THE NEW WORLD OF SCIENCE (1946–51)

CHAPTER VIII

"THE PECULIAR PEACE"

The war ended with a monstrous bang. In "the peculiar peace" that followed, the word "fallout" equally described a metaphorical truth and a new phenomenon loosed on the world. In a decade compounded of inflation, strikes, shortages, Russian intransigence and aggression, and the new presence of the atomic bomb, the Nation was to be ruled by uneasy fears.[1]

By the end of 1946, as price controls went off, living costs were an estimated 39 percent above those of December 1941, and strike after strike hobbled production and pushed prices still higher. Trolley and subway fares went up 2 cents and then a nickel. The 10-cent Sunday paper became 15 cents, then 20. A public with massive war savings fretted over shortages of food, furniture, nylons, electric irons, and clothing. Even razor blades and alarm clocks were hard to find, a new car meant signing up on a multiple of long waiting lists, and housing was either not to be had or the new ones promptly started falling apart. In the summer of 1946 came the meat "famine" as producers refused to send their cattle to market. The black market, a way of life in Europe, came to America.

"Had enough?" the Republicans asked the country, and in 1946 it elected the first Republican Congress since the days of Herbert Hoover. But the worst of the adjustment was already past. Raw materials were again becoming plentiful, the reconversion of industry neared completion, and production began approaching prewar levels.

New sources of tension arose in the United Nations, born in the last year of the war, where Russia, using the veto to shield her expansion in Europe, goaded the assembly, staged stormy walkouts, and sabotaged issue after issue raised, including the most critical of all, international control of atomic energy. Communism's growing threat in Eastern as well as Western Europe slowly impelled America to assume responsibility for restoring their war-wrecked economies.

[1] The material of the introductory pages of this section is largely drawn from Eric F. Goldman, The Crucial Decade: America, 1945–1955 (New York: Knopf, 1956).

The Truman Doctrine, announced on March 12, 1947, promised support to free nations resisting pressures from Communism, and a month later the phrase "cold war" was born. The aftermath of World War II was not to be depression but cold war. Out on Connecticut Avenue, Bureau reports echoed the national tension as it prefaced its plans for research with such phrases as "if war comes again," "in the event of any future emergency," "in time of emergency," and described some of its continuing programs as "the difference between obliteration and survival." [2]

A reluctant Nation delayed action on the Truman Doctrine until the fall of Czechoslovakia under Communist domination in February 1948, Russia's menace of Finland, the impasse marked by the Berlin airlift, and the threat of Communist Party takeovers in France and Italy. Russian aggression, aided by hunger, poverty, desperation, and chaos around the globe, could be contained only by long-range economic aid. Under mounting pressure, Congress adopted the Marshall Plan on April 2, 1948, to bolster the economies of Turkey and all the European countries outside the Iron Curtain. It called for an initial expenditure of $17 billion over approximately 4 years.

As the economies of the Western European nations swung upward under the Marshall Plan, containment became policy. The cold war was joined upon the signing of the North Atlantic Treaty Organization (NATO) in March 1949, as 10 nations of northwestern Europe, Canada, and the United States agreed to joint action should any one of them be attacked by Russia. In August of that same year the Marshall Plan received a serious setback when, despite $2 billion in aid, Chiang Kai-shek's nation fell to the Chinese Communist armies.

The cold war took still another turn for the worse. Some American scientists had predicted that Russia would not have an atomic bomb before 1952 or 1953. Others hazarded dates as late as 1956 or even 1960. But Stalin had expressed no surprise when at Potsdam he was first told of the event that had occurred at Alamogordo; Russian scientists may well have begun their study of the bomb as early as 1941, and certainly were at work by 1943, assisted by the knowledge that England and the United States were seriously engaged and, later, by acquisition of engineering designs of the structures raised in Britain and at Oak Ridge, Hanford, and Los Alamos. On September 23, 1949, 6 weeks after the actual event, the President announced the explosion of an atomic device in the U.S.S.R.

The cold war thus became a question of coexistence—a nebulous, uneasy way of life, shaped by the spectre of annihilation and made even more frightening by Truman's decision on January 31, 1950, to resume development of the hydrogen or fusion bomb. The Russians had dupli-

[2] NBS Annual Report 1947, pp. xiv, xv; Annual Report 1949, p. 49.

cated the fission bomb in 4 years; they were almost certainly at work on a fusion bomb, and might not require that much time again.

Stalinism abroad had its fright-counterpart in McCarthyism at home. And the cold war became hot when on June 25, 1950, the American Ambassador to the 2-year-old Republic of Korea cabled that the Chinese-supported armies of North Korea had crossed the 38th parallel. Six days later American planes, ships, and infantrymen put the United States irrevocably into the war. The initial United Nations forces under General MacArthur's command, consisting largely of South Koreans and American troops rushed from Japan, met Soviet-made tanks and fell back. At home the Nation went back on a war footing, back to wage and price controls. Two months after the start of the war a new boom was on as employment passed the 62 million mark.

It was August before the Americans and ROK's ended their retreat and another month before they took the offensive. They had advanced to the Yalu River in late November when 33 Chinese divisions crossed and hit the U.N. line. It fell back slowly to the 38th parallel and there stalemate set in. In June 1951 the Soviet Ambassador to the U.N. hinted that Russia was ready for a cease fire in Korea. The killing continued through 2 years and 17 days of conferences before an armistice was signed on July 27, 1953.

Eight months earlier, on November 1, 1952, this country detonated the first hydrogen bomb. Less than a month after the Korean armistice, on August 12, 1953, the Atomic Energy Commission announced its detection of a similar thermonuclear explosion in the Soviet Union. And both nations were already engaged in the development of intercontinental missiles that would replace planes for the delivery of either the fusion or fission bomb. There appeared to be no alternative to continued research in weaponry; more truly, mankind had no alternative but peace.

If World War II made science for the first time a political, economic, and social force in the Nation, the postwar years, under the pressure of "obliteration," magnified that fact manifold. Yet science could not remain mobilized in the Office of Scientific Research and Development, an emergency agency for military research, and with the end of the war the weapons research projects of OSRD were transferred to the War and Navy Departments for peacetime administration. In 1946 Congress divested the Army Engineer Corps of its Manhattan District and the atomic bomb project was returned to civilian control by creating the Atomic Energy Commission.

