

[46] "Boston Herald," Oct. 12, 1922, p. 1; "New York Times," Oct. 12, 1922, p. 14.

Ames of the Johns Hopkins University. The appointment was to become effective on the date of his termination of service as director.[47]

In a very real sense, Dr. Stratton never left the Bureau. As he told a Bureau member who wrote to him soon after his arrival in Cambridge, "* * * I can never cease to be a member of the Bureau which has been practically my life work, and I shall never hesitate to give counsel and support whenever the opportunity may afford itself." [48] Both as member of the Visiting Committee and as creator of the Bureau, Stratton's counsel and concern were to be frequent and voluminous and continued so throughout his tenure at MIT. Most of his correspondence was with Dr. Burgess, apprising him of details of Bureau operations, advising on Bureau procedures in cooperating with industry and Government agencies, and forwarding inquiries sent to him at MIT. Planning to buy a radio set in the fall of 1923, Stratton wrote asking about the latest radio developments at the Bureau. He recommended new members for the Visiting Committee, and was active in securing lecturers for the Bureau, writing Burgess on one occasion that he had invited the Danish physicist, Niels Bohr, to come to the Bureau. In turn, Dr. Burgess discussed problems of Bureau appropriations with Stratton, sent him new publications for comment, and frequently mailed slides and other material for lectures and addresses Stratton planned.[49]

An able administrator at MIT, Stratton nevertheless seems to have regarded the Institute as another Bureau of Standards, or as an extension of the Bureau. In training scientists and technologists for industry, the Institute offered complementary services to those of the Bureau. Stratton had exchanged one campus for another. Within a year after assuming the presidency, he began work on a reorganization and expansion program at Cambridge, much of it closely modeled on the Bureau, which undertook to establish at the Institute new departments of aeronautical engineering, automotive engineering, building construction, fuel and gas engineering, hydraulics, physical metallurgy, municipal and industrial research, public health engineering, and ship operation.

Throughout his tenure at Cambridge, Stratton's addresses and talks were filled with his memories of the Bureau. In the several score manuscripts and reading copies that survive, mention of the Bureau by name seldom occurs, but striking to anyone acquainted with its activities is the

[47] Letter, Hoover to SWS, Nov. 1, 1922 (NARG 40, Secretary of Commerce, file 67009/5).
[48] Letter, SWS to Walter A. Hull, Jan. 5, 1923 (Stratton Papers at MIT).
[49] Correspondence from 1923 on between Stratton, Burgess, and the assistant director, Fay C. Brown, will be found in NBS Boxes 42, 43, 46, 48, 52, 54, 55, 56, 57, 61, 62, 64, 70, 75, 81, 82, 174, 184, 185, and 214, and in NBS Blue Folder Boxes 4 and 8.

frequency with which Bureau investigations and undisguised Bureau experiences were drawn on for illustrative material. At the banquet he attended in Washington in 1926 to celebrate the 25th anniversary of the founding of the Bureau, he said, "I think of you still as members of my staff." [50]

GEORGE KIMBALL BURGESS

In his letter in November 1922 appointing Dr. Stratton to the Visiting Committee, Hoover asked that Stratton at once take up with the Committee the question of his successor, "as I'd like to have their advice on the subject." Stratton offered two names to his future colleagues on the Committee, that of Dr. Lyman J. Briggs, recently promoted from the aviation physics section to chief of the engineering physics division, succeeding Stratton himself who had held that position; and of Dr. George K. Burgess, chief of the metallurgy division.[51]

Although as chief physicist and senior in point of service and experience Dr. Burgess seemed the logical choice, both the Visiting Committee and the Secretary of Commerce, in deliberations that seem less than flattering, delayed decision.[52] For almost 4 months, until April 21, 1923, Dr. Fay C. Brown, technical assistant to Dr. Stratton, served as acting director of the Bureau. On that date President Harding's appointment of the new Director, Dr. Burgess, became effective.[53]

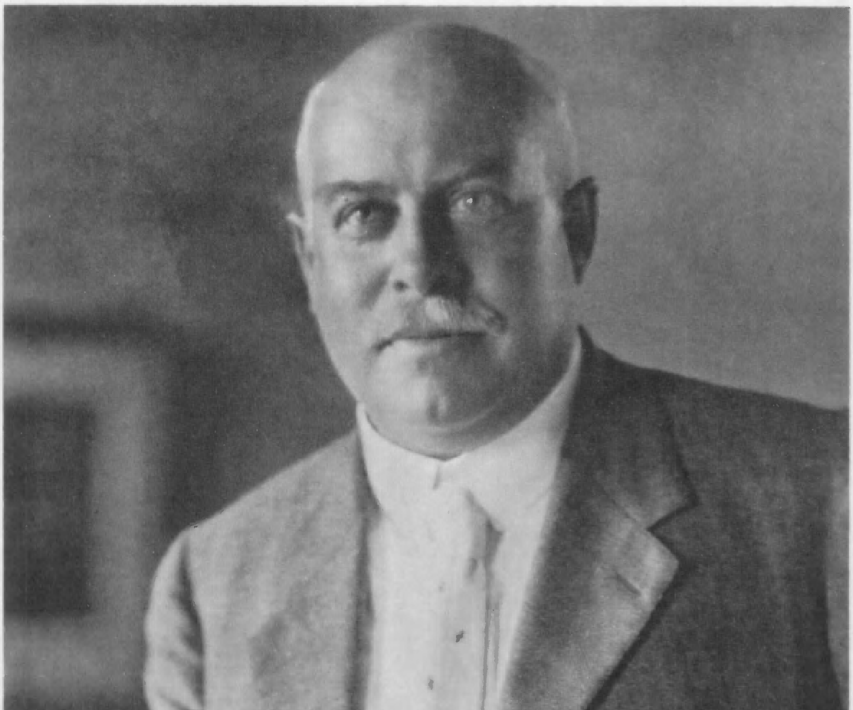
Dr. Burgess (1874–1932), who on the death of Dr. Rosa became the chief physicist at the Bureau, was born in Newton, Mass., and graduated from the Massachusetts Institute of Technology. He went abroad for graduate training, receiving his D. Sc. in physics with highest honors from the Sorbonne in 1901. His thesis was on a redetermination of the constant of gravitation, but courses he took under Le Chatelier in high-temperature measurements aroused a greater interest and led him to translate his teacher's classic work on the subject. A decade later, as a result of his own investiga-

[50] Speech, Dec. 4, 1926 (NBS Blue Folder Box 3, APW 301c). A brief biographical sketch of Dr. Stratton appears as app. M.

[51] Letter, Hoover to SWS, Nov. 1, 1922, and interview with Dr. Briggs, Nov. 1, 1961.

[52] Announcement of Dr. Burgess' appointment in Am. Machinist, 58, 680 (1923), said it "followed several months of futile search on the part of Secretary Hoover for an outstanding physicist who had not been connected with the Government service, with sufficient means to allow him to make the sacrifice of income * * * [in accepting] a Bureau directorship."

[53] In his letter of congratulation to Dr. Burgess, Prof. Joseph S. Ames, director of the Physical Laboratory at Johns Hopkins, wrote: "I heard with interest of your silent and theatrical way of announcing your appointment, by quietly sitting down in the Director's chair" (letter, Apr. 25, 1923, NBS Box 43, IDP).



Unlike Stratton, Dr. George K. Burgess, second Director of NBS, is said to have administered the Bureau from his desk and seldom toured the laboratories. The Bureau, "a vertiable city of science," had grown, he felt, too large for intimate supervision and he liberally delegated his authority over its detailed administration.

tions in the field of high temperatures, he rewrote the book completely, making extensive revisions and additions.[54]

In 1903, following a year as instructor at the University of California, Dr. Burgess came to the Bureau as an assistant physicist in the heat and thermometry division. His first assignment was an investigation of the use of optical pyrometers in industry. Not long after, he began the work with Dr. Waidner, chief of the division, that was to lead to the present internationally adopted Waidner-Burgess standard of light. In 1913, soon after the Bureau undertook its investigation of railroad track and wheel failures—largely a problem in the physics of metallurgy, concerning the thermal behavior of metals in the manufacturing process—Dr. Burgess organized the Bureau's division of metallurgy. It pleased him later to say that he had never had a course in metallurgy in his life, which was quite possible, since it was so new a field that there may not have been half a dozen metallurgists in the United States at that time.[55]

Ten years after the establishment of the division, Dr. Burgess, as a result of more than a hundred technical papers on heat measurement and metallurgy, had won international recognition. His staff comprised some 50 experts, largely trained by him, inquiring into almost every aspect of modern metallurgical technology, from the melting and casting of metals and alloys to their physical and chemical testing.

Few men ever came to know Burgess intimately, either as division chief or Director of the Bureau. A sociable man in working hours, he was nevertheless reserved, and as impeccable in manner as he was in dress. He has been described by those who worked under him as "quiet," "warmhearted," "very pleasant," "a nice person," yet a man "you couldn't get to know." [56] Recreation is said to have meant to him a good book—preferably a good detective or mystery story—and a plentiful supply of tobacco, or a long drive in an open car.[57] Of his private life little more was known. In 1901 he had married, in Paris, the daughter of a French Protestant family, but neither he nor his wife was gregarious and seldom entertained. They had no children.

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[54] Lyman J. Briggs and Wallace R. Brode, "George Kimball Burgess, 1874–1932," Natl. Acad. Sci., Biographical Memoirs, 30, 57 (1957). See Henri L. Le Chatelier, High Temperature Measurements, tr. G. K. Burgess (New York: J. Wiley, 1901); rev. and enl. 2d ed., 1904; rewritten as G. K. Burgess and H. Le Chatelier, The Measurement of High Temperatures (Wiley, 1912).

[55] Letter, Burgess to president, Carnegie Institute of Technology, Mar. 21, 1924 (NBS Box 77, IDP).

[56] Natl. Acad. Sci., Biographical Memoirs, above; interviews with Dr. Briggs (Nov. 1, 1961), Mrs. William Meggers (May 8, 1962), and Dr. Kasson S. Gibson (June 1, 1962).

[57] L. J. Briggs, "George Kimball Burgess," Science, 76, 46 (1932).

If Dr. Burgess was perhaps less impressive in figure or manner than Stratton, he was considered a better scientist. Yet as he saw the need for better technology in the field of metallurgy, he turned increasingly to the practical application of his earlier research.[58] As Director he was to be as concerned as Stratton in promoting Bureau cooperation with industry in solving its scientific and technical difficulties.

To the surprise of many, Dr. Burgess in the Director's chair displayed a marked talent for enlightened management. Unlike Stratton, who found it difficult to believe that the growth of the Bureau had put it beyond a personally directed operation, Dr. Burgess delegated authority widely. He worked from his office and his desk, but his door was always open. Dr. Hobart C. Dickinson, who succeeded Dr. Waidner as chief of the heat division, was to say that the Bureau under Dr. Burgess "became a democracy * * *. Meetings of the Division Chiefs for the free exchange of ideas under [his] skillful chairmanship * * * became the order of the day. Appointments, promotions, and salaries became matters of common knowledge. The needs and welfare of the individual employees became more and more important as compared with those of the institution as a whole." [59]

At the same time, the Bureau seems to have become a somewhat more rigid institution under Burgess. Stratton's encouragement of individual initiative and of new projects had permitted the wide latitude of research that characterized the work of Rosa's division. Similarly, when Dr. Paul Foote and Dr. Fred Mohler, members of the heat division, became interested in spectral phenomena in atomic physics, Stratton let them forget about pyrometry and pursue their research in a section set up in his own optics division. And Raymond Davis, who came to the Bureau in 1911 to establish a photographic service, after devising on his own time a number of ingenious photographic instruments, was rewarded with a new section, photographic technology. It was generally understood that if you had a good idea you could go ahead with it, even if it wasn't your particular job.[60]

Burgess on the other hand was inclined to be a stickler for academic orthodoxy, venerated the graduate degree and its symbol of competence, and had a strong sense of propriety. Despite the success of his own enterprise that had led to the metallurgy division, as Director he tended to dis-

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[58] References to important research results of Burgess and his group appear in H. M. Boylston, An Introduction to the Metallurgy of Iron and Steel (New York: John Wiley, 2d ed., 1936), pp. 416, 492n, 517, 543n, 544.

[59] Natl. Acad. Sci., Biographical Memoirs, above; MS, memorial address, H. C. Dickinson, "Dr. George Kimball Burgess" (Feb. 8, 1936), p. 18 (NBS Historical File).

[60] Interview with Dr. Mohler, Oct. 9, 1962; interview with Raymond Davis, Dec. 1, 1961. As Dr. Coblentz (From the Life of a Researcher, p. 132) said, Dr. Stratton gave promising men of his staff "an opportunity to pursue research unhampered, and with a freedom beyond all expectations."

courage ventures of staff members outside the field in which they had been trained. Though never spelled out, it was a policy that Burgess seems to have felt made for greater stability in the organization, greater efficiency and concentration of effort, and better research results.

To some extent, of course, both the looser rein and the check on adventuring stemmed from Dr. Burgess' initial unfamiliarity with the administration of the Bureau in general and with the work and scope of its divisions. Sedentary by nature and singleminded, as division chief he had seldom strayed far from his laboratory. And since there was no procedure—not even anything like a briefing handbook—for turning over the Director's office to a successor, Burgess for many months after moving into office had to grope his way through the complexity of Bureau operations left by Stratton. The Bureau correspondence of that period, heavily penciled with Dr. Burgess' "Who?" and "What?", seems to corroborate the degree of unfamiliarity.[61]

Besides the fact that the Bureau had outgrown the need for the highly personal and centralized leadership so effective in its formative years, certain recent events were to have a marked influence on Burgess' administration.

> The time-honored custom of a Chief of [a] Bureau going to the committees of Congress directly with his problems and need for funds had been replaced by a Budget Bureau * * *. No longer could an urgent need, or even a fancied urgent need, be presented by the Director in person and, sponsored by good friends, lead to an appropriation for some important new line of work for the Bureau.[62]

The Director continued to justify his budget to the House Appropriations Subcommittee each year, but it was no longer a budget subject to negotiation. Furthermore, under a succession of Republican administrations intent on economy in Government spending, the Director came to depend increasingly on funds transferred from other Government agencies. In this Dr. Burgess was encouraged by the Secretary of Commerce. And as the Bureau became a more integral and vital part of Commerce, "this led further toward limiting the actions of the Director." [63]

If Burgess could not negotiate with Congress for extension of Bureau research activities as Stratton had, he found a way to impress both Congress and the Bureau of the Budget with the value of Bureau research. The device

[61] Dr. Burgess was candid at his first meeting with the National Screw Thread Commission: "You will find that I shall be an impartial chairman because I know absolutely nothing about this subject." Minutes of meeting, May 10, 1923 (NBS Box 64, ST).

[62] MS, Dickinson (Feb. 8, 1936), p. 17.

[63] Ibid., p .18.

was to result in small but steady increases in Bureau appropriations throughout his tenancy. Apparently acting on a hint provided by a member of the House Subcommittee, who had requested that the Director include in his presentation a list of Bureau publications of the previous year, Burgess at his first confrontation with Congress early in 1924 deluged it with statistics. Annually thereafter he compiled imposing catalogs of Bureau operations, Bureau economies effected on behalf of other Government agencies and of industry, and current scientific and technological accomplishments of the Bureau, some of his presentations running to a hundred pages or more and much of it in fine print.[64]

One other influence on Bureau operations may be noted, that of the Visiting Committee, invigorated by the presence of Dr. Stratton.[65] The Committee had originally been set up to keep the Secretary of Commerce informed of "the efficiency of * * * [the] scientific work [of the Bureau] and the condition of its equipment." Perhaps to reassure Congress, or even with the thought of extending the influence of the Committee, Stratton had said soon after the first visitors were appointed: "The visiting committee we shall make an advisory board." [66] In the 1920's, more than ever before, the Committee became that board.

By 1923 the staff and plant of the Bureau of Standards made it the largest physical laboratory of its kind in the world. Dr. Burgess was fully conscious of the enormous responsibility over which he presided. He intended no further expansion of functions or of avenues of research. He was content to carry on the work of Rosa and Stratton. A cautious man, his was to be, as Dr. Briggs said, "a wise administration." [67]

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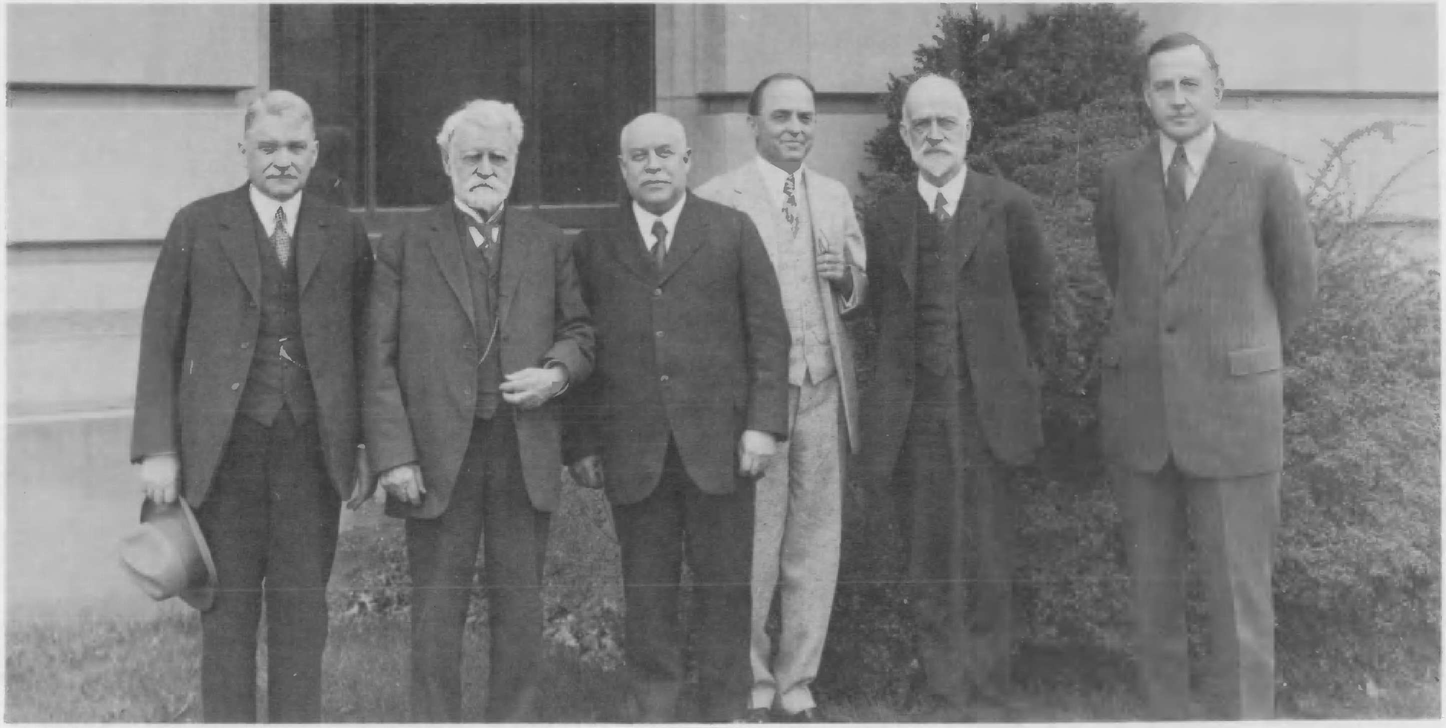
[64] Still other tabulations included the 82 advisory committees on Bureau research, the 56 conferences held at the Bureau in the past year, and a selection from a single random day's mail that comprised almost a hundred specific requests for services of one kind or another. Altogether, the tabulations spanned pp. 209–319 of Hearings * * * 1925 (Feb. 12, 1924). A year later Burgess included work-in-progress as well as accomplishments of the divisions, section by section, and added an impressive chart of the total value of products produced by each industry served by the Bureau, arranged according to Bureau appropriations for its work in those industries. Hearings * * * 1926 (Jan. 5, 1925), pp. 157–159.

