THE TIME OF THE GREAT DEPRESSION (1931–40)

CHAPTER VI

THE BUREAU IN THE PUBLIC VIEW

The better-homes movement and the standardization crusade of the twenties, fed by fountains of publicity, made the Bureau known to the public as it had never been before. The spate of articles in the Saturday Evening Post, Collier's, Popular Mechanics, Literary Digest, and Everybody's describing how Uncle Sam was saving millions for autoists, homeowners, and the consumer industries acquainted the general public with a helping hand in Washington, available to all, of whose existence many had not previously been aware. The publicity had some remarkable consequences.

The Bureau since its founding had been a high-level information center, an assaying office for inventions and ideas, and a court of appeal, to which Congressmen sent inquiries from their constituents, businessmen their production problems, and inventors their notions for appraisal. The Bureau, after making tests, had politely discouraged citizens of the Great Lakes States who saw their peat and its byproducts as unlimited substitutes for coal and oil, had sent investigators to examine clays, sands, and marls of hopeful economic value on behalf of owners of exhausted farmland, and explained repeatedly to would-be inventors the technical fallacies in their tide motors, and why a hole 12 miles deep, to harness the earth's heat, was impracticable.[1]

Incoming mail at the Bureau surged following the appearance in the early twenties of magazine articles on "Uncle Sam's Question-and-Answer Office" that pointed out that by "Federal law, every government department has to answer every letter which it receives, irrespective of whether the epistles come from lunatics or scientific ignoramuses." [2] The articles cited a dentist's request for a method of measuring wear and tear on false teeth, and a businessman's interest in a motor-driven letter opener to speed clear-

[1] Correspondence in NBS Box 12, IN; Box 13, INM.

[2] George H. Dacy, "Answering a hundred million questions," Illustrated World, 37, 823 (1922); S. R. Winters, "Uncle Sam's question-and-answer office," Sci. Am. 129, 114 (1923).

ance of his morning's mail. A potential voter had written to her Congressman for the recipe she was certain the Bureau of Standards had for a cosmetic to protect her complexion when she played tennis or went bathing.

Some of the queries sent to the Bureau were not as farfetched as they seemed at first glance, as Dr. Coblentz observed in one of his monthly reports:

> That the Optical Division of this Bureau should be called upon to help solve [the problem of increasing the birth-rate of pigs and decreasing the price of bacon] seems comical on first thought. Nevertheless, the question presented by a large forest-products corporation, of the proper windows for hog houses, was a fair one that is worthy of consideration. Perhaps the inquiry should have been turned over to the Housing Commission for more mature consideration. However, having had some experience with problems in solar radiation as well as the farrowing of pigs, advice was given on the proper arrangement of hog-house windows in order to trap and conserve the maximum amount of sunlight.[3]

But many of the inquiries from the public in that decade, whether addressed to the "Natural Bureau of Standards," "National Bureau of St. Andrews," "National Burrough of Standards," "National Brewer of Standards," occasionally the "Department of Science," or by its right name, defied the best minds of the Bureau. Would the Bureau describe "what the average American should be"? Had it a pamphlet on "what the well-dressed person should wear"? Would the Bureau please send its booklets dealing with "protection against the electric influence of radioactive Dictagraphs, the kind that follow people around everywhere * * * and influence * * * hypnotically"? [4]

Newspaper stories in the period announcing somewhat prematurely the imminence of an age of atomic energy aroused interest and apprehension.[5] How, wrote a correspondent, might he "avoid being hit by the 'death ray'"? Another asked whether he ought not to sell his gas and electric stock—to which Dr. Crittenden replied that he had better keep it, since no method was yet in sight to hasten or retard the natural disintegration of radium or other radioactive materials. Nor, wrote the Bureau to another correspondent, was science in a position to release atomic energy by the rapid withdrawal of the magnetic field in a quantity of matter, not even that containing the heavy atom of uranium, thorium, or radium. And to someone who proposed to obtain heat from the oxygen and hydrogen in water,

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[3] NBS Box 23, PRM, December 1922.

[4] Correspondence in NBS Box 162, IG.

[5] Contributing to the speculations were a series of speeches and articles by a member of the Bureau, Dr. Paul D. Foote. See his "Ancient and modern alchemy," Cml. Age, 31, 337 and 423 (1923), and "The Alchemist," Sci. Mo. 19, 239 (1924).

the Bureau offered the warning that this defiance of the law of conservation of matter, "would upset the whole structure of physics and chemistry." [6]

The Bureau received an average of a letter a month announcing the discovery of a perpetual motion device, and to the invariable request that it be tested, the Bureau answered that it would be delighted, upon submission of a working model. So many letters came asking for devices to locate buried treasure that the Bureau composed a form letter. It was really "cheaper to dig over the suspected region than to attempt to build such equipment," said the Bureau.[7]

Not all was chaff. Publicity given to the beneficial effects of airplane flights on those hard of hearing or even totally deaf led to many requests for treatment in the Bureau's high-altitude chamber. The Bureau always agreed to accept patients with types of deafness that might respond to this treatment, provided medical supervision was furnished.[8] But the medical panacea of the twenties was radium (it had been electric belts and electric accumulators before that), and the Bureau was besieged with requests from firms and factories to verify their radium appliances or certify their radium preparations. Sent to the Bureau for tests, in order to obtain American Medical Association approval, were numerous radium injection preparations, "facial radium applicators," and "radium salves," the latter offered as gangrene and cancer cures. Devices for inhaling radium emanations, a do-it-yourself "hydro-radium activator" for making potable radium salts (guaranteed to induce mental as well as physical stimulation), and "Radithor—the perpetual sunshine drink" found avid markets well into the 1930's.[9]

In 1924 the Bureau discontinued its certification of radioactive preparations, but continued to test them at the request of the Post Office, the Federal Trade Commission, and health authorities. On the basis of their minute or nonexistent radioactivity, the Bureau reported the patented waters, muds, slimes, and other concoctions "no more dangerous than a day out in the sun" and uniformly useless.[10] Radium was known to inflict superficial

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[6] Correspondence in NBS Box 14, IPXA; Box 41, ICG; Box 45, IEG. See also NBS Box 47, AG; Box 83, IG; Box 119, IG; Box 121, IM.

[7] Letter, GKB to Office of Secretary of Commerce, Jan. 18, 1926 (NBS Box 166, IN); letter, GKB, Dec. 1, 1927 (NBS Box 201, IE).

It may be noted here that by 1923 the Bureau was handling over 244,200 pieces of first-class mail annually or more than 800 incoming, and outgoing pieces each working day (NBS Annual Report 1923, pp. 320–321). A count made in 1939, in a 3-day period chosen at random, showed almost 800 incoming letters requesting technical information, the same number of telephone calls on technical matters, 450 letters asking for publications, and 429 visitors who called at the Bureau for scientific or technical information or help (Hearings * * * 1940, Apr. 21, 1939, p. 154).

[8] Letter, GKB, Feb. 11, 1926 (NBS Box 166, INA).

[9] Letter, SWS to AMA, May 13, 1922 (NBS Box 14, IPXR).

[10] NBS mimographed letter, June 30, 1924 (NBS Box 103, TPX).

burns when applied externally, but that skin lesions had insidious effects was not so well known. Despite this, and the total ignorance of the effects of radium when taken internally, the American Medical Association did not remove radium for internal administration from its list of recognized remedies until 1932.

The standardization crusade that did so much to fix the public image of the Bureau as a "great scientific business [operated] for the common benefit of all the people" acted in yet another way. Consumers and those interested in consumer welfare began asking what precise benefits the public derived from standardization. Critics of the Bureau appeared who saw only too well how its efforts at standardization and simplification saved money for industry but little evidence that those savings were passed on to the householder.

The Bureau was at some fault itself. It extolled its consumer research without making clear the distinction between the "organized consumer," meaning Federal, State, and city agencies and hospital, hotel and similar trade associations which were direct beneficiaries of its research, and the "over-the-counter consumer" or man in the street. Yet the Bureau was sincerely concerned for the individual consumer and assured him in correspondence and publications that he was the ultimate beneficiary of all its research, in better products and better quality.[11] Even more direct aid was available to the consumer through Bureau publications on incandescent

[11] An indirect consumer service of the Bureau was its unpublicized investigations for the Federal Trade Commission, Postal Service, Justice Department, and Treasury Department, particularly in the scientific detection of misrepresentation, fraud, and high crime. Misleading advertising and misrepresentation of products became subjects of Bureau investigation almost from its inception, but interest in crime did not begin until 1913 when Albert S. Osborn, author of Questioned Documents, sent some micrometers to the Bureau for calibration. By chance, the instruments were tested by Dr. Wilmer Souder of the weights and measures division, who became interested in the scientific detection of crime. His laboratory, with Dr. Stratton's encouragement, was for almost two decades the principal crime research center in the Federal Government, long antedating the organization of a crime laboratory in the Federal Bureau of Investigation. The FBI Laboratory acquired its first scientist in 1932.

Assistance from all the Bureau laboratories was available to Dr. Souder, especially the photographic technology laboratory, where Raymond Davis developed a method for photographing and deciphering almost completely charred records when the ordinary camera, the microscope, and chemical reagents failed (S454, 1922). Specializing in the identification of questioned documents, of typewriting, handwriting, bullets, cartridge cases, and firearms, Dr. Souder by the early 1930's was participating in some 50 to 75 Federal investigations a year involving extortion, kidnapping, theft of money orders, raised checks, forgeries, stolen securities, and threatening letters. Bureau testimony in a contract case in 1935 was reported to have saved the Government almost $300,000, and in another instance settled the payment of income taxes on $1 million (NBS Annual Report 1935, p. 66; correspondence in NBS Box 386, IWI).

lamps, on "gas-savers," "fuel-savers," reclaimed rubber, the care of automobile tires, on battery additives, antifreeze solutions, and the characteristics of "good gasoline." Directed wholly to the consuming public too were the Bureau circulars on household measurements, materials, and safety, and on care and repair of the home.

If industry resented this kind of Government research, the consumer protested it was not enough. The criticism came to a focus with the depression. In the considerable reorientation of Bureau research impelled by the economies of the depression, neither side was pleased.

The criticism that began shortly after the war swelled to a storm in 1923 and lasted for a decade. The Bureau was accused of meddling with the rights of private industry. It was said to be producing materials that should be made by industry. It served industry at the expense of the small consumer. It had become an adjunct of the Better Business Bureau. It was an engineering rather than a scientific research agency. It entertained too many interests outside the scope of its organic act. Many of the charges were exaggerated and, taken together, highly contradictory, but they possessed a common element of truth. The empire building of Stratton and Rosa, bequeathed intact to Burgess and maintained by him, made the Bureau vulnerable to the inference of expansionism.[12]

The censure of the Bureau began and, for all practical purposes, ended with the American Engineering Standards Committee (AESC), over whose reorganization in 1919, in order to commit industry to standardization, the Bureau had presided. Much concerned to define the role of the Bureau in the standardization program, an AESC affiliate had pointedly observed that the Bureau "originally dealt largely, if not exclusively, with scientific problems." Was it authorized "to include also engineering standards, that is, problems of applied science"? Stratton's reply, that he "most emphatically had no intention of limiting the activities of the Bureau of Standards exclusively to what you call 'problems of pure science'," was not reassuring.[13] Nor was the published remark of Russell McBride, Bureau gas engineer, calculated to calm representatives of industry, that the Bureau had become "now * * * what is in effect a 'Bureau of Technology,' closely interwoven with, and in some measure superseding parts of, the original 'Bureau of Physics'." [14]

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[12] Dr. Burgess acknowledged the criticism in a speech on "Policies, problems, and practices of the NBS," dated Nov. 4, 1923 (MS in NBS Box 42, ID).

[13] Letter, SWS to president, Am. Soc. Mech. Eng., Sept. 12, 1919, and attached correspondence (NBS Box 2, AG).

[14] McBride, "The National Bureau of Standards," Chem. & Met. Eng. 27, 1162 (1922). Cf. letter, H. D. Hubbard for Acting Secretary of Commerce to Secretary of State, Sept. 3, 1924: "The Bureau of Standards is primarily a laboratory for industrial research and standardization" (NBS Box 71, AG).

The first serious disagreement with the AESC arose over the degree of Bureau involvement in the simplified practices program, which, the committee asserted, increased the reluctance of some industries to accept the principles of simplification and standardization for which the AESC worked.[15] The establishment in 1927 of the trade standards division at the Bureau, for the purpose of bringing together the standardization, simplification, and specification activities of the AESC and the Bureau, at once met resistance.

In 1928, at the direction of Dr. Agnew, its executive secretary (and former member of the Bureau), the AESC was reconstituted as the American Standards Association (ASA), with authority, through acceptance by concensus of its members, to make standards and validate them as well, and thereby "draw to itself * * * the bulk of standardization and simplification" in industry.[16] Preliminary to the reorganization, the AESC formally requested Bureau withdrawal from all commercial standardization activities. A period of estrangement ensued during which Burgess and other Bureau members ceased to attend ASA meetings.[17]

The resolution was rescinded, but the estrangement continued as the Bureau reported that whole series of projects begun by its trade standards group were being held up or deliberately duplicated by ASA and that the attitude of the association had become antagonistic. Claiming interference and lack of cooperation, ASA retorted that the Bureau was usurping ASA functions and was promoting Federal specifications as commodity standards. As a result, ASA claimed, both producing and consuming industries, fearful of Government interference, resisted the validation by ASA of standards largely determined by Federal agencies.[18] The conflict of interests was not to be entirely resolved for another two decades.

The ASA estrangement was but one manifestation of increasing censure of Bureau research. In 1924 a Baltimore newspaper article, "What becomes of the money you pay in taxes," singled out the Bureau as representative of bureaucratic extravagance, claiming it wasted public funds on testing gas meters, recording the flight of golf balls, investigating fire hazards of motion picture film on ocean liners, testing watches, and making liquid air, all to no purpose.[19] An editorial in the "Washington Post" on "Futile putter-

[15] Letter, GKB to chairman, AESC, May 14, 1923 (NBS Box 43, IDP); memo, GKB for Durgin, Simplified Practices Division, Jan. 10, 1924 (Box 71, AG); memo, Crittenden for GKB, Sept. 30, 1925 (Box 141, PM, SSMC).

[16] Eng. News-Record, 99, 291 (1927); ibid., 101, 712 (1928).

[17] Minutes, AESC Executive Committee, Jan. 19, 1928, par. 1923; rescinded in letter, chairman, AESC to GKB, June 15, 1928 (NBS Box 231, IDS-AESC).

[18] Memo, Fairchild for GKB, Sept. 10, 1928 (NBS Box 231, ID-CS); letter, chairman, ASA to R. Hudson, Nov. 15, 1928 (Box 231, ID-SP).

[19] Attached to memo, GKB for Assistant to Secretary of Commerce, Feb. 15, 1924, and Bureau articles, in manuscript, in reply (NBS Box 71, AG).

ers in Washington," which was widely reprinted, rounded on "the paladins of precision" at the Bureau to which Congress had given "a blanket charter to go as far as it likes * * * [investigating] everything under the round and shining sun." Other research agencies of the Government, particularly in the Department of Agriculture, shared in the editorial complaints, but the Bureau was the focus of the storm. The rumbling had been of some duration and apparently had reached Congress. The "Post" editorialist, summing up the questionable research, recommended that in the promised general shakeup of Federal bureaus "this small dust in the balances of government may as well be swept out. It will never be missed." [20]

In this, as in each instance of attack, the Bureau answered with a statement of the need and authority for its research. It was to little purpose. Acting on complaints of industry, the Comptroller General in 1925 informed the Bureau that it had no right to manufacture optical glass for the Navy or to make special castings for the Coast and Geodetic Survey. Transferred funds for those purposes would be withheld. The Bureau replied that it alone manufactured a suitable optical glass in sufficient quantity for Navy requirements, and that its castings, made "in connection with the Bureau of Standard's investigation of such material," were experimental and noncompetitive. Satisfied, the Comptroller General released the funds.[21]

Industry was not alone in its criticism of the Bureau, nor was Dr. Agnew, executive secretary of the ASA, the only Bureau-trained censor. On a wholly different tack was the private war of Frederick J. Schlink, former technical assistant to Dr. Stratton and from 1922 to 1931 the assistant secretary of the ASA. He was to carry his feud with the Bureau into the thirties from the offices of Consumers' Research, Inc., which he founded with Stuart Chase in 1929.

In 1925–27, while an officer of the AESC, Schlink, with Stuart Chase, wrote a series of eminently readable articles for the New Republic (subsequently published as Getting Your Money's Worth) that had as a principal target the Bureau of Standards.[22] The authors estimated that the Bureau, operating on a budget of $2 million, saved the Government better than a hundred million dollars a year through its testing of products. That same

[20] The editorial also appeared July 2, 1925 in the "Philadelphia Public Ledger" and "New York Evening Post" (NBS Box 108, AG, and Box 139, PA).

[21] Letter, GKB to Secretary of Commerce, July 21, 1925 (NBS Box 112, FPG); letter, Acting Secretary of Commerce to Comptroller General of the United States, August 3, 1925 (NBS Box 111, FL); letter, GKB to Chairman, Navy BuOrd, June 14, 1926 (NBS Box 170, IRG).

[22] While probably not endorsed by the AESC, the articles and book may have had some support in the AESC's pique with the Bureau at the time. See Getting Your Money's Worth: a Study in the Waste of the Consumer's Dollar (New York: Macmillan, 1927, reprinted 1931), pp. 82, 98.

research and testing, said Schlink and Chase, would save the public at least a billion dollars annually if Bureau test results were made available in a form that the consumer could use. They declared invalid in an agency operated on taxpayers' money the Bureau argument that release of its test results on competitive products, and identifying them by name, would "promote commercial injustice." They proposed a consumers' rebellion, and urged the public to act through Congress to secure release of all Government information of consumer interest, particularly that concealed in the publications and files of the Bureau of Standards and the Department of Agriculture's Bureau of Chemistry.[23]

In a book he wrote in 1929, Dr. Harvey W. Wiley, former chief of the Bureau of Chemistry, father of the Food and Drug Act, inveterate polemicist, and at that time director of research on Good Housekeeping magazine, made one of the most virulent and comprehensive of the attacks on the character of research at the Bureau up to that time.[24] Besides his condemnation of Bureau investigations that encroached on provinces of other research agencies in the Government, he assailed at length, as did Schlink and other consumer-oriented critics, the research associate plan at the Bureau which performed research directly for the benefit of industry at the taxpayer's expense. And he struck at "the expansive activities of the Bureau of Standards," citing its use of transferred funds—

> to investigate oil pollution, radio direction for the Coast Guard, helium recorders, chromium plating, corrosion, fatigue and embrittlement of duralumin, electrically charged dust, optical glass, substitutes for parachute silk, goldbeaters skin, storage batteries, internal combustion engines, fuels, lubricants, photographic emulsions, stresses in riveted joints, machine guns, bomb ballistics, rope and cordage, chemical and metallurgical tests, wind tunnel tests of models, aircraft engines, velocity of flame in explosives * * * caroa fibers * * * and farm wastes

[23] The same criticism of the Bureau appeared in Dr. Robert A. Brady's article, "How Government standards affect the ultimate consumer," Ann. Amer. Acad. Soc. Pol. Sci. 137, 245 (1928), and in Schlink's article, "Standards and specifications from the standpoint of the ultimate consumer," ibid. issue.

The Bureau position has been repeatedly pointed out. The creation of a Government laboratory to test consumer goods sounds eminently reasonable. But the Bureau has long been aware how impossibly large and controversial such a project would be. Health hazards may justify the Food and Drug Administration, but to cover all consumer products in order to mitigate merely economic hazards would be a herculean task. Interview with Dr. F. B. Silsbee, Mar. 10, 1964.