Both the military and the AEC were to call on the Bureau for continued technological research on their behalf. In the fall of 1944, Dr. Briggs and Maj. Gen. Levin H. Campbell, Jr., Chief of Army Ordnance, signed an agreement under which the Bureau would continue its research and design of proximity fuze devices. In May 1945 ground was broken for the construction of a half-million-dollar ordnance electronics laboratory on the Bureau grounds. Concurrently, the Navy asked for continuation of the guided missile work, and upon the establishment of the AEC, support was offered for enhanced programs on its behalf. The Bureau was thus committed to a large amount of developmental research in the postwar period.[3]

At the same time, the store of basic research had been seriously depleted by the war and there was growing concern in the Federal Government for its replenishment. It was unlikely that this country could ever again rely on Europe for its basic science, or afford to depend on foreign research for its military strength.[4] This prospect became a major concern of OSRD during the demobilization period; vide Vannevar Bush's Science—The Endless Frontier (1945). The question was raised by the science committee of the Office of War Mobilization and Reconversion and was one of the first orders of business of the AEC. The naval establishment found its answer in the organization of the Office of Naval Research in 1946, to coordinate all research for the Navy and support basic as well as applied research.

With its system of grants and contracts for research in the universities and in public institutions, the Office of Naval Research played a key role in the formation of the National Science Foundation. The establishment of the Foundation in 1950, "to evaluate science research programs undertaken by agencies of the Federal Government," settled the 100-year-old question of a permanent central scientific agency in the Government offering support to basic science.[5]

Even before the establishment of its central agency, the Federal Government had sought to assure itself of a continuing fund of both basic and applied research through the creation of laboratories wholly supported with Federal funds but operated by non-Federal agencies, as were the Los Alamos Laboratory and Radiation Laboratory of the University of California, the Argonne Laboratory at the University of Chicago, the Lincoln Laboratory at MIT, and the Applied Physics Laboratory at the Johns Hopkins University.

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[3] Memo of agreement, LJB for Chief of Ordnance, Oct. 31, 1944, and attached correspondence (copies in NBS Historical File). In addition to the Navy and AEC research, memo, Joint Chiefs of Staff for Director, NBS, May 24, 1945, requested NBS to assume all obligations of the Interservice Radio Propagation Laboratory (IRPL) as a postwar Bureau function (NBS Blue Folder Box 24, FPE–674c). The magnitude of the defense research commitment by 1950 is described in 20-page memo, Director, NBS for Secretary of Commerce, Nov. 28, 1950 (NBS Historical File).

[4] Don K. Price, Government and Science: Their Dynamic Relation in American Democracy (New York University Press, 1954), pp. 32, 46.

[5] Ibid., p. 60.

Further augmenting its fund of research was the Federal policy of utilizing its own institutions through transferred funds and of entering into contracts with universities and industrial firms to carry out investigations required by its agencies. In the process of formation for many years, the policy was increasingly resorted to during the war and continued at an accelerated rate in the postwar years.[6]

The history of transferred funds at the National Bureau of Standards, for the conduct of research and development on behalf of other Federal agencies, provides an interesting note on the progress of science in the Federal Government. The first such funds formally authorized were transferred to the Bureau in 1921 by the Army, Navy, the National Advisory Committee for Aeronautics, the Coast Guard, the Bureau of Engraving and Printing, and the Department of Agriculture. They totaled slightly more than $60,000.[7] At the height of World War II they approached $9 million, or almost 70 percent of the Bureau's total operating funds. During the Korean war, transferred funds, almost wholly from the Department of Defense and the Atomic Energy Commission, were to exceed $40 million, or 85 percent of operating funds. A decade later they leveled off at approximately $14 million annually, or 40 percent of the Bureau budget. How this imbalance came about merits some discussion.

As early as 1942 the Visiting Committee to the Bureau began urging an end after the war to the Bureau's deep engagement with industry, almost wholly supported by transferred funds. The development of new weapons, new materials, and substitute materials during the emergency made the research for industry necessary, but in peacetime, the Visiting Committee felt, such research belonged in the universities and in the laboratories of industry and not at the Bureau.

> While research and development programs will, in the future, [said the Committee] be even more extensively adopted by American industry, the importance of the Bureau of Standards * * * will undoubtedly increase in respect to its most important function, namely, serving as a court of last resort on those matters of standards which depend upon scientific [determinations] * * *. Direct aid to industry, while very important, should not be allowed to

[6] Dupree, Science in the Federal Government, pp. 371–375.

[7] Exceptions to transferred fund research was the work of the U.S. Naval Radiotelegraphic Laboratory and the Signal Corps Radio Laboratory at the Bureau which from 1908 to 1932 were directly supported by those services (see ch. III, p. 140). The military research and defense funds of 1918–19 were emergency transfers of the President, outside legislative authority.

overshadow the Bureau's position of final arbiter on scientific and technical standards.[8]

Secretary of Commerce Jesse H. Jones was inclined to agree with his Visiting Committee. The Bureau involvement in both commercial and industrial interests seemed excessive. A survey made at his request in 1943 recommended that such purely commercial activities of the Bureau as its simplified practices and trade standards divisions should probably be transferred to Commerce. Industrial standards, not development, was its role, and the survey urged "stronger legislative authorization for contributing [the Bureau's] measurement skills to the anticipated new [industrial] developments." [9] As Under Secretary Wayne C. Taylor wrote:

> The Department of Commerce proposes to ask for funds to enlarge the basic research work of the National Bureau of Standards during the transition period. If our country is to maintain its economic position, research in physics, chemistry, and metallurgy must be sturdily supported to provide the foundation for new industries and greater industrial development.[10]

That burning issue of the thirties, consumer standards, also flared again, and briefly involved the Bureau, in the efforts of Jones and Taylor (and endorsed by Henry A. Wallace when he became Secretary) to expand the Department's interest in the field of standards for commerce, "particularly [in] the development of performance standards for goods sold to the ultimate consumer." [11]

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[8] Report of the Visiting Committee to Secretary Jesse H. Jones, July 11, 1942, p. 9 (NARG 40, Secretary of Commerce, Box 114, file 67009/5).