[65] Few references to the Visiting Committee appear in the annual reports prior to 1924. With NBS Annual Report 1925 (p. 38) and its announcement of the forthcoming NBS M63, "Report of the Board of Visitors * * * Nov. 1924," the recommendations of the Committee became a matter of public record. But the same economy that reduced the Bureau's annual report from 330 pages in 1923 to 38 pages in 1924 also ended the separate Visiting Committee report, and summaries of its recommendations thereafter appeared only in the Bureau's annual report.

[66] Hearings * * * 1903 (Jan. 28, 1902), p. 146.

[67] Interview with Dr. Briggs, Nov. 1, 1961; Briggs, "George Kimball Burgess," Science. 76, 46 (1932).



The Visiting Committee of the Secretary of Commerce to the Bureau in the mid-1920's.
Left to right: Dr. Stratton, president of MIT; Ambrose Swasey, founder of Warner & Swasey; Dr. Burgess, Director of NBS; W. R. Whitney, director of research, General Electric Corp.; W. F. Durand, professor of mechanical engineering at Leland Stanford University and president of the American Society of Mechanical Engineering; and Gano Dunn, president of J. G. White & Co.

Within a year after the war most of the research projects diverted or laid aside in 1917 had been resumed. They were increased now by continuing weapons research for the military, by the optical glass and gage work, investigations on behalf of industry and the public utilities, and the programs in housing technology, specifications, and simplified practice recently established by the Secretary of Commerce.

In certain areas, as in textiles, automotive engineering, and utilities, Bureau plans for research were to be modified as the decade progressed, owing to the organization or expansion of industrial research laboratories as the trade association movement grew, to increased research by public utilities, and to the rise of private research organizations.[68] Where this occurred, the Bureau entered into cooperative investigations with technical committees set up by the associations. Further assistance was rendered by accepting increasing numbers of research associates to work in the Bureau laboratories.

Despite its steady expansion of interest in industrial research, the Bureau both before and after the war carried out considerable basic research, much of it in determination and refinement of physical constants,

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[68] NBS Annual Report 1924, p. 22, was to say that the ceramic industry, for example, had begun doing much of its own plant development and practical research, permitting the Bureau to pay "more attention to the fundamentals required by the industry."

Dr. Paul R. Heyl of the mechanics and sound division making observations for his redetermination of the constant of gravitation, probably in the block house constructed behind West building for the project.

and often of more immediate interest to science than to industry. Such was the work of Vinal and his associates from 1912 to 1916 which resulted in more precise knowledge of the limitations in accuracy of the silver voltameter (the reference standard for defining the International Ampere), requisite to the later absolute determination of the ampere.[69] A fine achievement also was Heyl's redetermination of the Newtonian constant of gravitation (G) and later of the value at Washington of the local acceleration of gravity (g), completing as it did a "true weighing of the earth." [70] Significant too were Buckingham and Dellinger's work on a method of computing the constant of Planck's equation for the radiation of a black body,[71] Gibson and Tyndall's determination of visibility factors of radiant energy,[72] and Coblentz's new standards of thermal radiation, also involving Planck's equation, the latter published in a 75-page report on which Coblentz worked from 1909 to 1912. The values of those standards remain unchallenged to the present day.[73]

Although astronomers at the time, as Coblentz, said, would have seriously questioned the possibility of detecting "the heat of a candle 52 miles away," the series of highly sensitive radiometers which he devised for his research made possible new measurements of the heat of stars and planets. His instruments were destined to extend the fields of spectroscopy and colorimetry and find application in the biological and agricultural sciences.[74]

In one investigation Burgess joined Coblentz, when both became interested in the international research going on in the high-temperature optical-pyrometer scale and the laws of radiation upon which to base such a scale.

[69] S218 (Vinal and S. J. Bates, 1914); S285 (Vinal and Rosa, 1916).

[70] The work spanned almost 20 years. See letter, SWS to Superintendent, C. & G. S., Feb. 20, 1917 (NBS Box 2, AG); NBS Annual Report 1923, p. 200; Annual Report 1927, p. 6; RP256 (Heyl, 1930); RP946, "The value of gravity at Washington" (Heyl and Cook, 1936).

[71] S162 (1911). Other work at the Bureau involving Planck's constant was reported in S259 (Foote, 1916), S287 (Dellinger, 1917), S304 (Roeser, 1918), and Foote and Mohler, J. Opt. Soc. Am. 2, 96 (1919).

Planck had modified the earlier Wien equation for black-body radiation to better fit the experimental data of Rubens, Coblentz and others. It was his search for a theoretical explanation of this equation which led to his famous postulate of the energy quantum, hv, which laid the foundation for his quantum theory. His equation involving the constant c_2 gives the spectral energy distribution of the heat radiation emitted from a so-called black body at any temperature. Among many applications, the constant can be used to predict the light output of incandescent lamps, cooling time of molten steel, heat dissipation of a nuclear reactor, the energy radiated from the sun, or the temperature of the stars.

[72] S475 (1923).

[73] S204 (1913) and S227 (1914); Coblentz and Stair, "The present status of the standards of thermal radiation maintained by the Bureau of Standards" (RP578, 1933).

[74] Coblentz, From the Life of a Researcher, pp. 148, 154, 168–173.

"A certain amount of prestige and glamour surrounded the [work] in this field," Coblentz wrote later, and there was a good deal of friendly competition with the investigations in progress in the national laboratories abroad.[75] Certain phases of this research were to lead to the establishment of the present-day International Practical Temperature Scale.

The international scale had its inception in 1911 when the national laboratories of Great Britain, Germany, and the United States proposed that they adjust the minor differences in the temperature scales each was maintaining and that, in place of the practical values in use, they establish absolute values for their points. More than a decade passed. The absolute temperature scale they sought proved experimentally difficult to achieve. Finally, in 1927 the three laboratories proposed adoption of an "international temperature scale" that might be more readily realized than the absolute—a practical scale ranging from the temperature of liquid oxygen to that of luminous incandescent bodies—that would at least serve the immediate needs of industry. Agreement on the basic fixed points and the series of secondary reference points on this scale was reached a year later. For the first time it became possible to certify temperature measurements for a wide variety of industrial purposes.[76]

The early work on the temperature scale coincided with an investigation that began in 1913, to provide scientific data to the refrigeration industry in this country for the better construction of its cooling plants and machinery.[77] The Bureau's success in determining the specific heat of ice, the properties of ammonia, and other physical constants required by the industry led Stratton to request a special appropriation from Congress to continue Bureau research in physical constants. For a time Stratton dreamed of an American "Landolt," as a new and more practical engineering reference book of physical constants than was currently available in the German work by Landolt and Börnstein.[78] The appropriation was small and short-lived; the research was too fundamental for Congress. Using statutory funds the

[75] Ibid., pp. 134–135.

[76] Burgess, "The International Temperature Scale" (RP22, 1928); Science, 68, 370 (1928). Cooperation and exchange of information with national standard laboratories abroad and with the International Bureau of Weights and Measures has been continuous throughout the existence of the Bureau. Except in particular instances, the history of that exchange is not elaborated in the present work. The scope of cooperation is to be found in the annual reports of the Bureau. That for 1930, for example (pp. 3, 7, 9, 10), describes NBS exchanges of information and equipment relative to new intercomparisons of meter bars, the international temperature scale, standards of capacitance, resistance standards, and standards of candlepower during the previous year with the IBWM, NPL, PTR, and Japanese and Russian standards laboratories.

[77] See ch. III, p. 130.

[78] Letter, SWS to W. R. Whitney, General Electric, Jan. 6, 1920 (NBS Box 10, IG). For Stratton's first proposal, see Hearings * * * 1917 (Feb. 2, 1916), pp. 986–987.

Bureau nevertheless continued limited research on physical constants all through the 1920's and into the thirties, improving its ammonia tables, publishing steam tables for turbine engineering, petroleum tables, a series of papers and a book on the properties and constants of water in all its phases, and establishing new points on the international temperature scale.[79]

A note of considerable interest to physicists appeared just before the first of the airplane ignition troubles arrived in the electrical division in 1917 when Dr. Silsbee published a salient observation he had made on electrical conduction in metals at low temperature. It was well known that resistance to electrical current vanishes in certain metals at very low temperatures, resulting in electrical superconductivity. In 1911 the Dutch physicist, Kamerlingh Onnes, had found in separate experiments that this phenomenon of superconductivity was destroyed if the current exceeded a critical value, and was also destroyed if an external magnetic field of more than a critical value was applied.

Dr. Silsbee saw that these two effects were not independent. The result was the Silsbee hypothesis, "that the effect of electrical current on the critical temperature of a superconductor is caused by the magnetic field produced by the current"—a valuable clue to a more satisfactory theory of the superconductive state and of metallic conduction in general.[80]

Two publications illustrated the progress of 8 years of Bureau research in polarimetry and saccharimetry under Frederick J. Bates. The seven-page circular of 1906 on the simple verification of polariscopic apparatus became a 140-page work by 1914, establishing the basic principles of modern polarimetry.[81] In that period the sugar industry acquired through the Bureau a variety of improved instruments, better apparatus, and a wealth of fundamental data; and Bureau investigations of the rare sugars, in critical supply during the war, were to lead to a wholly new industry in this country—of which more later.

For almost a century before the founding of the Bureau, analysis of chemical elements through their emission spectra had been the subject

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[79] (1) C142, "Tables of thermodynamic properties of ammonia" (1923). (2) RP691, "Tables for the pressure of saturated water vapor in the range 0° to 374°" (Osborn and Meyers, 1934); NBS Annual Report 1939, p. 53. (3) RP1105 "Supercooling and freezing of water" (Dorsey, 1938); Dorsey, Properties of Ordinary Water-Substance (New York: Reinhold, 1940). (4) C57, "U.S. standard tables for petroleum oils" (1916); M97, "Thermal properties of petroleum products" (Cragoe, 1929). (5) RP-1189, "International Temperature Scale and some related physical constants" (Wensel, 1939).

[80] S307 (1917); interview with Dr. Silsbee, May 21, 1963. For later studies in superconductivity, see NBS Annual Report 1948, p. 207, and ch. VIII, pp. 466–467.

[81] C12 (1906) and C44 (1914; 2d ed., 1918). By 1942 the latter circular had been superseded by C440, a tome of 810 pages.

of studies in Europe. It was well known that each chemical element or combination of elements has distinctive spectra, either by emission or absorption, that are as characteristic of the element as the fingerprints of humans. Yet in that time practically none of the spectra of the elements had been completely described, although their importance, both theoretical and practical, was increasing more rapidly than the knowledge of them advanced. Except in astrophysics, there had been little application of spectroscopy, and in analysis the "wet" chemists continued to reign supreme.

Upon his arrival at the Bureau as a young laboratory assistant in 1914, Dr. William F. Meggers began the measurement of wavelengths of light and their application to an understanding of the spectra of chemical elements. By the sheer weight of accumulated evidence he was to establish standards of spectrographic measurement that were to gain worldwide acceptance. Some of the masses of spectrographic data that he and his assistants compiled over the next three decades for the analysis of chemical elements and compounds, noble gases, common and rare metals and their alloys, had to await the development of electronic computers for their resolution and final form. Out of the routine analyses made in the Bureau's spectroscopic laboratory of the thousands of samples of materials submitted for testing came new methods of quantitative analysis, some of them sensitive to amounts of impurities so small that they completely escaped detection by chemical methods.

The publication in 1922 of Dr. Meggers' paper with Kiess and Stimson on "Practical spectrographic analyses" drew attention to the simplicity and practicality of making chemical identifications and quantitative determinations by spectroscopic means. That paper, Dr. Meggers was to say, "finally put applied spectroscopy on its feet." [82] The tool of science became a tool of industry, owing much to Dr. Meggers' continuing research in improved methods of spectrochemical analysis. At the same time, he was to contribute materially to atomic physics studies going on at the Bureau through his search for better description of atomic and ionic spectra.

A chance assignment first launched the Bureau into areas of atomic physics well beyond its early investigations of radium and radioactivity when Professor John Tate, physicist at the University of Minnesota, came as a guest worker in the heat division during the war. Professor Tate had recently returned from Europe where he learned about the exciting work being done at Göttingen in the spectral analysis of mercury and other metal vapor atoms. At the Bureau he aroused the interest of Dr. Paul D. Foote and Dr. Fred L. Mohler, two youngsters in the heat division, in this work that appeared to support Bohr's theory of atomic processes.

[82] S444 (1922) and interview with Dr. Meggers, Mar. 13, 1962. Today there are more than 3,000 spectrometrical laboratories in the United States alone.

Although it was entirely outside the scope of the division, Stratton allowed Foote and Mohler remarkable freedom (though no funds) to pursue this atomic research. Their studies—described in the annual report of 1918 as "investigations in electronics" [83]—in experimental phenomena of the quantum theory of spectra, that is, the excitation and ionization potentials of simple molecules and photoionization of alkali vapors, culminated in their book published in 1922, The Origin of Spectra, a survey of recent experimentation in atomic physics as related to atomic theory.

The year the book came out, Stratton set up an atomic physics section, consisting of Foote and Mohler, in the optics division, where it remained until after World War II.[84] All through the 1920's, Dr. Mohler, with Dr. Foote and later with Dr. Carl Boeckner, continued their electrical and spectroscopic measurements of critical potentials of atoms, ions, and molecules. In the 1930's, as chief and sole member of the section, the smallest at the Bureau, Dr. Mohler began his pioneer investigations in the then sparse field of plasma physics, a field that was to have far more meaning three decades later than at that time.

The quiet islands of fundamental research at the Bureau in physical constants, in radiometry, spectroscopy, and atomic physics, particularly in the years immediately after the war, were in marked contrast to the din of industrial research going on almost everywhere else at the Bureau.

BUILDING AND HOUSING

Ready with a program more appropriate to the Chief Executive than to the Secretary of Commerce, Hoover entered office determined to recover the Nation, singlehandedly if necessary, from its wartime splurge, its consequent depletion of resources, and the general economic demoralization into which it had plunged. Recovery, by raising as rapidly as possible the level of productivity, was the first essential; reconstruction would follow.

Hoover's plan for recovery, in order to open employment offices again and start up the wheels of industry, was to stimulate building and housing, lend direct assistance to both new and established industries, and minister

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[83] NBS Annual Report 1918, p. 70. This appears to be one of the earliest uses of the word "electronics," although not in its present connotation. It did not come into general use until just before World War II.

[84] Apparently challenged to justify such research, Stratton in the annual report for 1922, pp. 85–86, declared that a thorough understanding of the nature of collisions between atoms and electrons might well lead to the development of more efficient illuminants, better "radio-bulb" design, and extension of the range of X-ray spectroscopy. Foote and Mohler's first acquisition of equipment, including an ionization chamber, a beta-ray chamber, electroscopes, and a 1,500-pound electromagnet, waited until 1925 (NBS Annual Report 1925, p. 36).

to the new aviation and radio industries. Reconstruction, providing long-range benefits to the economy, aimed at a progressive elevation of the standard of living, principally by a campaign to eliminate economic wastes.

Although the building trades themselves badly needed reconstruction, they offered the most likely means of achieving immediate and massive results in reviving depressed industry and providing maximum employment across the Nation. The housing shortage as a result of the war was estimated at more than a million units. Stimulate homebuilding, and the brick, lumber, glass, hardware, plumbing, appliance, textile, and furniture industries and all that served and supplied them would revive.

Poor home designs, high labor and material costs, antiquated and obstructive building codes and zoning regulations, and tight mortgage money were among the targets of the division of building and housing set up by Hoover under Dr. John M. Gries in the Department of Commerce on July 1, 1921. Dr. Gries also headed the administrative unit (subsequently raised to divisional status) at the Bureau, to take advantage of its experience with municipal and State codes and to coordinate its numerous investigations useful to the building industry in the electrical, heat, chemistry, structural engineering, metallurgical, and clay products divisions.

A whirlwind campaign was planned, in which the Bureau's role was to publish material on the economics of home building and home ownership, and recommend revisions making for greater uniformity in local building and plumbing codes and city zoning regulations. The Bureau was also to urge adoption of standards of building practice looking to better construction and workmanship, and seek simplification and standardization of building materials and dimensional varieties in order to reduce costs.[85]

The program was launched amid nationwide publicity. Chambers of commerce, women's clubs, and better homes and gardens organizations throughout the country participated, and Secretary Hoover himself headed the national advisory council of the Better Homes in America movement that was organized in Washington early in 1922. Volunteer committees crusaded for Better Homes in every State of the Union. At Commerce, the housing division consulted with building officials, architects, fire chiefs, engineers, building material experts, and the professional societies and associations connected with the building industry. It amassed information and statistics, and acted as liaison between Hoover's advisory committees on building, plumbing, and zoning codes, and the technical divisions at the Bureau.[86]

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[85] The Memoirs of Herbert Hoover, II, 92–93; NBS Annual Report 1922, p. 260; Hoover remarks at Hearings * * * 1924 (Nov. 16, 1922), pp. 171–73.
[86] NBS Annual Report 1923, pp. 304–305.

The spring of 1922 witnessed the first surge in home construction, and the Bureau issued its first publication in the campaign, on "Recommended minimum requirements for small dwelling construction." [87] Plumbing, zoning, building code, and city planning primers followed. A Bureau investigation of the seasonal irregularities in building activity, which kept building trades workers unemployed for 3 or 4 months out of each year, disclosed that most of the lagging resulted more from custom than climate, as generally believed. Slowly the custom began to yield to the campaign of publicity and persuasion launched against it.[88] The number of new homes built that year, more than 700,000, was almost double that of the previous year.

"How to own your home," a Bureau handbook for prospective home buyers, appeared in the fall of 1923 and sold 100,000 copies the first week and more than three times that number by the end of its first year. It was reprinted in magazines and serialized in newspapers across the country.[89] Eight years later its inevitable companion piece, "Care and repair of the house," came out and was similarly serialized.[90] In the fore-

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[87] Building and Housing publication No. 1(BH1, 1922).

[88] NBS Annual Report 1924, p. 26. A survey of the Bureau's building and housing activities appears in the series of articles by Delos H. Smith, "Our national building standards," House Beautiful, 1926–27.