[24] The recitation of grievances appeared in a remarkable digression in his History of a Crime against the Food Law (Privately printed, Washington, D.C., 1929), wherein a whole chapter (pp. 281–345) was devoted to the Bureau.

as evidence that the Bureau was in direct competition with private research laboratories such as the Mellon Institute of Industrial Research and Arthur D. Little, Inc. There was no more warrant in the organic act of the Bureau for this commercial research, Wiley declared, than there was for its "architectural excursions" in building pilot plants to manufacture dextrose and levulose. The Bureau, he concluded, was badly in need of policing.[25]

The recurring charge that the Bureau interpreted its authority over weights and measures as a license to investigate literally everything that could be weighed or measured, appeared also in a pamphlet entitled "Why not reorganize the Bureau of Standards?" published in 1929 by William E. Bullock, secretary of the antimetric society, the American Institute of Weights and Measures.[26] If this was simply a random gadfly attack, a letter that same year from Arthur D. Little, president of Arthur D. Little, Inc., was not. It was an ultimatum from industry. Many prominent chemists and chemical engineers, he wrote, were convinced that "the Bureau has extended its efforts far outside its legitimate field," and "threatened to take the whole question before the House Committee on Appropriations." [27]

Provoked by "the four-year furor" over its research in industry, Dr. Burgess submitted the controversy and a statement of the Bureau position and its program of research to the Department of Justice for a legal opinion. Justice ruled that the extension of Bureau activities beyond the organic act, as authorized by a succession of congressional acts, was completely valid.[28]

In the last months of the Hoover Administration, Congress finally held its long-promised investigation of Government interference in industry. (It paid no attention to the equally valid criticism of Federal apathy where the taxpaying consumer was concerned.) Acting on complaints of the U.S. Chamber of Commerce, the National Association of Manufacturers, and the Federation of American Business, Congress appointed a committee on May 31, 1932, to survey "the extensive commercial and manufacturing interests of Government bureaus seriously competing with private industry." Despite all the furor, the Bureau turned out to be the least of offenders.

Congress found that during World War I, owing to the reluctance of private industry to risk short-term, unprofitable ventures, Government agencies had organized a great number of manufacturing plants, factories, foundries, and services, and with the "overreaching zeal of governmental bureaus to retain authority and prestige," had continued to operate them after the war. Heading a list of 17 specific areas of serious competition were

[25] Many of Wiley's charges were longstanding. See 12-page letter, GKB to C, Bureau of Efficiency, Aug. 31, 1923 (NBS Box 40, AG).
[26] Pamphlet in Bureau of Budget records, NARG 51, file 86 (Bureau of Standards).
[27] Letter to GKB, Dec. 30, 1929, and attached correspondence (NBS Box 263, AG).
[28] Letter, Dr. Julius Klein, Assistant Secretary of Commerce, to R. O. Bailey, Dec. 30, 1931 (NBS Box 339, AG-Conf. for Dir. only).

Navy Department factories and foundries, Government Printing Office supply plants, Army and Navy clothing and leather factories, the Post Exchange organization, a wide range of Farm Board enterprises, and many of the Federal prison industries.

Nowhere in the 253-page report of the committee was the Bureau of Standards mentioned by name, though it might have answered to the indictment of "overdevelopment of industrial research in Government laboratories," buried in the last pages of the report. Much of that research had been initiated by industry itself, the committee found, but had "grown beyond the original intent or desired objective in many instances." [29] The Bureau might also have answered to the charges that technical specialists in the Government, acting as industrial consultants, thereby competed with professional consultants, and that Government patents taken out by Federal scientists on behalf of the public "prevented exclusive development by industry." Since the congressional committee felt that neither the intention nor extension of Government research for industry could be accurately defined, it recommended only "curtailment by limitation of funds appropriated for such investigations," as a brake on Federal competition.[30]

The report of the committee appeared at the depth of the depression, just as the incoming administration launched its massive drive against Federal expenditures. Curtailment of Bureau funds, and the investigations of Bureau activities that followed, were to end more of its research for industry than industry bargained for.

LYMAN JAMES BRIGGS

It has been said that any Republican could have been elected President in 1928. That the Republican was the incumbent Secretary of Commerce made Hoover the unluckiest President in American history. With the stock market crash, the national income between 1929 and 1932 fell with the value of the dollar from $87.4 billion to $41.7 billion. Unemployment, from an irreducible peacetime low of 1.8 million in 1925 (representing 4 percent of the civilian labor force), reached 4.3 million (8.7 percent) in 1930. In

[29] Report of Special Committee appointed to investigate Government competition with Private Industry (72d Cong., 2d sess., H.R. 1985), Feb. 8, 1933, p. 236 (L/C: HD3616.U45A3).

[30] Ibid., p. 237. The House questionnaire on Government competition, with Bureau answers, appears in letter, LJB to Hon. Joseph B. Shannon, Aug. 24, 1932 (NBS Box 339, AG). For the Chamber of Commerce attack on the Bureau's "overdevelopment of industrial research," see memo, Office of Secretary of Commerce for LJB, Oct. 4, 1932 (ibid.).

the wake of the financial collapse of Europe in early 1931, this country began the steep slide into the great depression.

By late 1932, 85,000 business firms and 5,000 banks had failed and unemployment reached 12.8 million (24.9 percent of the labor force), representing 1 out of every 4 workers in the Nation.[31] With varying intensity, the depression lasted for 10 years, until the vast pool of manpower and industrial capacity was absorbed by war.

Constitutionally opposed to emergency Government measures, President Hoover at first sought, as he had in his recovery program of the early twenties, to prod private enterprise into action by stepping up Federal construction, urging local governments to accelerate their spending, and businessmen to maintain wage rates.[32] By 1931, as State and city treasuries emptied and business and industry acknowledged their helplessness, the administration was forced to act. Much against his will, Hoover brought large areas of the economy—the banks, railroads, insurance companies, farmers, and finally the unemployed—into the Federal orbit. A Reconstruction Finance Corporation was set up to lend money to States and municipalities for self-liquidating public works and a Federal Home Loan Bank Act was passed to prevent home foreclosures. A "public works administration" was proposed to promote expansion of Government construction. In the presidential campaign of 1932 these and other measures intended to shore up the financial and industrial structure, relieve unemployment, and restore balance were rejected by the Democratic opposition as rampant socialism, encroachment of the Federal Government on States' rights, and radical spending of public funds.[33] By the summer of 1932 Hoover's influence was gone and a vast apathy, born of confusion and despair, settled over the Nation.

The Bureau gave no sign that it was in any way aware of the stock market crash of 1929. Its first recognition of "reduced industrial activities" occurred in mid-1931, following the collapse of Europe, with the note that "every effort [is being] made to operate economically." Still, the Bureau exhibited no alarm. That year in his annual report Dr. Burgess counted 525 projects under 22 research appropriations made to the Bureau, the largest number of projects ever. Both public and Government demands for tests continued to increase each year, and it was expected they would ac-

[31] Historical Statistics, p. 73. By comparison, at the height of the 1920–21 depression, unemployment did not rise above 5.01 million or 11.9 percent of the labor force.

[32] Leutenburg, The Perils of Prosperity, 1914–1932, p. 251; Dixon Wecter, The Age of the Great Depression, 1929–1941 (New York: Macmillan, 1948), p. 17.

[33] Arthur M. Schlesinger, Jr., The Age of Roosevelt: Crisis of the Old Order, 1919–1933 (Boston: Houghton Mifflin, 1957), pp. 416–417, 423, 433.

celerate "with returning prosperity." [34] Actually, from the viewpoint of appropriations, as Dr. Burgess wrote with great satisfaction to Gano Dunn of the Visiting Committee, 1931 had been "the banner year for the Bureau." Transferred funds and direct appropriations totaled more than $4 million, the largest sum in its history, exceeding even the appropriations of the war years. Besides increases in salaries, special appropriations, and transferred funds, almost a million dollars had been allocated for a new hydraulic laboratory, two radio stations, and some 15 acres of additional land to the north and west of the Bureau quadrangle.[35]

[34] NBS Annual Report 1931, pp. 1, 46. This report is the only one ever to state the number of projects carried on under each Bureau appropriation.

No special alarm, either, seems to have been felt at the Physikalisch-Technische Reichsanstalt (PTR), the Bureau's counterpart in Berlin. More interestingly, that year produced the only comparison between the Bureau and the PTR that has been found. Five years earlier, in 1926, Paul D. Foote while in Europe had written Dr. Burgess that from his observations the Bureau, with better equipment, now excelled the PTR in practically every line of work (letters in NBS Box 157, ID and IDP). A German article on the state of the PTR in 1931 confirmed Foote's reports.

By comparison with the NBS and Britain's National Physical Laboratory, the writer said, the PTR "in these past years, has considerably receded into the background." It had become preoccupied with testing to the exclusion of basic physical-technical research, it suffered from lack of team work, and the technically important work it should be doing for industry was instead being done by industry itself.

Where the NBS budget for 1929 amounted roughly to $2.75 million or 11.5 million RM, with a "material" (nonsalary) budget of 8.8 million RM, the PTR budget for 1931 of 1.5 million RM allowed but 400,000 RM for all material expenditures, of which only 170,000 RM were earmarked for research. As for productivity, "The staff of the Reichsanstalt would really have to consist of half-gods * * * to achieve the same results as the Bureau of Standards." J. Zenneck, "Werner von Siemens und die grundung der Physikalisch Technische Reichsanstalt," Munich Deutsches Museum Abh. u. Ber. 3, 13 (1931) L/C: AM101.M9743.

[35] Letter, Mar. 4, 1931 (NBS Box 330, ID). The National Hydraulic Laboratory established at the Bureau was described in Science, 72, 7 (1930), and Civil Eng., 1, 911 (1931).

Surveying the 9 major and 12 minor buildings spread over the Bureau heights, Burgess beheld "a varitable city of science." Outside Washington, the new radio research station on 17 acres at Beltsville, Md., was to be used to send continuous standard frequency signals to broadcasting stations, the station on 200 acres at Meadows, Md., to study upper atmosphere radio phenomena. Aviation engine testing, too rackety for the householders down on Connecticut Avenue, had been moved to a new station at Arlington, Va. Other field stations included that for radio aids to aviation at College, Park, Md., electric lamp inspection laboratories in the New York and Boston districts; farm waste stations at Ames, Iowa, and at Auburn and Tuscaloosa, Ala.; cement and concrete test stations at Northampton, Pa., and Denver, Colo.; cement, concrete, and miscellaneous materials test units at San Francisco, and ceramics research at Columbus, Ohio. Burgess, "The National Bureau of Standards," posthumously published in Sci. Mo. 36, 201 (1933). For an earlier report by Burgess on the Bureau plant, see Hearings * * * 1928 (Dec. 5, 1927), p. 43.

The Bureau was also fully staffed. Not long before, Dr. Burgess observed that "for the first time in many years the Bureau now has a complete administrative and scientific roster.[36] The addition of more than 300 new members in 1931 brought the total Bureau staff to 1,066, despite the recent loss of some of its best people who had left for better pay elsewhere.[37] In order to maintain this staff, Burgess proposed not only to operate as economically as possible but to give special attention to those activities "tending to relieve the business depression and unemployment," that is, industrial research, stimulation of new industries, standardization, and building and housing.[38]

The sense of well-being was brief. In the spring of 1932 Dr. Burgess learned that Bureau funds for the coming year were to be reduced by one-fifth, affecting every item in his budget.[39] But he did not live to see this disaster or the subsequent effects of the depression on the Bureau.

Six months previously, in October 1931, while presiding at a Wednesday meeting of his division chiefs, Dr. Burgess suffered a slight stroke resulting in a partial paralysis from which he recovered after 3 months of care.[40] A second and fatal stroke occurred on July 2, 1932, while he was working at his desk in South building. He had been with the Bureau for almost 30 of his 58 years.

Dr. Briggs, assistant director for research and testing, became acting director upon the death of Dr. Burgess. A week later Secretary of Commerce Robert P. Lamont wrote to the Visiting Committee asking its assistance in recommending a successor to Dr. Burgess. He was, Lamont said, a strong believer in filling vacancies from within the service and for that reason suggested Dr. Briggs's name. Charles F. Kettering, a senior member of the committee, replied that he himself did not know Briggs very well, but it had been his experience that it was often better to bring in someone from outside. The point was discussed in committee correspondence for several months. It was December before the Visiting Committee met and formally recommended Dr. Briggs.[41]

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[36] NBS Annual Report 1926, p. 1.

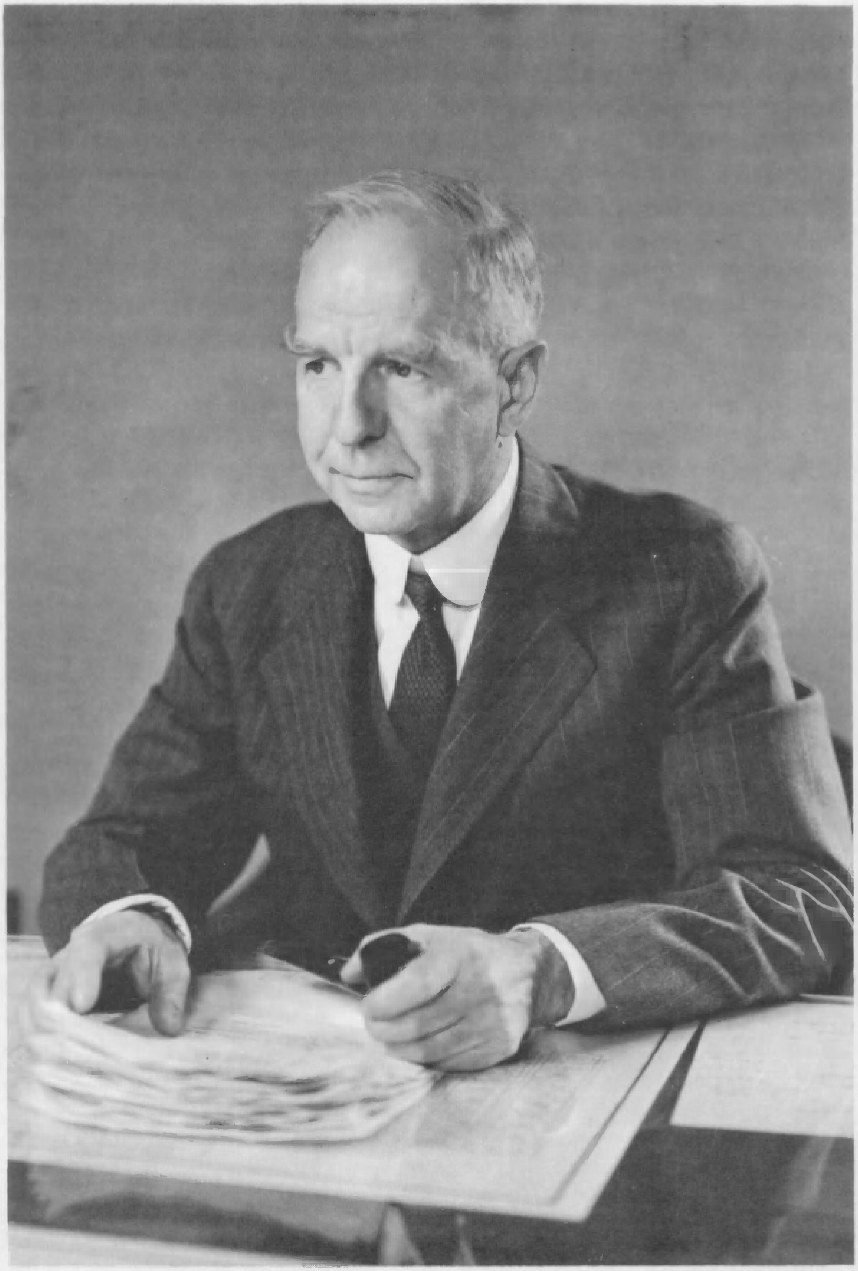
[37] Letter, GKB to Office of Department of Commerce, June 11, 1930 (NBS Box 296, AP), named 28 in the professional group at the Bureau who had resigned since mid-1928. Memo, GKB for Secretary of Commerce Lamont, Apr. 16, 1932 (NBS Box 339, AG), told of 8 members of the automotive section, including its chief, who left in 1927 to set up a research department at the Studebaker Corp., at almost three times their Bureau salaries.

[38] Memo, GKB for Administrative Assistant to Secretary of Commerce, May 14, 1931 (NBS Box 331, IG).

[39] Science, 75, supp. 11 (April 1932).

[40] Letter, Lamont to Kettering, Oct. 30, 1931 (Department of Commerce, Visiting Committee file, NARG 40, 67009/5); Briggs at Hearings * * * 1933 (Jan. 8, 1932), p. 212.

[41] Letter, Lamont to K. T. Compton, July 13, 1932; letter, Kettering to Lamont, July 20, 1932; letter, Compton to Chapin, Dec. 1, 1932 (NARG 40, file 67009/5, pt. 2).



Dr. Lyman J. Briggs, third Director of NBS, in his 6th year as chief and 5th year of the New Deal. Under the glass top of his desk is an organization chart of the Bureau. The advice of Satchel Paige may also be under that glass, but this cannot be verified.

Receiving the recommendation from interim Secretary of Commerce Roy D. Chapin, Hoover offered Dr. Briggs's name to the Senate. In view of the imminent change of administrations, the Senate did not act on the appointment. In the patronage scramble of 1933, Roosevelt was pressed to name "a good Democrat" to the office. He is said to have replied: "I haven't the slightest idea whether Dr. Briggs is a Republican or a Democrat; all I know is that he is the best qualified man for the job." On March 27, 1933, Roosevelt renominated Dr. Briggs and on June 13 the Senate confirmed the appointment.[42]

Dr. Lyman J. Briggs (1874–1963), born the same year as Dr. Burgess, grew up on a farm north of Battle Creek, Mich. He acquired his copy of Ganot's Physics at 18, in his third year at Michigan State College. Transferring to the University of Michigan for graduate work, Briggs studied under Dr. Karl E. Guthe, who was to be chief of an electrical section at the Bureau of Standards in its early years. In 1895 Briggs graduated with a master of science in physics.[43] That same fall he entered the Johns Hopkins University, where he worked under Prof. Henry A. Rowland, investigating with him the recently discovered Roentgen rays.[44] But his principal interest had been fixed earlier at Michigan State, in what was then a new science called "soil physics." To learn more of the subject, and to support his approaching marriage, Briggs in June 1896 obtained a position as physicist in the Bureau of Soils of the Department of Agriculture.[45] His Hopkins thesis,

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[42] Wallace R. Brode, "Lyman J. Briggs * * *," Sci. Mo. 78, 269 (1954).

The delay in acting on the nomination of Dr. Briggs was occasioned by efforts of certain members of the Senate to name a director of their own choice. Their candidate was Winder Elwell Goldsborough of Maryland, electrical engineer, teacher, inventor, businessman, and from 1923 to 1932 director of the Henry L. Doherty Research Laboratories. The impasse that ensued was apparently broken when Secretary Roper informed Goldsborough's sponsors that contrary to their belief "that he is a Democrat and entitled, because of this as well as because of his qualifications, to this position," he was in fact "a consistent Republican" (letter, Secretary Roper to Senators Harrison, Lonergan, and Sheppard, June 10, 1933 [NARG 40, Correspondence of Secretary of Commerce Roper, Box 24–S]). Additional correspondence on Goldsborough's candidacy, dating from September 1932, appears in NARG 40, file 93067).

[43] His thesis was published as Guthe and Briggs, "On the electrolytic conductivity of concentrated sulfuric acid," Phys. Rev. 3, np (1895).

[44] Rowland, Carmichael, and Briggs, "Notes of observations on the roentgen rays," Am. J. Sci. 1, 247 (1896); Rowland, Carmichael, and Briggs, "Notes on roentgen rays," Elec. World, 27, 452 (1896).