[9] Report, Carroll L. Wilson, consultant to Secretary of Commerce, "Standards in Commerce—A Basis for Action," Dec. 8, 1943, revised Sept. 15, 1944, p. 7 (NBS Box 490, IDS–ASA). The report agreed with the view of the Visiting Committee "that the true function of the NBS lay in that domain of standarization that rested upon exact physical measurement, and not on such standardization as involved negotiations, opinion, judgment, and compromise."

[10] Letter, Taylor to Executive Secretary, Committee on Economic Demobilization, OPA, Mar. 10, 1944 (NBS Box 489, AG). The same intention appears in two studies made for Senator Kilgore's Subcommittee on War Mobilization to the Senate Committee on Military Affairs: the 326-page report, "The Government's Wartime Research and Development, 1940–44" (Senate Subcommittee Report No. 5, GPO, 1945), and the 418-page report, "Wartime Technological Developments" (Senate Subcommittee Monograph No. 2, GPO, 1945), the latter prepared as a working basis for the postwar development of new industries and cheaper and improved products. The two studies were represented as sequels to the report, "Research—A National Resource," issued in 1940.

[11] Letter, Acting Secretary of Commerce Taylor to Gano Dunn, Jan. 6, 1944 (NARG 40, Box 114, file 67009/5). For plans proposed by Jones and, later, Wallace to reorganize the Department to make "Washington the home of business," see Bus. Week, Mar. 30, 1945, p. 82, and Feb. 8, 1947, p. 52; also Hearings * * * H.R., 79th Cong., 1st Sess., on first deficiency appropriation bill for 1946, pt. I, Oct. 29, 1945, p. 319.

Dr. Briggs agreed that the Bureau might undertake certain basic research in consumer goods and materials but reserved his enthusiasm for resumption of industrial research. "We need a steady flow of new industries to take up the slack in employment," he wrote in April 1945, with strengthened research facilities at the Bureau to handle its responsibilities for "providing new opportunities for industry." [12] Frail and tired, he had little interest in the new fields of science created by the war. He was content to return to the familiar, to supplying industry and small business with technical information, assisting industry with standardization, continuing basic research in standards. Meanwhile, the Bureau must complete the military projects on hand, and continue to serve other Government agencies and the State governments.

Legislation to strengthen basic research at the Bureau, recommended in the survey for Jesse Jones, also won Wallace's aproval. Explicitly, Wallace proposed amending the organic act of 1901 to include areas of research previously covered by special legislation and, somewhat vaguely, "a limited enlargement of the Bureau's powers in a specified direction with respect to increased freedom in securing high types of personnel." [13]

Vannevar Bush, on the committee, demurred at the apparent implication of the "enlargement." He wanted no fundamental research for science or industry carried out at the Bureau except in the field of metrology. Nevertheless, he made unanimous the Visiting Committee's approval of the proposed legislation:

> I am entirely in sympathy with the Bureau's conducting basic research in the sciences, especially those which involve standards. However, the Bureau of Standards is the only body which has both the responsibility and authority to perform the exceedingly important function of establishing standards of all kinds, and in the future the Bureau is going to be subjected to a heavy and increasing burden in this regard as a result of the rapid progress of science, particularly in the field of atomic energy. The problem of formulating standards in their field alone will be a major challenge to the Bureau.
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> Hence, while I believe that it [the legislation] is important to the effective organization of the Bureau and to its ability to conduct basic research in science, nevertheless I think it should be unmis-

[12] Memo, LJB for Secretary of Commerce, Apr. 5, 1945 (NBS Box 502, AG).

[13] Discussed in letter, Gano Dunn to Secretary of Commerce Wallace, Nov. 23, 1945 (NARG 40, Box 114, file 67009/5), and Wallace correspondence in Box 112, files 67009/1 and 67009/12.

takably clear that the major emphasis should remain on its unique assignment in the field of standards.[14]

The amendment of the organic act of the Bureau was to be accomplished in 1950. With the cold war growing hot, the question of industrial research and of consumer standards had become academic. Furthermore, the postwar bent of the Bureau had already been determined by its new Director, Dr. Edward U. Condon.

EDWARD UHLER CONDON

On May 7, 1945, 4 months before the end of the war in the Pacific, Dr. Briggs quietly celebrated his 71st birthday. A year beyond the compulsory retirement age, he had served as Director since 1932 under five Secretaries of Commerce, Roy D. Chapin, Daniel C. Roper, Harry L. Hopkins, Jesse H. Jones, and, since the first of the year, under Roosevelt's new Secretary, Henry A. Wallace. Anxious to return to the comfort and quiet of his old laboratory in West building, Dr. Briggs submitted his resignation to Secretary Wallace.[15]

Two members of the Bureau, Dr. Eugene C. Crittenden and Dr. Hugh L. Dryden, came under consideration by the Secretary's Visiting Committee to the Bureau as Dr. Briggs' successor. Dr. Crittenden, at 65, was the senior, with 36 years of service in the Bureau. But he felt his health was not up to the task, and Dr. Briggs urged the candidacy of Dr. Dryden. Secretary Wallace, however, did not have the advice of his Visiting Committee in selecting a successor.[16] Moreover, he was strongly inclined to find someone outside the Bureau for the post. He first met his new Director of the Bureau at a conference of scientists in Chicago.

The successful test of the atomic bomb at Alamogordo in July 1945 had almost at once aroused concern among scientists over the control of the

[14] Letter, V. Bush to Gano Dunn, Nov. 21, 1945, attached to letter, Dunn, Nov. 23.

[15] Dr. Briggs' first years of retirement were spent, at Secretary Wallace's request, compiling the report on NBS War Research (1949). Letter, Wallace to LJB, Oct. 11, 1945 (NARG 40, Box 112, file 67009, pt. 1, 7–12). See also E. U. Condon, "Lyman James Briggs (1874–1963)," Year Book, Am. Phil. Soc., 1963, pp. 117–121.