[89] BH4, superseded by BH17 (1931). The "New York Sun" serialization, for example, spanned January and February of 1932. A supplement to BH4 appeared as BH12, "Present home financing methods" (1928).

[90] BH15 (1931). LC366, LC381, and LC383, all in 1933, covered "Bringing your home up to date."

NOTE.—Letter circulars, numbered from LC1 (1921) to LC1040 (1961), have been reproduced at the Bureau to make information available to the public prior to formal publication, to supplement information in formal reports prior to their revision, to supply information too brief for publication, or to excerpt material from Bureau publications for which there was a continuing or voluminous demand. In some instances LC's also reproduced information from reports of the American Society for Testing Materials and the American Standards Association.

Until recently when mimeographed lists of publications (LP) began to appear, perhaps the largest single category of LC's were bibliographies of the published work of Bureau sections (e.g., LC5, "List of communications of the gage section") or of special areas of research, whether done at the Bureau or elsewhere (e.g., LC35, "Publications pertaining to petroleum products").

Some of the subjects that have eluded formal publication include "Good gasoline," "Cellophane," "Color harmony," "Neon signs," "Motorists' manual of weights and measures," "Dry ice," "Metric and English distance equivalents for athletic events," "Matches," "Horology," "Porcelain and pottery," "Abrasives," and "The legibility of ledgers." Others are cited elsewhere in the present history.

The only known complete set of these ephemeral letter circulars, as well as LP's, is presently located in the Office of Technical Information and Publications at the Bureau.

word to Vincent B. Phelan's 121-page handbook, Secretary of Commerce Lamont impressed on the reader that its data came "from the people's own science laboratory, the National Bureau of Standards." The accolade in no way lessened the howls that went up from the service trades at the idea of Government encouragement of do-it-yourself repairs. But the twenty-cent handbook, which sold over half a million copies between 1931 and

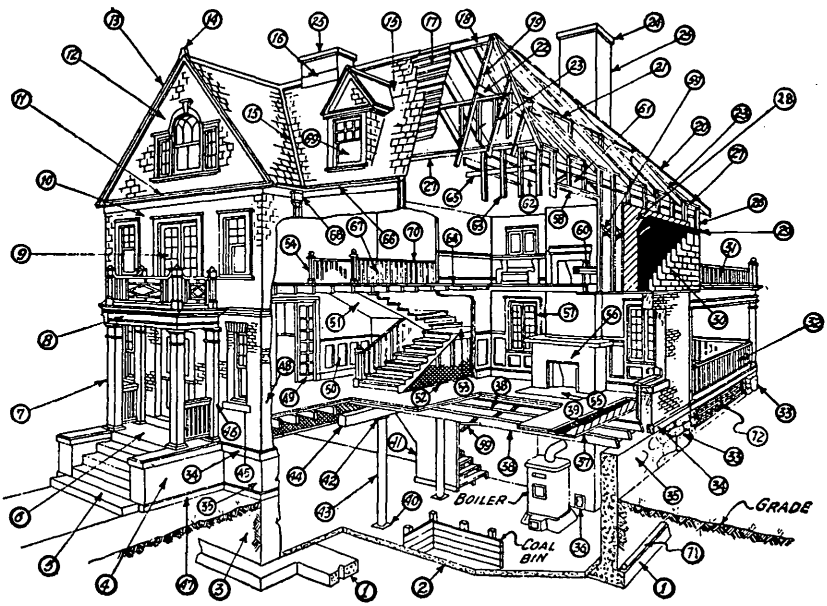

FIGURE 1.—*Essential parts of a house*

1. Footings.
2. Basement floor.
3. Foundation wall.
4. Buttress.
5. Steps.
6. Platform.
7. Porch column.
8. Porch cornice.
9. French doors.
10. Frame wall.
11. Eaves cornice.
12. Gable end.
13. Rake cornice.
14. Finial.
15. Valley.
16. Chimney flashing.
17. Shingle battens.
18. Ridge board.
19. Common rafter.
20. Hip rafter.
21. Purlin.
22. Collar beam.
23. Jack rafter.
24. Chimney cap.
25. Chimney.
26. Corner post.
27. Plate.
28. Diagonal sheathing.
29. Sheathing paper.
30. Shingle.
31. Balcony.
32. Veranda.
33. Piers.
34. Water table.
35. Underpinning.
36. Clean-out door.
37. Subfloor.
38. First-floor joists.
39. Finish floor.
40. Column base.
41. Plaster partition.
42. Column cap.
43. Iron column.
44. Girder.
45. Window sill.
46. Pilaster.
47. Ground course.
48. Brick wall.
49. Sliding door.
50. Wainscoting.
51. Stair soffit.
52. Metal lath.
53. Platform.
54. Newel post.
55. Hearth.
56. Fireplace.
57. Casement window.
58. Rough head.
59. Bridging.
60. Rough sill.
61. Truss over opening.
62. Ceiling joists.
63. Studding.
64. Second-floor joists.
65. Ribbon board.
66. Gutter.
67. Balustrade.
68. Leader head.
69. Dormer window.
70. Handrail.
71. Drain.
72. Lattice.

The first pages of the publication, "Care and repair of the house," took the owner on an inspection tour of the essential parts of his dwelling. It was a fine lesson in terminology but an exhausting tour, and the potentialities for repair were guaranteed to awe any home owner with the responsibility he had assumed.

1940, remained available to the public until the early fifties, when a new reprinting threatened sales of similar commercial publications in the bookstores.[91]

Construction of new homes reached a peak in 1925 when 937,000 units were completed. At the start of the program it had been estimated that a minimum of 450,000 homes a year would be necessary to overcome the postwar shortage. New construction in the 8 years of the program, through 1929, actually averaged 750,000 homes annually.[92]

The housing emergency long past, the building division at the Bureau became an early casualty of the depression. By June 1933 the staff, which had numbered 36, was down to 2. In 1934 its code sections and the safety standards section in the electrical division were merged with the Bureau's specifications division and transferred from Commerce out to the Industrial building at the Bureau.[93] There the regrouped division continued the research that was to serve the New Deal low-cost housing program organized in the late 1930's.

"THE CRUSADE FOR STANDARDIZATION"

In 1920, while President of the Federated American Engineering Societies, Hoover initiated a survey to determine the extent of wasteful use of materials and wasteful operations in industry. Twenty-five percent of the costs of production could be eliminated, the report disclosed, without affecting wages or labor. In six typical industries, wasteful practices accounted for almost 50 percent of materials and labor.[94]

If waste was most prevalent in industry, industry had no monopoly on it. Owing as much to long-established custom as to the wake of war, it was to be found throughout the economy. The great reconstruction program that Hoover proposed upon taking over the Department of Commerce had for its objectives: (1) Elimination of waste in transportation; (2) elimination of waste of natural resources; (3) husbandry of fuel and labor

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[91] The service trades had some justification, for upon its publication in 1931 the Bureau distributed posters and other advertising matter for the handbook to hardware and paint dealers and put up displays at trade conventions. See monthly reports, Div. XI, 1931 (NBS Box 334, PRM). The trades also had to contend with Doubleday, Doran's publication for Better Homes in America of a hard cover edition of "Care and repair" that same year, 1931. For the outcome of the handbook, see ch. VIII, pp. 481–582.

[92] The Memoirs of Herbert Hoover, II, 96.

[93] NBS Annual Report 1934, p. 73; Annual Report 1935, p. 83.

[94] Waste in Industry (New York: McGraw-Hill, 1921), briefed in H. P. Dalzell, A. B. Galt, and R. M. Hudson's "Simplification data for survey of 'Recent economic changes'," July 2, 1928 (NBS Box 253, PA). See also NBS Commercial Standards (CS–0), 1930, p. 2.

through greater electrification; (4) curtailment of the swing of business cycles and of seasonal unemployment; (5) improvement of the distribution of agricultural products; (6) reduction of waste arising from litigation and from labor disputes, and two areas within the special province of the Bureau,

> [The] reduction of waste in manufacture and distribution through the establishment of standards of quality, simplification of grades, dimensions, and performance in non-style articles of commerce; through the reduction of unnecessary varieties; through more uniform business documents such as specifications, bills of lading, warehouse receipts, etc.,

and through

> Development of pure and applied scientific research as the foundation of genuine labor-saving devices, better processes, and sounder methods.[95]

Certain that industry and commerce succeeded best when acting in their own interests, Hoover sought no enforcement legislation. The Commerce Department would supply guidance, information, and assistance, but compliance would be voluntary. Alarmed by the depression, industry expressed itself eager to cooperate.

"Elimination of waste," as a phrase, did not lend itself to slogan-making as did the word "standardization," but with some loss of clarity and even objectives, they became synonymous. Long advocated by the Bureau, made imperative during the war by the necessity for mass production, and now elevated to something close to national policy, "the crusade for standardization,"[96] became a three-pronged attack on waste in commerce and industry. It comprised *standardization* of business practices and of materials, machinery, and products; *specifications* to insure good quality of products; and *simplification* in variety of products.[97] Where the wartime effort had been to achieve mass production through standardization, the postwar effort sought to achieve standardization by establishing mass production techniques—as Henry Ford was doing in the automobile industry—in every field of commerce and in the company office no less than in the shop or factory.

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[95] The Memoirs of Herbert Hoover, II, 29, 62–63. Hoover was to single out Dr. Stratton for his assistance in organizing the program and Dr. Burgess for his contributions to its achievements (ibid., pp. 62, 185).

[96] The phrase first appeared in Burgess' article, "Science and the after-war period," Sci. Mo. 8, 97 (1919). It is the title of Hoover's article in National Standards in a Modern Economy (ed., Dickson Reck, New York: Harpers, 1956).

[97] Norman F. Harriman, Standards and Standardization (New York: McGraw-Hill. 1928), pp. 78, 116–17, 129. NBS Annual Report 1922, p. 6, described the phases of standardization as those of nomenclature, of variety or simplification, of dimension or interchangeability, and of specifications.

The machinery for committing industry to standardization had been set up in 1919 upon the reorganization of the American Engineering Standards Committee. Associated with the Bureau since its establishment in 1909, the AESC learned during the war how vital standardization was to production and how little had been accomplished up to that time. The War Industries Board, dealing with businessmen through their trade associations to simplify enforcement of its rules, had also demonstrated the need for greater cooperation between Government and industry.[98]

In the spring of 1919, therefore, Stratton, Rosa, and Burgess proposed to the AESC that it become the central agency required to "provide a better connection * * * between the agencies of Federal, State and municipal government and the technical and commercial organizations concerned with engineering and industrial standards." Securing the agreement of the technical societies, trade and business organizations, and professional organizations it spoke for, the AESC that fall adopted a new constitution, broadened to include representation of government agencies and other national organizations.[99]

As its executive secretary the AESC chose Dr. Paul G. Agnew, a member of the electrical division of the Bureau since 1906, and as assistant secretary, Frederick J. Schlink, former technical assistant to Dr. Stratton. Dr. Agnew had been the Bureau representative at the meetings of manufacturers and industrialists that had wrestled with the technical aspects of Gov-

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[98] Beginning with the formation of the National Association of Manufacturers in 1895, trade organizations by the thousands arose throughout industry. Each acted for the mutual benefit of its particular industry by collecting and distributing information on prices, methods of production, standardization, shipping problems, credit ratings, public and employee relations and the like, by setting up codes of fair practices, and by lobbying on behalf of State and National legislation affecting its industry.

Although frequently charged with monopoly and restraint of trade in the age of reform, when war came the trade associations proved indispensable to the war effort, providing central agencies through which whole industries could be reached. The favorable climate of the 1920's saw over 400 new associations formed, so that by the end of the decade there were almost 7,000 in the country. See Paxson, American Democracy and the World War, II, 123–24; John D. Hicks, The Republican Ascendancy, 1921–1933 (New York: Harper, 1960), p. 50; Bining, The Rise of American Economic Life, p. 586.

[99] Rosa, "Reorganization of the Engineering Standards Committee," Eng. News-Record, 82, 917 (1919); and the symposium on the new AESC in Ann. Am. Acad. Pol. Soc. Sci. 82 (1919).

Among the organizations then associated with the AESC were the American Society for Testing Materials, the American Institute of Electrical Engineers, the Society of Automotive Engineers, the Illuminating Engineering Society, the Institute of Radio Engineers, the Electric Power Club, the American Society of Mechanical Engineers, the American Society of Chemical Engineers, the American Society of Mining and Metallurgy, the American Chemical Society, and the American Railroad Association.

ernment purchases during the war and became the leading spirit in urging the reorganization. He was to serve the AESC for almost 30 years.[100]

The American Engineering Standards Committee thus became the national clearinghouse for engineering and industrial standardization throughout the country. Officially accredited to the Committee by 1927 were representatives of 365 national organizations—technical, industrial, and governmental—including 140 trade associations and 60 or more agencies in the Federal Government. Its title long since a misnomer, in 1928 the AESC was renamed the American Standards Association.[101]

By then, standardization had become "the outstanding note of this century," its influence pervading "the remotest details of our industrial regime," tapping "all sources of scientific knowledge and [affecting] every phase of design, production, and utilization." So trumpeted the opening paragraph of the "Standards Yearbook," a new Bureau publication first issued in 1927, to furnish key information on standardization to manufacturers, industrialists, engineers, and governmental purchasing agencies. Its 392 pages described the fundamental and working standards of the United States, the organization and work of the Bureau, of the national and international standardization agencies abroad, those of the executive departments and independent establishments of the Federal, municipal, and State governments, the central agencies for industrial standardization in this country, and those supported independently by technical societies and trade associations. Succeeding issues of the "Yearbook" detailed the annual accomplishments of all these agencies and described their current activities.[102]

The rage for standardization in the 1920's was not confined to this country. It swept every nation with any degree of industrial development, as the Bureau's compendious "Bibliography on Standardization" bears wit-

[100] NBS Report 6227, "American Standards Association, Inc." (December 1958), app. I.

[101] P. G. Agnew, "Work of the AESC," Ann. Am. Acad. Pol. Soc. Sci. 137, 13 (1928). By 1941, according to NBS M169, "Standardization activities of national technical and trade associations," issued that year, more than 3,000 national and interstate trade organizations and 450 technical societies were carrying on standardizations and simplification activities.

[102] The "Yearbook" was issued as NBS M77 and revised annually for the next 6 years as M83 (1928), M91 (1929), M106 (1930), M119 (1931), M133 (1932), and M139 (1933). The brief notice of consumer testing in the "Yearbook" was expanded in M90, "Directory of commercial testing and college research laboratories" (1927), superseded by M125 (1936), M171 (1941), and M187 (1947). A similar need for better coverage prompted M96, "Organizations cooperating with the NBS" (1927)—there were a total of 212. A decade after the last "Yearbook," a revision of its most generally useful sections appeared as M169, "Standardization activities of national technical and trade associations" (1941).

ness.[103] In most countries abroad standardization was Government-directed; here it was largely an industrial effort, the work of technical committees in each industry determining as a matter of profit and loss where standardization of processes and products and adherence to specifications most benefited them.

Among the earliest results ascribed by the Bureau to standardization was the reduction in price of incandescent lamps from $1.30 to $0.16, and reduction of the cost of Army and Navy shoes from $7 to $8 to $3 or $4.[104] Another kind of standardization, said to have been hailed by the building trades, established a new standard for an inch board. Where formerly it had varied anywhere from 7/8 to 1¼ inches, by industrywide agreement, a dressed board was set at a uniform 25/32 of an inch.[105] Despite the misnomer, it was at least a consistent "inch board."

As fundamental as standardization itself were specifications of quality, first established by the Bureau in 1909 in its standard samples of metals, minerals, and chemicals. The first official U.S. Government specification, authorized by Presidential order, was published as a Bureau circular in 1912 and applied to portland cement, which then as later constituted probably the largest volume purchase of a single item by the Federal Government. Often revised, the original specification declared that an acceptable cement must take an initial set in 45 minutes and after 7 days possess a tensile strength of 500 pounds per square inch. An earlier specification, in 1907, for incandescent lamps purchased by Government agencies, ruled that any lot in which 10 percent of the lamps was found with defects in workmanship or service threw out the lot. The specifications for weighing and measuring devices, published in 1916, permitted, among other things, a deficiency of no more than one-eighth ounce in a pound or 4 drams in a quart. And those for oils and paints, in 1919, set minimum percentages each of pigment, oil, thinner, and drier in their composition, as determined by quantitative analysis.

One of the first acts of the Bureau of the Budget upon its establishment in 1921 was to create the Federal Specifications Board, to unify specifications already available to some 40 Government purchasing agencies and effect greater economies in the quarter of a billion dollars worth of

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[103] M136 (1932).

[104] General Electric's simplified line of "bread and butter" lamps (standard household sizes) set up in 1925 made it possible to reduce the price of the 100-watt lamp from $1.10 (1920) to $0.50. By 1942 it was $0.15. The single bulb shape in 6 voltages replaced 45 different types and sizes. Paul W. Keating, Lamps for a Brighter America (New York: McGraw-Hill, 1954), pp. 143, 145, 191.

[105] Hearings * * * 1923 (Feb. 1, 1922), p. 521; Hearings * * * 1925 (Feb. 12, 1924), pp. 6–7.

supplies bought annually by the Government. Thereafter, Bureau of Standards specifications accepted by the Board became official standards, binding on all departments of the Federal establishment.[106]

In immediate charge of Federal specification work at the Bureau was Norman F. Harriman. In an adjacent office Dr. Addams S. McAllister maintained liaison with the AESC, through whose offices drafts of Federal specifications went out to industry and differences of opinions on requirements were ironed out. Between 1921 and 1924 the Bureau alone prepared 72 specifications. Among them was one for fire hose, insisting it contain 75 percent of new wild or plant rubber. That for pneumatic tires required at least 70 percent new rubber on their tread. Glass tumblers had to withstand 6 hours in boiling water. Threads on wood screws were to extend two-thirds of their length. Red ink was given fixed proportions of crocein scarlet to distilled or rain water. Bull and buffalo hides could not be used in sole leather. And precise proportions of ground cork, burlap, and binder were fixed for light, medium, and heavy battleship linoleum.

Preparing specifications and revising those already promulgated became so extensive an effort at the Bureau that it soon proved "a serious drain on nearly all of the appropriation units of the Bureau." [107] The drain continued as the Bureau between 1925 and 1928 prepared over 150 new specifications, covering supplies as diverse as huck towels and cheesecloth, pneumatic hose and wire rope, asphalt and firebrick, quicklime and chinaware, ice bags and friction tape, plumbing fixtures and builders' hardware.

In September 1925 the Bureau, in cooperation with the AESC and associated industrial representatives, issued its "National directory of commodity specifications," 3 years in the making, listing 27,000 specifications for 6,650 commodities. This was Hoover's "Buyers' Bible," as he called it,

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[106] Memo, N. F. Harriman, "Organization and work of the FSB," Oct. 29, 1923 (NBS Box 42, ID); report, Burgess to Secretary Hoover [1924], p. 11 (NBS Box 96, PRA); NBS Annual Report 1926, p. 3; Burgess, "Relation of public purchases to the national standardization movement," MS report, 1925 (NBS Box 116, IDS–AESC). Another Burgess report dated Jan. 9, 1925 is in Box 139, PA.