[45] At that time, according to Dr. Briggs, there were only three soil physicists in this country, Eugene W. Hilgard at California, Franklin H. King at Wisconsin, and Milton Whitney in the Department of Agriculture. Interview with Dr. Briggs, Nov. 1, 1962.

for which he received his doctoral degree in 1901, was on an aspect of the physical action of moisture in soil.[46]

Dr. Briggs headed the biophysical laboratory of the Bureau of Plant Industry, which he had organized in 1906, when he was detailed by Executive order to the Bureau of Standards upon America's entry into the war and set to work constructing a wind tunnel for aviation research.[47] Two years later he brought into his aviation physics section Hugh L. Dryden, a graduate student from Johns Hopkins, recommended by Professor Ames as "the brightest young man he had ever had, without exception." By then Briggs was wholly won to the study of aerodynamics and formally severed his connection with the Department of Agriculture. Briggs and Dryden were to remain closely associated throughout their careers at the Bureau.[48]

Chief of the mechanics and sound division when Stratton left the Bureau, Briggs had declined the proposal of the Visiting Committee that his name be submitted with that of Burgess for the directorship, saying that he considered Burgess the better fitted at the Bureau for the position. Soon after he became Director, Burgess asked Congress that a position of Assistant Director be established at the Bureau, to take over some of the burden of supervising research and testing. Dr. Briggs was offered the position and declined, but when in 1926 Secretary of Commerce Hoover proposed that Dr. Ray M. Hudson of his office be made Assistant Director at the Bureau, Burgess asked Briggs to reconsider. On September 29, 1927, two Assistant Directors were appointed, Briggs for research and testing and Hudson for commercial standardization.[49]

Dr. Brigg's assumption of the Director's chair after 6 years of supervising research and testing and a year as Acting Director was therefore without incident, except that it occurred at the nadir of the depression. He was already confronted with the task of preserving a working organization in the face of repeated reduction in salaries, staff, and programs, and was about to participate in a series of congressional and special committee inves-

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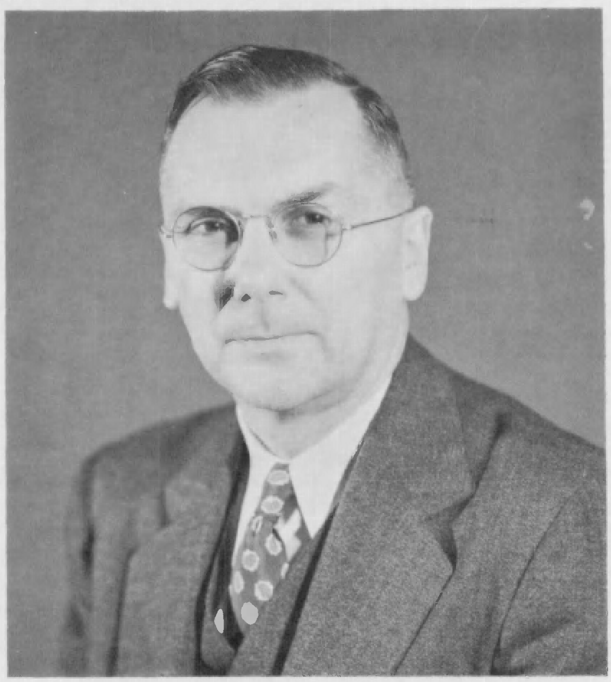
[46] Briggs, "On the adsorption of water vapor and of certain salts in aqueous solution by quartz," J. Phys. Chem. 9, 617 (1905).

[47] The request for the transfer of Dr. Briggs to the Bureau said he was needed "in connection with the organization of a division for the purpose of certifying all gages in the manufacture of munitions." Letter, Secretary of Commerce to Secretary of Agriculture, May 22, 1917 (Department of Commerce records, NARG 40, file 67009/43). The gage work, however, remained a section in the division of weights and measures, and Dr. Briggs went into aeronautics.

[48] Interview with Dr. Briggs, Nov. 1, 1962. Dr. Dryden succeeded Briggs at the Bureau as section chief in 1922, as division chief in 1934, and as associate director in 1946, leaving in 1947, 2 years after Brigg's retirement, to become research director of the National Advisory Committee for Aeronautics.

[49] Interview with Dr. Briggs, Nov. 2, 1962. The positions are described in NBS Annual Report 1928, p. 1.

Dr. Eugene C. Crittenden, who came in 1904 to develop standards in photometry and remained 50 years, was to become the most knowledgeable man about NBS operations and activities and the Bureau's chief diplomat in negotiating national and international agreement on the establishment of new standards.



Dr. Hugh L. Dryden made some of this country's earliest studies of airfoil characteristics near the speed of sound. He was associate director of the Bureau until 1947, when he became research director of NACA, forerunner of NASA, and first deputy administrator of NASA when that agency was created in 1958.

tigations of Bureau operations, ordeals that deeply pained Dr. Briggs's gentle spirit. The time called for a ruggedness and ruthlessness he did not have, and in his later years he preferred not to think of the problems of that troubled era, turning questions about them to peripheral subjects more agreeable.

Unlike Stratton and Burgess, Dr. Briggs was of slight, slender build and of warm, affectionate, and unfailingly kind demeanor and manner. Dr. Stratton, when harassed by demands upon his time and attention or in a stormy mood, often sought out Briggs' company in his laboratory in West building, for as he once said: "You always have something nice to report to me and I appreciate it. These other fellows give me a lot of trouble." [50] The "something nice" was usually a new and ingenious piece of apparatus or testing device, for, like Stratton, Dr. Briggs was strongly mechanical and an inveterate tinkerer. When he came from the Department of Agriculture he brought with him his mechanic, Mr. Cottrell, and for years the two designed and constructed many of the special devices that Briggs used in his measurement studies.[51] His laboratory was a wonderful clutter of apparatus in various stages of assembly, a tangle of piping and tubing and ticking instruments, but it was comfortable and a tranquil spirit filled it.

His serenity of temper was Dr. Briggs's outstanding characteristic, and he was to have need of it under the frustrations of the depression years and the pressures and harassments of security in World War II. Asked after he resigned the direction of the Bureau and returned to his laboratory for the secret of his unfailing patience, he liked to say that the "precepts of that great philosopher and baseball player, Satchel Paige," best summed up his own:

> Avoid fried meats which angry up the blood.
>
> If your stomach disputes you, lie down and pacify it with cool thoughts.
>
> Keep the juices flowing by jangling around gently as you move.
>
> Go very lightly on the vices, such as carrying on in society. The social ramble ain't restful.
>
> Avoid running at all times.
>
> Don't look back. Something might be gaining on you.

The last was the precept he set greatest store by and delighted to quote at interviews.[52]

Dr. Briggs had two outside enthusiasms during his years at the Bureau, scientific exploration and baseball. Succeeding Dr. Burgess on the board of trustees of the National Geographic Society, Dr. Briggs took a highly

[50] Interview with Dr. Briggs, Nov. 3, 1962.
[51] Interview with Dr. Dryden, Aug. 26, 1963.
[52] The NBS Standard, April 1963; interview, Nov. 2, 1962.

active interest in its expeditions, and in his laboratory supervised the design and construction of many of the scientific instruments required by the Society. In the 17 years he held the chairmanship of the research committee of the Society, he personally directed or was closely involved in its many expeditions.[53]

Well past retirement age when he left the Director's office, Dr. Briggs spent the last years of his long life in his old laboratory in West building. A baseball player while at Michigan State and avid fan in the stands at Griffith Stadium in Washington, he was in his 85th year when he determined to settle a long disputed phenomenon: scientific proof of the degree a baseball can be made to curve in the 60-foot throw from the pitcher's box to the plate. With the aid of the wind tunnel he designed in 1918 and the pitching staff of the Washington Senators, he made a series of quantitative measurements of the relation of spin to deflection of a pitched baseball at various speeds.

In laboratory tests to measure spin, Dr. Briggs repeatedly projected baseballs, rotated on a rubber tee to provide spin, out of a mounted air gun at a paper target 60 feet away. Air flow phenomena were measured in the wind tunnel, and still other studies with a suspended camera measured the curvature of the ball in flight. Finally, at Griffith Stadium, members of the pitching staff hurled endless balls to which light, flat tapes were fastened, and the number of completed turns in the twisted tape were counted at home plate.

With baseballs thrown at a speed of 100 feet per second, roughly 68 miles per hour, and well within a professional pitcher's capability, Briggs recorded lateral deflections in the 60-foot flight from the pitcher's box of 11.7 inches at 1,200 revolutions per minute and 17.5 inches at 1,800 revolutions per minute as the maximums attainable. The spin rather than the speed of the ball, he found, determined its "break." The feat, reported in every newspaper in the country, was a logical development in the field of mechanics, Dr. Briggs said, closely related to the low-speed ballistics and projectile work of the Bureau. And it had been fun.[54]

As the new Director, Dr. Briggs presided over a temporary eclipse of the Bureau. For several years his paramount concern was to hold on to his scientific staff by all means available and to justify research that was not immediately productive of depression-thwarting results.[55] Throughout the decade he was aware of something less than enthusiasm on the part of the

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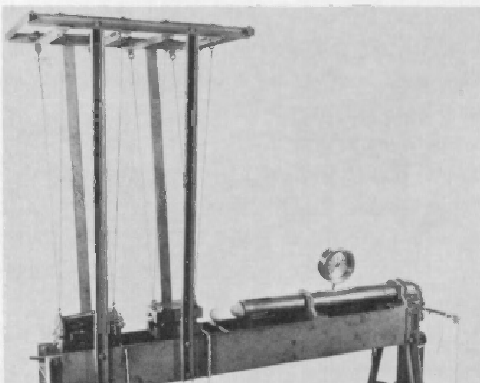
[53] See below, pp. 355–357.

[54] Briggs, "Effect of spin and speed on the lateral deflection (curve) of a baseball; and the Magnus effect for smooth spheres," Am. J. Phys. 27, 589 (1959); interview, Nov. 2, 1962.

[55] Letter, LJB to Secretary of Commerce, Oct. 10, 1932 (NBS Box 339, AG).

Dr. Briggs, Director Emeritus, and Mr. Ossie Bluege, comptroller of the Washington Baseball Club and formerly third baseman and manager, at Griffith Stadium in 1959, measuring the spin of a pitched ball with the aid of a flat measuring tape fastened to the ball.



The baseball impact machine constructed at the Bureau for measuring the coefficient of restitution (evidences of liveliness) of baseballs.

new administration toward his organization. The stature of the Bureau in the Department of Commerce and its close identity with industry and commerce linked it with the policies of the Hoover administration and therefore the depression.

Daniel C. Roper, Roosevelt's appointee as Secretary of Commerce, said that his Department, "important under normal conditions, was at this time suffering from the fact that business was in the doghouse." [56] On the other hand, as a living memorial to Herbert Hoover, it was "looked upon by Congress as the 'last stronghold of sanity in the New Deal.' " [57] To the New Dealers the Department, whose body of civil servants continued in office during the greater part of the Roosevelt administration, was anathema. At the very outset of the new administration, Sam G. Bratton, Senator from New Mexico, went so far as to propose a joint House and Senate committee "to consider the advisability of abolishing the Department of Commerce and the transfer of its indispensable services to other agencies." [58]

The threat of dispersal persisted, and some thought it imminent when at the start of his second term Roosevelt proposed legislation to reorganize the departments of the Government. Ignored at Cabinet meetings and unable to gain the President's ear, Roper wrote to his bureau chiefs asking them whether they had "knowledge of any proposed action by other Government agencies or by Congress looking to transfer of your Bureau or any part of it from the Department." [59] The bureau chiefs knew no more than the Secretary. Badgered by rumors at fourth and fifth hand "that there would not be much left of the Department of Commerce after this reorganization," Secretary Roper resigned in December 1939 to make way for Harry Hopkins.[60] The talk of reorganization ended.

Apart from the drastic cuts made in its funds, the Bureau was in no way further endangered by the political trafficking downtown. Yet through-

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[56] Roper, Fifty Years of Public Life (Durham, N.C.: Duke University Press, 1941), p. 288.

[57] Grace Tully, F.D.R.—My Boss (New York: Scribner, 1949), p. 196.

[58] Congressional Record, vol. 76, pt. 2, 72d Cong., 2d sess., 1933, pp. 1720–1721. The National Association of Manufacturers maintained that "throughout both the New Deal and the war production programs, Commerce was all but ignored. Special agencies and executive offices were created by the dozen to perform functions that should naturally have fallen to this department." Hearings * * * on First Deficiency Appropriation Bill for 1946 (Oct. 25, 1945), p. 320.

[59] Letter, Administrative Assistant to Secretary of Commerce to Heads of Bureaus, June 29, 1938, and attached correspondence (NBS Box 414, AG).

[60] Roper, Fifty Years of Public Life, pp. 347–348.

out the period the recurring tremors had their effect in the office of the Director out on Connecticut Avenue.

TOWARD A REDEFINITION OF BUREAU FUNCTIONS

Out of the welter of emergency measures, experiments, and planned programs of the new administration, three impinged importantly on the Bureau: the initial drive for economy in Federal spending, the effort to define the relations between Government and non-Government research, and the exertions on behalf of the common man in his role as ultimate consumer.

Campaigning on a platform of Federal frugality, Roosevelt on taking office ordered a slash of 25 percent in the funds of every Government department and agency, making it retroactive by impounding current as well as projected appropriations. The 10-percent cut in Government salaries voted by the previous administration in the Economy Act of June 30, 1932, had necessitated an 8-day furlough without pay for all at the Bureau but had not cut the staff.[61] As a result of the new 25-percent slash, almost one-third of the Bureau force was dismissed, and to stretch remaining funds, a second payless 8-day furlough was decreed for those not separated.[62]

In mobilizing the resources of the Nation for recovery, Roosevelt exercised his penchant for creating new agencies, particularly in order to bypass such of his executive departments as seemed to him ingrown and incapable of adapting to the New Deal emergency.[63] His precedents were the all-powerful agencies of World War I, his guide Bernard Baruch's report on the War Industries Board of 1918, which Baruch in 1931 had supplemented with a detailed program for the creation of a central agency to control industrial

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[61] Letter, Secretary of Commerce Chapin to Visiting Committee, Nov. 10, 1932 (NARG 40, file 67009/5).

[62] Schlesinger, The Age of Roosevelt: Crisis of the Old Order, p. 256; NBS Annual Report 1933, p. 45; Annual Report 1934, pp. 51, 75. Hearings * * * 1935 (Jan. 4, 1934), p. 131.

A startling economy proposed by Roosevelt in late 1932 involved transfer of the National Advisory Committee on Aeronautics to the Bureau of Standards. NACA's Langley Field Laboratory was to be maintained as an independent agency, but considerable savings in the NACA budget of $900,000 were anticipated in consolidating its Washington staff with that of the Bureau. Questioned at a House committee hearing about the transfer, Dr. Briggs admitted he had not been consulted, but he "liked" it, and pointed out that in Britain, aeronautical research had always been under the National Physical Laboratory (Hearings * * * 1934, Dec. 12, 1932, pp. 175–77). NACA, now the National Aeronautics and Space Administration (NASA), which had strong roots in Bureau aeronautics research, was not of course turned over to the Bureau.

[63] Schlesinger, The Age of Roosevelt: The Coming of the New Deal, 1933–1934 (Boston: Houghton Mifflin, 1958), pp. 534–535.

mobilization in the event of war.[64] That war had come, a war of relief, recovery, and reform.

As the major experiments of the New Deal's planned economy, industry was mobilized through the National Recovery Administration (NRA), agriculture through the Agricultural Adjustment Administration (AAA). Science was not included in the planning. As the adjunct of industry, identified with laissez faire and classical economics and divorced from modern economic theory, science was suspect. To find a possible future place for it in the social experiments of the New Deal, however, called for a reassessment of the scientific agencies in the Government and the role of Government in both the physical and social sciences.[65]

To that end, on July 31, 1933, an Executive order created a Science Advisory Board under the jurisdiction of the National Research Council and National Academy of Sciences to study the functions and programs of the principal scientific agencies of the Government and propose a more effective relationship between governmental and nongovernmental research organizations. It was to examine the place of science in the Government structure with a view to establishing a policy both for economic recovery and for future national welfare.[66] As it turned out, the Board at once became more concerned with the current plight of Federal research agencies than with the goal that was sought by the New Deal, namely, to effect a conjunction between the natural and social sciences that would provide solutions pointing the way out of the depression.

The Bureau of Standards came under special scrutiny during the study, since four of the nine members of the Science Advisory Board—its chairman, Karl T. Compton, and Gano Dunn, Charles F. Kettering, and

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[64] The two Baruch reports were reprinted in a special edition as American Industry in the War: a Report of the War Industries Board, with an introduction by Hugh S. Johnson (New York: Prentice-Hall, 1941). For Roosevelt's great interest in Wilson's wartime administration, see Roper, Fifty Years of Public Life, pp. 320 ff.

[65] Dupree, pp. 347–350.

An extremist point of view then current saw science as a cause of the depression. Notice of the charge that the physicist and chemist made discoveries too rapidly for the good of the world, and did not heed or care what misapplications were made of their discoveries, appeared in Science, 80, 535 (1934) and Science, 81, 46 (1935). For the opposite viewpoint, that this country had succumbed to the depression because it had lived on its resources and had not put science to work for the national welfare or to combat its present difficulties, see Science Advisory Board correspondence in NBS Box 382, ID-Misc.

[66] Science Advisory Board, Report, 1933–34 (Washington, D.C., 1934), pp. 9, 11, 13, 15, 40–42. The Board reported scientific services functioning in 41 Federal bureaus, of which 18, on which the Board focussed its attention, could be called primarily scientific and essential to the national welfare, in agriculture, manufacturing, commerce, health and safety (p. 12).

Frank B. Jewett—were on the Visiting Committee to the Bureau. As it happened, the Visiting Committee was already engaged in a study of Bureau problems. The same four men were also members of the Business Advisory and Planning Council, which had recently been appointed by Secretary of Commerce Roper to survey the program of research of the Bureau and other Commerce agencies in the light of the economies forced on them. Thus, the Bureau entertained simultaneously three investigative groups in 1933–34. Except for details in the reports of the two Commerce committees, the essential findings of all three groups were by agreement embodied in the comprehensive report of the President's Science Advisory Board.

Perceptibly waiving the purpose for which it had been created, at least so far as the Bureau of Standards was concerned, the Board declared that the drastic reductions in its funds "prompted a critical examination of the Bureau's situation and program." [67] The slashes in Bureau appropriations for 1933 and 1934, together with the impounding of funds, amounted to a reduction of 50 percent since 1932. But Bureau testing of materials for Government departments and State institutions, an essential service not specified in the organic act or explicitly provided for in appropriations, represented a fixed charge of 45 percent against Bureau funds. The actual reduction in Bureau funds since 1932 therefore amounted not to 50 percent *but to about 70 percent* [italicized in the Report].[68] In the same period the Bureau staff had been reduced by 200 to 300 members through separation or indefinite furlough.[69] This much the three investigating groups agreed upon, and noted with concern the necessary but serious drain on Bureau time and energies involved in its representation on 825 committees in scientific, engineering, testing, standardizing, interdepartmental, and international organizations.[70]

In its separate study, the Business Advisory group acknowledged the validity of much of the late criticism of the Bureau by industry and urged that the greatest economies be made in some of the more recently acquired functions giving offense. Somewhat more specifically, the Joint Committee recommended curtailment of those projects which were in a

[67] Science Advisory Board, Report, 1933–34, p. 23.

[68] Dr. Briggs described the actual working funds even of the full 1932 appropriation as "only the equivalent of one 3-cent postage stamp during the year for each inhabitant of this country" (Ann. Am. Acad. Pol. Sci. 173, 153, 1934).

[69] The total was 348, out of a staff of 979, according to memo, C. J. Humphreys for LJB, July 31, 1933 (NBS Box 358, ID).

[70] Science Advisory Board, Report, 1933–34, pp. 23, 62–63, 65. By February 1934, with 613 members, the Bureau had the smallest staff since 1917 (letter, LJB to F. J. Schlink, Feb. 3, 1934, NBS Historical File).

measure completed or could be continued by non-Government agencies, and elimination of all others, insofar as they left the basic functions of the Bureau unimpaired. Those functions, vital to the industries of the Nation, must be maintained on an effective basis at all costs.[71]

The Business Advisory group particularly argued against the commercial standards activities of the Bureau as not matters of scientific fact and accuracy but matters of convenience. Every one of these activities had created problems of one kind or another, now made acute by the enforced economy.[72] Similar conflicts had arisen in the Bureau's industrial research, and the Business Advisory group therefore recommended that Bureau research should be strictly limited to the development of fundamental standards for science, medicine, and industry.[73]

The Science Advisory Board, equally concerned about the reduced funds of the Bureau and the necessity for some adjustment in its activities, was both less drastic and more concrete in its recommendations. It urged that official approval be given to a redefinition of Bureau functions it proposed that would formalize current Bureau activities and, of more import, that direct appropriations be made to cover the testing work of the Bureau for Federal agencies.[74]

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[71] Minutes of the joint meeting of the Visiting Committee of the Bureau of Standards and the Committee on the Bureau of Standards of the Business Advisory and Planning Council, Dec. 5, 1933 (NARG 40, Box 114, file 67009/5).

[72] The report traced the progress of Bureau acquisition of these activities, from the work on safety codes in the early century through building and housing codes, standards and specifications for Federal and State purchasing agencies, and testing of materials purchased by the Government. Closely allied were the trade standards and simplified practices programs for industry.