[16] Interview with Dr. Briggs, Nov. 1, 1961

Dr. Briggs put his request for retirement on the agenda for the meeting of the Visiting Committee on June 22, 1945, just prior to his notification to Secretary Wallace. The chairman of the Visiting Committee subsequently accepted responsibility for the failure of the Visiting Committee to submit promptly its nominations, in response to his request, for the Secretary's consideration. In turn, Secretary Wallace acknowledged that he sent in his own nomination earlier than he had originally contemplated. Reports of the Visiting Committee to the Secretary of Commerce, July 5, 1945, and Oct. 31, 1945 ("Gen Corresp Files of the Director, 1945–1955," Box 6).

weapon and the peacetime development of atomic energy.[17] Ranged against continued military control were most of those who had worked on the bomb at Los Alamos and in the universities. One of the first of the many conferences that were called to discuss the future of atomic energy was that convened by Robert M. Hutchins, Chancellor of the University of Chicago. It met in September 1945 at the opening of the university's new Institute of Nuclear Studies. Lending his support to the conference, Secretary of Commerce Wallace attended and brought with him as special advisor, Dr. Philip M. Hauser, a sociologist on leave from the University of Chicago, then with the Bureau of Census.

Meeting Dr. Condon, associate director of research of the Westinghouse Electric Corp., for the first time at the conference, Dr. Hauser found him "a most amiable and knowledgeable fellow * * * [with] broad interests in the physical sciences." Aware that the Secretary was searching for a replacement for Dr. Briggs, Hauser suggested to Wallace that "this was a man he should meet and consider for the post of Director of the National Bureau of Standards." As Wallace remembers it, he discussed the directorship with several others at the conference, but "Dr. Condon was the only one who was available and really interested." [18]

Dr. Condon's name was submitted by President Truman to the Senate and confirmed without a dissenting vote. On November 7, 1945, he was formally appointed Director.

As Dr. Condon told an Appropriations Subcommittee not long after, he was "born * * * actually in the town where the bomb was tested, but there [was] no connection between those two events." [19] Then in his 43d year, he had indeed been born in Alamogordo, N. Mex., on March 2, 1902, but had spent his early school years largely in California. Taking his doctorate in physics at the University of California at Berkeley in 1926, he went to Germany for a year's study, where the new quantum physics of Heisenberg, Born, Schrödinger, and Dirac was being taught. He returned to lecture in physics at Columbia University and in 1928 went to Princeton as assistant and then associate professor.

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[17] One result of that concern was the publication of One World Or None (eds. Dexter Masters and Katharine Way, New York: McGraw-Hill, 1946), a report to the public on the meaning of the atomic bomb. Contributors to the report included Einstein, Bohr, Compton, Bethe, Langmuir, Oppenheimer, Szilard, Shapley, Seitz, Urey, Wigner, and Condon.

[18] Communications to the author from Henry A. Wallace, Jan. 7, 1964, and from Dr. Hauser, Jan. 29, 1964 (NBS Historical File). See also Wallace letter in New Republic, 118, 10 (1948). For Wallace's possible prior interest in Dr. Condon, see letter, LJB to H. A. Wallace, Aug. 2, 1945, sub: Standing of certain scientists (NBS Box 504, IG).

[19] Hearings * * * 1947 (Jan. 29, 1946), p. 175.

Dr. Edward U. Condon, fourth Director of the Bureau and the first theoretical physicist to head its operations. Reorganizing the Bureau in the postwar period, he cleared its attics of 50 years of accumulated lumber and began the modernization and systematizing of present Bureau operations.

While at Princeton, he coauthored the Frank-Condon principle in molecular physics; developed the theory of radioactivity decay, with Ronald W. Gurney; a theory of optical rotary power; the theory of proton-proton scattering, with Gregory Breit; and the theory of charge-independence of nuclear forces, with B. Cassen. His definitive treatise on the theory of atomic spectra, with George H. Shortley, established his reputation as an outstanding theoretical physicist.[20]

In 1937, Dr. Condon went to the Westinghouse Electric Corp. at Pittsburgh as associate director of research and there developed a program of nuclear research.[21] Appointed a consultant to the National Defense Research Committee in 1940, he helped organize the Radiation Laboratory at MIT, where America's microwave radar program was started, and wrote a basic textbook on the subject of microwaves for the laboratory. During the war he introduced and directed the microwave radar research program at Westinghouse.

While setting up the radar program, he served on Dr. Briggs's S–1 Committee, meeting monthly at the Bureau. In April 1943 he went to Los Alamos at the request of General Groves as associate director under Dr. Oppenheimer. Later that year he was called to the Radiation Laboratory at the University of California to head the theoretical physics group working on the electromagnetic (mass spectrograph) separation of uranium isotopes. Toward the end of the war he started the nuclear reactor program at Westinghouse which later produced the power plant for the Navy's atomic submarine.

Dr. Condon was no stranger to the Bureau laboratories when he became their Director. Actually, his acquaintanceship dated back to the late 1920's, when as a Princeton professor he attended the annual meetings of the American Physical Society, regularly held for many years at the Bureau. But Dr. Condon had no sooner seated himself in the Director's chair in South building, to learn something of the dimensions of his office, when he was called to Capitol Hill as scientific adviser to the Special Senate Committee on Atomic Energy. The hearings of Senator Brien McMahon's committee on the question of civilian control of atomic energy began on November 27, 1945, and lasted until April 8, 1946.[22]

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[20] Biographical note, "About Edward U. Condon," What Is Science? ed. James R. Newman (New York: Washington Square Press, 1961), pp. 105–108; interview with Dr. Condon, Oct. 27, 1963. With P. M. Morse, Condon wrote Quantum Mechanics (1929) and with G. H. Shortley, The Theory of Atomic Spectra (1935), both standard works in their fields.

[21] Time, 35, 44 (Feb. 12, 1940), called him "king of the atomic world at Westinghouse," where its new Van de Graaff generator, the only one in industry, was being used to make artificially radioactive substances for studies of nuclear structure.