The Federal Specifications Board, consisting of representatives of the 10 executive departments, the Panama Canal authority, and the General Supply Committee, with Dr. Burgess its ex officio chairman, utilized the staffs of the Bureau of Standards, Bureau of Mines, Bureau of Chemistry and other Federal and civilian scientific agencies for the preparation of its specifications. By 1924 the Board had 65 technical committees engaged in their preparation, 24 headed by members of the Bureau of Standards.

[107] Letter, GKB to Secretary Hoover, Sept. 13, 1924 (NBS Box 72, FPE). A list of commodity experts at the Bureau, responsible for almost 200 commercial products, is attached to letter, GKB to Assistant Secretary of Commerce, Oct. 27. 1923 (NBS Box 41, AP).

intended to systematize both industrial and Federal purchasing.[108]

Because its results were most readily understandable and lent themselves to impressive statistics, the aspect of the standardization program that captured the greatest public interest was simplified practice. A Bureau study made in the spring of 1921 found "many sizes and styles of material and devices [in use], not through any real demand for such a variety * * * but through the undirected natural expansion of * * * business." The collective waste in commerce and industry from this source alone was said to represent an annual "loss of 30 percent of America's energies." [109]

Under Ray M. Hudson and later Edwin W. Ely, the division of simplified practice, organized in December 1921, got some startling results. The first 2 recommendations issued reduced paving bricks from 66 to 7 sizes, and metal and wood beds from a score or more varieties to 4 widths of one procrustean standard length.[110]

Begun with a congressional appropriation of $52,000 made in 1920 for "the general standardization of equipment," by 1925 the simplified practice program alone was spending twice that amount annually. Adopted recommendations had reduced hotel chinaware from 700 to 160 varieties, files and rasps from 1,351 to 496 types, milk bottles from 49 to 9 different designs, and book and magazine paper from 267 to 11 sizes.[111] Recommendations on the verge of acceptance ranged from warehouse and invoice forms to paintbrushes and paper bag sizes. Totting up the rewards as leaders in the crusade, representatives in nine important industries cooperating with the division estimated that their annual savings through simplification already exceeded $293 million.[112] The figure, rounded off to $300 million, received wide publicity.

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[108] Hearings * * * 1925 (Feb. 12, 1924), p. 216. The "bible" was M65, superseded by M130 (1932) and M178 (1945), the latter a volume of 1,311 pages. It was followed by a subject index to U.S. Government master specifications, issued as M73 (1926), superseded by C319 (1927), C371 (1928), and C378 (1929). Three volumes of a planned multivolume "Encyclopedia of Specifications," covering products of wood-using industries (1927), nonmetallic mineral products (1930), and metals and metal products (1932) came out before the project was canceled. NBS Annual Report 1926, p. 39; Memoirs of Herbert Hoover, II, 67.

[109] NBS Annual Report 1921, pp. 22–23; Annual Report 1922, p. 265.

[110] NBS Annual Report 1922, p. 266. NBS Simplified Practice Recommendations run from R1 in 1923 through numbers above R250 in the 1960's.

[111] Science, 57, 649 (1923), reported that simplified practice in the American instrument industry had eliminated 1,800 of 3,200 items in its apparatus catalogs, including 99 out of 227 items of chemical porcelain, 123 of 190 forms of gas analysis apparatus, 70 of 148 types of gas burners (some of them over 50 years old), and 107 of 199 sizes and types of funnels.

[112] NBS Annual Report 1925, pp. 23–24; Dalzell, Galt, and Hudson, pp. 42–43; pamphlet, "Simplified practice: what it is and what it has to offer" (Washington, D.C., 1924); "Saving millions by standardization," Lit. Digest, 98, 62 (1928).

A year later, in 1926, a total of 3,461 individual acceptances of recommendations, involving more than 60 commodities, had been received from trade associations, manufacturers, and distributors. Special surveys made in 12 commodities that year indicated an adherence to published recommendations of 79.5 percent.[113] This was a matter of some congratulation, for it was expected that some people would insist on longer beds than the standard, and there were always bound to be manufacturers reluctant to discard a serviceable form or die.

By 1928 acceptances had almost tripled as the program spread from large manufacturers and distributors to smaller firms, to hotel, hospital and other institutional supply firms, and to city, county, and State purchasing agencies. Manufacturers reported savings in reduced inventories, in interest charges, in reduced obsolescence, and in payrolls among the benefits of simplified practice, and in at least two reported instances (concrete blocks and shovels), prices to the trade had been reduced by as much as 25 percent.[114]

The culmination of the standardization program came with Hoover's establishment in 1927 of the division of trade standards at the Bureau. Its purpose was to consolidate Bureau activities relating to standards, extend to the commercial specification field the cooperative methods of simplified practice, and make more readily available to industry the results of the Federal Specifications Board.[115] Where specifications formulated by industry up to that time had principally served the needs of individual industries, the commercial standards published by the trade standards division were to be specifications with industrywide application.[116]

To facilitate the use of Federal specifications and commercial standards by Government purchasing agencies, the Bureau compiled lists of more than 3,000 "willing-to-certify" manufacturers. But industry sought more than Government approval. What industry also wanted was certification

[113] NBS Annual Report 1927, p. 35. The next year adherences reached a high of 86.86 percent in 31 commodities surveyed. Annual Report 1941, p. 83, reported the peak number of commodities affected, over 130.

[114] NBS Annual Report 1928, p. 32; Annual Report 1929, p. 38; Dalzell, Galt, and Hudson, p. 30. LC504 (1931), "Variety reduction * * * by simplified practice," included 7 pages in fine print of such reductions.

[115] It had another purpose too. "The necessity to detach the Division of Simplified Practice from the Office of the Secretary [of Commerce] and * * * align it with the permanent organization of the Bureau of Standards is a major reason for the Commodity Standards group." Memo, Hudson to GKB, Feb. 3, 1928 (NBS Box 231, ID–CS).

[116] NBS Annual Report 1927, p. 42; CS–O, "The commercial standards service and its value to business" (1930), p. 3; chapter on NBS in [Robert A. Brady], Industrial Standardization (New York: National Industrial Conference Board, Inc., 1929).

of grade and quality of certain of its products, such as clinical thermometers, surgical gauze, fuel oils, textiles, and metal products, for greater consumer acceptance. Manufacturers wanted labels to identify or guarantee commodities complying with the standards they had adopted, and consumers wanted the information and protection thus provided. The labeling was approved and by the early thirties over a hundred trade associations were utilizing labels to identify products that conformed to commercial standards.[117]

If there was substance to the idea that standardization would contribute to a new industrial revolution, as Secretary Hoover hoped, it was attenuated by its voluntary nature. The reluctance of even a few members in a trade group was sufficient to bar any consideration of joint agreement, and as often as not carefully worked out programs suddenly collapsed at the point of success.[118] Moreover, despite unsparing publicity and the exertions of such trade-wide organizations as the National Association for Purchasing Agents, gaps in agreement and compliance spread.

The flaw in the standardization program appeared early, and of all places at the Bureau itself. Ray Hudson, setting up the simplified practice division at Commerce, requested Royal typewriters with elite type for his staff. Dr. Burgess demurred, pointing out that more than 20 years before the Bureau had settled on the L. C. Smith, for its superior construction, and pica as the most legible type. This machine was standard throughout the Bureau. Badgered for over a month by Hudson, Dr. Burgess at last gave in and signed Hudson's purchase order. On an attached note he wrote: "Your office is the only one in the Bureau of Standards that appears to insist

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[117] M105, "Certification plan significance and scope: its application to federal specifications and commodity standards" (1930); NBS Annual Report 1931, p. 38. Commercial standards run from CS1, "Clinical thermometers" (1928) through current numbers above CS260.

Earlier proposals by industry to certify its products, particularly those for export, are reported in NBS Box 21 (1909); NBS Annual Report 1915, p. 147; and Hearings * * * 1917 (Feb. 2, 1916), pp. 989–990.

[118] Dalzell, Galt, and Hudson, pp. 24–27.

So consuming had the Bureau's standardization work for the Government become by the middle of the decade that a member of the Visiting Committee queried Burgess about the real aims of the Bureau. Was its purpose supporting new and first-class scientific work, as the PTR was doing abroad, or "standardizing old products"? The VC report to the Secretary of Commerce in 1926 expressed concern over the demands on the Bureau for this standardization testing, saying it was crowding out work on basic standards and research, "especially the determination of constants and the discovery of new laws and relations, which may be applied by scientific workers and more particularly by industry." Letter, W. R. Whitney to GKB, Nov. 20, 1925, and report, VC to Secretary of Commerce, Dec. 4, 1926 ("General Correspondence Files of the Director, 1945–1955," Box 6).

on non-standard makes and sizes of types. I am sure you are interested, with us, in the simplification of varieties." [119] The flaw, of course, was in the consumer, at the far end of the production line, who wanted variety in type styles, and a choice in the design of beds.

While the Bureau felt that through the standardization program "the ultimate consumer [was] getting better quality and better service, in some instances, at lower cost, and * * * [enjoyed] greater protection against unfair trade practices," high wages, the high cost of raw materials, and the increasing cost of doing business tended to operate against him as the decade progressed. At the same time, with increasing prosperity, consumer demands for more styles and varieties became an increasing obstacle to simplification. Inevitably, too, the restoration of confidence also increased the reluctance of business and industry to cooperate with Government, lest it lead to regulation or control and ultimately to Government prosecution of one kind or another.[120]

The great depression ended the crusade for standardization as appropriations plummeted and staffs shrank. But there was no thought of wholly abandoning the standardization work of the Bureau. Just before leaving office in 1932, Hoover asked Burgess to take the Commerce Department groups concerned with specifications and trade standards out to Connecticut Avenue. They were installed alongside the simplified practice unit, brought to the Industrial building in 1929, and there they remained until after World War II.[121] In 1950, following the postwar reorganization of the Bureau, they were transferred back to the Department of Commerce.

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[119] Memo, GKB to Hudson, Oct. 31, 1924, and attached correspondence (NBS Box 72, EI).

[120] Dalzell, Galt, and Hudson, pp. 66, 70–72, 80–81. Perhaps the most notable arguments of industry against standardization were those presented on behalf of General Electric in John H. Van Deventer's "Extreme variety versus standardization," Ind. Management, 66, 253 (1923).

Inevitable were the early excessive hopes for standardization, the warnings against its excesses, and finally the revolt of the intellectuals, as reported in F. C. Brown, "Standardization and prosperity," Am. Rev. 2, 396 (1924); G. K. Burgess, "What the Bureau of Standards is doing for American industry," Ind. Management, 70, 257 (1925); P. G. Agnew, "A step towards industrial self-government," New Republic, 46, 92 (1926); N. F. Harriman, "The sane limits of industrial standardization," Ind. Management, 73, 363 (1927); Carl Van Doren, "The revolt against dullness," Survey, 57, 35 and 152 (1926); and "Standardization," Sat. Rev. Lit. 3, 573 (1927). Popular accounts of the controversy appeared in the Saturday Evening Post, May 11, 1928 and Dec. 21, 1929, under "These standardized United States" and "Standardized and doing nicely."

[121] Dr. Briggs summed up the status of standardization as World War II began: "It appears to me that the standardization which was accomplished during the last war has to a considerable extent been lost sight of and that the whole subject has again to be subjected to a searching study." Letter to Secretary, SAE, May 29, 1940 (NBS Box 445, IG).

RESEARCH FOR INDUSTRY

Spurred by Hoover's campaign against waste in industry, the Bureau seized the opportunity to extend its investigations in the utilization of raw materials, the quality of manufactured articles, and the quest for new uses for the by-products of industry. By 1922 work in progress included research on automobile engines to find ways to increase their operating efficiency, studies of electric batteries, of power losses in automobile tires, and reclamation of used lubrication oil. New public utility studies looked to improved efficiency of gas appliances and, for electric service, improved methods of measuring dielectric losses as indicators of insulation quality or deterioration. Under way in the construction field were stress studies of building materials, which for lack of scientific data were often used in excess amounts, and studies of fire resistance properties of building materials. With the expertise acquired in the wartime work on sound, the Bureau also began studies of sound transmission in structural materials—the scientific shushing of noise.

Other studies sought to determine heat flow in structures and in structural materials, thermal conductivity of materials at high temperatures, spectroscopic analyses of metals, elimination of gases in metals, uses for low-grade cotton, utilization of American clays in the manufacture of paper, utilization of flax straw and tow in making paper, utilization of refuse molasses, and recovery of waste sugar.[122]

Some account of one or two of these investigations may serve as representative of Bureau research for industry in the 1920's. The work on gas appliances, for example, had important results both for the public and the industry.

Without any specific legislative directive, but using funds first granted by Congress in 1915 for the "investigation of public utility standards," the study of gas appliances began as a result of the sharp rise in the cost of household gas after the war. About half the cities and towns in the United States which were supplied with gas used natural gas, the ideal and cheapest fuel, but like petroleum, widely believed to be in limited supply. The Bureau investigation, therefore, centered on its conservation. It soon traced the greatest waste of natural gas, estimated as costing consumers a million dollars a day, to faulty or poorly installed domestic appliances. Hoping to ameliorate some of the worst conditions found, the Bureau pre-

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[122] NBS Annual Report 1922, p. 8; Hearings * * * 1923 (Feb. 1, 1922), pp. 501–508. A summary of NBS research for industry, 1921–27, appears in letter, GKB to Exec. Council, Amer. Eng. Council, July 5, 1928 (NBS Box 253, PA).

pared a circular for householders on "How to get better service with less natural gas in domestic gas appliances." [123]

With the rising cost of gas, a rash of inventions appeared, so-called gas-saving devices, to be used on the top burners of gas ranges. Tests showed their claims of economy to be worthless and, where manufactured gas was used, proved that some of these devices created hazards even greater than those in the appliances themselves.[124] But the real problem was the poor design of most of the gas appliances then on the market.[125]

The appliance makers were naturally reluctant to change their products and charged that the Bureau was prejudiced and favored the electrical industry. Bureau suggestions of better design for greater thermal efficiency and safety in gas cooking stoves, water heaters, and room heaters, therefore, met with little acceptance by the industry. Then, in the winter of 1922–23 an unusually large number of deaths occurred in many parts of the country from gas poisoning.

Upon Bureau inquiry of the health departments it was learned that New York had had 750 carbon monoxide deaths during the previous year, Chicago 500, Baltimore 42, Cincinnati 13, and Los Angeles 24. Because the industry tended to attribute all reported fatalities by gas to suicide, the last two cities were of particular interest since they were supplied with natural gas, which does not contain carbon monoxide, and therefore cannot be used successfully for suicide.

The investigation made by Bureau engineers with the cooperation of Baltimore's Consolidated Gas & Electric Co. and city public health officials confirmed the previous findings of badly designed or badly adjusted gas appliances. When the results were published, the president of the American Gas Association came to the Bureau and demanded that further publication be withheld. More forward-looking members of the industry realized the value of the research and persuaded the association to support a research associate group at the Bureau to assist in the work. Little more than a year later the association set up its own laboratories, hired away a Bureau gas engineer as supervisor, and shortly after established a seal of approval and inspection system that quickly brought the appliance industry into line. Two years later, deaths in Baltimore traceable to faulty gas

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[123] C116 (1921). Antiquated plant equipment and inefficiency also contributed to the waste, Stratton told Congress, and these were compensated for by the industry through periodic increases in the rates. Hearings * * * 1921 (Jan. 2, 1920), pp. 1560–1561.

[124] NBS Annual Report 1922, p. 71. LC397 (1933) and C404, "Cautions regarding gas-appliance attachments" (Eiseman, 1934), summed up more than a decade of investigation of these "gas-savers."

[125] See T193 (1920) and C394 (1931) on the design of gas burners for domestic use.

appliances fell to 1 or 2 instead of 40, and the next year no such deaths occurred at all.[126]

Considerably more complex is the history of Bureau research in the rare sugars, said to be the first new industry created in the United States by the war.[127] Cut off from German sources, the sugar technologists of Bates' polarimetry section undertook to prepare and supply small standard samples of pure sucrose (ordinary sugar) and dextrose (corn sugar) for use in standardizing saccharimeters, testing the heat value of fuels, and for the differentiation of bacteria in medical laboratories. So obscure were the manufacturing processes as described in German patents that reconstruction of the sugars required almost completely original research.

The preparation of dextrose and other rare sugars (arabinose, raffinose, xylose, rhamnose, melibiose, ribose, dulcite, mannite) in the few industrial laboratories willing to undertake such work was, therefore, both difficult and expensive, some of the sugars costing from $10 to $500 per pound. Even so, the products were not wholly satisfactory, for lack of even the most fundamental data on their properties. On behalf of the industry the Bureau undertook a systematic study of the whole group, looking to purer forms than the manufacturers could achieve. If ways to reduce the cost of the sugars could also be found, it might well increase their commercial importance.[128]

In 1917 Dr. Richard F. Jackson, a member of Bates' group, solved the problem of producing hard refined dextrose. Two years later the theoretical and technical work for large-scale manufacture of an almost chemically pure low-cost dextrose was completed by W. B. Newkirk, another member of the Bureau's carbohydrate group, for the Corn Products Refining Co., and a new industry was launched.[129]

Although the Bureau produced experimental quantities of many of the rare sugars, it chose to concentrate on levulose, as a sugar potentially acceptable for diabetics. The sweetest of all sugars, it was also the most

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[126] NBS Annual Report 1923, p. 78; T303, "Causes of some accidents from gas appliances" (Brumbaugh, 1926); memo, Crittenden for A. V. Astin, Apr. 10, 1953 (NBS Historical File); Elmer R. Weaver, MS, "History of the Gas Chemistry Section, NBS, 1910–1957," pp. 35–36 (NBS Historical File).

[127] Letter, GKB to Executive Secretary, Am. Eng. Council, July 5, 1928 (NBS Box 253, PA).

[128] NBS Annual Report 1919, p. 120–121; Annual Report 1921, p. 112.

Many of these naturally occurring rare sugars are of interest to chemists and bacteriologists for their biological function in the human body and have, as well, industrial applications. Some are also necessary as starting materials for the preparation of synthetic sugars.

[129] S293 (Jackson, 1917); S437 (Jackson and C. G. Silsbee, 1921); LC500 (1937); interview with Dr. Horace S. Isbell, Apr. 23, 1963.

difficult to isolate and purify, and therefore, one of the most costly. Found in honey and fruits, levulose was equally available in the common dahlia and in the jerusalem artichoke, the latter a prolific weedlike plant whose bulbous roots contained an abundance of the raw material.[130]

The year was 1920 and the wheat farms of the West, their wartime markets gone, were in distress. If large-scale commercial production of refined levulose proved economically feasible, wheatfields could be converted to growing artichoke tubers and so ease the Nation's surplus wheat problem. Under that impetus the Bureau investigation lasted almost 20 years.