[73] Report of the Committee on the Bureau of Standards of the Business Advisory and Planning Council, Dec. 9, 1933, pp. 15–16 (NARG 40, file 67009/5).

[74] Science Advisory Board, Report, 1933–34, pp. 67–68. The proposed Bureau functions (ibid., pp. 64–65), harmonizing those of the organic act with those subsequently sanctioned by acts of Congress, were:

1. To maintain the national standards of measurement and conduct research necessary for the development of such standards.
2. To calibrate and certify measuring instruments in terms of the national standards, for the Federal Government and the various States (without charge), and for scientific, engineering and industrial groups and individuals (at cost), in order that accurate and uniform standards of measurement may be used throughout the Nation.
3. To develop improved methods of measurement for use in industry, engineering, and scientific research.
4. To determine physical constants and the properties of materials and physical systems "when such data are of great importance to scientific or manufacturing

Nothing like formal approval of the new functions was considered, although the Board later reported that the restatement was "to a large degree * * * officially approved" by the appropriations act of 1935. That act replaced the 29 specific appropriation items in the budget of the previous year by grouping the work of the Bureau into 4 general funds: (1) for operation and administration, (2) testing, inspection, and information service, (3) research and development, and (4) standards for commerce, the latter to provide for Bureau cooperation in the work of the American Standards Association.[75]

Turning from its extended study of the Bureau and other scientific agencies in the Federal establishment, the Science Advisory Board briefly

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interests and are not to be obtained of sufficient accuracy elsewhere" [quoted from the organic act].

5. To serve, insofar as is practicable, as a centralized laboratory for physical, chemical and engineering investigations for governmental agencies, thus utilizing effectively the special facilities of the Bureau, avoiding unnecessary duplication among Government agencies and preventing unnecessary development of new laboratories in the future.
6. To conduct investigations looking to broader and more effective utilization of materials and the development of better processes and methods of fabrication, in cooperation and with the financial assistance of engineering societies, trade associations, industrial and consumer groups, provided such investigations are of public and governmental interest.
7. To cooperate with the Federal Specifications Board and national standardizing agencies in the development of (a) specifications for equipment and supplies, and (b) safety and engineering codes; and to conduct research when necessary to provide a satisfactory technical basis for such specifications and codes.
8. To serve as a testing agency for governmental purchases to determine whether purchases of equipment, materials, and supplies meet the purchase specifications.
9. In connection with national standardizing organizations to develop simplified practice recommendations and commercial standards in cooperation with manufacturers, distributors, and consumers, provided such activities are of public and governmental interest; and to encourage the use of nationally recognized specifications by purchasing agencies expending funds derived from taxes.
10. To serve Federal, State and municipal agencies in an advisory capacity on technical matters in the fields of physics, chemistry, and engineering; and to indicate to citizens of the United States, upon request, available technical information relating to these subjects.

[75] Science Advisory Board, Report, 1934–35 (Washington, D.C., 1935), pp. 52–53; letter, LJB to Secretary, SAB, Aug. 6, 1935 (NBS Box 383, IDS–SAB).

The House Appropriations Committee had suggested consolidation of Bureau funds to Dr. Stratton in 1922. But special appropriations had served him well and he hesitated. "On the whole," he had replied, "it is not a bad plan. * * * The best thing from many points of view is to have a lump sum for all purposes to carry on * * * research work, but on the other hand it is good business to have a specific appropriation for a specific thing" (Hearings * * * 1924, Nov. 16, 1922, p. 207). In his annual reports of 1927 and 1928, Dr. Burgess strongly recommended to Commerce consolidation of funds into three or four classes, to simplify office procedure.

considered the relation between governmental and nongovernmental research. The Board saw "no need for the Government to embark upon comprehensive programs on pure science, invention or industrial development." That was the province of industry, the universities, and private institutions.[76] The proper scientific activities of the Government, which alone justified its scientific bureaus, were "scientific services of such wide scope and universal utility that no agency except the Government is competent adequately to handle them" (e.g., the development of scientific and technical standards); those "essentially supplementary to nonscientific governmental activities" (e.g., standards for Government purchases); and those "which hold evident promise of benefiting the public but which are not proper or practical fields for private initiative" (e.g., NACA).[77]

The "social objectives of science," whose consideration had been a prime purpose in the creation of the Board, appeared in a section awkwardly entitled, "Recovery Program of Science Progress." In effect, the Board recommended a new deal for science based on enlistment of "the science and engineering groups in the country in a cooperative effort for the quick success of the National Industrial Recovery Program." But the proposal that a fund of $16 million (subsequently raised to $75 million) be spent over a period of 5 years on research for public works programs, for

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[76] The discussion of the "place of science in the Government" in the reports of the Science Advisory Board (1933–34, pp. 15–17; 1934–35, pp. 40, 269) reflected the concern of the National Research Council since the end of World War I for fundamental research in this country.

A recurring anxiety voiced in the 1920's was that the war years had used up the basic research of the previous century and it was not being adequately replaced. Industrial research laboratories annually spent almost $200 million on applied science, Secretary of Commerce Hoover wrote in 1925, while funds for all pure research did not exceed $10 million. Yet the applied science laboratories were wholly "dependent upon the raw material which flows from the laboratories and men engaged in pure science. And the industrial investigators are the first to demand more support to pure science."

> It is unfortunately true [Hoover declared] that we can claim no such rank in pure science research as that which we enjoy in the field of industrial research. Instead of leading all other countries in the advancement of fundamental scientific knowledge, the United States occupies a position far in the rear of the majority of European nations. A list of the awards of the Nobel prizes to men of various nationalities reveals the small proportion of first rank minds that we support. Other tests lead to the same conclusion, namely, that the number of first rank investigators developed in the United States is far below what our population, education, and wealth would lead one to expect.

("The vital need for greater financial support of pure science research," an address before Am. Soc. Mech. Eng., Dec. 1, 1925, reprinted by National Research Council [L/C: Q11.N293]). See also Dupree, Science in the Federal Government, pp. 340–343.

[77] Science Advisory Board, Report, 1934–35, p. 15 and n.

conservation, and for the creation of new industries was not apparently what the administration had in mind. The Science Advisory Board was dissolved.[78]

The year 1935 came and the depression persisted. The WPA and other relief agencies were at their peak, giving work to 20 million persons, and Federal employees, numbering 588,000 when the depression began, headed toward the total of 1,370,000 reached in 1941. But across the Nation over 11 million remained unemployed and close to that same number would still be unemployed on the eve of war.[79]

Industry was moving again but cautiously, and consumers, growing wary of the rising public debt, tended to hoard the little they had. To the economists and social scientists of the administration more planning was the answer. To scientists, including Dr. Briggs, who wrote and spoke repeatedly on the subject, new discoveries, inventions, and enterprises were needed to prime the economy, stimulate the consumer, and start up industry again.[80]

Federal agencies, notably the Public Works Administration (PWA), successfully employed tens of thousands in reclaiming and developing the natural resources of the country, completing Boulder [Hoover] Dam in Nevada and the Triboro Bridge in New York, harnessing the Mississippi,

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[78] Science Advisory Board, Report, 1933–34, pp. 267 ff.; Dupree, Science in the Federal Government, pp. 353–358.

[79] Schlesinger, Coming of the New Deal, p. 294; Wecter, The Age of the Great Depression, p. 82.

[80] Dr. Briggs's promise of "rich returns in employment in new industries" was made repeatedly, in a speech of Mar. 25, 1936 (NBS Box 400, PAC), memoranda for the Secretary of Commerce between July 26 and Nov. 4, 1936 (NBS Box 394, AG; Box 400, PA; Box 401, PRA); letter to the Civil Service Commission, Dec. 22, 1936 (NBS Box 394, AP).

Before the House Appropriations Subcommittee in 1938, Briggs said: "We need more industries in this country; but new industries must have something to work with—new facts, new discoveries which they can develop. To get new discoveries and new facts we must support research" (Hearings * * * 1939, Jan. 31, 1938, p. 139).

Stimulated as much by the need to replenish the stock of pure science as to create out of it new industries that would absorb some of the unemployed, Roosevelt from 1936 to 1941 gave his approval to a number of bills proposed in both the House and Senate designed to support programs of basic research in physics, chemistry, metallurgy, and engineering. In several of the bills the research was to be carried out by the National Bureau of Standards and other nonprofit research institutions, through grants administered by the Bureau and the National Research Council. Other bills proposed basic research stations affiliated with State universities, in cooperation with the Department of Commerce, or engineering experimental stations at the land-grant colleges, on the model of the Department of Agriculture experimental stations. To Dr. Briggs, the most promising was the Lea bill (H.R. 3652), proposed in 1939, which called for almost $60 million to be expended over a period of years, 75 percent of that sum going to research in the natural sciences and engineering. Half of the funds were to be appropriated to the Bureau, the other half to universities for specific research projects. By June 1941, as war approached and debate continued, all chances of enactment ended. See correspondence in NBS Blue Folder Boxes 30, 31, 58.

setting up the Tennessee Valley Authority, and planning hydroelectric power dams such as that at Passamaquoddy Bay.[81] But science proved unamenable to planning. In the latter half of the decade, the National Planning Board and its successors, the National Resources Board and National Resources Committee, all sought, unsuccessfully, to establish a sound Federal relation with scientific research that would harness the scientific resources of the Nation.[82]

As stirring in its implications for the Bureau as the search for the role of Government in scientific research was the revival in the thirties of concern for the consumer. In the national emergency of 1918, Bernard Baruch had shown the possibilities of an economy oriented to "engineered consumption" instead of uncontrolled production for individual profit. A controlling idea in the early years of the New Deal was the plan to shift from a producer economy to a consumer economy. Thus arose "consumerism" as a major remedy for the depression, its mystique in the recent books of Stuart Chase, Schlink, Kallet, and others.[83]

Hope for Government support and direction of consumer interests centered in the National Recovery Administration, Roosevelt's chief prescription for recovery, set up on June 16, 1933, as a cooperative system of industrial self-government under Federal supervision. Under an NRA code system, industry, in exchange for Federal aid in regulating prices, would increase minimum wages and shorten work hours, thereby accelerating consumption. To maintain a balance between the interests of management, labor, and the consumer, NRA was to have the advice of three official boards, an Industrial Board, to secure the cooperation of the trade associations in support of NRA codes; a Labor Advisory Board, to work with the labor

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[81] Among civic structures whose completion provided much needed employment was the new monumental Commerce Building at 14th and E Streets in Washington, its cornerstone laid on Apr. 5, 1929. Its acres of office space, reported the "New York Sun," were to house all the scattered activities of Commerce "except * * * the experimental gentlemen of the Bureau of Standards—perhaps the most interesing single agency of the Government of these United States" (file in NBS Box 263, AG).

[82] The remarkable "study of Federal Aids to Research and the place of research (including natural and social sciences) in the Federal Government," prepared by the science subcommittee of the National Resources Committee, under Dr. Charles H. Judd, University of Chicago psychologist, made two notable recommendations, destined to be implemented in the vast Federal research programs of World War II and after: That research agencies of the Government be authorized and encouraged to enter into contracts for the prosecution of research projects with * * * recognized research agencies, and that research agencies of the Government extend the practice of encouraging decentralized research in institutions not directly related to the Government and by individuals not in its employ. National Resources Committee, Research—A National Resource. I. Relation of the Federal Government to Research (Washington, D.C., November 1938), p. 2.

[83] Schlesinger, The Coming of the New Deal, pp. 128–130.

unions; and a Consumers' Advisory Board, to represent consumer interests.[84] A brief account of the latter agency as it impinged on the Bureau of Standards is of interest.

The Consumers' Advisory Board was charged with promoting greater use of specifications and labeling in consumer products by recommending such provisions in NRA codes. It was assumed that the necessary consumer standards could be promulgated in existing Government and Government-connected agencies. A committee of the Board, headed by Dr. Robert S. Lynd, professor of sociology at Columbia University, disagreed. In a report made public on December 1, 1933, the committee declared that the American Standards Association, the Bureau of Standards and other available agencies were so strongly oriented to the point of view of industry that they could not be entrusted with the task.[85]

The Lynd report aroused wide interest, but its proposal for an independent consumers' research laboratory wholly within the Government was turned down.[86] During its brief career, the Consumers' Advisory Board, without facilities of its own, had to rely on the Bureau and the ASA for its research and testing. The Bureau reviewed almost 500 of some 830 NRA codes of fair competition involving consumer standards that the Board submitted.[87] ASA, asked to aid in quality labeling of consumer goods, set up its Committee on Ultimate Consumer Goods, on which the Bureau was also represented. But neither agency, nor NRA itself, satisfied the requisites of the Board, and with the death of the NRA in 1935 went its hopes for some kind of Federal department of the consumer.[88]

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[84] More than 2.5 million firms enrolled under the Blue Eagle and nearly 800 trade associations came to Washington for their codes before enthusiasm for the NRA waned and cynical violations began to vitiate its promise. On May 27, 1935, the Supreme Court declared invalid the NRA as an attempt to control the national economy through regulation of intrastate commerce.

[85] See Paul G. Agnew, "The movement for standards for consumer goods," Ann. Am. Acad. Pol. Soc. Sci. 173, 60 (1934).

[86] Persia Campbell, Consumer Representation in the New Deal (New York: Columbia University Press, 1940), p. 49.

Bolder than Lynd's laboratory was Schlink's proposal for a Federal Department of the Consumer, to be comprised of the oil, gas, coke, and fuel laboratories of the Bureau of Mines, all of the Bureau of Standards, the Office of Education, and the Bureaus of Home Economics, Chemistry, and Entomology in the Department of Agriculture. Schlink, "What the Government does and might do for the consumer," Ann. Am. Acad. Pol. Soc. Sci. 173, 125 (1934).

[87] NBS Annual Report 1934, p. 74; correspondence in NBS Blue Folder Box 19, 669c–CAB.

[88] Helen Sorenson, The Consumer Movement (New York: Harper, 1941), pp. 183–184. Campbell, pp. 54, 172, reported that the influence of CAB recommendations on NRA codes was negligible.

The consumer movement responded to a real public need and persisted as a militant force throughout the decade, but it was unable to present the united front, as did industry, labor, and agriculture, necessary to make a place for itself in the alphabetical agencies of the New Deal.[89] Sparking that movement, Schlink and Chase in 1927 had brought out their Consumers' Research Bulletin, as a mimeographed letter of the Consumers' League of New York. Two years later, upon the acquisition of laboratory facilities, the Bulletin appeared under the imprimatur of Consumers' Research, Inc. In 1933 the Consumers' Council of the Agricultural Adjustment Administration (AAA) inaugurated a biweekly Consumers' Guide, and in 1936 Arthur Kallet's organization, Consumers Union, began publication of Consumer Reports. A number of city and State agencies established consumer laboratories, as did the "New York Herald-Tribune" and the magazines Delineator, Modern Priscilla, and Good Housekeeping. By the end of the decade, as textbooks became available, some 25,000 secondary schools were giving consumer education courses, and in 1937 Stephens College, in Missouri, set up one of the first of the college and university consumer laboratories.[90]

The Bureau, as its extensive correspondence files witness, was never entirely happy in its relations with these consumer groups. It was, by law and organization, oriented to industry, as the Consumers' Advisory Board said. Schlink's avowed objective in setting up his Consumers' Research was "to translate everything that the National Bureau of Standards and the National Physical Laboratory [in England] had done into consumer terms." [91] But except in the most general terms, this was not possible with the technical reports of the Bureau, since its tests centered on the determination of those physical properties and characteristics of commodities or materials which made them most suitable for Government use. Efforts of Schlink and others to obtain useful and authoritative test results from the Bureau by sending consumer products to its laboratories had to be rebuffed. They were referred to commercial testing laboratories.[92]

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[89] Sorenson, pp. 19, 20.

[90] Wecter, p. 279. Among widely used textbooks were Charles S. Wyand's The Economics of Consumption (New York: Macmillan, 1937), Alfred H. Hausrath and John H. Harms's Consumer Science (New York: Macmillan, 1939), and Leland J. Gordon's Economics for Consumers (New York: American Book Co.. 1939).

[91] Interview with F. J. Schlink, June 7, 1962.

[92] See Consumers' Research General Bulletin, II, 309 (January 1933); public and congressional correspondence with the Bureau, largely incited by Schlink's publication, in NBS Box 356, AG; Schlink's own correspondence with the Bureau, in NBS Box 400, AG; and D. W. McConnell, "The Bureau of Standards and the ultimate consumer," Ann. Am. Acad. Pol. Soc. Sci. 173, 146 (1934).

The Bureau acknowledged that consumer testing might well be a function of the Federal Government and that it ought to be concentrated in a single institution. Indeed, the Bureau frequently expressed itself as willing to become that agency. It doubted, however, whether Congress was ever likely to appropriate the estimated hundred million dollars annually that a really comprehensive program of consumer testing would cost.[93]

Although oriented to research for industry by the nature of its organic act, the Bureau insisted that its ultimate beneficiary was the consumer, whether represented by a public purchasing agency or private citizen. It was therefore in sympathy with the consumer movement and did what it could. Besides its assistance to the Consumers' Advisory Board it advised consumer laboratories on test instruments and equipment and developed new equipment, such as the standard abrasion machine for the American Home Economics Association, to measure the durability of textiles. It revised its directory of commercial laboratories that tested consumer products, issued a letter circular on "the availability to the public of research and testing facilities of the National Bureau of Standards," and issued periodically its list of "publications of interest to household purchasers." [94] Perhaps most widely circulated was the illustrated brochure, "Services of the National Bureau of Standards to the consumer," which went through five printings totaling 15,000 copies between 1937 and 1940. Besides explaining the relation of Bureau testing to over-the-counter buying, the brochure informed readers of the Bureau's useful mimeographed letter, "Aid for over the counter buyers," and of the range of letter circulars and published reports of

[93] Letter, Crittenden for LJB to Prof. Robert S. Lynd, Nov. 15, 1933, and letter, Crittenden to Executive Secretary, Peoples Lobby, Inc., June 16, 1949 (NBS Historical File); Hearings * * * 1939 (Jan. 31, 1938), p. 138.

In a resurgence of interest in the consumer in 1938–39, several bills were proposed in Congress to extend the services of the Bureau to consumer testing, one of them authorizing an initial sum of $250,000 to "provide performance standards in the public interest," and permit the Bureau to grant firms and factories the right to label tested goods as "U.S. Consumer Standard," such standards to be policed by the Federal Trade Commission. Letter, LJB to Secretary of Commerce, June 14, 1939 (NBS Blue Folder Box 19, 669c); letter, Assistant Secretary of Commerce to Gano Dunn, Visiting Committee, Sept. 15, 1939 ("General Correspondence Files of the Director, 1945–1955"); LJB correspondence in NBS Box 430, ID-Misc; letter, LJB to Wm. E. Ames, Jan. 3, 1940, and attached correspondence (NBS Box 445, IG).

[94] M125 (1927), revised 1936; LC490 (February 1937); LC322 (1932), superseded by LC416 (1934), LC586 (1940), LC696 (1942), LC849 (1946). See letter LJB to Department of Agriculture, Aug. 6, 1927 (NBS Box 428, SPD), for a complete listing of Bureau publications of consumer interest.

interest and use in the purchase of hundreds of products from automobiles to window glass.[95]

The failure of national consumer interests to mobilize Government action on their behalf recoiled on the Bureau. Its products testing and its continued association in the specifications, simplified practices, and commodity standards work even after that work was transferred to ASA in 1933 sustained the hopes of consumer groups and kept the Bureau in something of a bind for the next two decades. As late as 1952 the Bureau still found it necessary to maintain a form letter explaining the limitations inherent in its testing of products for Government and industry and why it could not issue comparative ratings of brand-name commodities.

Despite the alarms, apprehensions, and hardships of the period, many of the seniors at the Bureau later remembered the time of the depression as not unrelievedly bleak. The respite in committee assignments, curtailment of travel, and decline in supervisory duties left welcome time for research. The paper load was further lightened as testing, which had long accounted for almost half of all annual funds and occupied more than half the time of the staff, fell off.