[22] As a result of the hearings, Congress established the Atomic Energy Commission on Aug. 1, 1946, with complete civilian control over all atomic affairs of the United States,

In the interim, Dr. Crittenden served as Acting Director and Dr. Condon contented himself with brief visits to the Bureau to acquaint himself with its operations and activities. With only his Sundays free, he came with his master key and toured the unpeopled laboratories looking at work in progress, read the reports of current research left on his desk, and studied reports on operational procedures at the Bureau.[23]

Late in January 1946, Dr. Condon appeared for the first time before the House Appropriations Subcommittee for the annual hearing on the budget. Unaware of the deep affection of the committee members for Dr. Briggs and their long-standing interest in the Bureau under his direction, Dr. Condon brought up the subject of Bureau administration. The immediate order of business, Dr. Condon told the committee, was "to modernize and systematize the entire administrative activity of the Bureau, which has just grown up over the years without any special organization unit to coordinate and supervise the work.[24] Dr. Briggs and two division chiefs acting as Assistant Directors had borne the responsibility not only for all research at the Bureau but for the work of the 141 members of the administrative staff.[25] It seemed to Dr. Condon an impossible task.

Dr. Condon asked for funds for three full-time Assistant Directors to administer the professional and scientific functions of the Bureau, and an Executive Director to supervise business management functions. These four, he said, would "do what Dr. Briggs was doing before." As for the Director of the Bureau, he should not have 13 division chiefs and 4 or 5 administrative heads reporting directly to him for decisions and policy determinations. The greater part of his time should be devoted to "main-

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peaceful and military. All Manhattan District facilities, including the Los Alamos weapons laboratory, the isotope separation plants at Oak Ridge, and the plutonium piles at Hanford, were turned over to the AEC. It became responsible for procuring ores of the fissionable heavy metals, uranium and thorium, for converting them into concentrated pure metal, for manufacturing weapons as well as radioactive isotopes, electric power reactors for ship propulsion, and generators for electricity. The AEC was also charged with conducting all research necessary to keep the United States ahead of the world in atomic development. Finally, the act authorized free international exchange of basic scientific information when an international arrangement and techniques of inspection made that possible. See James R. Newman and Byron S. Miller, The Control of Atomic Energy (New York: McGraw-Hill, 1948).

[23] Interview with Dr. Condon, Oct. 27, 1963.

[24] Hearings * * * 1947 (Jan. 29, 1946), p. 183.

[25] The assistants were Dr. Crittenden, chief of the electricity division, and Dr. McAllister, chief of codes and specifications. The latter retired in the spring of 1945 and had not been replaced when Dr. Condon took over.

taining appropriate relations with the Secretary's Office, other activities of the Department and other Federal agencies, and commercial concerns and educational and scientific societies and institutions with which the Bureau is associated in cooperative or allied work." [26]

Asked by Congressman Louis C. Rabaut, chairman of the subcommittee, if the increased staff would promote greater efficiency at the Bureau, Dr. Condon replied: "That is my hope, and if it does not we will have to do something about that. It is my own feeling * * * that we have a great many overlapping operations and practices there that have just grown up over the years * * *." It was not a diplomatic note and Mr. Rabaut, and many at the Bureau hearing it later, reacted to it.[27] Steeped in an academic rather than industrial or even bureaucratic tradition, the Bureau, with almost a hundred on the staff who had been there since Stratton's time, braced itself for the shock.

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[26] Hearings * * * 1947, pp. 183–184.

[27] Ibid., p. 184. For Chairman Rabaut's great affection for and delight in Dr. Briggs, see Hearings * * * 1945 (Jan. 11, 1944) and Hearings * * * 1946 (Feb. 2, 1945), passim. For his reactions to Dr. Condon's criticism, see Hearings * * * 1947, passim.

The House subcommittee seems to have resented Dr. Condon's remarks on the state of Bureau facilities and equipment, his observations that there was serious duplication and overlapping in laboratory equipment and in shops, but that "with a complete reorganization of the administrative functions * * * we can introduce many simplified practices"; that the laboratories had become storehouses of obsolete records and equipment, "housing * * * useless items which should be disposed of"; and that despite its famed safety code experts, "the Bureau itself is probably one of the worst violators of its own safety codes" (Hearings * * * 1947, pp. 190–191).

The Congressmen queried Dr. Condon on his choice of speech and efforts at explanation. Despite his acknowledged unfamiliarity with Bureau statistics, they sought from him breakdowns in appropriations, work loads, expenditures and other data that neither Crittenden, Parsons, Thompson, Dellinger, nor other administrative officers at the hearing with Condon could answer offhand.

Three years later the House subcommittee sent up a group of investigators, including inspectors from the Public Buildings Administration, who over a 6-months' period surveyed Bureau grounds and buildings maintenance, the shops and laboratories, efficiency of operations and activities, use of personnel, and administration of research and testing. The questioning of Dr. Condon on the line-by-line details of the resulting House survey report, which everywhere found "the administration of the Bureau * * * weak and timid," occupied almost 75 pages of the hearings for 1951 (Feb. 23, 1950, pp. 2179–2230, 2242–2246, 2249–2260, 2288–2293). Midway in the quizzing, Congressman Daniel J. Flood of Pennsylvania interrupted to ask: "What is the most exciting thing that has happened in the Bureau of Standards in the year outside of this investigation by the

Dr. Condon was not to project a father image as had Stratton, softening the severity of his strictures. He was not to capture cooperation by his appeal for help, as had Burgess, or to inspire devotion by his presence, as had Briggs. Genial, gracious, and the world's best company away from his desk, Dr. Condon brought to an organization largely staffed with experimental physicists the new-broom outlook of the theoretical physicist. Perhaps more than most at the Bureau, he was aware that the war years had revolutionized science and scientific thought and, always a prolific writer, he had for some

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Appropriations Committee?" Dr. Condon could only deny it had been exciting; it had been rather depressing (p. 2237).

Prior to that questioning, Dr. Condon had talked steadily for over 2 hours (pp. 2158–2181) on the scope of activities of the Bureau, in answer to the repeated queries of the subcommittee: "What does a 'Bureau of Standards' mean?" "Does the Bureau's work embrace all of science and technology?"

At the next year's hearing, in March 1947, Congressman Karl Stefan of Nebraska replaced Rabaut as chairman. Stefan requested that Dr. Condon use layman's language before the committee, and raised again the joke about the scientist and the plumber, alleging that in reply to a New York plumber who had asked the Bureau about the use of hydrochloric acid for clearing drainage stoppages, a Bureau physicist had answered: "The efficacy of hydrochloric acid is indisputable, but the corrosive residue is incompatible with metallic permanence." Assuming that meant it was all right, the plumber wrote thanking the Bureau. The Bureau supposedly replied "We cannot assume responsibility for the production of toxic and noxious residue with hydrochloric acid and suggest you use an alternative procedure." The plumber wrote that he agreed with the Bureau: hydrochloric acid worked fine. Frightened at what might happen to the drainage of New York skycrapers, the Bureau was alleged to have resorted finally to simple speech: "Don't use hydrochloric acid. It eats hell out of the pipes." (Hearings * * * 1948, p. 289). The joke was brought to Dr. Condon's attention in each of the next 2 years. (Hearings * * * 1949, p. 538; Hearings * * * 1950, p. 493).