As an ideal solution for a major surplus crop, the program had the full approval of the Harding, Coolidge, and Hoover administrations. The Bureau set up a special laboratory. In cooperation with the Bureau of Plant Industry of the Department of Agriculture, successively improved types of jerusalem artichokes were grown in the West under contract and shipped to the Bureau for processing. In 1929 a pilot plant for the production of crystalline levulose went up in the Industrial building, and there sirups of 99-percent purity, yielding crystallization of 75 percent of the sugar, were finally achieved.[131] A semicommercial plant for the development of a continuous process approached completion when in 1933 the depression brought the program to an end.

The years of reseach made the Bureau probably the greatest repository of sugar technology in the country but they left unsolved the problem of wheat surplus. Nor were levulose, ribose, mannose, raffinose, xylose or any other rare sugar produced at the Bureau ever to compete economically with dextrose, the corn derivative, which was equally satisfactory for scientific and medical purposes.[132] The wheat surplus continued.

The drive in the early twenties to utilize waste materials and products activated other investigations in the sugar laboratories, some brief, some lasting through the decade. One inquiry had its inception when the sugar industry called on the Bureau for help with the impurities in cane and beet molasses. While working on a method to minimize the deleterious effect of the waste molasses on sugar crystallization, the Bureau became aware of other uses for the waste besides fertilizer and cattle feed. German patents described many valuable chemical compounds produced both from waste

[130] NBS Annual Report 1920, p. 119.

[131] S519 (Jackson, C. G. Silsbee, and Proffitt, 1925); Hearings * * * 1926 (Jan. 5, 1925), pp. 121–123; NBS Annual Report 1926, p. 25; Annual Report 1933, p. 53. As a sugar for diabetics, chemical saccharine eventually proved better than any of the rare sugars.

[132] Continued Bureau research on ribose eventually resulted in an improved method of manufacture that reduced its cost from $40 to $2 per gram, but was still more expensive than dextrose. NBS Annual Report 1937, p. 66.

molasses and the waste waters of sugar manufacture. Despite an intensive search, the Bureau to its surprise found little or nothing on the subject in the scientific literature, in any language.

A closely guarded commercial secret, the processes for recovering amines, ammonia, cyanides, nitrogenous nonsugars, potash, alkalies, and miscellaneous products such as glycerine, esters and fatty acids from sugar wastes, were carefully buried in the patent literature. More than a thousand of these processes were found in German patents alone. As was true of German dye, drug, glassmaking, rare sugar and other patents confiscated at the outbreak of the war, it was unmistakable "that every legitimate means had been used by foreign patentees to create as many difficulties as possible in the trailing of patents." [133]

After considerable research, the Bureau compiled a "Summary of the technical methods for the utilization of molasses" and made these findings available to the industry.[134] Before the decade was out much simpler and far less expensive processes for producing industrial chemicals were to be developed by the petroleum industry, and waste molasses substantially remained an ingredient of cattle feed.

The early promise of the levulose and waste molasses research suggested to the Bureau and the Secretary of Commerce that gums, sugars, and cellulose products of great economic value might well be recovered from such farm wastes as cornstalks and straw, and that this research warranted Government initiative and support.[135] Under a special congressional appropriation to investigate the "utilization of waste products from the land," the miscellaneous materials division of the Bureau was reorganized as the division of organic and fibrous materials and Warren E. Emley was brought from the Pittsburgh laboratory as its chief.

Before long a stream of products issued from the new division, including a stout wrapping paper made from the waste fibers in manila rope manufacture; wall, insulating, and pressed board from cornstalks; fertilizer from cotton burrs; and textile sizing from sweet potato starch. With the hope of utilizing the fifty million tons of cereal straws wasted on American farms annually, the Bureau developed a satisfactory kraft paper from wheat and rye straw pulp. Shortly before the program was transferred to the Department of Agriculture in the midthirties, the group developed a process for making a high-grade cellulose from cornstalks, oat hulls, and straw. Together

[133] NBS Annual Report 1920, pp. 121–122; Annual Report 1922, pp. 109–110.

[134] C145 (1924).

[135] NBS Annual Report 1926, p. 44. Industry and Government were anticipated in this type of research by George Washington Carver, famed chemist at Tuskegee, who by 1920 had evolved over 145 byproducts from the peanut, including face powder, coffee, wood stains, and relishes.

with the gums, pentoses, and lignins separated in the process, recovery totaled more than 80 percent of the substance of some of these farm wastes.[136]

A group brought into the fibrous materials division upon its organization in 1927 began a rival investigation to the levulose research going on in the optics division. Where the levulose group concerned itself with planted crops, Hudson, Isbell, and Acree, working with farm wastes, sought to convert cottonseed hulls, corncobs, and peanut shells into useful industrial chemicals. Attention centered for a time on the considerable quantities of the rare sugar xylose available in these cellulose wastes, which had important medical uses and also might, if economically extracted, be readily converted to organic acids useful to the tanning industry.

Within 2 years a process had been developed for the production of 100 pounds of 99.99-percent-pure xylose per day.[137] But as both levulose and xylose approached the commercial development stage, interest in them waned. Their high cost repelled industry and Congress refused further research support as an invasion of industry's domain. Nor were efforts to utilize farm wastes to survive their relatively high cost of conversion or the avalanche of chemicals from petroleum distillation in the 1940's. In the depression years the Bureau turned from its technological development of specific rare sugars to the chemistry of carbohydrates and later to the study of labeled (radioactive tracer) carbohydrates, extensively used in current biological and medical research.[138]

The investigation of paper made from waste materials was but one of more than a dozen paper studies going on in the Bureau's fibrous materials division. Some were continuations of the wartime search for new sources and substitutes, others wholly new research, looking for fundamental data in the properties and performance of paper. Elsewhere in the Industrial building similar lines of search went on in rubber, leather, and textiles. In the electrical division the investigation of electroplating, which began with studies of zinc-, lead-, and nickel-coating protection for military supplies, broadened to include fundamental studies for the industry, particularly the silverware and printing trades. And when chromium plating became commercially feasible in the midtwenties, some of the first scientific data on this process was produced at the Bureau.[139]

By 1921 pyrometric control stations in heavy industry had become "nearly as intricate as a telephone central station," a far cry from the days when high temperatures were estimated by visual observation. At the re-

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136 NBS Annual Report, 1933, p. 61.

137 NBS Annual Report, 1929, p. 41; Hearings * * * 1934 (Dec. 12, 1932), p. 179; NBS Annual Report, 1933, p. 61; interview with Dr. Gordon M. Kline, May 7, 1963.

138 Interview with Dr. Horace S. Isbell, Apr. 23, 1963.

139 NBS Annual Report, 1925, p. 13. See ch. III, p. 128.

quest of the industry, the Bureau made a compilation of almost 20 years of its research data on the industrial applications of pyrometry. The original printing of 2,000 copies of the 326-page manual, the first book on the subject in this country, was exhausted within 2 months.[140]

Not only pyrometers and thermocouples but hundreds of other instruments, military and nautical, optical and aeronautical, were being made in this country largely as a result of Bureau research and Bureau encouragement of the instrument industry. "We now manufacture over 85 percent of our industrial and scientific instruments and appliances," Burgess reported to the Secretary of Commerce in 1924, "where before the war over 80 percent of these were imported."[141] Among the optical instruments alone made in this country were spectrometers, spectroscopes, refractometers, interference apparatus, and spectrophotometers, colorimetric and optical pyrometers, polarimeters and saccharimeters, microscopes and binoculars, astronomical telescopes and heliostats, surveying instruments, and military instruments. Most glass volumetric apparatus was American made, as were hydrometric and thermometric instruments and fire-resistance and automotive-test instruments.[142]

Long interested in fostering new industries, the Bureau took even more satisfaction in the changing attitude of established industry. "Not long ago," Burgess noted in his annual report for 1923, "it was a matter of considerable difficulty to obtain the cooperation of industrial groups in the small amount of research then carried on [for them] by the Government." Now,

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[140] T170, "Pyrometric practice" (Foote, Fairchild, Harrison, 1921); NBS Annual Report 1921, p. 92.

Another compilation for heavy industry was made when in 1920 the Smithsonian asked the Bureau to assist in revising its physical tables. They appeared in C101, "Physical properties of materials" (1921). Twenty years later the original 20-page circular had become the 480-page C447, "Mechanical properties of metals and alloys" (1943).

[141] Letter, Sept. 13, 1924 (NBS Box 72, FPE). Similarly optimistic was Science, 57, 649 (1923), but it pointed out that scarcity of skilled labor, high labor costs (75–80 percent of the cost of constructing a delicate analytical balance went for labor), and the American penchant for mass production would act to retard the young instrument industry.

Seeming confirmation appears in a recent report that in the period 1948–56 "imports of laboratory balances and analytical weights increased 1,096 percent, microscopes 671 percent, and other scientific instruments basic to military victory 131 percent," all "strategic 'tools' of atomic research, public health, and scientific education." James R. Irving, The Scientific Instrument Industry. Vocational and Professional Monograph Series No. 98 (Cambridge, Mass.: Bellman Publ. Co., 1958), p. 13 (L/C: TS500.I7). Cf. Frederick A. White, Scientific Apparatus (University of Michigan dissertation, 1960), p. 65 ff. L/C: Microfilm AC-1, No. 59-3296.

[142] Letter, GKB to U.S. Tariff Commission, May 10, 1923 (NBS Box 52, IPO); NBS Annual Report 1935, p. 65.

he said, problems were brought to the Bureau by almost every industry in the country.[143] Large corporations, some with research organizations almost the size of the Bureau, were "as insistent as the small manufacturers in their demands on the Bureau for research and standardization." [144]

The field of research at the Bureau in which undoubtedly the greatest variety of industries and interests had a vital concern was the standardization of color. As early as 1912, to settle disputes raging at the time, a cottonseed oil firm and representatives of the butter and oleomargarine industries called on the Bureau for help with the color grading of their products. The search for answers opened a whole new branch of physics for investigation. Three years later Irwin G. Priest, brought into the Bureau in 1907 to take charge of spectroscopy and applied optics, became head of a new colorimetry section set up in the optics division.

By then color problems collected in Bureau correspondence ranged from those of glass (in signal lamps, headlights, and spectacles for eye protection), of petroleum oil, turpentine, rosin, paper, and textiles to flour, sugar, eggshells, egg yolks, dyes, and water (as an index of purity). Still other queries asked for color measurement of chemical solutions, paints, portland cement, tobacco, porcelain, enamels, and even blood and human skin—the latter of concern to biologists and anthropologists.[145]

Available to Priest and his group were the Lovibond color scale (dating back to 1887), used in the color grading of vegetable oils, and the recently published (1915) Munsell color system, both of them excellent but of narrow application and uncertain foundation.[146] The Bureau made plans to estab-

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[143] Simply by reason of its limited staff and facilities, not every problem could be handled at the Bureau. Many inquiries involved testing that could be done as well by commercial testing laboratories. LC209, "General policy of the NBS with regards to testing" (Dec. 2, 1926), distinguished between permissible and nonpermissible testing. The Bureau accepted material or products for testing where it had equipment, technicians, or was able to provide scientific data not available elsewhere, and where, as a central and unbiased agency, it was in a position to act as arbiter or final authority in the settlement of technical disputes.

In the "Standards Yearbook," 1927, pp. 284–285, the Bureau distinguished between its fundamental tests (of standards for industry and science), routine tests (of measures, devices, and materials, principally for Government agencies), referee tests, and cooperative tests (where the results might be of mutual concern to industry and the Bureau). The testing program alone, said the "Yearbook," consumed approximately half the Bureau's resources each year.

[144] NBS Annual Report 1920, p. 121; Annual Report 1923, p. 4.

[145] NBS Annual Report 1915, p. 75.

[146] The years of Bureau work on these systems culminated in two papers: Newhall, Nickerson, and Judd, "Final report of the OSA subcommittee on the spacing of the Munsell colors," J. Opt. Soc. Am. 33, 385 (1943); and Judd, Chamberlin, and Haupt, "The ideal Lovibond color system," J. Res. NBS 66C2, 121 (1962).

lish a broad scientific basis for color specification, color standards, and color grading.

Limited during the war to color and light investigations for the military and to the development of spectrophotometric methods of color analysis, Priest became convinced as a result of the latter work that "the keystone of the whole structure" of color and color standardization was a rigidly defined and accurately reproducible "white light." [147] But color standards were not to depend on this single factor, which is as much psychological as it is measurable, as Priest thought.

The breakthrough came in 1921 in a pioneer report published by the Optical Society of America, to which Priest contributed, pointing out that definition of a standard white light solves but one of the three conditions or functions that had to be satisfied in the measurement of color. In addition to specifying the characteristics of the light source, the report declared it also necessary to specify those of the object (by its spectral-reflection curve), and those of the observer who is to view it (specified by three color-matching functions).[148]

The major step on this psychological front during the decade was the experimental determination of the luminosity curve, which serves as one of the three color-matching functions. Along with the work of Gibson and Tyndall on the visibility of radiant energy, assembled data from over 150 persons of assorted ages and both sexes yielded a curve truly typical of human eyesight. The curve shows for radiation of a given energy at any wavelength how much sensation of light is produced in the human consciousness. The diplomatic skill of Dr. Crittenden secured adoption of this standard curve by the International Commission for Illumination in 1924, and it remains the cornerstone of all photometry and colorimetry to this day.[149]

With this basis laid, exploration and application of the new color-matching functions, along with efforts to standardize nomenclature, occupied the Bureau colorimetrists through the next three decades. The result was the Bureau's dictionary of colors and color names.[150]

Bureau research in dental amalgams, begun late in 1917 at the request of the Surgeon General of the Army when he was suddenly confronted with an army of teeth in disrepair, disclosed a mass of confusion and conflicting data in this and other areas of dental science. In 1922, upon the urging of the dental industry and the profession, Dr. Wilmer S. Souder and Dr. Peter

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[147] S417 (Priest, 1921); NBS Annual Report 1921, pp. 129, 132; Annual Report 1922, pp. 119–120.

[148] Leonard T. Troland, chm., "Report of the Colorimetric Committee of the OSA, 1920–21," J. Opt. Soc. Am. 6, 547 (1922).

[149] S475 (Gibson and Tyndall, 1923); interview with Dr. Deane B. Judd, Nov. 26, 1963.

[150] C553, "The ISCC–NBS method of designating colors and a dictionary of color names" (Kelly and Judd, 1955).

Hidnert of the Bureau expanded their initial investigation of dental inlay materials and dental techniques.

Assisted by research associates from private laboratories and practicing dentists representing the American Dental Association, the Bureau physicists studied the physical and chemical properties of inlay materials, amalgams, plasters, and waxes, and began to establish specifications and standards for dental testing laboratories and manufacturers of dental materials.[151] Prior to this research, rejection of dental materials tested at the Bureau for the Government had run as high as 50 percent or more. One Bureau report about to be made public, disclosing that 6 out of 10 dental amalgams available to the profession were unsatisfactory, and only 4 out of 10 would stay in any appreciable time if used as fillings, was suppressed by the Commerce Department lest it result in loss of public confidence.[152]

By the early 1930's rejections amounted to less than 10 percent. Before long it became "possible for dentists to use amalgam fillings that [would] not shrink and drop out, cements that [would] not dissolve, bridgework that [was] practically permanent, and gold inlays lasting [far beyond the] 3 to 5 years as was the case a short time ago." [153]

A persistent difficulty encountered with certain types of metallic alloys used for fillings was their tendency to become deformed in use and require replacement. Interferometry studies disclosed that, extending over a period of 1 to 4 days, the expansivity of some amalgams was about four times that of the teeth. For many years the trouble was attributed, in the absence of other discernible causes, to variations of the alloy from package to package.[154] The source of the difficulty, at least in amalgams containing zinc, was eventually traced to the dentist's office, in the moisture added to the filling by his palming or hand mulling of the amalgam. The moisture and salt contamination from the hand, acting on the trace of zinc in the amalgam, formed hydrogen gas, and in a short time out came the filling.[155]

Research for the textile industry in the 1920's covered basic investigations into the physical and chemical properties of fibers, yarns, and fabrics, the conservation of textiles (for the peace of mind of dyers and cleaners), utilization of low-grade cotton and of waste silk materials, estab-

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[151] T157 (Souder and Peters, 1920); superseded by C433 (Souder and Paffenbarger, 1942), the latter a résumé of dental research at the Bureau since 1919.

[152] Letter, P. J. Crogan, Bureau of Foreign and Domestic Commerce to F. C. Brown, Aug. 25, 1926 (NBS Box 179, PA).

[153] NBS Annual Report 1931, p. 43; Annual Report 1936, p. 62; Science, 92, 527 (1940).

[154] NBS Annual Report 1919, p. 148; Annual Report 1922, p. 174; T157, p. 9.

[155] Schoonover, Souder, and Beall, "Excessive expansion of dental amalgam," J. Am. Dental Assoc. 29, 1825 (1942).

lishment of standard tests for color fastness, of textile specifications, and standardization of textile products, from hosiery to cordage.[156]

In textile research, as in many other fields, it was through research associates, trained men from industry itself, that the Bureau rendered its most direct assistance to industry. Every division had its associates, the largest numbers in the metallurgy and building materials laboratories of the Bureau. They were to be found alongside Bureau staff members in almost every investigation into the manufacture of iron and steel, in the heat, optical, mechanical laboratories of the metallurgy division and in its experimental foundry, studying foundry sands, rail steel, high-speed tool steel, and the spectrographic analysis of atomic composition in metals.[157]

Investigations for the building and construction industry ranged all over the Bureau, from the elevator safety code work of the electrical division to fire-resistance studies in the heat division. Almost 100 projects in the chemistry, mechanics and sound, structural engineering, and ceramic divisions were on behalf of heavy construction or the homebuilding program of the twenties. One device, made in the mechanics division for an investigation of riveted joints in the construction of Navy ships, was to have wide application. This was Tuckerman's optical strain gage, devised in 1923, which gave consistent readings sensitive to two-millionths of an inch of deformation. It proved as reliable in measuring strains in the duralumin members in the framework of dirigibles, in concrete models of dams, or in steel and cement models of building structures, as in ship construction.[158]

While industry was for the most part highly cooperative, particularly where the Bureau dealt with problems of research or standardization beyond the capabilities or resources of industry, it could be stubborn on occasion. A case in point was the resistance to the idea of uniform screw threads. The war had amply demonstrated the need for uniformity but the cost of retooling and fear of competition prevented any real agreement. As the Bureau reported in 1922: "The manufacturing world is not yet fully awake to the advantages of this type of standardization." [159]

Throughout the twenties the National Screw Thread Commission, the American Engineering Standards Committee, and the Bureau continued to urge standardization and unification of screw threads and adoption of a consistent series of allowances and tolerances for greater efficiency in inter-

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[156] NBS Annual Report 1923, pp. 230–231. H. T. Wade, "Textile research laboratory," Sci. Am. Supp. 2, 153 (1920). Some 20 current problems of the cotton industry were sent to the Bureau in letter, president, National Association of Cotton Manufacturers to Director, NBS, Feb. 4, 1920 (NBS Box 15, IST).

[157] NBS Annual Report 1923, p. 262; LC197, "Work shops of science" (May 2, 1926).

[158] NBS Annual Report 1923, p. 210; Annual Report 1928, p. 15.