It was a time of moratoriums and petty economies. The annual conference on weights and measures, first postponed in 1932, was not resumed until 3 years later. The Director's annual report was reduced by half and printed with that of the Secretary of Commerce. The master scale depot at Chicago, the farm-waste laboratory at Tuscaloosa, Ala., and the ceramic station at Columbus, Ohio, were closed, and the Bureau's cotton mill in the Industrial building was shut down. Reduction of the building and housing division from 36 to 2 members and the automotive research section from 40 to 13 members had counterparts in almost every building at the Bureau.[96]

Although hiring of technicians and scientists, no matter how available or desirable, was out of the question, large numbers of "clerks," "draftsmen," and "technicians" were offered the Bureau through the Federal Emergency Relief Administration (FERA).[97] A Works Projects Administration

[95] The material of the brochure first appeared as an article by Dr. Briggs in Ann. Am. Acad. Pol. Soc. Sci. 173, 153 (1934). In the same brochure series were "Services of the National Bureau of Standards to the home building industry and to the household" (1936) and "Services * * * to governmental purchasing agencies" (1937).

[96] NBS Annual Report 1932, p. 2; Annual Report 1934, p. 73; correspondence in NBS Box 356, AB and AG, and Box 399, IST.

[97] Early in 1935 the President allotted $75,000 of FERA funds to the Bureau, "to assist educational, professional, and clerical persons in a study of materials for low-cost housing." Few of the 189 persons assigned to the Bureau possessed the specified training and were given cleaning and repairing chores. By autumn only half were still at the Bureau, on a part-time basis. The other half had been transferred to other Federal agencies. Report, A. S. McAllister, Oct. 4, 1935 (NBS Box 388, PRM).

(WPA) allotment of $100,000 in 1934, distributed over some 20 projects, made possible long-deferred repairs to walks, walls, storm sewers, wiring, and general enhancement of the buildings and grounds.[98] Several of the abler mechanics and technicians of the Bureau, let go earlier, found their way into these projects and tarried there until they could be restored to the Bureau payroll.

It was a time of petty economies. The most elementary tools and supplies could not be obtained through customary supply channels, and Bureau members vividly recall raiding junk heaps for usable parts, and sending assistants with a dollar to Woolworth's downtown to buy pliers, friction tape, wire, and the like. A small compensation in that period was Dr. Brigg's successful effort to restore the word "National" in the original name of the Bureau. For over 30 years, through an administrative whim, the agency had been simply the "Bureau of Standards." It was "nationalized" again in 1934.[99]

With salaries down and insecurity rife, it was a time of tight money. Across the Nation car sales slumped and nightclubs closed. Theaters gave away dishes and held bank nights. Hobbies of all sorts boomed. A craze for crossword puzzles swept the country and contract bridge became a national pastime. The spirit of speculation found new outlets in card games and the game of monopoly. And satisfying both the speculative and acquisitive impulses at small cost, stamp collecting in the mid-thirties zoomed from a hobby to big business, dignified by a President who was an ardent collector himself, and made profitable by an enterprising Postmaster General, James A. Farley.

The first slight upturn in the depression came in 1935 when the Bureau reported "a distinct increase in * * * requests * * * from industries * * * for scientific and technical data." At the same time, as building activity by Federal and State agencies accelerated, tests and calibration for Government agencies increased fully 15 percent over the highest previous year in Bureau history. That year also brought a small increase in Bureau appropriations, sufficient to rehire some 20 former staff members separated 2 years previously.[100] And the next year, 1936, the consolidation of funds went into effect, greatly simplifying the Director's bookkeeping and his sessions before Congress.[101]

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[98] Hearings * * * 1936 (Dec. 27, 1934), p. 109; letter, LJB to Secretary of Commerce, Feb. 20, 1936, sub: Emergency funds administered by the Bureau (NBS Box 394, FA). The first group of laborers came under the Civilian Works Administration ($50,000) and NRA ($20,500) in late 1933. Hearings * * * 1935 (Jan. 4, 1934), pp. 134, 137–39.

[99] See ch. I, p. 47.

[100] NBS Annual Report 1935, p. 61. In 1936 half the 10 percent salary cut of 1932 was restored, the remainder in 1937.

[101] Hearings * * * 1937 (Feb. 18, 1936), p. 127.

The first approval of new construction since the turn of the decade occurred in 1938 when Congress agreed to the erection of a high voltage laboratory to replace the obsolete structure built alongside East building in 1913.[102] Up to that time the electrical industry had been content with laboratory measurements in line-to-line voltages in the range of 100,000 volts. By the late thirties the industry, transmitting power at 285,000 volts, was in need of new measurements. At a cost of $315,000, the new laboratory, with a 2 million-volt generator for high voltage work and a 1,400,000-volt generator for X-ray studies, was completed late in 1940.[103]

Reflecting less the upturn than the relentless outpouring of Federal funds into construction projects was the expansion of Bureau branch laboratories in the latter half of the decade. A new laboratory was established in Seattle to test cement for the Grand Coulee Dam. The staff at Denver was augmented for the building of the Austin and Hamilton Dams in Texas and the Conchas Dam in New Mexico, as were the test groups at Riverside, Calif., and Allentown, Pa., for local construction projects.[104]

Despite the relief programs and the massive construction projects, the Nation still failed to recover its normal momentum, a fact the President bitterly attributed to the deliberate machinations of the economic royalists in industry.[105] The answer was more pump-priming, and the administration turned to new efforts on behalf of housing, the railroads, and utilities.

The better homes movement of the 1920's became the low-cost housing program of the 1930's, administered on a series of fronts by the housing division of the Public Works Administration, the Federal Emergency Relief Administration, the Home Owners' Loan Corporation, and the Tennessee Valley Authority. For some time a consultant to these agencies on building materials, the Bureau was now brought directly into the program and provided with special funds for research in low-cost housing. Its studies in the structural and fire-resistant properties of materials for these houses were

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[102] The original laboratory was not planned but acquired as an alternative to invoking a penalty clause in the construction contract for East building. The structure, Building No. 26, was later converted into a telephone exchange for the Bureau. Interview with Dr. Silsbee, May 21, 1962.

[103] NBS Annual Report 1937, p. 59; Hearings * * * 1939 (Jan. 31, 1938), pp. 146–152; Annual Report 1940, pp. 63–64, 70.

[104] NBS Annual Report 1936, pp. 75–76.

[105] James A. Farley, Jim Farley's Story (New York: McGraw-Hill, 1948), pp. 101, 104. For Morgenthau's diary entry on the "conspiracy" of business, see The Memoirs of Herbert Hoover: The Great Depression, 1929–1941 (New York: Macmillan, 1952), p. 482.

published in a new series, 'Building Materials and Structures Reports' (BMS).[106]

With the approach of war, New Deal sponsorship of the program ended and the special funds for the Bureau ceased. At the urging of the building trades, of engineers, and architects, the work continued under both research and transferred funds and was broadened to include all building construction. Halted during the war, building technology achieved divisional status in 1950 as a necessary and permanent Bureau function.

One other line of research extending earlier work, reactivated in the year of the Great Crash, was that on the permanence of paper and paper records. With funds provided by the Carnegie Foundation, studies were made of the permanence of Government writing papers, the preservation of records, and of library storage conditions. Light, heat, humidity and many other deterioratives of papers and books were assessed, but the principal

[106] NBS Annual Report 1935, p. 84; Annual Report 1938, pp. 90–92. The program, under the direction of Dr. Hugh L. Dryden, was formally launched in 1937. See Arch. Rec. 82, 34 (1937); NBS LC 502 (1937).

The Bureau preserves the Declaration of Independence by air-sealing it in a frame against air pollutants.

enemy of records proved to be the common air pollutant, sulphur dioxide. The investigation, extended to newspaper records, motion picture film, records on photographic film, microfilm, and lamination, culminated in the Bureau's work on the preservation at the National Archives of the originals of the Declaration of Independence and the Constitution of the United States.[107]

After the unsettling events of the early decade, the Bureau made its adjustment to the new limitations on research and working force. Few of the professional staff had taken their imposed furloughs, preferring to work without pay, unhampered by administrative duties. Others, under indefinite furlough, sought on their own initiative, with some success, funds from other Federal agencies, in order to return to their laboratories. Looking back on those years, many at the Bureau were to have the impression that with industrial research at low ebb the period was particularly fruitful in fundamental research.

SOME FUNDAMENTAL WORK ON STANDARDS

The Seventh General Conference on Weights and Measures held in Paris in the fall of 1927, with Dr. Stratton, on leave from MIT, and Dr. Burgess as the American delegates, was later pronounced the most important since that of 1875, when the international prototype meter and kilogram were adopted. The 31 nations attending the Conference established an international temperature scale, accepted the principle of defining the international meter in terms of light waves, instead of the prototype meter bar maintained in Paris, and urged the national laboratories to reach agreement on a new basis for the international electrical units.[108]

Establishment of the international temperature scale was discussed in the previous chapter. Equally gratifying to the Bureau delegates was the adoption by the Conference of the American proposal to define the international meter in terms of the wavelength of the red radiation from the cadmium lamp. Not only were many precision measurements in science and industry then being made in terms of light waves, but acceptance of this definition would greatly increase accuracy in the intercomparison of gage blocks and in determining the subdivisions of the meter and yard. Moreover, it

[107] NBS Annual Report 1930, p. 28; Annual Report 1931, p. 26; NBS M128 (1931) and intermittently through M168 (1940), and NBS C505 (1951).

[108] In no danger of being supplanted, as was the international meter, this country's national prototype kilogram was taken to the International Bureau at Sèvres in 1937 and recompared for the first time in 50 years with the international standard. Its mass had changed by only 1 part in 50 million, a reassuring high degree of constancy (NBS Annual Report 1937, pp. 60–61).

was hoped that with acceptance many of the difficulties in the way of international interchangeability of parts in industry might be satisfactorily solved.

No serious competitor of the cadmium red line had been found since Michelson's comparison of that wavelength with the international meter in 1893. Now, in the light of advances in spectroscopy, the search for possibly superior lines was renewed. The arc and spark spectra of the elements krypton and xenon disclosed very narrow lines when subjected to low temperatures obtained with liquid air, though none compared favorably with the cadmium lamp line.[109] For its own purposes, however, the Bureau developed a method for the use of cadmium and krypton wavelengths in the measurement of master precision gage blocks that permitted their certification to an accuracy of 0.000001 inch per inch or three times closer than previously.[110] Not until after World War II were krypton and mercury lamps devised that made possible a redefinition of the light wave to give more precise values for the inch and yard.

Earlier, in 1932, as a matter of industrial convenience, the Bureau and the American Standards Association agreed on a new ratio between the American inch and the millimeter. Arbitrary reduction by 0.00005 millimeter in the American inch made its equivalent to the 25.4-mm inch that was standard in England, and the new agreement put precision measuring in the two countries on the same basis, with consequent advantage to American export industries.[111]

Because the national laboratories both here and abroad had fewer calls on them from industry, the depression years were remembered as a time of international conferences, of many interlaboratory comparisons and exchanges of data and equipment looking to new or improved international standards. Besides the work in thermometry and standards of length, much was done in the standards upon which electrical, heat, photometric, X-ray, and radio measurements depend.[112]

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[109] NBS Annual Report 1928, pp. 2–3; Annual Report 1929, p. 8.

For the earlier research see S441, "Notes on standard wave-lengths, spectrographs, and spectrum tubes" (Meggers and Burns, 1922); Meggers, "Measuring with light waves," Sci. Am. 129, 258 (1923) and Sci. Am. 134, 258 (1926); S535, "A fundamental basis for measurements of lengths" (Bearce, 1926).

[110] NBS Annual Report 1935, pp. 66–67. The early work on standardization of precision gages was done on the Hoke blocks of World War I (ch. IV, p. 200) and reported by Peters and Boyd in S436 (1922).

[111] Science, 76, supp. 8 (1932). See app. B.

[112] NBS Annual Report 1929, pp. 2–3, marks the first appearance of a series of yearly notes on interlaboratory cooperation and on international visitors to the Bureau.

An excellent review of the fundamental research in the decade appears in Briggs, "The national standards of measurements," Annual Report, Smithsonian Institute, 1940, pp. 161–176.

Meeting in Paris the year after the Conference of 1927, an international advisory committee on electricity proposed the establishment of electrical units based on the fundamental units of mechanical energy, the centigrade-gram-second system, rather than the practical but arbitrary units then in use. To this end the Bureau in 1934 published Dr. Curtis's absolute determination of the ampere and its relation to the accepted international unit, and in 1936 his absolute determination of the ohm.[113] Moreover, the new apparatus constructed for these determinations made it possible to maintain and transfer working standards of the units to other laboratories for purposes of intercomparison.

Anticipating a rapid conclusion to the work, the international advisory committee predicted general agreement on the new electrical values within 2 years and their formal adoption by January 1940. But by 1939, as the laboratories in Europe continued to delay reporting their work, the Bureau had constructed still better apparatus than that used in its original determinations and was working toward even greater precision in its measurements. The adjustment of discrepancies and final agreement with the laboratories abroad were suspended until after the war.[114]

Also deferred by the war was final adoption of new and practical photometric units, based on a scale of color temperatures developed during the 1930's.[115] While the photometric measurements involved psychological factors and could not be put on an absolute basis, the national laboratories subsequently reached agreement on a single, practical, worldwide system of units, in place of the diverse units and standards then prevailing.

The new photometric units were made possible by the adoption of a standard visibility curve, based mainly on earlier work of Coblentz, Emerson, Gibson, and Tyndall,[116] and by the realization of the Waidner-Burgess absolute standard of light, first proposed in 1908 and achieved experimentally for the first time in 1931.[117] Together with absolute units of electricity, international adoption of the photometric units was accomplished at last in 1948.

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[113] RP685 (H. L. Curtis and R. W. Curtis, 1934); RP857 (Curtis, Moon, and Sparks, 1936).

[114] NBS Annual Report 1936, pp. 58–60; Annual Report 1939, pp. 49–50. In RP1606 (1944), Curtis reviewed the experimental work on the absolute units and in C459 (1947) announced their international adoption, along with the photometric units, effective Jan. 1, 1948. The former electrical units, last adjusted in 1912, were then 50 years old.

[115] The reproducible color temperature scale, consistent with the International Temperature Scale, was reported by Wensel, Judd, and Roeser in RP677 (1934).

[116] S303 and S305 (Coblentz and Emerson, 1918); S475 (Gibson and Tyndall, 1923).

[117] See ch. III, pp. 111–112; NBS Annual Report 1930, p. 10; "A primary standard of light," Science, 72, 109 (1930); RP325 (Wensel, Roeser, Barbrow, and Caldwell, 1931); RP699, "Determination of photometric standards * * * (ibid., 1934); NBS Annual Report 1937, p. 64; Annual Report 1938, pp. 69–70.

Much of the success in securing cooperation and final agreement on these standards was owing to the skill and diplomacy of the Bureau's chief representative over those years, Dr. Eugene C. Crittenden.[118]

In the lull of the depression, Dr. Coblentz found time to reassess his standards of thermal radiation, kept at the Bureau for precise calibration of thermopiles and other radiometers used by industry, and to work on his standards of ultraviolet radiation.[119] Hospitals, as well as many industries, had long been concerned with control of both the beneficial and harmful effects of ultraviolet radiation, and sought means for precise calibration of the photoelectric dosage intensity meters used for measuring radiation. Under study since 1931, about the time ultraviolet lamps first appeared on the market as household health aids, the Bureau standard, consisting of a quartz-mercury arc lamp whose ultraviolet rays were calibrated in absolute units, was ready in 1936.[120]

An even more critical aid to the medical profession than the standard of ultraviolet radiation was the Bureau's standardization of X-ray dosages. The need arose when World War I saw new X-ray apparatus that increased the voltage from 50,000 to 200,000 volts, and soon after the war these new voltages began to be widely used in cancer therapy.

Even after a quarter century of experience hospital technicians and private practitioners still operated their X-ray equipment empirically. Although the early postwar apparatus, unlike previous equipment, had some lead shielding, in cancer therapy the voltage, more or less arbitrarily established at 140,000 volts, presented a tremendous hazard. Patients were relatively safe since exposure times were fairly well known, but cumulative injuries to the operators working constantly with the apparatus were frequent and often severe. The question of these radiation hazards was first raised at the International Congress of Radiology, held at London in 1925. Con-

[118] Crittenden, who came to the photometry section of the Bureau from Cornell in 1909, succeeded Rosa as chief of the electrical division in 1921, became Assistant Director of the Bureau in 1933, Associate Director in 1945, and consultant to the Director from his retirement in 1950 until his death 4 years later. As chairman of the personnel and editorial committees of the Bureau for many years, he set the standards for personnel policies and for the high quality of the scientific output of the Bureau. Serving under all five Directors, he came to possess the most complete knowledge of the Bureau at every level of its operation and administration.

[119] RP578 (Coblentz and Stair, 1933).

[120] RP858 (Coblentz and Stair, 1936); NBS Annual Report 1940, p. 71. Two projects dear to Coblentz still unsolved at the time of his retirement were establishment of a unit of dosage of biologically effective ultraviolet radiation and a primary standard meter for measuring ultraviolet solar and sun radiation, for use in heliotherapy. Coblentz, "Reminiscences of the radiometry section," Dec. 9, 1944 (NBS Historical File). Without Coblentz, his group turned to more pressing work in the field of X rays. Interview with Harry J. Keegan, Feb. 12, 1964.

cerned at the time principally with the certification of radium and not with radiation measurement, the Bureau had sent no one to the Congress.

In the spring of 1926 the president of the Radiological Society of North America came to the Bureau and in some desperation asked it to undertake the determination of proper X-ray and radium dosages. At the urging of the society, Congress provided funds for the radiation research, and Lauriston S. Taylor, a young physicist working in X rays and electronics on a Heckscher Foundation grant at Cornell, was brought to the Bureau for the work.[121]

Taylor found the war surplus equipment that had been acquired by the Bureau wholly inadequate for the research to be done and successfully constructed from odd parts new apparatus of 200,000-volt capacity, setting it up in East building. A year later, in 1928, Taylor attended the Second International Congress, which proposed the "roentgen" as the unit of quantity for expressing X-ray and gamma-ray protection. The American counterpart of the councils working on standards in Europe was established with the founding of the National Committee on Radiation Protection and Measurements (NCRP) in 1928, its chairman, Dr. Taylor.[122]

Taylor's work on the absolute measurement of X rays, published in 1929, showed that the roentgen could be precisely measured, and resulted in the first real quantitative data on X-ray dosage standards in this country. Working through NCRP, his X-ray safety code in 1931 established guides for the shielding of operating rooms and of high voltage equipment and for protective devices for patients and operators. The first NCRP handbook on radium protection, prepared by Taylor's colleague, Dr. Leon F. Curtiss, for the use of industry and the medical profession, followed in 1934.[123]

The initial measurements of X rays had been made with heavy and bulky equipment. Construction in 1930 of a portable, guarded-field ionization chamber provided means for a much needed, accurate primary standard in convenient form. With the chamber, intercomparisons were made in 1931 with measurements obtained in the laboratories abroad. The excellence of results led in 1934 to international agreement between the laboratories of England, France, Germany, and the United States on procedures in X-ray

[121] Interview with Dr. Taylor, Sept. 24, 1963.

[122] NBS Annual Report 1928, pp. 35–36. The work of the Second Congress was reported in NBS C374 (1929).

Represented on the NCRP was the American Roentgen Ray Society, the Radiological Society of North America, the American Medical Association, X-ray equipment manufacturers, and the Bureau. See Taylor, "Brief history of the NCRP * * *," Health Physics, 1, 3 (1958).

[123] RP56 "The precise measurement of X-ray dosage" (Taylor, 1929); H15, "X-ray protection" (1931), superseded by H20 (1936); H18, "Radium protection" (1934), superseded by H23 (1938).

measurement, using the Bureau method of characterizing the quality of X radiation.[124]

After years of careful compilation of data here and abroad on X-ray and radium effects and "tolerances," NCRP established as a specific maximum permissible exposure level of radiation a value of 0.1 roentgen per week.[125] Any hospital or industrial technician reaching that level had to transfer at once to other work or be furloughed. This "tolerance dosage" appeared in the revision of the X-ray safety code handbook in 1936 and remained in force for 12 years. It was that used by the Manhattan District throughout its operations.[126]

A threat to Bureau measurements appeared in the late thirties with advances in X-radiation therapy. While its so-called high voltage equipment was limited to work between 200,000 and 600,000 volts, hospitals began using higher and higher voltages—up to a million volts—in the treatment of cancer. The gap was closed with the construction in 1940 of the new high voltage laboratory on the Bureau grounds, its 1,400,000-volt constant potential X-ray generator the most powerful that had been built up to that time.[127]

One area in the field of X radiation long overlooked was that of radioactive luminous compounds. A formula for the manufacture of luminous paint, a zinc sulphide-radium mixture (later, mesothorium, a cheap radioactive isotope of radium) was devised in 1915 for application on clock and watch dials. During World War I the paint was extensively used on military instruments and equipment, as well as wristwatches, and at the request of the military services the Bureau made a series of studies of its composition, effectiveness, and possible hazards.