Representative Walt Horan of the State of Washington quizzed Dr. Condon about the purpose of the Bureau: "The title 'Bureau of Standards' should have some meaning. Otherwise we are going to get lost in a maelstrom of scientific research. What does 'Bureau of Standards' mean?" Continuing the questioning at the next hearing, Congressman Stefan advised Dr. Condon: "Give it to us as Dr. Briggs used to do * * * so that we can understand." At that and subsequent hearings, Dr. Condon was told, "Remember, we are laymen" (Hearings * * * 1948, p. 299; Hearings * * * 1949, p. 526; Hearings * * * 1950, p. 485).

Few men have written more clearly and simply about the complexities of modern physics or are more lucid in general exposition on any subject than Dr. Condon. His sole public rejoinder to his "problem of relations with Congress" occurred in a speech on Sept. 25, 1951, wherein he urged at some length the establishment of a committee of Congress concerned exclusively with science and scientific research in the Government (Physics Today, 5, 6, 1952).

time expounded the new physics in a steady stream of articles in the periodicals.[28]

The Bureau as presently established, Dr. Condon told the Appropriations Subcommittee, is "one of the finest scientific laboratories in the country, and it would be wise to maintain and extend its functions at this time, when there seems to be a disposition to recognize the importance of pure science in the Government's activities more than ever before." [29] As one who had made important contributions to pure science and at Westinghouse brought it to bear on industrial work, he was determined to advance pure science at the Bureau and to move the Bureau rapidly into the postwar world. "Think big!" he repeatedly told the Bureau staff. There was no alternative, and he challenged the staff with his cry, "Are you going to think in terms of peanuts or watermelons?" [30]

Dr. Condon himself thought big. His outstanding characteristic, it proved unnerving to some of the older members of the Bureau, and frightening to congressional appropriation committees. At his second appearance on the Hill, in March 1947, he was to stagger the committee members with a proposed $25 million budget, up from $5 million the previous year.[31] He talked of acquiring not one but three mass spectrometers for the Bureau, not one but two giant betatrons. He requested a fourfold increase in publication

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[28] See "Making new atoms in the laboratory," Sci. Am. 158, 302 (1938); "Sharpshooting at the atom," Pop. Mech. 74, 1 (1940); "Physics in industry," Science, 96, 172 (1942); "Tracer bullets of science," Pop. Mech. 77, 170 (1942); "Physics gives us nuclear engineering," Westinghouse Eng. 5, 167 (1945); "Science and our future," Science, 103, 415 (1946); "Is war research science?" Sat. Rev. Lit. 29, 6 (1946); "Science and the national welfare," Science, 107, 2 (1948); "60 years of quantum physics," Physics Today, 15, 37 (1962). See also file of his speeches and addresses on electronics, nuclear physics and other fields of Bureau research in NBS Historical File.

[29] Hearings * * * 1947, p. 178.

In the Steelman report to the President in 1947 on the role of the scientific agencies of the Government in the Nation's total scientific effort, the National Bureau of Standards was described as "* * * the principal Federal agency for research in physics, chemistry, and engineering; it acts as custodian of the Nation's standards of measurement, carries on research leading to improved measurement methods, determines physical constants and properties of materials, develops and prescribes specifications for Federal supplies and generally serves the Government and industry as adviser in scientific and technical matters and in testing, research, and development in the physical sciences." (The President's Scientific Research Board, Science and Public Policy, II, The Federal Research Program, Washington, D.C., 1947, p. 151.)

The statement reflected the view of Dr. Condon, who served as an alternate on the President's Scientific Research Board that prepared the report.

[30] Interview with Dr. John D. Hoffman, Apr. 28, 1964.

[31] Only 15 years later the Bureau's operating budget, exclusive of construction appropriations and transferred funds, would rise to $28.5 million.

funds, to expand the regular series of Bureau reports and prepare and publish multivolume tables of atomic energy levels, tables of the thermodynamic properties of chemical compounds, and a new and comprehensive handbook of physics. The Bureau had lately become the central agency in the Federal establishment for radio propagation research and service. Dr. Condon proposed that it also assume direction of all Federal research in synthetic rubber and in mathematical analysis and machine computers.

Was all this, the committee asked, contemplated in the act that created the Bureau? What about the present program? "Are all of your tremendous, gigantic activities out there carried on under a two-page law?" Congressman Stefan asked. Did the Bureau actually intend to "spend about nine or ten million dollars during the next fiscal year on the basis of a two-page law?" [32] The committee began vigorously debating with Dr. Condon on what he thought the phrase "bureau of standards" meant and what such a bureau was really supposed to do. He explained point by point how the new science, enormously stimulated by the war, had changed the Bureau and the Nation.

In many ways Dr. Condon was the very man for the Bureau in the years after the war, sparking new ideas and impulses among his associates and energetically recruiting a new scientific staff.[33] He acknowledged that recent technological developments demanded continuance of the Bureau work on rubber, plastics, textiles, liquid fuels and lubricants, on structural materials, ceramic and electroplated coatings, metallic alloys, electronic devices, and new ranges of radio wave frequencies. But "it would be a serious mistake * * * to let these projects in the fields of applied science interfere with the Bureau's work on fundamental problems of physics and chemistry and on methods of measurement and the standards and instruments which provide the basis for measurements of every kind," as primary responsibilities of the Bureau.[34]

New industries and wholly new technologies were to make unprecedented demands upon the laboratories. Perhaps no one at the Bureau com-

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[32] Hearings * * * 1949 (Jan. 20, 1948), p. 526.