[159] NBS Annual Report 1922, p. 42.

changeable manufactures. Yet not until the very end of the decade was there sufficient general acceptance to warrant extending this line of research at the Bureau.[160]

Because of the technical difficulties, relatively small market for the products, and ease of obtaining an adequate supply from Europe, efforts to turn over to industry the making of optical glass met with little response.[161] To assure sufficient glass for scientific purposes, the optical plant behind the Industrial building continued its operations with annual appropriations from Congress. Besides its research in optical and other types of glass for the industry, the Bureau yearly melted approximately 30,000 pounds of optical glass for the production of optical blanks, most of them going to the military services. Allowing for wastage and imperfections, the yield of serviceable glass from this weight of melt approximated 20 percent or 6,000 pounds.

The most ambitious undertaking in the history of the Bureau glass plant was its casting of a 69.5-inch disk for the mirror of a large reflecting telescope. At the time there were not more than 10 optical glass plants in the world, all abroad, capable of making such a disk. The two largest in this country, the 40-inch at the Yerkes Observatory and the 100-inch at Mount Wilson, had both come from Europe. Challenged by the lack of information on methods of making glass for a large telescope reflector—it was of course a trade secret—the Bureau borrowed on its own experience and began to experiment.

The first great disk was poured in 1924. It cracked during cooling. So did the next three. Trying still another method, the Bureau cast a fifth one in May 1927. Cooled in the first weeks at the rate of only 1° per day and at no time more than 10° per day, in January 1928 the great disk, some 10.5 inches thick and weighing 3,800 pounds, was pronounced a success. Polished and silvered elsewhere, the mirror was subsequently presented to the Perkins Observatory at Ohio Wesleyan University.[162]

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[160] M89, "Report of the National Screw Thread Commission" (rev. ed., 1928). The Commission was placed on a permanent basis by Congress in 1926, abolished as an economy measure by Executive order in 1933, and reestablished as an agency of the War, Navy, and Commerce Departments in 1939.

[161] Of the firms that began making optical glass during World War I, all but Bausch & Lomb ceased production with the armistice. Hearings * * * 1922 (Dec. 20, 1920), p. 1248.

[162] NBS Annual Report 1927, p. 23; Annual Report 1928, p. 21; RP97, "Making the glass disk for a 70-inch telescope reflector" (Finn, 1929); Harlan T. Stetson, "Optical tests of the 69-inch Perkins Observatory reflector," J. Opt. Soc. Am. 23, 293 (1933); conversation with Clarence H. Hahner, May 20, 1963.

Prior to the casting of the 200-inch mirror for the Hale telescope at Palomar, the largest disk the Corning Glass Works had attempted was 30 inches. With the Bureau experience as guide, work on the 200-inch, 15-ton disk began in 1931. For 2 months after the

Prof. Clifford C. Crump, director of the Perkins Observatory and Dr. Burgess examining the Bureau's 69.5-inch telescope disk after an 8-inch hole had been drilled through its center for mounting. The disk after polishing was set up in the observatory at Ohio Wesleyan University.

If the most ambitious project of the optical glass section was the telescope disk, perhaps one of its greatest pieces of craftsmanship was the construction in 1926 of the Bureau's first standard of planeness. This standard of straightness, as well as planeness, in the form of highly polished disks of clear fused quartz, was the work of John Clacey, a remarkable self-trained hand craftsman of fine lenses who came to the Bureau in his 54th year back in 1911 and worked with Michelson during the war. The disks he shaped a decade and a half later, three in number in order to provide a self-checking standard, proved when tested interferometrically to have an accuracy of five-millionths of an inch. Aside from its application in testing the plane-

successful cast in 1934, the temperature was held at 1,200° F. The mirror was then cooled at the rate of 1° a day for 8 months. It was shipped to Palomar in 1936 to be ground and polished, but interrupted by the war the work was not completed until 1947. Six and a half million dollars went into the making of the mirror. The Corning Glass Center (Corning, N.Y., 1958), pp. 6, 8; Frederick A. White, American Industrial Research Laboratories (Washington, D.C.: Public Affairs Press, 1961), pp. 47–48.

ness of surfaces, the straightness of edges, and the limiting surfaces of end gages, the Bureau's standard plane was to serve as a basis for producing standard angles and for calibrating instruments that measured curvature.[163]

All the major industries reached new peaks of development and production in the twenties, and in the glass industry few so spectacularly as the manufacturers of automobile windows and windshields. But the three giants, and the symbols of the age, were the automobile, aviation, and radio industries.

AUTOMOBILES AND AIRCRAFT

Between 1920 and 1930 the number of cars registered in the United States leaped from 9 to 26.5 million, well over half of them Henry Ford's Model T. With them came the first officially numbered highway, the first automatic traffic light, the first concrete road with banked curves, the six-lane highway, one-way street, parking problem, tourist home, and tourist cabin.[164] Enclosing the tonneau in glass and canvas or in steel and installing more efficient and more powerful engines converted the car from a family horseless carriage to a family locomotive. With moderate prices and installment payments, the acquisition of an automobile moved rapidly from luxury to convenience to necessity. But it might not have happened if the geologists had been right.

Bureau research on the automobile and airplane, in adjoining laboratories in West building and in the dynamometer chambers, began on a pessimistic note: the Nation's supply of gasoline and oil must be conserved. Depletion of this country's known petroleum resources was said to be as little as 10 years away. The need for conservation was unquestioned.[165] A secondary problem, partly resulting from the producers' efforts to conserve the supply, was the poor quality of much of the gasoline on the market. If, by improvement of combustion through better knowledge of fuels, ignition, lubrication, and carburation, the Bureau reported, it could assist "in lowering the gasoline consumption of automobiles only 10 percent for a given mileage, it [would] represent a saving to the country of something like

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[163] C. A. Skinner, "Making a standard of planeness," Gen. Elec. Rev. p. 528 (1926); "John Clacey—Optician," Pop. Astron. 38, 1 (1930); NBS Annual Report 1937, p. 65.

[164] Frederick Lewis Allen, The Big Change, p. 110.

[165] Hicks, The Republican Ascendancy, pp. 27-28. As late as 1926, "the dwindling supply of crude oil" still marked the "urgent necessity for rigid economy in the use of fuel." Hearings * * * 1927 (Jan. 25, 1926), p. 107. The Bureau was to lose 8 or 10 of its best young physicists to industry in the search for oil in the 1920's, including Karcher in 1923, McCollum and Eckhardt in 1926, and Foote in 1927 (interview with Dr. Paul D. Foote, July 23, 1963).

$100 million per year." [166] The phrasing was in terms of consumer savings, but the objective was conservation.

Working largely with funds transferred from the Quartermaster Corps of the Army, with the assistance of research associates from the Society of Automotive Engineers, and the cooperation of the American Petroleum Institute, the Bureau issued a series of papers establishing the most efficient characteristics of motor engines, fuels, and oils. Among other considerations, it became evident that more knowledge of engine starting factors was necessary as use of closed cars over the new network of paved roads greatly increased winter operation of automobiles. (The Bureau refused to recommend any of the dozens of antifreeze solutions that appeared, finding none better than plain alcohol and water.) [167] Previously given little attention, extensive studies were made of fuel-air ratios, jet size, spark advance, fuel volatility, throttling and choking, and air and water temperatures in the engine.[168]

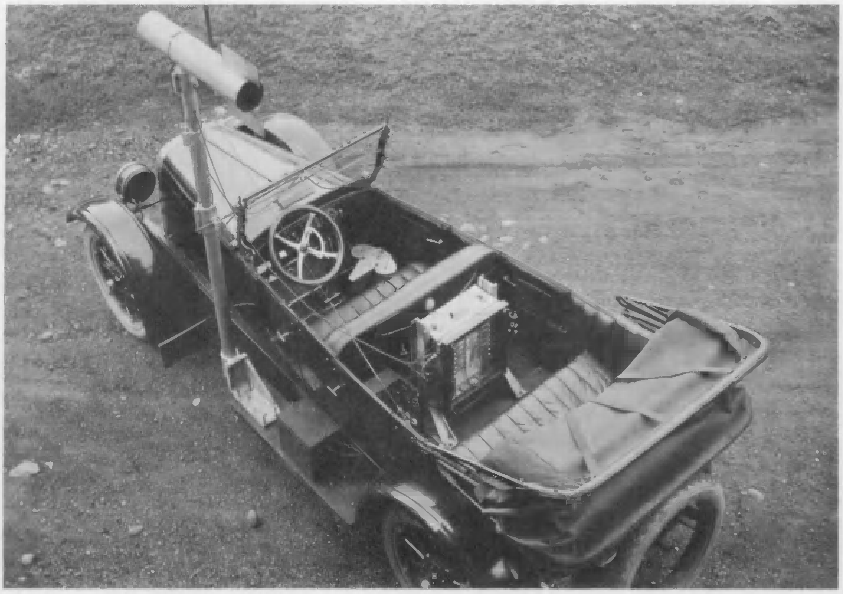
When Bureau technicians learned that laboratory and road performances of automobiles and trucks often differed widely, they constructed an ingenious array of complicated apparatus that automatically recorded 18 different measurements of the performance of the engine and the vehicle itself in operation. A Bureau investigation of brakes and brake linings for the Army Motor Transportation Corps, begun as better engines and roads made speeds above 25 miles an hour common, was used by the automobile industry to induce parts manufacturers to improve these products. Out of this work came the Bureau's recording and inspection decelerometer that measured the braking ability of cars, and the Bureau's famous study of the reaction time of drivers, as well as minimum stopping distances, when brakes were applied on automobiles, trucks, or busses. A chart showing these

[166] NBS Annual Report 1922, p. 8; Annual Report 1936, pp. 62–63. Inevitably, almost as many "gasoline-savers" as there were household "gas-savers" came on the market, the most spurious a device that was built into a Hudson Super Six touring car and alleged to give 54 miles to a *quart* of gasoline. It proved to be a series of concealed spare gas tanks. Memo, GKB for Department of Commerce, Sept. 17, 1923 (NBS Box 58, PA).

[167] NBS Annual Report 1920, p. 162; H. K. Cummings, "Anti-freeze solutions and compounds," J. Soc. Auto. Eng. 19, 93 (1926).

[168] NBS Annual Report 1925, p. 8.

It was while making an acceleration test at low temperature and atmospheric pressure on a Ford engine using aviation gasoline—part of a Bureau investigation "to determine the grade of gasoline for cars that would best utilize our petroleum resources"—that on Sept. 20, 1923 a gasoline leak resulted in an explosion and fire in the altitude chamber that caused four deaths and injured six among the test staff. Science, 58, supp. 12 (1923); file in NBS Box 40, AG.



Freighted with apparatus designed and constructed at the Bureau, this touring car was ready to measure and record 18 points of performance of its engine and operating equipment on the road.

The instrument mounted on the running board measured wind speed and direction relative to the car. The apparatus on the floor of the front seat measured and recorded graphically the instantaneous rates of gasoline flow to the carburetor. The equipment in the rear seat recorded 16 separate measurements of various factors in engine and car performance on a moving strip of paper.

To measure a Bureau motorist's reaction time in applying his brakes, his car was rigged with two pistols. When the first pistol under the running board was fired it made a mark on the roadway. The sound was the signal for the driver to apply the brakes, the application of which automatically fired the second pistol, making another mark on the road. The reaction time was obtained by dividing the car speed by the distance measured.

reaction times and stopping distances at speeds up to 45 m.p.h. was widely publicized and found its way into many drivers' manuals. A Bureau member recalls that the chart continued to appear in at least one of these manuals as late as the early 1950's, long after high-speed cars had made the data dangerously obsolete.[169]

Besides engine research, the Dynamometer Laboratory was also used to make studies of the durability of tires—of which there were more than a hundred makes and sizes available. Together with the tire data acquired during the war, these tests enabled the Bureau to prepare its first Government master specifications for pneumatic and solid tires and inner tubes.[170] The specifications brought no special joy to the industry.

The center of rubber investigations was in the Industrial building, where Holt and Wormeley were testing rubber goods of all kinds. Until the rubber section was set up at the Bureau about 1911 there had been almost no rubber research in this country. Making rubber and rubber products was an art, with closely guarded trade secrets, and with wide ranges in quality as a consequence. The exhaustive testing of rubber products at the Bureau constituted some of the first real research in the field, and the successive editions of the Bureau circular on testing rubber products that first appeared in 1912 became the bible of the industry.[171]

By the mid-twenties the Federal Government alone was spending almost a million dollars a year on tires, and much of the Bureau work in

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[169] NBS Annual Report 1925, p. 9, cites a report in preparation on "The maximum possible deceleration of an automobile." The report seems not to have been published, but a chart of braking distances, showing speeds up to 20 m.p.h. and possibly prepared for that report, appears in Standards Yearbook, 1927, plate 36. The brake work was consolidated in M107, "Safety code for brakes and brake testing" (1930), its chart on braking distances based on a maximum speed of 45 m.p.h.

Dr. Hobart C. Dickinson, chief of the heat and power division and automobile enthusiast, personally directed the many braking studies made by the Bureau. He was most proud of his paper with C. F. Marvin, Jr., on "What is safe speed?" (J. Soc. Auto. Eng. 17, 81, 1925) that recommended a "clear course principle" in place of fixed speed limits for safe driving. Several States adopted its conclusions, he reported in the paper, as well as its splendid formula, $v=\int(2as+a^2t^2)-at$, in which v represented the safe speed, a the rate of acceleration, s the clear course ahead, and t the time lag of the driver.

[170] C115 (1921; 2d ed., 1925).

[171] C38 (1912; 5th ed., 1927). Another aspect of rubber research occurs in a Bureau letter of 1944 asserting that so great was the difference between Government and industrial salaries for rubber technologists that for 25 years the Bureau had not employed a single chemist for that work who had had any previous rubber training or work. Letter, A. T. McPherson to War Manpower Commission, Aug. 3, 1944 (NBS Box 493, ISR).

rubber was concerned with their construction, quality, care, and use.[172] In the late twenties, as British control of natural rubber resources in the Far East shot prices sky high, the Bureau extended its product testing to more basic research, including comparative studies of natural, reclaimed, and synthetic rubbers.

Attention first turned to the possibility of growing natural rubber in Mexico and California, and some progress was made at the Bureau in producing from the guayule bush a sheet rubber that compared favorably with the latex from plantation rubber.[173] A preliminary investigation was also made in the chemistry of synthetic rubber, a project abandoned in the depression thirties when rubber prices fell with everything else. Work on synthetic rubber was not resumed until the eve of World War II.[174]

All through the 1930's rubber manufacturers stoutly maintained the merits of reclaimed rubber, which was being used in larger and larger proportions in the making of tires. Bureau tests of tires and other products from reworked scrap and waste rubber indicated little basis for the manufacturers' claims. The reduced quality and durability of the tires, said the Bureau, actually made them more costly than tires from high-priced new rubber. Not until natural rubber became available again with victory in the Pacific did the tire industry admit that the Bureau had been right all along.[175]

Investigations in 1917–18 of storage batteries used in the electric trucks and tractors of the Army, in submarines, submarine mines, and airplanes resulted in numerous improvements in their construction, the data appearing in a circular issued shortly after the war.[176] Scarcely any of the improvements, however, found their way into the batteries offered to the general public. As a result, few products were more deficient electrically and mechanically or stood in greater need of standardization and reduction in sizes and kinds than the storage batteries used for starting and lighting automobiles.[177] Working with the standards committees of the American Institute of Electrical Engineers and the Society of Automotive Engineers, Dr.

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[172] NBS Annual Report 1926, p. 31. The tire research was reported in T283 (1925), T318 (1926), C320 (1927), C341 (1927), all by Holt and Wormeley, and J. Walter Drake, "The automobile: its province and problems," Ann. Am. Acad. Pol. Soc. Sci. 116, 1 (1924).

[173] T353 (Spence and Boon, 1927).

[174] C427 (Wood, 1940).

[175] T294 (Holt and Wormeley, 1925). C393 (McPherson, 1931), p. 17, said that reclaimed rubber at 7 cents per pound cost the consumer more per unit of abrasion than new rubber at 20 cents or even 40 cents.

[176] C92 (Vinal and Pearson, 1920).

[177] NBS Annual Report 1920, p. 86.

George W. Vinal of the electrochemistry section sent out a stream of research and test results to the manufacturers. Automobile batteries slowly improved. Simplification, in that highly competitive field, was more difficult, but a start was made in 1922 when the Bureau, on behalf of the Army, prepared specifications limited to 17 of the some 150 sizes of batteries available.[178]

A sequel to a battery study made for the Navy in the late spring of 1921 was to vex the electrochemists at the Bureau off and on for the next 30 years. The Navy came to the Bureau reporting trouble with the negative plates of its submarine batteries. Chemical and spectroscopic tests of the battery electrolyte and plates traced the repeated battery failures to impurities in the electrolyte. While studying electrolyte impurities, Vinal also tested a new jelly electrolyte that had come on the market, as well as several patent electrolytes, all being sold "with extravagant and impossible claims [of extending the life of storage batteries] at relatively high prices." Where these battery additives did not contain substances actually harmful to storage batteries, as most did, Dr. Vinal reported, they were useless.

The results of the Bureau tests were used "both as a basis for specification for [battery] acid and in published warnings widely circulated to protect the public from fraud." [179] The warnings went unheeded. Before the decade was out, dozens more of the additives appeared on the market, and at the request of Government transportation agencies, the Post Office, and the Federal Trade Commission, were tested by the Bureau. The answer to the claims made for them, again made public, was still a resounding no.[180] The continued encouragement by a credulous public of the manufacture of these spurious additives was some years later, as we shall see, to make headlines from coast to coast and imperil the reputation for scientific integrity of the Bureau.

Another long-term study in applied electrochemistry begun during the war centered on the dry cell batteries used in telephones, flashlights, and radios. In the subsequent standardization crusade specifications for their construction and operating life were prepared and under simplified practice a successful effort was made to reduce the multitude of sizes and shapes that

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[178] Letter, SWS to Secretary of Commerce, Dec. 14, 1921 (NBS Box 8, IEB); Hearings * * * 1923 (Feb. 1, 1922), p. 519.

[179] NBS Annual Report 1921, pp. 70–71; Annual Report 1923, pp. 83–84; Annual Report 1925, p. 5; NBS TNB No. 94 (Feb. 10, 1925), p. 1.

[180] LC302, "Battery compounds and solutions" (May 15, 1931). Later Bureau letters to motorists included LC512, "Automobile costs" of owning and operating a car (1938), superseded by LC520 (1938), and for travelers, LC517, "Motorists' manual of weights and measures" (1938).

had proliferated. The annual tests of hundreds of samples of dry cells by the Bureau, on which Government purchases of millions annually were based, served to keep manufacturers on their toes and thus led to improvement in the quality of the billions of dry cells sold to the public.[181]

Apart from the conservation and consumer studies of the Bureau, the automobile industry before long took over most of its own research. But aviation remained a fledgling, of interest principally to the National Advisory Committee for Aeronautics, the Army Air Service, the Navy Bureau of Aeronautics, and, after 1927, the aeronautics branch of Commerce. All of these agencies transferred funds to the Bureau of Standards for their research. Besides engine research, to improve power and fuel economy of aircraft engines at high altitude, investigations continued in ignition, aviation metallurgy, instrumentation (including radio), and the aerodynamics of flight.