Radium, it is now known, is far more damaging to the body on ingestion than, for example, strontium 90.[128] The amount used on watch dials,

[124] RP397 (1932); Radiology, 23, 682 (1934); NBS Annual Report 1934, p. 60; Annual Report 1935, p. 62.

[125] The ambiguity possible in the word "tolerance" led in 1947 to substitution of the phrase "maximum permissible dose."

[126] Taylor, "Brief history of the NCRP." "Because [0.1 roentgen] was not definitely known to be safe, the tolerance dose at the atomic plant at Hanford was set at one-hundredth of a roentgen per day" (Leslie R. Groves, Now It Can Be Told, New York: Harper, 1962, p. 87).

[127] NBS Annual Report 1933, p. 54; Annual Report 1940, p. 70; Taylor, "New X-ray laboratory of the NBS," Radiology, 37, 79 (1941).

The structure and equipment, shared with the electrical division at the Bureau, is described in F. B. Silsbee's "New high-voltage laboratory at NBS," Elec. Eng. 59, 238 (1940). RP1078 (Brooks, Defandorf, and Silsbee, 1938) described construction of an absolute electrometer for direct measurement of high voltages in electrical measurement in the new laboratory.

[128] The "permissible body burden" of radium is considered only one-twentieth that of strontium 90.

though measurable, was and, with some qualifications, still is considered harmless. Ingestion of the radium paint was something else again, yet no one gave any thought to the hundreds of girls who during the war painted the dials, putting the radium-tipped brushes in their mouths to point them. In the early twenties a number of the girls fell mysteriously ill and died. It was 1927 before their illness was identified as radium sickness.[129]

Staff artists on the tabloids drew lurid front-page pictures of young girls in nightgowns glowing in the dark of their bedrooms before full-length mirrors, while captions beneath described this terrifying experience in the night as the initial clue to the sickness. If the drawings were medically unsound, the poisoning was real, and in 1932, after extensive studies of the radium nostrums on the market, the American Medical Association removed radium for internal administration, in any form, from its list of remedies. Bureau research on radioactive luminous compounds, particularly their safe handling in industry, found it way into the handbook on radium protection in 1934 and by 1941 merited a handbook (H27) of its own.[130]

Among other fundamental studies accelerated in the thirties was Dr. Meggers' work in spectroanalysis, leading to the compilation of new and accurate measurements of the atomic emission spectra of chemical elements, rare gases, rare metals, and to analyses of their structures. In a specially equipped laboratory, Meggers began an investigation to standardize the emission spectra of elements, with the intention of developing methods for quantitative chemical analysis by means of partial spectra. The systematic observation of the relation of various spectral lines to atomic structure pointed the way to fundamental factors that were to provide a valuable guide later in the chemical purification of metals, in testing materials of specific purity, sorting scrap metal, and controlling the composition of alloys.[131]

The progress in spectrochemical analysis, increasingly used in both research and industrial laboratories, was mirrored in an index, published by the American Society for Testing Materials, that listed almost a thousand papers on the subject spanning the period 1920–37.[132] Even as the stacks of graph paper with their six- and eight-digit columns of figures mounted in the spectrographic laboratories in Washington, another tabular project of the Bureau, equally ambitious, got under way in New York City.

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[129] Daniel Lang, "A most valuable accident," The New Yorker, May 2, 1959, pp. 49–92. For Surgeon General—NBS conferences on radium sickness, see memo, L. F. Curtiss for GKB, Dec. 21, 1948 (NBS Box 230, ID–Div IV).

[130] In the 1960's the watch industry began using tritium, a radioisotope of hydrogen, as a substitute for radium in dial paints, its radiation so slight it cannot be detected outside the watch.

[131] NBS Annual Report 1933, p. 53; Annual Report 1937, pp. 64–65.

[132] NBS Annual Report 1939, p. 55.

An indispensable tool of physicists are the mathematical tables of functions, such as exponentials, logarithms, and probability functions, necessary in determining mathematical problems as varied as the diffraction of sound and electromagnetic waves, the potential of radiofrequency transmission lines, and electrical and thermal diffusion. The tables are fundamental in the solution of problems ranging from heat conduction and wave motion, the diffusion of a searchlight beam by fog, and the production of knock in gasoline engine cylinders, to the oscillations of an ultrahigh frequency radio tube.

Scientists in this country as a rule relied on partial tables made up as needed. In the universities sporadic attempts had been made to formulate more comprehensive tables, but there was nothing comparable to the mathematical services available to scientists abroad, such as that established in the early thirties by the British Association for the Advancement of Science.[133] Then in January 1938 at a conference called by the Works Projects Administration to aid unemployed scientists (it was assumed there must be some, though they had not been heard from), Dr. Briggs proposed that the Bureau sponsor establishment of a central agency for computing fundamental tables of importance in various fields of applied mathematics. Dr. Arnold N. Lowan, Hungarian-born professor of physics in residence at the new Institute for Advanced Study at Princeton and part-time teacher at Brooklyn College, was offered the directorship of the project. That summer the program was set up in a vacant loft building off Columbus Circle in New York.

As it was WPA policy to provide work in its projects for as many unemployed as possible, and as almost no equipment of any kind could be provided, the planning staff assembled by Dr. Lowan devised a self-checking, hand-computing procedure of preparing tables that could be performed in a series of simple, single stages. Over 400 individuals from the relief rolls, with a variety of talents but none of them trained scientists, and in most instances with no mathematical background whatever, were set to work with paper and pencils on the initial basic projects. These were to prepare the 16-place values of natural logarithms, the 15-place values of probability functions, and the 10-place values of Bessel functions of complex arguments. A few desk calculators and adding machines were acquired by the directing staff to check the tabulations and were also used by a select group whose more complex task it was to determine values of polynomials for integral arguments.

Electronic equipment that became available less than a decade later performed in minutes what 400 pencil-computers took months to do, but the

[133] Some German tables were available to their scientists but were not in print. The British work was still in progress, and most of the Bureau tables came out before theirs did. Conversation with Miss Irene A. Stegun, Feb. 18, 1964.

procedure devised by the Mathematical Tables Project insured nearly flawless tables that received wide and grateful recognition. Before long universities, industry (General Electric), the Bureau itself, and other Federal agencies (the Bureau of Marine Inspection and Navigation, the Corps of Engineers, the Navy's Bureau of Ordnance) began suggesting or requesting much needed tables for their research. By 1943, 27 book-length tables had been published in the Bureau's Mathematical Tables (MT) series, and as many more short tables had appeared in specialized periodicals. That spring the project staff, reduced to 60 by induction into the Armed Forces or employment in industry, was transferred from WPA administration to that of the Bureau, to continue its work on behalf of the National Defense Research Committee. Four years later the project moved from New York to the National Applied Mathematics Laboratories established at the Bureau.[134]

Another fundamental study begun in the thirties was concerned with the physical constants of pure substances. The Bureau had long been aware of the need for accurately determined constants as offering the best criteria of the identity and purity of many industrially important organic compounds. A new technique in this field had been devised abroad, that of ebulliometry, providing a comparative method for determining the vapor pressure, boiling point, and purity of organic substances by comparison with water as a primary reference standard. In 1935 the Bureau invited Dr. Mieczyslaw Wojciechowski of the Polytechnic Institute of Warsaw, the student of Wojciech Swietoslawski, originator of the technique, to Washington. Under his direction, Bureau chemists began preparation of a number of high purity organic reagents and organic substances, including benzene, dioxane, isoprene, as well as of the aliphatic hydrocarbons and alcohols. The work continued up to the eve of war.[135]

The considerable fundamental research of the depression years, useful alike to science and industry, won wide acknowledgment. Unlike some of the research earlier in the decade, which had found little welcome though it was equally fundamental, none of these new lines of work impinged on or

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[134] Lowan, "The computer laboratory of the National Bureau of Standards," Scripta Math. 15, 33 (1949); interview with Mrs. Ida Rhodes, Sept. 10, 1963. For the status of staff and equipment just prior to the transfer of the project from WPA to NDRC auspices, see memo, Warren Weaver, Applied Math Panel, NDRC, Nov. 13, 1942 (OSRD records, NARG 227, file MTP General Correspondence).

[135] NBS Annual Report 1936, p. 67; Annual Report 1941, p. 73; interview with Dr. E. R. Smith, Jan. 14, 1964. Swietoslawski visited the Bureau 3 years later and with Smith published RP1088, "Water as a reference standard for ebulliometry" (1938). See memo, Crittenden for LJB, Aug. 15, 1940 (NBS Box 490, IDM), for a program of standard substances at the Bureau.

threatened to disclose industrial processes. Almost all of them found important uses and applications when war came.

"CURTAILMENT BY LIMITATION OF FUNDS"

In September 1934 Science magazine reprinted an excerpt from the bulletin of the Société Française de Photographie et de Cinématographie concerning an event that had occurred almost a year earlier:

> The budget retrenchments which the Government of the United States have made has forced the Bureau of Standards to close its laboratory devoted to the study of photographic emulsions, a laboratory in which Messrs. Burt H. Carroll and Donald Hubbard have carried on researches the publication of which has for the first time given quantitative information on the preparation of modern photosensitive emulsions. * * * Our society will be honored in awarding to Messrs. Carroll and Hubbard two of its medals, thus expressing its appreciation of their important contributions in a field heretofore mysterious.[136]

Research in photographic emulsions, initiated at the Bureau in 1921, grew out of the need in the spectroscopy laboratory for emulsions sensitive to infrared spectra. Commercial film was not very satisfactory, particularly for spectrographic purposes. Its sensitivity was of a low order, its base of cellulose nitrate was flammable, and it shrank badly. The search for a better infrared emulsion led the Bureau to the study of emulsions in general.[137]

With funds transferred from the Army Signal Corps, which was equally concerned with better film, Dr. Meggers went to Germany and obtained pilot plant machinery for making emulsions. To operate the plant installed in the basement of the Chemistry building, he brought to the Bureau two skilled technicians, Carroll, a chemist from the Chemical Warfare Service, and Hubbard, a recent University of Florida graduate in chemistry.

For 7 years results were largely negative. The first notice of their efforts, now with funds provided by Congress for "industrial research," appeared in the Director's annual report of 1926 and spoke only of the difficulties under which they labored:

> The science of lens design has received a great amount of attention which is almost classical in character. The preparation of photo-

[136] Science, 80, 263 (1934).

[137] S422, "Studies in color sensitive photographic plates * * *" (Walters and Davis, 1922); S439, "Sensitometry of photographic emulsions * * *" (Davis and Walters, 1922); interview with Dr. Meggers, Mar. 13, 1962.

> graphic emulsions, on the other hand, is largely a secret and empirical art known to relatively few. There is probably room for ten times more improvement in making emulsions than in making lenses.

That year Carroll and Hubbard had made over 400 batches of emulsion. Under more exact controls, they were turning out emulsions with superior keeping qualities, but the secret of emulsion sensitivity still eluded them.[138] The breakthrough came 2 years later, and they published their first paper, on the sensitization of photographic emulsions by colloidal materials.[139]

In 1933 Carroll and Hubbard published their seventeenth report on the mechanism of photographic hypersensitivity, and their preparation of new "grainless" emulsions.[140] Not only were these emulsions superior to the best commercially available, but disclosure by the Bureau of the method of their preparation threatened to make public vital trade secrets. It was the time of the great depression, and the advisory committees surveying Bureau research and mindful of recent complaints of Government interference with private industry had to recommend retrenchments. The emulsion project was among the first to be terminated in the interest of economy.[141]

The emulsion work was one of seven investigations which the Visiting Committee specifically "questioned whether the Bureau ought to continue": (1) its research in heavy hydrogen, (2) its work on dental cements and alloys, (3) distinctly industrial problems like temperature measurements in the pouring of cast iron, (4) ignition phenomena and flame propagation in internal combustion engines, (5) development of large-scale production methods for levulose, (6) design of a telephoto astronomical objective, and (7) development of special photographic developers.[142]

The precise areas of industrial research terminated or curtailed under the pressure of economy are difficult to identify or document, since they

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[138] NBS Annual Report 1926, p. 34.

[139] RP20 (1928).

[140] NBS Annual Report 1933, p. 52. The key paper in the group was RP447, "The photographic emulsion: analysis for nonhalide silver and soluble bromide" (1932).

[141] Dr. Briggs' outline of the project and unavailing efforts to interest the Carnegie Institution of Washington in its support appear in letter, Sept. 7, 1933 (NBS Box 361, IPS). Subsequent photographic research at the Bureau was limited to work on the international standardization of photosensitometric methods and, in cooperation with the ASA, preparation of specifications for films and plates. See NBS Annual Report 1940, p. 71.

NOTE.—In 1934 Burt Carroll and his assistant, Charles M. Kretchman, went to Eastman Kodak. Hubbard remained at the Bureau.

[142] Minutes of meeting of the Visiting Committee, Aug. 23, 1934 (NARG 40, 67009/5).

were determined by verbal agreement between Dr. Briggs and the committees to the Bureau. Acting on an earlier House recommendation for "curtailment by limitation of funds," Congress in 1933 made the deepest of its cuts, 54 percent, in its appropriation to the Bureau for "industrial research." It alone affected more than 100 projects.[143]

Notable was the cut in the special fund for the "investigation of automotive engines." Supporting some 40 projects in 1932, funds for that work a year later were down by 30 percent. Among the investigations abandoned was one on the measurement of the road performance of automobile engines, undertaken at the request of interested Government agencies. The comparative tests made by the Bureau, indicating marked superiority of one make (the new Ford V–8 engine) over all others on the market, understandably displeased the rest of the industry, and termination of the study precluded publication of the test results.[144]

Appropriation cuts, together with impounding of funds, came close to putting an end to all Bureau participation in both the building and housing and the standardization programs. With the initial reduction of 40 percent in standardization funds, Secretary of Commerce Roper, with Dr. Briggs' concurrence, proposed to the American Standards Association that it take over the major role in that program.[145] The work on specifications, simplified practices, trade standards, and building and safety codes was, however, to the advantage to many industries, and at once, through their Congressmen and trade groups, they protested the transfer to ASA, arguing for the Bureau's impartiality and superior facilities.

As a compromise, Commerce agreed that the Bureau would cooperate in ASA standardization "under the procedure of the association," continue

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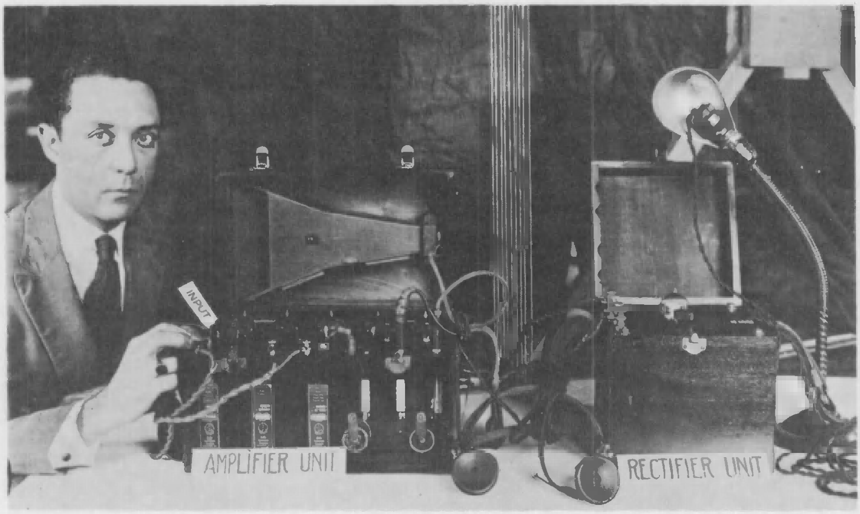
[143] NBS Annual Report 1931, p. 37, reported 103 projects under this fund. Dr. Briggs later said that funds for industrial research were finally cut by 88 percent. Hearings * * * 1935 (Jan. 4, 1934), p. 132.

Obviously incomplete was the list in memo, C. J. Humphreys (of the radiometry laboratory) for LJB, July 31, 1933 (NBS Box 358, ID), which noted that besides discontinuance of the specifications, simplified practices, building and housing, and trade standards divisions, and the safety standards work, other projects dropped included soil corrosion, telephone standards, preparation of levulose, testing of commercial aircraft engines, and radio aids to air navigation.

[144] See NBS Annual Report 1931, p. 43; Annual Report 1932, p. 34; interview with Dr. Meggers, Mar. 13, 1962.

[145] Letter, Secretary Roper to Senator A. Lonergan, July 7, 1933; letter, president, ASA to H. S. Dennison, Nov. 2, 1933, and related correspondence in NBS Blue Folder Box 19, 669c, and NBS Box 356, AG. The proposal for complete transfer of the standardization work was reported in Science, 78, 95 (1933).



Percival D. Lowell with his invention in 1922 that made it possible to use ordinary house current instead of storage batteries to operate a home radio. For the first time, the 60-cycle alternating current that operated the lights in the house could, with Lowell's rectifier, equally well supply power to the filament and plates of the radio.

its representation on almost a hundred sectional committees of ASA dealing with technical subjects, and sponsor certain projects assigned to it by ASA. When the formal transfer was made, some of the staff members separated earlier by the Bureau were taken on by ASA, to continue their work at the Bureau as ASA employees.[146]

To what extent Bureau research was terminated in areas susceptible of patentable ideas that industry might otherwise discover for itself cannot be determined. Suggestive, however, is the example in radio research, where fundamental investigations in radio transmission phenomena were continued, while the entire group in applied radio research at College Park, Md., involving 20 members, was dismissed in June 1934 and the station closed.[147]

All three committees advising the Bureau on retrenchment and reorganization of its research expressed concern over the current patent policy of the Bureau. Their investigations came at a time when Dr. Briggs was in

[146] NBS Annual Report 1934, pp. 52–53; Annual Report 1937, p. 59. Upon consolidation of Bureau funds in 1936, the standardization work remaining at the Bureau was performed under the appropriation for "commercial standards."

[147] Interview with W. S. Hinman, Jr., Dec. 28, 1963. Three of the group, Hinman, Diamond, and Dunmore, were brought back to Washington not long after.

the midst of serious litigation over patents taken out by members of the staff, in defiance of long-standing practice.[148] No solution was offered at that

[148] Traditionally, the Government retained rights to the use of inventions of Federal employees but otherwise left title to them with their inventors. The Bureau of Standards did not follow this policy. For 20 years under Dr. Stratton it was understood that any innovation or invention of a Bureau staff member was to be patented in the name of the Government for the use of the public.

The understanding was not seriously challenged until the summer of 1921 when two members of the radio section, Percival D. Lowell and Francis W. Dunmore, while working on a radio relay project for the Air Corps, conceived the idea of substituting house power for the storage batteries then used with radio apparatus. The method they devised for operating radio on ordinary house current also eliminated the principal obstacle to its use, the hum of alternating current in the radio. Their inventions were only remotely related to the Air Corps project.

In March 1922 Lowell and Dunmore filed the first of three related patents in their own names and in October 1924 granted manufacturing rights to the Dubilier Condenser Corp. of Delaware. The devices were described in NBS S450, June 17, 1922, and in a paper in the AIEE Journal, 41, 488 (1922).

Shortly after filing their first patent, the Government, at the prompting of the Bureau, submitted the case for judgment to the U.S. District Court for Delaware. And on Nov. 2, 1922, in a memorandum to all Bureau employees, Dr. Stratton for the first time formally established as policy the assignment of all patent rights in inventions and discoveries of the staff to the Government (memo in NBS Box 40, AGP).

Almost a decade later, on Apr. 27, 1931, the District Court handed down its decision, deciding against the Government. Although the court declared that the devices of Lowell and Dunmore had been developed on Government time, with Government funds, and with the assistance of other Government employees, the devices had not been a part of their assigned work and therefore the inventions and patents were their property (The United States Daily, May 2, 1931, p. 52). The decision was appealed by the Justice Department.