[33] As he told the committee, in addition to the prewar cuts in staff, budget, and services, during the war much of the Bureau's basic research had been reduced and its best men put into war work, from which they had not yet been released. The Bureau was therefore very shorthanded in the field of fundamental research, and it was that area he sought to rebuild and expand. He hoped "to be allowed to do for peacetime fundamental research [in the Bureau] something of the sort that [had] recently been announced as part of the Navy's research plans, involving a high degree of collaboration, and intimate cooperation at the working scientists' level with universities throughout the country" (Hearings * * * 1947, pp. 178–179). Dr. Condon referred to the Office of Naval Research, organized later that year.

[34] Hearings * * * 1947, p. 176.

prehended better than the new Director the implications of nuclear technology, just emerging from its pioneer state, or the need for new instruments, materials, and processes spawned by that technology. More than administration and organization, the thought at the Bureau needed redirection, and as the cold war and then the Korean war came and research for defense intensified, Condon's redirection paid off in the years that followed.

New direction required new men, and Dr. Condon's arrival happened to coincide with an almost complete turnover of the top echelon. Age had begun to make its claims and many, like Dr. Briggs, past the retirement age, had waited only for the war to end. The five division chiefs who retired in 1945 had been with the Bureau since World War I or earlier.[35] Submitting requests for retirement with them were two section chiefs and a number of nonadministrative scientists and technicians with long years of service.[36] Still other division chiefs and 14 additional section chiefs reached retirement age over the next 4 years.[37] By 1950 the top echelons of the working force was essentially new, and the average age level at the Bureau had plummeted by some 20 years.[38]

In most instances division chief replacements were found among senior heads of sections. Continuity was further maintained by appointing Bureau-bred members to top administrative positions. The redirection of the Bureau was carried out principally through changes in organization, through new men that came in to head new fields of research, and the special assistants that Dr. Condon brought in from outside.[39]

Appointed Associate Directors early in 1946 were Dr. Crittenden and Dr. Dryden, the latter, upon going to NACA as director of research in 1947, replaced by Dr. Wallace R. Brode, organic chemist and spectroscopist from Ohio State. From the Navy Bureau of Ships that spring came Dr. John H. Curtiss as assistant to the Director, to take charge of mathematical and statistical research and analysis. From Westinghouse came two other assistants, Dmitri I. Vinogradoff, as liaison between the Bureau and foreign scientific and engineering laboratories, and Hugh Odishaw, to oversee sci-

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[35] They were Bearce of weights and measures, Dickinson of heat and power, Rawdon of metallurgy, P. H. Bates of silicate products, and Fairchild of trade standards.

[36] The section chiefs were Acree in chemistry and Stutz in mechanics.

[37] Retiring section chiefs were Curtis and Dellinger in electricity, Miss Bussey, Wensel, Van Dusen, and Ingberg in heat and power, Bridgeman, Brooks, and Peters in optics, Smither in chemistry, Tuckerman and Whittemore in mechanics, Wormeley in organic materials, and McAdam in metallurgy.

[38] Dr. McPherson of organic materials was to say that in 1943 he was the youngest division chief in point of service; by 1950 he was the oldest. Interview, Dec. 5, 1961.

[39] In a few instances, senior section chiefs were made assistant division chiefs as areas of the Bureau research were phased out or several sections were combined.

entific and technical information and Bureau publications.[40] And in a reorganization of housekeeping elements, budget and management, personnel, plant, and shops became formal divisions.

Changes in Secretary Wallace's Visiting Committee to the Bureau included the appointment in 1945 of Harold C. Urey, research chemist at the University of Chicago and Nobel laureate, and in 1946 of Eugene P. Wigner, physicist at Princeton and director of research at the Oak Ridge laboratories, who was to receive the Nobel Prize in 1963. The appointment of two theoretical physicists resulted in a significant change in the composition of the Visiting Committee, long dominated by representatives of industry. Urey and Wigner joined long-time members Gano Dunn of the J. G. White Engineering Corp., Karl T. Compton, president of MIT, and William D. Coolidge, director of research at General Electric.

In place of the informal notices and occasional memoranda on administrative matters that previous directors had issued were the numbered Bureau Orders, Administration Procedural Memoranda, and Bureau Memoranda introduced in December 1945. They were timely, for the next decade was to see more changes in organization, policies, and staff than in all the previous years put together. For one thing, the wartime influx of workers that raised the staff above the 2,000 level for the first time in Bureau history did not recede with the end of hostilities but increased steadily. Administration grew proportionately more complex.

Between serving on the McMahon committee and familiarizing himself with the Bureau establishment, it was May 1947, a year and a half after assuming the directorship, before Dr. Condon completed his initial reorganization of the Bureau structure.[41] In the new order, divisions were merged to bring related interests or functions together,[42] new divisions and new sections were created,[43] and still other sections were relocated as a matter of logic. Several sections, some of them one- or two-man units, were absorbed

[40] A third special assistant, Nicholas E. Golovin, trained in physics but then a management specialist from Naval Ordnance, arrived in the spring of 1949 to take over the analysis and planning of Bureau technical programs.

[41] Announced in NBS BuOrder 47–14, May 19, 1947.

[42] The new electricity and optics division included three sections from optics (photometry and color, optical instruments, and photographic technology) that depended upon electrical standards. Simplified practices and trade standards were combined as the commodity standards division.

[43] The atomic physics division grouped all Bureau facilities and activities relating to atomic and molecular physics and also certain phases of optics and of electronic physics. The Central Radio Propagation Laboratory stemmed from the radio section in electricity. Building technology division took over the fire resistance and heat transfer sections of heat and power, the masonry section (renamed structural engineering) from silicate products division, and the whole of the codes and specifications division. The applied mathematics division had its origin in the New York mathematical tables project.

in larger units elsewhere.[44] Two divisions saw little more than a name change as weights and measures became the metrology division, and clay and silicate products became the mineral products division.[45] And as Dr. Stratton had once headed his own optics division, so Dr. Condon for a time doubled in brass, as chief of his new atomic physics division.

Laboratory space became critical even before the President's decision in 1950 to construct the hydrogen bomb and the onset of the Korean war. Under the shadow of atomic war, talk of dispersal of military installations and defense facilities was translated into policy. The pressure for space and Truman's refusal to permit expansion of facilities in Washington led to the establishment of two Bureau stations far from the Nation's Capital, the Corona Laboratories in California and the Boulder Laboratories in Colorado.