The military in the 1920's displayed some interest in better plane design but, inherently conservative and on reduced appropriations, was to express only passing interest in such innovations as the helicopter and jet propulsion. Back in 1917 the National Physical Laboratory at Teddington had sent the Naval Consulting Board, at its request, a two-foot model propeller for a proposed helicopter. Asked to look it over, the Sperry Gyroscope Co. sent it on to Dr. Edgar Buckingham at the Bureau to work out its aerodynamic equations. It seemed promising to him. Within the limits set by the model, Buckingham reported, a small one-man helicopter was entirely practicable. The only "real problem [was] motor stoppage." And, indeed, in view of the unreliability of aircraft engines at that time, Buckingham was probably right.[182] Twenty years passed before Heinrich Focke, in Germany, demonstrated the successful achievement of vertical flight. Two years later, in 1939, Sikorski's helicopter made its first flight in this country.

Jet propulsion fared even less well in the twenties. In the spring of 1920 Dr. Robert H. Goddard, father of rocket engineering, who had proposed the use of rocket weapons during the war, published the first of his papers on "ejectors and new systems of propulsion" for airplanes. Both the National Advisory Committee for Aeronautics and the Army Air Service, aware that jet propulsion was being worked on in Europe, offered the Bureau funds to study its principles and possibilities. As it happened, Buckingham, knowing of the work in Europe, had for some time been studying the aerodynamics involved.

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[181] A brief history of dry cell testing, beginning with NBS C79 (1918), appears in H71, "Specification for dry cells and batteries" (1959).

[182] Letter, SWS to Elmer A. Sperry, Aug. 18, 1917 (NBS Box 12, INA).

From a theoretical point of view, he said, fuel consumption would be so much greater than that with the motor-driven screw that there was no prospect of using jet propulsion. (The petroleum industry was still experimenting with the cracking of oil, and Buckingham could not foresee better fuels than those available.) Moreover, said Buckingham, in what seems now masterly understatement, no further fundamental work on the subject was needed, since the principles of jet propulsion were "all well known." Only the engineering problems remained, and these could be better done by the Air Service than by the Bureau.[183]

A member of the Bureau who followed Buckingham's work at the time has a distinct impression that "jet motors may not have got off the ground because the idea of airplanes spouting 2,000° F flames on an airport was a far from welcome thought."[184] Even into the next decade top-flight engineers considered jet propulsion impractical, in the belief that no material but fire brick could be used for facing the combustion chamber of a jet engine. The weight alone would keep it earthbound.

The real interest of the military in the 1920's was not so much in airplanes as in lighter-than-air craft. Bemused by Count Zeppelin's invention and totally undismayed by their poor record of survival—of some 80 built by the Zeppelin Co. during and after the war, 66 were destroyed by enemy action, burned, broke up in flight, or smashed in landings—the Army began building its RS series of semirigid airships, the Navy its nonrigid dirigibles and ZR series of rigid airships. Considerable research for these ships, especially in instrumentation, was supported at the Bureau with NACA and Navy funds. Designed originally for ship navigation but adaptable to dirigibles and airplanes as well was the earth inductor compass invented in 1922 by Dr. Paul Heyl and Dr. Lyman J. Briggs. Equipped with this compass, the navigator after presetting his compass course had only to keep the galvanometer needle of the earth inductor at zero to stay on course. In an airplane, the compass, an armature driven by a cup propeller projecting through the fuselage and responding to the magnetic field of the earth, was housed in the rear of the fuselage, its indicator in the cockpit. But the career of the compass

[183] Letter, SWS to Engineering Division, Air Service, Dec. 2, 1920, and attached report by E. Buckingham, June 28, 1920 (NBS Box 12, INA). Even stronger was Buckingham's conclusion in a restudy of jet propulsion made 2 years later, in which he said that publication of his calculations by the NACA might "prevent engineers or inventors from attempting impossibilities" (NBS Annual Report 1922, p. 168). Cf. George W. Gray, Frontiers of Flight: The Story of NACA Research (New York: Knopf, 1948), p. 276. The fuel problem is discussed in NBS TNB 189, 10 (1933).

[184] Interview with Howard S. Bean, Apr. 24, 1962.

was brief, giving way to improved magnetic compasses, simpler in design and operation.[185]

The enthusiasm of the military for the zeppelin as a hovering gun platform throve on adversity. The dirigible ZR-2, built for the Navy in England in 1921, broke and exploded on its first trial run. The Army's *Roma,* a 410-foot semirigid built in Italy, crashed over Virginia in February 1922 on its fourth flight. A month later the NACA recommended that Germany's Zeppelin Co. build the next ship, as part of war reparations. This was the 670-foot ZR-3, christened the *Los Angeles* upon her arrival in 1924.[186]

Meanwhile, the Navy, using German plans, began construction of the ZR-1, the 680-foot *Shenandoah,* using in its framework the same lightweight alloy, duralumin, that the Germans had developed for their zeppelins. Although fatigue tests made at the Bureau of sheet duralumin members were not wholly satisfactory and the Bureau expressed itself as reluctant "to draw general conclusions," the Navy believed the duralumin ship indestructible, particularly since it was to be filled with helium and not the explosive hydrogen used abroad.[187]

All the dirigibles proved constitutionally fair weather vessels when brought out of their hangars. In a winter storm in 1924 the *Shenandoah* tore loose from her mooring mast and rode the gales for a night and a day before she could be brought home. Less than 2 years later, in September 1925, while cruising over Ohio, she broke apart in a squall and crashed.

Structural specimens from the wreckage, sent to the Bureau for examination, revealed widespread corrosion, yet insufficient, it seemed, to cause her destruction. American-made duralumin was found to have a fatal flaw: with time it became brittle. "Embrittlement by corrosion," the Bureau described it.[188] Experimentation indicated it could be made durable by apply-

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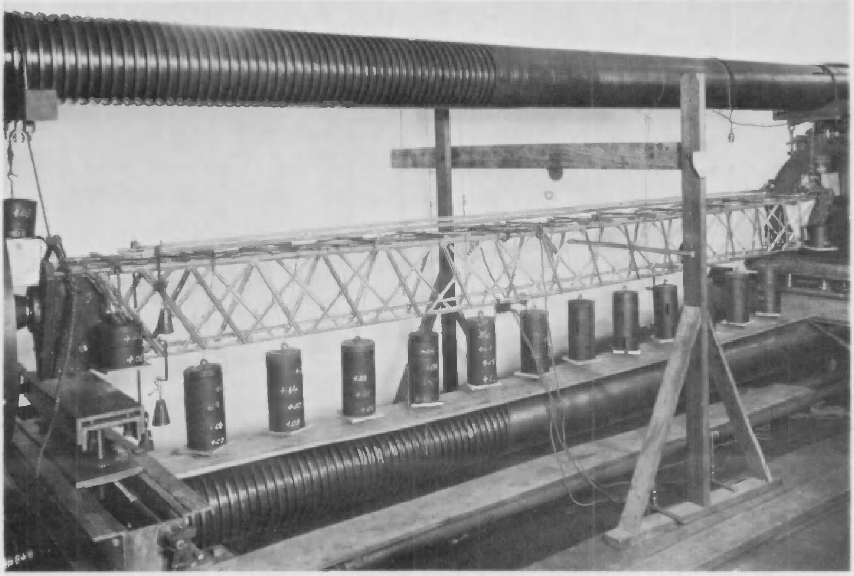
[185] Letter, Engineering Division, Air Service to Director, NBS, Feb. 13, 1922 (NBS Box 12, INA); NBS Annual Report 1922, p. 162. The earth inductor compass, often reported as the only navigation instrument in Lindbergh's *Spirit of St. Louis* in 1927, was not that of Heyl and Briggs but a similar, and simultaneous, development of the Pioneer Instrument Co. of St. Louis. In his memoir of the flight, Lindbergh said this earth inductor compass developed trouble shortly after the takeoff and he had to rely solely on his "liquid compass" for bearings. Lindbergh, The Spirit of St. Louis (New York: Scribner, 1954), pp. 135, 337, 349; conversation with Dr. William G. Brombacher, June 19, 1963.

[186] For Bureau development of new gas cells for the *Los Angeles,* see Annual Report 1928, p. 40.

[187] NBS Annual Report 1922, pp. 172-73.

[188] T270, "An analysis of the deformation of the mooring spindle of the *Shenandoah*" (Tuckerman and Aitchison, 1925); editorial, "Deterioration of duralumin in the *Shenandoah,*" Eng. News-Record, 95, 1000 (1925); NBS Annual Report 1926, pp. 8-9; Annual Report 1927, p. 41.



Testing a duralumin girder from the wreckage of the Shenandoah *in 1925. The girder is shown ready for combined column and transverse tests in the 2,300,000-pound capacity Emery testing machine at the Bureau. The verdict was "embrittlement by corrosion."*

ing a protective coating of aluminum, but the last two U.S. dirigibles were not to survive long enough to prove the coating. Although the German-built *Los Angeles* flew for 9 years before it was decommissioned in 1932, neither the Navy's 785-foot *Akron* (ZR–4), completed in 1931, nor her sister ship the *Macon* (ZR–5), ready in 1933, lasted 2 years beyond their maiden flights.[189]

Reacting as much to the *Shenandoah* disaster as to the unpopular court-martialing of air-power enthusiast Brig. Gen. William Mitchell, who believed in planes, not dirigibles, Congress in 1927 raised the Army Air Service to corps level and authorized assistant secretaries for aeronautics in the War, Navy, and Commerce Departments. Design was standardized to enable industry to build up a reserve of war planes. And in support of civil aviation, the National Bureau of Standards, designated the research agency of Commerce's new Aeronautical Division, was directed to accelerate

[189] See John Toland, Ships in the Sky (New York: Holt, 1957), passim. Germany's *Graf Zeppelin* lasted almost 10 years before it was decommissioned in 1938, but the explosion of the *Hindenburg* while landing at Lakehurst that same year put an end to further investment in sky queens.

its work on the radio direction beacon, ground-to-air radiotelephony, and develop a marker beacon system both to guide and track planes in flight.[190]

If the recent war saw the development of specialization in planes, better planes and engines, sturdier airframes, wind tunnel research, and aerial photography, postwar spurs to aviation were to include the experience gained in flying the U.S. mails and inventions like the radio beacon, radio compass, gyroscopic automatic pilot, streamlining, development of the monoplane, and of retractable gear. The glamor of the dirigible was only to be exceeded by the headline performances of the planes that crisscrossed the skies in the decade that began with Lindbergh's flight to Paris.

"POLICING THE ETHER"

The cross-licensing agreements of General Electric, Western Electric, and Westinghouse in 1920–21, involving some 1,200 radio patents, ended the long patent war in radio. For the first time since its discovery in 1907 the three-element vacuum tube was free from danger of infringement and could be manufactured and sold to the general public. It was exempt from Government monopoly, and there were no taxes on receiving sets, as in Europe The radio boom was on.

In 1920 Westinghouse's experimental station KDKA at Pittsburgh made history by broadcasting the election returns to a radio audience estimated at less than a thousand. By the end of the first year of the patent peace there were 508 broadcasting stations in the United States for the hordes of crystal set and vacuum tube enthusiasts. The great radio craze really began after Armstrong's superheterodyne, with its superior reception, came out in 1922.[191] Whereas in 1921 there were probably not more than 7,000 privately owned sets in the Nation, by 1928 there were nearly 10 million, not counting home-made sets.[192]

As much as anyone, the Bureau fired up a nation of do-it-yourself addicts by issuing a series of mimeographed letter circulars in the spring of 1922 on how to construct a simple crystal detector set for $10;[193] a two

[190] NBS Annual Report 1927, p. 40. See below, pp. 295, 297.

[191] Armstrong's modification in the heterodyne introduced another oscillation with the incoming high frequency signal which produced a third "beat frequency." This lower intermediate frequency could be amplified much more effectively, permitting very high selectivity of the original signal.

[192] Schubert, The Electric Word, pp. 212–214.

[193] Not to be outdone by the Bureau's radio engineers, Clarence A. Briggs of the gage section built a crystal set with coils on cardboard that, except for the antenna and telephone receiver piece, cost 60 cents, and on which, without amplification, he picked up Schenectady, 300 miles away. Letter, H. G. Boutell to Assistant to Sercetary of Commerce, May 23, 1922 (NBS Box 21, PAC).

circuit crystal set capable of picking up stations beyond 50 miles, at a cost of $15; and an electron-tube set, reaching out a hundred miles, for between $23 and $37, including the tube ($5) and the storage battery ($15–$20). Other Bureau letter circulars that spring and summer furnished sources of elementary radio information to amateurs and described auxiliary condensers, loading coils, and an audiofrequency unit for receiving sets.[194] Even before these letter circulars appeared as formal publications, they were widely printed on the new radio pages introduced by newspapers everywhere.[195] Altogether, in that first year of the radio boom the Bureau issued almost a hundred reports, most of them typewritten or mimeographed, to meet the demand for radio data and instruction of radio technicians.[196] Available too was the Bureau's compendious Circular 74, "Radio instruments and measurements," an encyclopedia of the theoretical and practical aspects of radio measurements. Less than a year after the boom started so many types of radio sets were on the market that the Bureau urged that a national movement be launched for the standardization of radio apparatus and service.[197]

The proliferation of radio receivers attracted thousands of hopeful station owners into the potentially lucrative broadcasting field, and for every one that succumbed, two stood ready to take his place. But there was more to it than building a station and selling air time even in those days. Of fewer than a thousand channels or noninterfering wavelengths in the then utilizable radio wave spectrum, only 89 were available to American broadcasting. Interference between stations as some 500 of them competed in these wavelengths raised immediate difficulties, and became insufferable when, in order to drown out competition and reach more people, stations that could afford it increased their power.[198]

Since radio had long been used almost exclusively by ships, the Federal Radio Law of 1912 had made the Bureau of Navigation in the Department of Commerce responsible for licensing stations and assigning wavelengths. It was a toothless law, for Commerce could not deny or revoke a license, and bills proposed by Commerce for "policing the ether" repeatedly

[194] LC43 (Feb. 15, 1922) described the crystal set, LC48 (July 26, 1922) the vacuum tube set. The other letters were LC39, LC44, and LC46.

[195] C120, C121, C122, and C133 were published in 1922; C137 and C141 in 1923. Two commercial publishers not only reprinted C120, on the crystal set, but copyrighted their booklet, and had to be enjoined. NBS Progress Report, May 1922 (NBS Box 24, PRM)

[196] NBS Annual Report 1922, p. 56.

[197] LC66 (June 1922) offered a partial list of almost 275 manufacturers and distributors of radio receiving equipment.

[198] As late as 1928 most stations still operated on 500 watts, with some up to 1,000 watts. The most powerful, 50,000 watts, had a radius of less than 500 miles. Schubert, The Electric Word, pp. 223–224.

Above, Mrs. W. F. Harlow of the radio division, NBS, listens with something like incredulity to a radio broadcast picked up by a homemade crystal set. Below, the widely circulated wiring diagram and details of that Bureau crystal set that could be built for $10.

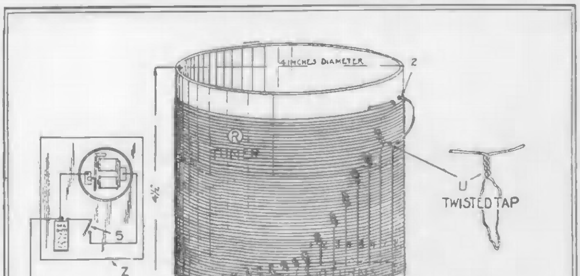


FIG.3. WIRING DIAGRAM AND DETAILS OF RECEIVING SET

died in committee.[199] Without the least power to regulate a licensee, Commerce could only propose solutions and seek the compliance of the stations.

At a conference called in March 1923, the Department and the stations agreed to abolish the term "wavelength" for that of "frequency," the latter representing the number of oscillations of the radio wave per second, expressed in kilocycles per second.[200] The band of frequencies between 550 and 1350 (later 1500) kilocycles was to be set aside for commercial broadcasting, and by dividing the country into 5 radio zones and setting station frequencies 5 kilocycles apart, 570 broadcasters could be accommodated in the 89 available channels.

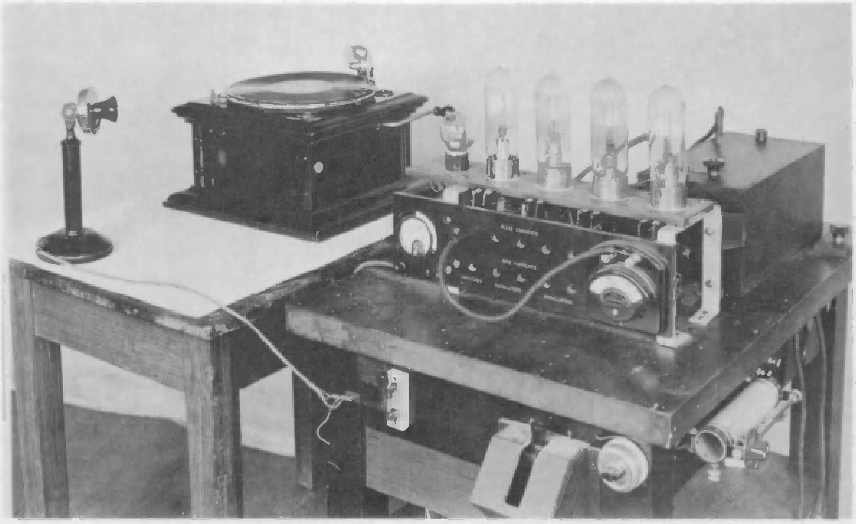
Stations continued to proliferate and the air waves grew crowded again. Conferences in 1924 and 1925 moved ship traffic out of the broadcasting band, and by duplication on the east and west coasts, room was found for an additional 30 stations. By 1926, another 155 new stations raised the total on the air to more than 730 and the chaos had become complete. The radio industry begged to be regulated and Congress had to oblige. On February 23, 1927, the Federal Radio Commission (to become the Federal Communications Commission in 1934), with policing power over its decisions, established public ownership and regulation of the air waves. The boom and battle of the stations came to an end.

Members of the radio section of the Bureau participated as technical advisers at all the early radio conferences, chief among them Dr. J. Howard Dellinger and Dr. Charles B. Jolliffe, who laid the groundwork for the formation of the FRC. As brilliant and sound in radio research as he was in planning and directing its research by others, Dellinger become the first chief engineer of the FRC. He was to leave his name in radio terminology a decade later with his discovery of the simultaneous occurrence of visible solar eruptions and semi-worldwide sudden radio fadeouts, a phenomenon known as "the Dellinger effect." [201]

Jolliffe, who joined the Bureau radio group on getting his doctorate at Cornell in 1922, succeeded to the Commission post when Dellinger returned to the Bureau in 1930. A researcher and organizer himself, Jolliffe moved on the the RCA Laboratories in 1935, later becoming executive vice president and technical director of the company and its laboratories.[202]

In order to learn about radio transmitting at first hand, the Bureau itself became one of the first of the broadcasters, antedating KDKA by several months, when in 1920, at the request of the Bureau of Markets in the

[199] Herbert Hoover, "Policing the ether," Sci. Am. 127, 80 (1922).
[200] NBS Annual Report 1923, p. 71.
[201] See ch. VI, p. 351.
[202] Correspondence on the FRC work of Dellinger and Jolliffe appears in NBS Box 234, IEW (1928); Box 296, AP; Box 303, IEW; and Box 321, PRM.