When on May 24, 1932 the U.S. Circuit Court upheld the decision of the district court, the Government filed a petition in the Supreme Court. No similar case of patent rights had come up at the Bureau in the intervening years, but after the district court decision of 1932 some members of the Bureau continued to assign their rights to the Government, while others were advised that the Bureau would raise no objection to a private patent, pending a final court decision (letter, Acting Director LJB to Secretary of Commerce, Dec. 17, 1932, NARG 40, 67009/5). On Apr. 10, 1933, the Supreme Court, one member dissenting, decreed that in the absence of a specific contractual agreement, all commercial rights to patents belonged to the inventor, whether or not the work was performed on Government time.

Aware of the lack of uniformity in patent policy in Government agencies and the impasse at the Bureau, the Visiting Committee to the Bureau and the Business Advisory Council of the Department of Commerce in their joint report issued on Dec. 5, 1933, suggested that a Government ownership of patents clause be written into the standard employment contract of the Bureau. For unknown reasons, the Business Advisory Council reversed its stand and in a separate report of Dec. 9, 1933, formally recommended that Bureau employees be permitted to patent devices developed at the Bureau, with the warning that exercise of their right must not "interfere with free communication and cooperation time, and Bureau policy, as elsewhere in the Federal establishment, continued vague and uncertain for almost another two decades.

Bureau appropriations between 1932 and 1933, as the Science Advisory Board reported, fell by half, and further diminished by the sums diverted to the testing work of the Bureau, left its research funds reduced by almost 70 percent. Equally imperiled was the fundamental research carried out under statutory salaries and investigations under special appropriations. Among projects in the latter category, two were scheduled for early termination, the whole of the levulose program and all research on utilization of waste products of the land, the second by transfer to the Department of Agriculture.[149] Except in the Bureau's huge industrial research and standardization programs, however, most of the other cuts in special appropriations did not exceed 15 percent. And in the research funds transferred to the Bureau from other Government agencies, slashes ranged between 10 and 50 percent. The necessity for economy was the sole justification offered.

A member of the metallurgy division who had left the Bureau several years before to become director of the Battelle Memorial Foundation wrote

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between Bureau members or between the Bureau of Standards and industries and other organizations."

Lowell and Dunmore gained little from their revolutionary invention. Granted a license by the inventors to manufacture the device in 1922, Dubilier in turn licensed it to Philco and several other interested makers of radios. Then in 1924 the Radio Corp. of America (RCA), largest of the radio manufacturers, developed a heater type of vacuum tube that performed as well with alternating house current as the Lowell-Dunmore unit. Within a year or two most radios sold to the public were operating on house current with the RCA tube (see "The electric light socket and our vacuum tubes," Sci. Am. 132, 240, 1925.)

Dubilier at once sued RCA for infringement of the patents and won the first round in the Delaware courts. When RCA offered to settle out of court and Dubilier refused, RCA appealed. The case was finally adjudicated in 1937 in favor of RCA when it was decided that the Lowell and Dunmore patents were not valid by reason of priority and the only new element in the invention, the suppression of a.c. hum, was inherent in the RCA tube and constituted no infringement (interview with P. D. Lowell, Nov. 12, 1963).

Stratton's patent policy announced in 1922 continued in force until modified in 1940, when patents were procured by the Justice Department and assigned to the Secretary of Commerce for licensing under terms he prescribed (Hearings * * * 1942, Feb. 11, 1941, p. 219, and policy letter, LJB, Feb. 16, 1944, NBS Box 489, AGP).

The long-accepted Federal policy of permitting employees to retain title to their inventions ended on Jan. 23, 1950, when by Executive Order 10096 it was announced that all rights to any invention developed by a Government employee in the course of his assigned work belonged to the Government (see app. C).

[149] Some cherished research died hard. As late as 1939, Dr. Briggs requested experiments on the possible use of levulose or xylose in the quick-freezing process for preserving fruits and strawberries. Nothing apparently came of the study (memo for F. J. Bates, Dec. 7, 1939, NBS Box 490, IDM).

frankly to Dr. Briggs that he believed the enforced curtailment of Bureau activities a good thing:

> * * * In the course of time there are likely to creep into a long term program, and to stay there because there is always one more thing to try, projects that are not of very great import, or in which the economic condition has passed that once made them important. * * * In the long run the necessity for * * * a clean-cut decision as to the relative importance of the work in hand * * * will improve the patient.

Dr. Briggs, who saw science the handmaid to new industries, with reservations reluctantly agreed.[150]

One area of investigation which felt the knife of economy directed wholly at its applied research was radio. By 1935 staff and funds for radio research were approximately half what they had been in 1932. As a consequence, research was narrowed to the most pressing concerns: The improvement of primary and secondary frequency standards and of Bureau broadcasting of standard radio and audio frequencies for the control of station transmitters; research in the character and cause of variations in radio wave intensity and direction (i.e., radio wave propagation phenomena); and accurate determination of the height and characteristics of the ionosphere layers, the primary factor in long-distance radio transmission.

Outgrowing its radio laboratory and its reliance on commercial and Government broadcasting stations for additional operating facilities, the Bureau in 1932 received funds to establish two experimental stations just outside Washington. One was a transmitting station, in several frame buildings erected on the site of the Department of Agriculture experimental farm near Beltsville, Md.; the other a receiving station for radio wave research, in similar structures on 200 acres purchased near Meadows, Md.[151]

With new and improved equipment at Beltsville, the Bureau continued its transmission of standard radio frequencies to permit stations to calibrate standard oscillators and check their broadcast frequencies, and in 1935 began transmitting standard time intervals in the form of spaced pulses, as well as a standard musical pitch.[152]

Long-distance radio transmission continued to present the greatest difficulties, owing to the character of the ionosphere layers, some 60 miles up. In cooperation with standards laboratories and radio agencies abroad, the Bureau set up automatic equipment at Meadows and began making con-

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[150] Letter, H. W. Gillett, July 13, 1933, and attached correspondence (NBS Box 356, AG).
[151] NBS Annual Report 1932, pp. 16–17.
[152] The services were described in LC453, "Standard frequencies and other services * * *" (1935), superseded by LC498 (1937), LC565, (1939), and LC591 (1940).

tinuous recordings at varying heights of the critical frequencies of the ionized layers responsible for reflecting radio waves back to earth.

Not a single surface, as originally believed, the ionosphere phenomenon apparently consisted of a series of layers, each affecting differently the distance obtained in radio transmission at various frequencies, at different times of day, different seasons, and even in different years. From "the most complete body of data in existence on this subject," the Bureau reported in 1934, the radio section began the first of its deductions about the roles played in long-distance transmission by reflection and refraction and the relative effects of ultraviolet light, electrons, and heavy ions. The amassed data on sudden fadeouts in long-distance transmission, obtained through cooperative research, led in 1935 to Dellinger's confirmation of their source in sudden eruptions on the sun, a phenomenon subsequently known as "the Dellinger effect." [153]

By 1937 the data at the Bureau made it possible to inaugurate a service of monthly predictions of ionospheric and radio conditions. For the first time Government long-distance stations and commercial air services were provided with information on the selection of radio frequencies for transmission over specified distances at various times of day and year, alternative means of radio communication when sun disturbances interfered with normal communications, and other vital transmission information.[154]

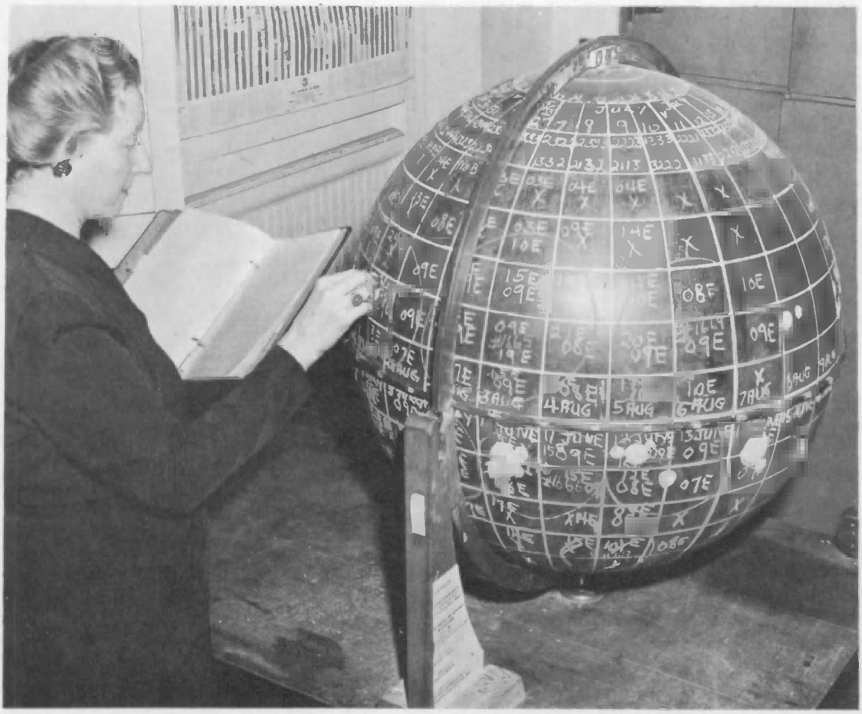
One investigation in the field of applied radio in the 1930's—long before the advent of CONELRAD or EBS (Emergency Broadcast System)—struck a faintly ominous note, when the Federal Bureau of Investigation requested the Bureau to make experiments to see whether voice broadcasting

[153] NBS Annual Report 1934, p. 54; Dellinger notes in Science, 82, 351 and 548 (1935); NBS Annual Report 1936, p. 61; RP1001, "Characteristics of the ionosphere * * *" (Gilliland, Smith, and Reymer, 1937); RP1061, "Sudden disturbances of the ionosphere" (Dellinger, 1937).

[154] The service was announced in LC499, "The weekly radio broadcast of the NBS on the ionosphere and radio transmission conditions" (1937). LC565, "Standard frequencies and other services broadcast by NBS" (1939), said the Bureau's ionospheric reports would offer information on vertical-incidence critical frequencies, heights of the ionospheric layers, maximum usable frequencies for radio transmission, and information on ionospheric disturbances, thereby permitting a choice to be made in selecting optimum frequencies for long-distance transmission.

LC614, "Radio transmission and the ionosphere" (1940), was a 22-page description of the new ionosphere observation, reporting, and predicting service of the Bureau, analogous to the Federal weather reporting service.

LC615, "Radio distance ranges" (1940), provided the first detailed data for long-distance radio stations on ionospheric heights and ionization density of ionosphere layers, and determination and control of optimum conditions for long-distance radio for the coming year. This circular was superseded by LC658 (1941), with ranges for the summer of 1941 and winter of 1941–42. It was withdrawn on Jan. 2, 1942, as classified information. The series was resumed after the war.



Recording radio-weather forecasting data as a preliminary to preparing monthly predictions of ionospheric and radio conditions. Systematic measurement of the height and density of the ionospheric layers, the highly electrified region of the upper atmosphere produced by solar radiation and greatly influenced by high-speed particles discharged from the sun, is basic in the predicting of radio weather.

to cover the entire United States was possible from a single station. The Bureau engineers came up with a system that seemed feasible, but whether any part of it was ever tested, and what the FBI proposed to do with it is unfortunately nowhere recorded at the Bureau.[155]

A happier career was promised in two kindred projects first reported in 1935. They grew out of the experimental work in telemeteorography then going on in Germany, France, and Finland, where compact packages of radio equipment were being sent aloft via unmanned balloons to gather upper air weather data and record their transmission on a ground receiver.[156]

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[155] NBS Annual Report 1936, p. 61.

[156] The principle of telemetry or remote measurement was not new to the Bureau. In 1924 McCollum and Peters devised an electric telemeter for remote reading and recording of strain and force measurements, especially in inaccessible places, for use in testing bridge members and airship girders already in place in units under construction (T247, 1924).

At the request of the U.S. Weather Bureau, Leon Curtiss and Allen V. Astin of the electrical division undertook similar research at the Bureau, to devise a practical system of radiometeorography for the weather service.[157] When the aerological division of the Navy's Bureau of Aeronautics requested a high-altitude weather recording system of its own, a second project was initiated in the radio laboratory under Diamond, Hinman, and Dunmore.

As the Diamond apparatus seemed better suited to both Weather Bureau and Navy needs, Curtiss and Astin, more interested in radiation phenomena than in weather, equipped the radio telemeter they devised with special Geiger counters and began lofting them 20 miles and more into the stratosphere to gather cosmic-ray data.[158] Cosmic rays, the source of high energy particles that impinge on the earth from space, are of interest not only as radiation phenomena but for their effect on radio communication and also as possible keys to the study of atomic structure. The 18 ascensions made with the Curtiss-Astin telemeter confirmed earlier views reported from abroad, that the greater part of cosmic-ray phenomena was apparently caused by secondary effects generated not in outer space but within our own atmosphere.[159]

A year after beginning construction of their unit, Diamond and his group sent up their first model and demonstrated its effectiveness in transmitting continuous data on cloud height and thickness, temperature, pressure, humidity, and light intensity in the upper atmosphere. Effective from ground level to heights of 15 or more miles and at distances up to 200 miles, the radiosonde, as it was called, enormously increased the range and quantity of weather data, previously gathered by observing devices strapped to kites, zeppelins, or the wings of airplanes. By 1940 the radiosonde had become an integral part of U.S. weather and meteorological services and some 35,000 units were being built and sent up each year in this country and its territories.[160]

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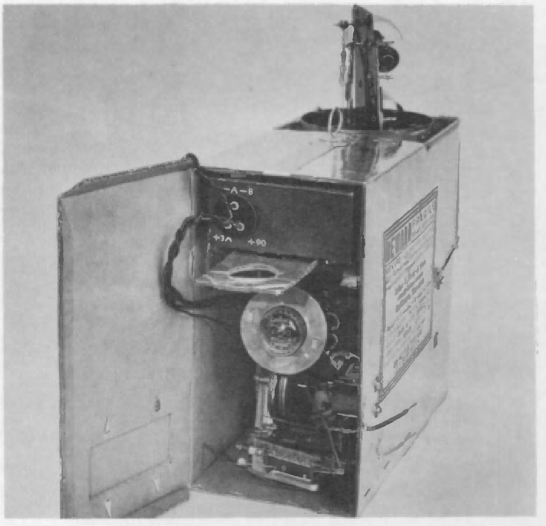
[157] Curtiss and Astin, J. Aeron. Sci. 3, 35 (1935).

[158] In 1928, with the recent incorporation of the vacuum tube in the Geiger-Muller ion counter (the principle had been established by Rutherford and Geiger in 1908), Dr. Curtiss began a long series of studies on routine quantitative measurements with the counter which led to the later cosmic-ray studies and development of new types of counters. See RP165 (1930), RP191 (1930), RP509 (1932), RP526 (1933), RP1154 (1938), RP1525 (1943).

[159] RP1169, "An improved radio meteorograph on the Olland principle" (Curtiss, Astin, et al., 1938); Curtiss and Astin, "Cosmic ray observations in the stratosphere," Phys. Rev. 53, 23 (1938); RP1254, "Cosmic-ray observations * * *" (Curtiss, Astin, et al., 1939).

[160] NBS Annual Report 1936, p. 65; Annual Report 1937, p. 60; RP1082 "A method for investigation of upper air phenomena * * *" (Diamond, Hinman, and Dunmore, 1937);



The radiosonde, developed for the Navy by the Bureau in 1936, telemeters information on upper air pressure, temperature, and humidity from unmanned balloons. It employs an ultra-high-frequency oscillator and a modulator. The frequency of the latter is controlled by special resistors whose electrical resistance varies with the atmospheric phenomena. At the receiving station on the ground or on shipboard, a graphic frequency recorder, connected in the receiving set output, provides an automatic chart of the variations of the phenomena with altitude.

Subsequent refinements in the radiosonde included improved instruments such as the electric hygrometer,[161] superior electronic components, and more recently, miniaturization. These were also used in the special radiosonde designed for the Navy to operate as an automatic weather station. Installed on isolated islands or in mountainous regions, the radiosonde transmitted data on temperature, pressure, humidity, wind velocity and direction, and rainfall via keyed frequencies picked up and recorded at the nearest Navy base.[162]

The international interest in telemeteorography that led to the radiosonde coincided with a new age of exploration—ionospheric, stratospheric, and terrestrial—marked early in the decade by the Second International Polar Year of 1932–34. Available to that Year were the airplane, radio, and a range of scientific instruments and equipment denied the First Polar Year, held 50 years earlier, in 1882–83. In that initial cooperative assault of science on the icy unknown, meteorologists and astronomers of 11 nations had acted in concert to explore the polar regions and, from 12 bases around the Arctic and in the southern ocean, make observations of polar weather,

RP1329, "An improved radio sonde and its performance" (Diamond, Hinman, et al., 1940); Science, 90, 246 (1939).

Mass production of the radiosonde was turned over to several companies in 1937, including Bendix-Friez of Towson, Md. In the next 26 years, Bendix alone manufactured more than 2 million units. "Baltimore Evening Sun," Sept. 6, 1963, p. B6.

[161] RP1102, "An electric hygrometer * * *" (Dunmore, 1938), and its improvement, RP1265 (1939).

[162] RP1318, "An automatic weather station" (Diamond and Hinman, 1940).

the aurora borealis, and of sun-spot activity and its attendant magnetic storms.[163]

The Second Polar Year, with more countries and more branches of science involved, again centered its studies on meteorology, magnetism, and aurora in the the Arctic, where their effects are strongest and most free from the contamination of civilization. Among prominent new objectives of the Year was the work planned in space phenomena, primarily the study of their effects on radio transmission. Representing the United States were the National Bureau of Standards, the Coast and Geodetic Survey, the Department of Terrestrial Magnetism of the Carnegie Institution, and the Naval Research Laboratory.

The Year unfortunately fell during the worst phase of the worldwide depression. The Bureau had planned to carry out extensive new measurements of the heights and degree of ionization of the ionosphere layers at the station set up at Fairbanks, Alaska. Instead, its participation was limited to the preparation of certain computations for the expedition and construction of some of the automatic recording instruments used by members of the Department of Terrestrial Magnetism.[164] More active participation and extensive research awaited the International Geophysical Year of 1957–59.

The strides of radio and aeronautics in the 1920's made possible the far-ranging exploration that created headlines all through the thirties. Byrd's flight to the North Pole in 1926 was followed by his Antarctic expeditions, sponsored by the National Geographic Society, in 1933 and 1934. Through Dr. Briggs's chairmanship of the special advisory committee and later the research committee of the society, the Bureau took part in the Antarctic studies, as it did in almost every expedition of the society during that decade, actively assisting in the preparation, providing special instrumentation, and in many instances sending staff members along on the expeditions.

With Dr. Briggs, Dr. Tuckerman, and other Bureau members assisting in instrumentation and computations, the National Geographic Society in 1934 and 1935 sponsored two flights into the stratosphere in the largest free balloons constructed up to that time. In the first ascension, the balloon carried more than a ton of scientific instruments arranged by Dr. Briggs, including special meteorographs, electric thermometers, and spectrographs designed or constructed at the Bureau. Manned by two Army Air Corps officers, the huge balloon reached the unprecedented height of 72,395 feet or almost 14 miles. Instruments aboard the gondola recorded data on cosmic radiation, sun and sky spectra, and the ozone layer, collected air samples and information on the functioning of radio equipment at extreme altitudes, and

[163] The two Polar Years are compared in J. Tuzo Wilson, I.G.Y.: The Year of the New Moons (New York: Knopf, 1961), pp. 6–8.

[164] Science, 76, 187 (1932); NBS Annual Report 1933, p. 48.

Dr. Gardner's specially designed camera for photographing the solar corona. It was used at Ak Bulak in Asiatic Russia in 1936 and at Canton Island in the South Pacific in 1937. The lens was made at NBS from optical glass poured in the Bureau glass plant.

made comparisons of photographic and instrument measurements at high altitudes.[165]

The next year, in 1936, the National Geographic and the Bureau jointly sponsored an expedition to the Kazak region of Asiatic U.S.S.R., to observe the June solar eclipse. New data on the sun's corona, its prominences, and solar spectra were recorded by the Soviet and Harvard University groups with the expedition. Dr. Irvine C. Gardner of the Bureau brought back the first natural-color photographs ever made of a total eclipse, with a 14-foot eclipse camera and 9-inch astrographic lens wholly designed and constructed at the Bureau.[166] The giant camera went again on the National Geographic-U.S. Navy Eclipse Expedition to Canton Island in the South Pacific the following year.[167]

Another joint National Geographic-Bureau eclipse expedition was made to South America in 1940, and a year later the Bureau itself sponsored the Louise A. Boyd Arctic Expedition, to make new radio, geomagnetic, and auroral measurements for a special study of ionospheric characteristics.[168]

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[165] Briggs, "Laboratories in the stratosphere," Sci. Mo. 40, 295 (1935), et seq.; Capt. A. W. Stevens, "Man's farthest aloft," Nat. Geo. 69, 59 (1936).