The phonograph playing into the high-power radiotelephone transmitter may be the experimental "broadcast station" pioneered by the Bureau. The date of the photograph is September 1920.

Department of Agriculture, it pioneered an experimental radio market and crop report service. Even before that the Bureau had successfully transmitted music and speech for short distances over its station, but—such was the novelty of broadcasting—for the sake of reliability the Bureau resorted to Morse telegraph for the market reports. After operating the service for 4 months, the Bureau turned it over to the Post Office, whose stations already served the air mail.[203]

It was not transmission but reception that harbored the real gremlins of radio communication. The first of the technical difficulties that came to the Bureau as commercial broadcasting began was that of fading or variations in the intensity of received signals. A statistical study conducted by the Bureau traced still other forms of interference to their source in amateur equipment, radiating receiving sets, and powerlines, arc lights and other nonradio electrical equipment.[204] Although queries about fading and noise began arriving at the Bureau in 1921, little was done about them at the time because of the even greater obstacle to reception, the interference between stations in the overcrowded air.

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[203] NBS Annual Report 1921, p. 69; letters, SWS to Secretary of Agriculture, May 17 and Sept. 7, 1921 (NBS Box 10, IEW).

[204] Dellinger and Whittemore, "Radio signal fading phenomena," J. Wash. Acad. Sci. 11, 245 (1921); LC182, "Electrical interference with radio reception" (September 1925).

If simple restriction on their proliferation, as the obvious solution to station interference, impinged on free enterprise, a degree of order seemed possible if the stations would operate exclusively on the frequency assigned to them, use as small power as was required to reach the necessary distance, and use waves as sharp as possible. The first two remedies were outside the realm of the Bureau, and it therefore concentrated on the measurement and control of the radio waves emanating from the stations, since the fluctuations in their width determined their capacity for interference.[205] Typical was the experience of a listener in Baltimore who reported interference between two broadcasting stations, one in Cincinnati, the other in California. The interference arose, the Bureau learned, because one of the stations was off its assigned frequency by one-half percent.

Bureau development of new and improved types of wavemeters, wavemeter scales, and devices for rapid radiofrequency measurements gave the Radio Inspection Service of Commerce better instruments for detecting and monitoring broadcasting frequencies.[206] Then in 1923, in order to provide means of self-policing, by enabling broadcasting and other stations to hold exactly to their assigned frequencies, the Bureau set up a standard of frequency and began sending out precise signals over its laboratory transmitter, WWV, set up at Beltsville, Md. The frequency signals were transmitted in groups each day so that the range from 125 to 6000 kilocycles was covered every 2 weeks for all stations within range of the Bureau signal. The obvious advantage of the service soon led to more frequent transmission of the signals and to their broadcast over a nationwide system of standard frequency stations.[207]

Holding to an assigned frequency was not always enough in the noisy crowded air at that time. In January 1924 when the dirigible *Shenandoah* tore loose from her mast at Lakehurst during a winter storm and with only a skeleton crew aboard was lost for almost 20 hours, all New York broadcasting stations went off the air to keep from interfering with her messages.[208]

An enormous improvement on the original frequency standard—a tuning fork device—was the piezo oscillator which used a quartz plate vibrating at a radio frequency.[209] As modified by the Bureau, it furnished an

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[205] NBS Annual Report 1923, pp. 64–65.
[206] Dellinger, "The Bureau of Standards lends a hand," Radio Broadcast, 2, 40 (1922).
[207] Letter, Acting Director, NBS, to Department of Electrical Engineering, Pennsylvania State College, Jan. 26, 1923 (NBS Box 46, IEW); NBS Annual Report 1923, pp. 66–69; Southworth, Forty Years of Radio Research, p. 40; LC171 (1925), superseded by LC280 (1930).
[208] John Toland, Ships in the Sky, p. 85.
[209] The piezo or pressure electricity effect on quartz was first identified by Pierre Curie in 1880. Its application to radio stations was described in LC223, "Use of piezo oscillators" (1927).

Dr. J. Howard Dellinger examines the continuous recording of super-power tests of station WGY, Schenectady. In 1926 when this picture was taken, WGY had been granted permission to broadcast regularly twice a week on 50,000 watts. WGY assisted the Bureau for a number of years in both its studies of radio interference and its compiling of radio propagation data.

extraordinary selective, precise, and portable frequency standard both for the use of radio inspectors and for the stations themselves. The remarkable accuracy of about 0.01 percent attained with the oscillator closely agreed with that of the national laboratories abroad, as comparison tests disclosed, but it was not enough for the Bureau. Mechanical ingenuity and capital had already created a far more acute situation in broadcasting in this country than abroad. The Bureau therefore aimed at absolute frequency values with a certainty of 0.001 percent. It achieved them before the decade was out.[210]

Upon formal adoption by the Federal Radio Commission in 1927 of frequency standards for broadcasting stations, the Bureau was made responsible for their testing. New allocation of broadcasting channels and station restrictions imposed by the Commission, as well as the improved instruments, equipment, and filtering devices that had become available, ameliorated the problem of station interference for the time being. The

[210] Dellinger, "The status of frequency standardization," Proc. IRE, 16, 579 (1928). That certainty, to within 1 part in 100,000, was exceeded in 1930 when the Bureau devised a primary frequency standard with an error of 1 part in several million (NBS Annual Report 1930, p. 22; RP759, 1935). By 1960, with frequency standards based on atomic radiation beams, reliability was in the range of parts in 10 billion. (Dellinger, MS, "Fifty years of radio in the NBS," 3 March 1961, p. 6, NBS Historical File.)

Bureau turned again to the study of radio fading—"the vagaries of radio wave propagation," in the Bureau's blanket term—that by the mid-twenties had come to be considered "the principal obstacle to radio development." [211]

A survey several years before had dispelled the belief that increasing transmitter power would overcome fading, or that high power itself contributed to the fading phenomenon. It was learned that appreciable fading occurred as close as 8 miles distant from a broadcasting station and that the irregularities in reception resulted in part at least from the multiplicity of paths followed by the wave from the station to the receiving set. The primary sources of fading seemed associated with the ionized air of the Kennelly-Heaviside layer, a radio-wave conducting surface identified with the ionosphere, some 60 miles up.[212]

Aware that the task of measuring even some of the phenomena of radio fading was beyond its powers, the Bureau group under Dellinger secured the cooperation of 23 university, industrial, and commercial radio laboratories in recording fading data. General Electric's station WGY and the Westinghouse station KDKA provided the transmission. It took more than a year to sort out the collected data, but the figures seemed to establish a number of facts that had previously been only surmises.

Fading was greatest from 60 to 125 miles from the broadcasting stations, and was almost certainly due to variable absorption of the transmitted waves in the upper atmosphere. The phenomenon occurred between the ground-transmitted wave and the wave that returned from the ionosphere. While there seemed no consistent correlation between fading and weather conditions, day and night variations in the degree of fading were consistent, and during the solar eclipse that occurred in 1925, the fading phenomenon mimicked the day and night fading pattern.[213]

Although fading was quite pronounced on the shorter wavelengths of high frequency transmission, the Bureau was to learn that it presented even greater difficulties at very high frequencies. Except for Austin's work in the Navy radio laboratory at the Bureau,[214] the possibilities of shortwave (very high frequency) radio communication had been neglected in the excitement of the work in broadcasting. The shortwave spectrum had been briefly explored in 1922 when the Army Air Service complained to the Bu-

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[211] NBS Annual Report 1926, p. 19. Dellinger discussed the scope of the problem in "The International Union of Scientific Radio Telegraphy," Science, 64, 638 (1926).

[212] The first suggestion of ionized or "electrically conducting strata" in the upper region of the atmosphere in connection with radio wave propagation was reported simultaneously by Sir Oliver Heaviside in England and Arthur H. Kennelly in this country at the turn of the century. See Kennelly in Elec. World & Eng. 39, 473 (1902), and account in S476 (Dellinger, Whittemore, and Kruse, 1923).

[213] S561 (Dellinger, Jolliffe, and Parkinson, 1927); NBS Annual Report 1928, p. 8.

[214] Described in LC194 (Mar. 10, 1926).

reau of increasing interference in its radio reception. Dellinger's group found at that time that in the narrower band of frequencies utilized by radio telephony interference was greatly reduced. Although uncertain of the practicability of using that band, the Bureau developed apparatus transmitting and receiving on a frequency of 3000 kc for the Air Service. The two-way tests between Washington and Pittsburgh proved successful, with materially less broadcast interference as well as less atmospheric fading.[215]

By 1925 the vast and previously untrammeled range of frequencies between 1500 and 23,000 kc had come into extensive use by transocean communication companies, in ship telephony, and airplane-to-ground communications, and by the military services, amateurs, and broadcast relay stations using it to set up the first radio networks. Three years later, the high frequency channels, as yet unallocated and in common use by all nations, were as congested as the broadcast channels had been. Moreover, real knowledge of the high frequency spectrum was still meager, use of high frequencies was admittedly still in the experimental stage, and despite early optimism it was now known that they were "subject to greater vagaries than radio waves of lower frequency." [216]

Many of the questions raised by these preliminary observations on radio wave propagation and the phenomena of fading would, as Dellinger reported, require years of research and development. He might better have said "decades," for the quest goes on to this day, increasing in scope as knowledge increases.[217] In applied radio, where Federal agencies continually sought new radio equipment for their air and sea commerce, progress was more rapid.

From its very beginning broadcast radio raised hob with the Bureau's radio direction finder (radio compass) on ships trying to pick up signals from the shore stations along the coast. No sooner had the Bureau designed

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[215] NBS Annual Report 1923, p. 66, and correspondence in NBS Box 10, IEW.

[216] Dellinger, MS, "The high frequency spectrum," Jan. 17, 1928 (NBS Historical File). Of interest is Dellinger's report in the American Year Book for 1928, p. 462, of the first transmission by broadcasting and high frequency stations "of pictures and of moving pictures and television [via rotating discs and photoelectric cells]. * * * The received moving images were crude silhouettes or barely recognized faces." Television remained a laboratory novelty as late as 1940, the year radio reached the peak of its popularity, with 45 million sets in 33 million homes, serviced by 882 broadcasting stations. William Kenney, The Crucial Years, 1940–45 (New York: Macfadden-Bartell Corp., 1962), p. 116.

[217] The American Telephone & Telegraph laboratories began studies of the ionosphere in the 1920's, in the interest of long-distance radio communication, but "later recognized that this type of work should be carried out by more centralized bodies [i.e., the Carnegie Institution's Department of Terrestrial Magnetism and the National Bureau of Standards] for the benefit of the whole industry." Maclaurin, Invention and Innovation in the Radio Industry, pp. 161–162.

a special high-frequency radiotelephone for a new fleet of patrol boats put in service by the Coast Guard than the Bureau was asked to convert their radio compasses to similar high frequency reception. The new radio compass, using a frequency of 2100 kc led next to a portable unit that the Bureau of Navigation sought for shipping, with a useful range of 90 to 7700 kc.[218]

While the radio compass was useful for locating a radio signal source, acting as a radio beacon to guide ships at sea or planes in flight, Federal aviation, when it added passengers to its mail flights and extended its operations, required greater safeguards than the compass could provide.[219] (European aviation was to rely entirely on radio direction finders for another two decades at least.) Shortly after the establishment of the Aeronautical Division in Commerce, the Bureau was asked to begin work at once on better air navigation aids.

The Bureau's first crude radio guidance system for aircraft was tested in 1921, when a pilot flew along a course designated by signals sent from two transmitting coils on the ground. The prototype radio beacon produced 2 years later for the Army Air Service was put aside for further work on the radio compass. Without passengers, flying the mail was high adventure and the pilots liked it that way. Work on a beacon was not resumed until 1926.[220]

It was the inventive talents of Harry Diamond, who came to the Bureau in 1927, that resulted 2 years later in the first visual-type radiobeacon system anywhere, enabling a pilot to keep on course and know his approximate position at all times while in flight.[221] Incidental to the system, the Bureau constructed receiving sets of special design for use in planes and improved shielding against interference from the engine ignition. A year later, in 1930, a 15-pound unit that Diamond added to the radio range beacon

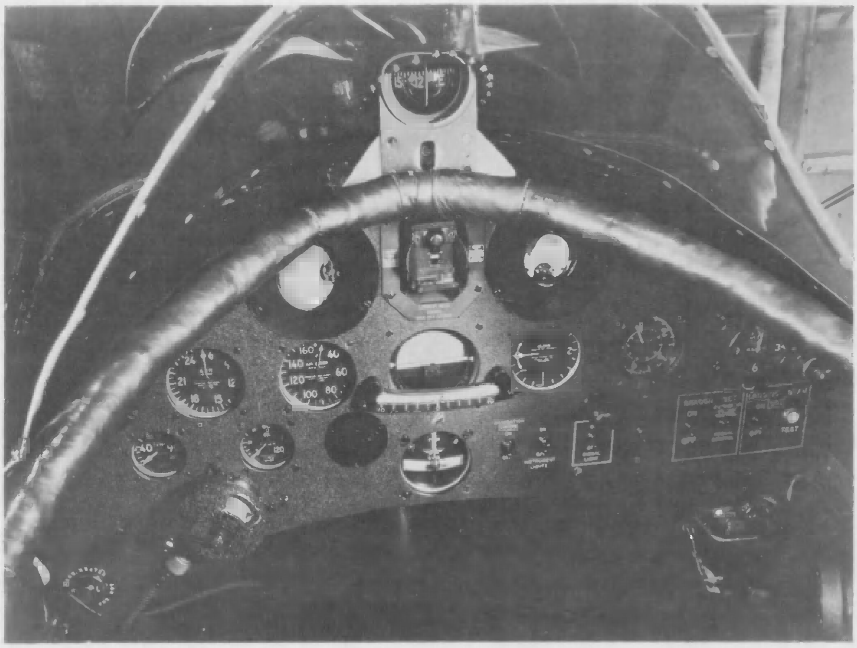
[218] S428 (Kolster and Dunmore, 1921); NBS Annual Report 1922, p. 57; S525 (Dunmore, 1926); S536 (Dunmore, 1926).

[219] By 1924 regular day and night mail service had been established between New York and San Francisco via Chicago and Cheyenne. By the end of 1928, 48 airways covering 20,000 miles linked 355 cities in the United States. Slosson, The Great Crusade and After, p. 401; Aircraft Year Book, 1929 (New York: Aeronautics Chamber of Commerce of America, Inc.), p. 103.

[220] NBS Annual Report 1921, p. 68; S480 (Engle and Dunmore, 1923). Letter, Harry Diamond to Leland Jamieson, Nov. 16, 1939 (NBS Box 431, IEW), credits P. D. Lowell of the Bureau with the suggestion for the radio range beacon about 1922, the experimental work carried out under his guidance in 1922–23 by Engel and Dunmore.

[221] RP159 (Dellinger, Diamond, and Dunmore, 1929).

Born in Russia at the turn of the century, Diamond graduated from MIT and taught for 4 years at Lehigh University before he came to the Bureau as a radio engineer. His electronic genius served the Bureau and the Nation well, notably during World War II. His driving, tireless energy was to bring him to an untimely death in 1948.



A Curtiss Fledgling was equipped in 1931 with the first complete system for blind landing of an aircraft and demonstrated its practicability by an extensive series of hooded landings at College Park, Md., and at Newark Airport.

The dual-pointer landing indicator on the instrument panel gave the pilot a visual indication of his position in space with respect to the approach glide path. Adopted and adapted by the Civil Aeronautics Administration, this NBS radio instrument landing system is basic to the present universally used ILS blind landing system.

and radiotelephone in the cockpit made possible the first blind landing of an airplane entirely by radio guidance.[222]

Blind flying and blind landing—that is, flying under conditions of no visibility—required the pilot to know his position in three dimensions at all times. This was achieved with indicators on his instrument panel which recorded signals from a small direction beacon, giving the pilot his lateral or landing field position; a marker beacon, giving the pilot his longitudinal or approach position; and an inclined ultrahigh frequency radio beam that continuously reported his height. One important difficulty remained. The Commerce Department transmitted weather information to planes on the same frequency it used for ships, while the radio beacon operated on a different frequency. This meant that the pilot had to keep switching his frequencies and also contend with interference from marine radios. The difficulty was solved by adding a device allowing voice communication without interruption to the range service.[223]

Diamond himself operated the radio in the first of the test series of directional and blind flights made between the Bureau experimental air station at College Park, Md., and Newark Airport, the latter chosen because of its heavy traffic—even then. The system proved highly satisfactory, and in 1933 it was turned over to the Department of Commerce.[224]

That same year the Bureau devised a new type of radio direction finder that operated on the radio waves of broadcasting stations. It was designed for the use of itinerant fliers, such as barnstormers and other non-government fliers, who did not have the special equipment necessary to use the radio range beacon.[225]

The twenties witnessed extraordinary developments in radio technology, and extraordinary radio sales. The radio and automobile industries were the bellwethers of that most prosperous-seeming of decades, paying the highest wages and leading the way in mass production and mass consumption techniques. Salaries and the standard of living inched up, goods and groceries were plentiful and relatively cheap, and boom followed boom, real or inflated, in industry, in consumer services, in real estate, and utilities. The Nation speculated, buying stock on margin as it bought appliances. The bootblack and the grocer took fliers, and life savings went into marginal ac-

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[222] A previous blind landing was achieved in July 1929 when Lt. James Doolittle brought down a hooded plane using a sensitive barometric altimeter, a gyro-stabilized horizon, together with a radio lateral course indicator and marker beacon supplied by the Bureau.
[223] RP238 (Diamond and Dunmore, 1930); RP341 (Kear and Wintermute, 1931).
[224] RP602 (Diamond, 1933); Frank G. Kear, "Instrument landing at the NBS," IRE Trans. on Aeronautical and Navigation Electronics, vol. ANE–6, No. 2, June 1959.
[225] RP621 (Hinman, 1933).

counts. [226] The fever struck the Bureau too, but was to some extent contained. Because of the Bureau's close connection with industry and possible access to knowledge that might be useful, a matter of ethics was involved and speculation was quietly discouraged. But no one was exempt from the consequences of the delirium as the Nation headed for the crash.

[226] Not "everyone" was in the market, but active speculators, as distinguished from those who took fliers, probably numbered close to a million, in a nation of 30 million families. John K. Galbraith, The Great Crash, 1929 (Boston: Houghton Mifflin, 1961), pp. 82–83.

The Winchester bushel of Henry VII, a corn bushel, with a capacity of 2,150.5 cubic inches. This was the first English standard measure of capacity of which there is any cognizance.