[166] Gardner, "Observing an eclipse in Asiatic Russia," Nat. Geo. 71, 179 (1937).

[167] NBS Annual Report 1937, p. 65.

[168] Sci. Mo., 51, 305 (1940); Science, 93, 420 (1941); Science, 94, 324 (1941).

Dr. Briggs himself led and directed the scientific work of "one of the most extensive efforts ever organized" for spatial and radio research, the 76-man team of scientists, Air Force, Army, and National Geographic members that went to Brazil for the eclipse of 1947.[169]

In light of present knowledge, the First Polar Year of 1882 sought no more than superficial clues to the makeup of the solar system and to spatial influences on weather. The Second Polar Year and the decade of exploration that followed it were not much broader in horizon or more sophisticated in their inquiry, in spite of the progress of radio, aviation, and the new physics. The advances in these three fields of science were not to yield their fruit—foreshadowing command of the atom, human flight in space, and near approach to the planets—for another half a dozen years.

HEAVY WATER

The Bureau studies of cosmic radiations, weather and radio phenomena, of X rays, radium, and their emanations bore only distant relation to far more sophisticated investigations going on elsewhere in the thirties in this country and abroad into the nature of matter and its atomic structure.

Following Roentgen's discovery of X rays in 1895 and Becquerel's demonstration of radioactivity, the new century witnessed a train of discoveries extending illimitably the boundaries of physical knowledge: "the quantum character of light energy (Max Planck and Albert Einstein), the theory of relativity (Einstein), the nuclear structure of the atom (Lord Rutherford and Niels Bohr); interpretation of the light-emitting properties of matter (Prince Louis de Broglie, Erwin Schrödinger, and Max Born), of heavy hydrogen (Harold Urey), of the neutron (Sir James Chadwick), and of means of producing artificial transmutations of the elements (Sir John Cockcroft and Ernest Walton, Frédéric Curie-Joliot, Enrico Fermi, and others)." [170]

The initial concern of the Bureau in the atomic adventure may be said to stem from Becquerel's finding of radioactivity in uranium salts, and was in the chemistry rather than the physics of the atom.

Mapping the group of radioactive elements that had been identified since Becquerel's discovery, the English chemist Frederick Soddy in 1913 found a number of them, because they had identical chemical characteristics,

[169] Gilbert Grosvenor, "Earth, sea and sky; twenty years of exploration by the National Geographic Society," Sci. Mo. 78, 296 (1954).
[170] E. U. Condon, "Physics," What Is Science? ed. James R. Newman (New York: Washington Square Press, 1961), p. 110.

occupying the same space in the Periodic Table of Elements even though they possessed different atomic weights. He coined the word "isotope" to describe chemically identical substances with different atomic weights.

The 1920's saw the development of the mass spectroscope, an electromagnetic device that sorted out atoms, both normal and isotopic, according to their masses, and projected them as sharp clear lines in a spectrum. Analysis of the true weights of the atoms of various elements thus became possible, and with this instrument, F. W. Aston of the Cavendish Laboratory at Cambridge showed that not only radioactive elements, but almost all elements, have isotopes.[171]

One element, hydrogen, gave particular trouble. Precise measurement of its atomic weight indicated that it had a heavy isotope, but apparently in so small concentration that Aston could find no trace of it on the spectroscope. At this point the Bureau of Standards became actively associated with this field of atomic research.

In the summer of 1931, Harold C. Urey, associate professor of chemistry at Columbia, then lecturing at the Johns Hopkins University, became convinced that an isotope of hydrogen of mass 2, though unknown, could be found.[172] In conversation with Fred L. Mohler of the atomic physics section of the Bureau, Urey told him that in his studies of the hydrogen spectrum he had found a satellite line next to the hydrogen alpha line that he thought might be heavy hydrogen. Urey sought a way to enrich the suspected isotope, and wondered whether liquid hydrogen might not make better definition possible. Mohler suggested the Bureau's cryogenic laboratory, where Brickwedde was studying ortho- and para-hydrogen. There, successive low-temperature distillations of liquid hydrogen resulted in a concentration whose spectrum left no doubt of the existence of the isotope.[173]

Urey had earlier suggested the possibility of separation of the isotope by electrolysis, but the procedure had been tried and given up as unpromising. Acting on a suggestion of Dr. Washburn, chief of the Bureau chemistry division, Edgar R. Smith on December 9, 1931, began an experiment in the isotopic fractionation of water by repeated hydrolysis of solutions of caustic potash. When 98 percent of the water had been decomposed in this manner, the density of the hydrogen in the residual water proved measurably higher

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[171] "In the early nineteen-thirties, many atomic masses were very accurately measured and the energy of products of many nuclear reactions became known * * * [making] possible the full quantitative verification of Einstein's 1905 prediction that mass and energy are equivalent." E. U. Condon, "Physics," pp. 145–146.

[172] See Urey, "The natural system of atomic nuclei," J. Am. Cml. Soc. 53, 2872 (1931).

[173] NBS TNB No. 179 (March 1932), p. 23; Urey, Brickwedde, and Murphy, "A hydrogen isotope of mass 2 and its concentration," Phys. Rev. 40, 1 (April 1932); interview with Dr. Mohler, Oct. 1, 1963.

than in normal water, by 164 parts in a million, that is, possessing a specific gravity of 1.000164.[174]

Urey's discovery of the isotope of hydrogen and Washburn's actual separation were revolutionary.[175] The new isotope, winning Urey the Nobel Prize in chemistry in 1934, was given the name "deuterium," with the symbol D (in the form of deuterium oxide or heavy water it is D_2O). Within 2 years it had been prepared in a pure state, its specific gravity 1.015.[176]

Another event in 1932, James Chadwick's discovery of the neutron, was to prove even more important in subsequent events than that of heavy water. In the atom compounded of protons and electrons (its positive- and negative-charged particles), Chadwick in England identified yet another fundamental particle, not electrically charged, which he called the neutron. Its neutral characteristics made it highly penetrating and therefore very effective as an agent in nuclear transmutation. That same year, Cockcroft and Walton, working in Rutherford's laboratory at Cambridge, bombarded a lithium target with high-speed protons. In the experiment, a hydrogen atom reacted with a lithium atom to produce two helium atoms. The first artificial nuclear reaction and true transmutation of elements had occurred.[177]

For a time physicists showed great interest in the deuteron, the nucleus of deuterium or heavy water that Urey had found, because of its "remarkable properties as a projectile for producing transmutation of elements and particularly for the production of neutrons." [178] But while deuterium had a

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[174] NBS Annual Report 1932, p. 8; Washburn and Urey, "Concentration of the H^2 isotope of hydrogen * * *," Proc. Natl. Acad. Sci. 18, 496 (1932); Washburn, Smith, and Frandsen, "The isotopic fractionation of water," J. Chem. Phys. 1, 288 (1933); RP601, "The isotopic fractionation of water" (Washburn, Smith, and Frandsen, 1933). Urey and Teal summarized deuterium research in Revs. Mod. Phys. 7, 34 (1935).

[175] Dr. Edward W. Washburn came to the Bureau as its chief chemist in 1926, when he was 45. He had recently completed a 4-year project as editor in chief of the monumental International Critical Tables of Numerical Data of Physics, Chemistry, and Technology. He was one of the best scientists ever to work at the Bureau, his research on the fractionation of petroleum, the crystallization of rubber, and on heavy water among his most important achievements in the 8 years there before his untimely death. See Natl. Acad. Sci., Biographical Memoirs, XVII (1935).

[176] NBS Annual Report 1933, p. 54. In Science, 78, 555, (1933), Dr. Washburn urged construction of a plant for quantity production of "deuterium water." The 6 to 10 gallons produced annually would be enough, he believed, for all current needs of physics, chemistry, and biological and medical research. Urey was no more prescient. Many years later he recalled that when he discovered heavy water he never dreamed that it would become a vital ingredient in the making of the atomic bomb. "I thought it might have some practical use in something like neon signs." Time, Feb. 19, 1965, p. 42.

[177] E. U. Condon, "Physics," p. 143.

[178] Sci. Mo., 38, 390 (1934).

part in the final process of nuclear disintegration, the deuteron was not to be the trigger of atomic power as the chemists hoped. This role was reserved for the neutron.

Enrico Fermi, then in England, reasoned that neutrons, lacking charge, should be highly effective in penetrating nuclei, especially those of high atomic number, with consequent release of energy. He selected uranium, at No. 92 the last of the naturally occurring elements, with atomic weight 238. But his bombardment in 1934 of uranium by neutrons slowed down by the use of deuterium proved inconclusive. He obtained only a "confusion" of radioactive substances, two of which, however, proved to have atomic numbers larger than 92. In Germany in late 1938, Otto Hahn and Fritz Strassmann at the Kaiser Wilhelm Institute for Chemistry performed the same experiment and obtained a large variety of radioactive isotopes of chemical elements having half the atomic weight of the original uranium. Announcement of the significance of these two findings was near.

Lise Meitner in Sweden, a refugee physicist from Germany, and her nephew Otto R. Frisch in Denmark, informed of the work of their former colleagues in Berlin and pursuing Fermi's line of investigation, hit on the answer. Meitner and Frisch conjectured that the uranium nucleus, with low stability of form, had divided into two nuclei of roughly equal size, releasing in the process enormous quantities of energy—the "confusion" Fermi had observed. They estimated the total energy resulting from that splitting of the uranium atom as about 200 MeV (200 million electron volts).[179] Their letter explaining the Hahn and Strassmann observations and Frisch's experimental verification, "Disintegration of uranium by neutrons: a new type of nuclear reaction," appeared in Nature magazine on February 11, 1939.[180]

With full knowledge of Frisch's experiments, Niels Bohr arrived in this country the month before the appearance of the paper, and while visiting at Princeton told Einstein, in residence there, and Eugene P. Wigner, Princeton professor of theoretical physics, of its import. He also saw Prof. George B. Pegram at Columbia and Fermi, who had come to work in Pegram's laboratory. He impressed on them the significance of these experiments, told them of the work of Hahn and Strassmann, and something they did not

[179] The sum of the mass of the 2 fission fragments, totaling less than the mass of the original uranium nucleus, suggested that the matter that had disappeared had been transformed into energy. Although the matter transformed was small, Einstein's formula $E=mc^2$ indicated the enormity of the energy released, considering that the mass must be multiplied by the square of the speed of light, which is 185,000 miles per second. James P. Baxter, Scientists Against Time (Boston; Little, Brown, 1946), p. 420.

[180] Nature, 143, 239. Niels Bohr's account of the verification, confirmed to him in a telegram from Frisch, appeared in this country in Phys. Rev. 55, 418 (Feb. 15, 1939).

know, that Hitler had placed an embargo on Czechoslovakian uranium, the only source of the ore then known in Europe.[181]

Fermi and Leo Szilard at Columbia, Richard B. Roberts at the Carnegie Institution in Washington and other groups at Johns Hopkins, Princeton, and California independently confirmed the Hahn-Strassmann results.[182] Their success at once raised the fear that other scientists in Germany had done the same, realized the probability of uranium fission, and soon the full resources of German science would be organized in a massive assault on the problem.

Aware that the magnitude of difficulties that had yet to be resolved required Government support, Szilard and Wigner in July 1939 conferred with Einstein in Princeton. In letters addressed to President Roosevelt, Einstein and Szilard explained the significance of the uranium experiments, the probability of achieving a chain reaction, and the urgency of proving out that probability before Nazi Germany did. Alexander Sachs, economist and

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[181] Testimony of Alexander Sachs, Hearings before the Special Committee on Atomic Energy * * * on S. Res. 179 [McMahon Committee] (Nov. 27, 1945), pt. 1, pp. 2–7.

There seemed reason for alarm, but German research in nuclear physics was thwarted by Nazi ideology. That ideology is illuminated in a note that appeared in Science, 85, 262 (1937):

The Manchester Guardian prints in its issue of February 7 the following: "The Berliner Tageblatt reports a lecture given by Geheimrat (Privy Councillor) Professor Dr. Stark, president of the National Physical and Technical Institution (Physikalisch-Technische Reichsanstalt), on 'Dogmatism and Experience in Atomic Research.' Professor Dr. Stark, according to this report, rejected the theory of the form of the atom the moment it was put forward by Lord Rutherford and Niels Bohr—less on technical (sachlichen) grounds than from fundamental objections to their acceptance of views and dogmas of Jewish physicists. He now wished not only to criticize but to bring forward something better as an alternative. He described his new model of the atom with the aid of a short film. Its main feature is that the electron has not the form of a sphere, assigned to it by the Jewish physicist Abraham, but that of a vortex-ring (Wirbélring). Jewish influence, said Professor Dr. Stark, has gone so far that even non-Jewish scientists like Planck, Bohr, Von Laue, Schrödinger and Heisenberg had become partisans of the false doctrine (Irrlehre), and no young lecturer who gave a thought to his career dared to oppose the dominant theory. Some particularly pushing physicists married Jewish women in order to advance their careers. Now that these monstrous circumstances had been discovered, German and authentic (arteigene) physics would forge ahead. 'Privy Councillor Stark's lecture is to serve,' the report concludes, 'as a new thrust to eliminate from German physics the effects of the Jewish mind.' Unfortunately, Stark said in conclusion, in the two decades no important discovery had been made by physicists of the German alignment."

[182] Szilard and Zinn, "Instantaneous emission of fast neutrons in the interaction of slow neutrons with uranium," Phys. Rev. 55, 799 (1939). Other confirming letters in that issue of Phys. Rev. appeared on pp. 509, 510, 511, 516, 797. That of Bohr and Wheeler, which suggested that fission was more likely in U^{235} than U^{238}, appeared in Phys. Rev. 56, 426 (1939).

director of Lehman Bros., friend of Einstein, and since 1932 an economic adviser to the administration, with direct access to the President, offered to put the letters in the President's hands.

The letters were transmitted on October 11, 1939. After reading them Roosevelt said he must have the advice of Dr. Briggs, his principal counsellor in the official family on scientific matters. With the President's permission, Sachs informed Dr. Briggs the same night of his visit to the White House.[183] That week the President appointed an Advisory Committee on Uranium, with Dr. Briggs as chairman and Col. Keith F. Adamson of Army Ordnance and Commander Gilbert C. Hoover of the Navy Bureau of Ordnance his associates. to look into the question of uranium fission.

The first meeting of the committee on October 21, 1939, attended also by Mohler of the Bureau, Sachs, Szilard, Wigner, and Edward Teller, resulted in a report to the President, dated November 1, saying that a chain reaction, though unproved, was a distinct possibility. In tentative terms it speculated on the potential energy that might be released by splitting of uranium atoms, looking toward the possibility of both a new explosive, in which the military was interested, and a new source of energy, long sought by the Navy to drive its submarines without the need of frequent surfacing. Specifically, the report recommended that 4 tons of pure-grade graphite be obtained at once for research, and later acquisition, if justified, of 50 tons of uranium ore.

Three months after the report, in February 1940, the sum of $6,000 from Army and Navy Ordnance funds was made available to purchase a small quantity of graphite for experiments on its absorption qualities. The war in Europe was then 6 months old. Seven weeks later Hitler invaded Denmark and Norway, preliminary to his attack on the Low Countries and France.

It was an awesome responsibility that had been thrust upon Dr. Briggs. In his 66th year—and seventh as Director of the Bureau—he had gone through a series of investigations of Bureau operations and witnessed a serious reduction in Bureau funds and staff. The depression was still on, and so were many of the constrictions of a planned economy. And no end was in sight. A younger man might have seized on the adventure into the unknown promised by nuclear fission, but Dr. Briggs had learned to be cautious. Nor was he at all certain that this was the kind of research, or direction of

[183] Testimony of Alexander Sachs. Roosevelt's choice of Dr. Briggs was also probably dictated by the absence of any other real liaison between Government and science, and the fact that security as well as policy restricted him to official circles. See Richard G. Hewlett and Oscar E. Anderson, Jr., The New World, 1939–1946; A History of the U.S. Atomic Energy Commission (Pennsylvania State University Press, 1962), pp. 19–20.

research, in which the Bureau ought to become involved.[184] He and his committee hesitated.

In April 1940, when the committee met at the Bureau for a second time, with Pegram and Fermi also in attendance, it learned that only the U^{235} isotope of uranium fissioned under bombardment by neutrons of thermal (slow) velocities—a significant discovery, provided U^{235} could be sufficiently concentrated. And it heard that a large section of the Kaiser Wilhelm Institute in Berlin had recently been set aside for research on uranium. Yet on that occasion, and at another meeting in June, the committee adjourned without making any definite recommendation except that funds should be sought to support further investigation of isotope separation and the possibility of a chain reaction with U^{235}.[185]

A month later the committee, with Pegram, Urey, Jesse W. Beams of Virginia, Merle A. Tuve of the Carnegie Institution, Ross Gunn of the Naval Research Laboratory, and Gregory Breit of Wisconsin as new members under Dr. Briggs's chairmanship, became the Uranium (or S–1) Section of the National Defense Research Committee (NDRC), set up by the President under Dr. Vannevar Bush to mobilize science for war.[186] As with other research for national defense turned over to it, NDRC was to contract for S–1 research and thereby accelerate the program.

Responsible for formulation of the S–1 program, Briggs at once urged support for the determination of the fundamental physical constants of uranium and graphite and experimentation in the chain reaction. Fermi began his first uranium and graphite pile at Columbia. Urey, with Briggs's encouragement, continued his study of heavy water as a graphite substitute in a chain reaction.[187]

In June 1941, as the scope of research expanded, NDRC was subordinated to the Office of Scientific Research and Development (OSRD), established to direct the entire research resources of the Nation and close the gap between research and procurement for national defense. The S–1 Section, now directly under Dr. James B. Conant as head of NDRC, but with Dr. Briggs continuing as chairman, was transferred to OSRD. When in September 1941 reports of British progress in nuclear research aroused concern over the lack of results here, Samuel K. Allison of Chicago, Edward U.

[184] Continued investigation of heavy water had been the first area of research that the Visiting Committee in 1934 strongly recommended be discontinued at the Bureau. See above, p. 345.

[185] Henry D. Smyth, Atomic Energy for Military Purposes (Princeton University Press, 1945), pp. 48–49; Hewlett and Anderson, pp. 22–23.

[186] A facsimile of the letter from the President to Dr. Bush appears in Robert E. Sherwood, Roosevelt and Hopkins: an Intimate History (New York: Harper, 1948), pp. 155–156.

[187] Hewlett and Anderson, pp. 26–29.

Condon, than associate director of the Westinghouse Research Laboratory, and later Director of the National Bureau of Standards, Lloyd P. Smith of Cornell, and Henry D. Smyth of Princeton, with Henry T. Wensel, a Bureau specialist in temperature measurements, were brought in to strengthen the Uranium Section.[188]

As laboratory research and experimentation evolved processes requiring large-scale plant construction, the final stages of research and production were taken over by the Manhattan District, organized in the Army Corps of Engineers in August 1942 to conceal the making of the bomb in the anonymity of the military establishment. A year later the S–1 Section, though never formally dissolved, became inactive.[189]

Acceleration of research and engineering development of the bomb was achieved under NDRC and OSRD by means of contracts let to universities, industry, and research agencies both in and outside the Government, a number of the research contracts falling within the special province of the Bureau. That part of OSRD and Manhattan District development work in which the Bureau laboratories became actively involved is told in the next chapter.

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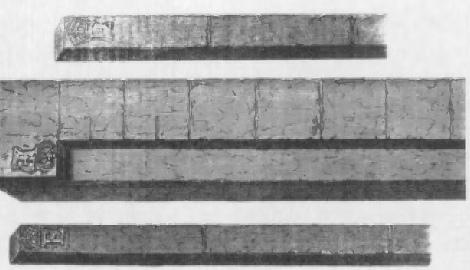
[188] Ibid., pp. 35–36, 44.
[189] Ibid., 41, 82; Smyth Report, pp. 83–84.



Above, the standard yard and ell bed of Queen Elizabeth I, with inches marked in the yard bed. Below, the ell, with sixteenths of the ell marked.