Two major Bureau projects stepped up when the Korean war began were those in nonrotating proximity fuzes for Army Ordnance and guided missiles for the Navy. Additional temporary structures across Van Ness Street were sufficient to accommodate the augmented fuze group, but the missile staff was approaching a hundred members and its development mission had been accelerated by the requirement for an expanded series of production models for possible use in the Pacific. The project needed space quickly and there was no time to build.[46] On June 1, 1951, the project left Washington and moved into surplus Navy hospital structures, idle since the war, at Corona.[47]

Still another cooperative project, for the Atomic Energy Commission, called for large-scale assistance from the Bureau and required facilities for which space was lacking in Washington. The year before, in 1949, a 220-acre tract had been donated by the citizens of Boulder, Colo., at the foothills of the Rockies, on what was then the outskirts of the city, for new radio facilities for the Bureau. On the slope back of the site marked out

[44] Underground corrosion went to metallurgy. The huge special projects section (i.e., guided missiles) in mechanics became part of the ordnance development division, and a ballistics group in electricity was transferred to the new division. Transferred to chemistry and no longer separate units were the polarimetry, radiometry, and interferometry sections of optics. Combined with the temperature measurements section of heat and power were the division's thermometry and pyrometry sections. One section in heat and power, aircraft engine research, was discontinued in 1948 when the work was taken over by the NACA laboratory at Cleveland.

[45] Weights and measures administration, for a time a section in metrology, became a separate Office of Weights and Measures in October 1947, and was later joined by an Office of Basic Instrumentation. All of these organization changes are shown in app. J.

[46] Letter, EUC to Secretary of Commerce, Dec. 13, 1949, and letter, EUC to Director, Bureau of the Budget, Sept. 13, 1950 ("General Correspondence Files of the Director, 1945–1955," Boxes 4 and 6).

[47] BuOrd 51–18, June 1, 1951; Hearings * * * 1952 (Apr. 10, 1951), pp. 497–502; interview with Dr. Condon, Oct. 27, 1963.

for the radio laboratories, ground was leveled for the erection of new Bureau cryogenic laboratories.[48]

TECHNOLOGICAL vs. BASIC RESEARCH

In 1944 Harry S. Truman was nominated to the Vice-Presidency, succeeding Henry A. Wallace who had held that office during the previous term. On the day after the inauguration Wallace replaced Jesse Jones as Secretary of Commerce.[49] It was a brief tenure. Truman became President a month later, and in the fall of 1946 Wallace's differences with the President's policy toward the U.S.S.R. led to his resignation.

Jesse Jones, as had his predecessors under Roosevelt, Daniel Roper and Harry Hopkins, found that "The President was never genuinely friendly to business, and there was little the Secretary of Commerce could do for business and industry * * *."[50] Nevertheless, Wallace asked for the Commerce post, in exchange for his loss of place on the ticket.

Wallace had reform in mind, for he was convinced that "not until businessmen were educated could any sort of economic justice be attained in this country."[51] A biographer has said: "As Secretary of Commerce, Wallace * * * settled down into relative obscurity for nearly a year. However, during this period significant changes took place within the ornate walls of the Commerce Building. A strong friend of small business was now in power. Expansion of technical and other assistance for small firms from $300,000 to $4,500,000 per year was initiated."[52] He intended the Bureau to assist in the aid to business.

In a prepared statement before the House Appropriations Subcommittee in January 1946, Wallace outlined his proposed reorganization of the Department. It proved rather a reemphasis of effort than a reorganization,

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[48] The site was acquired in mid-December 1949 and construction began in the summer of 1951 (Department of Commerce records, NARG 40, file 83583; NBS BuOrd 52–7, Aug. 15, 1951).

[49] For behind the scenes accounts of the juggling of posts and men, see James A. Farley, Jim Farley's Story, pp. 371 ff; Grace Tully, F.D.R.—My Boss, p. 188; Raymond Moley, 27 Masters of Politics, (New York: Funk & Wagnalls, 1949), pp. 84 ff.

[50] Jesse Jones, Fifty Billion Dollars, p. 257. Almost wholly taken up with the operations of the Reconstruction Finance Corporation he also headed, Jones left Department of Commerce details to his Under Secretary, Wayne C. Taylor. Ibid., p. 538.

[51] Russell Lord, The Wallaces of Iowa (Boston: Houghton Miffln, 1947), p. 615.

[52] Karl M. Schmidt, Henry A. Wallace: Quixotic Crusade, 1948 (Syracuse University Press, 1960), p. 7. For the fear that Wallace as Secretary would establish, through the National Bureau of Standards, Federal consumer standards in place of trademarks, see George E. Sokolsky article in "New York Sun," Feb. 27, 1945, copy in NBS Box 503, IDA–ASA.

a new deal designed to promote foreign trade and provide special services to business in the fields of science, technology, management, and marketing. He intended to expand the Department's output of basic statistical information and provide detailed analyses on the economic outlook for the use of business, Government, and the public, and to this end the scientific and technical bureaus of his Department must be strengthened. What he had in mind for the National Bureau of Standards was not spelled out, except that it was to be responsible for "technological research and development on problems of direct and practical interest to industry." [53]

Before the same subcommittee 2 weeks later, Dr. Condon asked for increased funds for intensified activity by the Bureau "from an industrial and economic point of view" in the fields of metallurgy, high polymers, building materials, thermodynamics, rubber, hydraulics, atomic energy, electronics, and radio propagation. Their research was "no more than simple national wisdom." The four fields in which the Bureau planned to concentrate its greatest resources, however, were nuclear physics, building materials and structures, radio propagation, and rubber chemistry. They would require "research in fundamental science of a long-range and basic character" and "a great deal closer cooperation in fundamental research by the universities." [54]

Dr. Condon's remark, that his Assistant Directors would "see that appropriate research work is initiated in new fields * * * [and] that there is not too much effort expended on routine tests [at the expense of basic research]" did not entirely satisfy the subcommittee, the Bureau of the Budget, or senior members of the Bureau who viewed testing—with an appropriation of $1.5 million annually—as a primary and irreducible function of the Bureau.[55]

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[53] Hearings * * * 1947, p. 5. Considering its importance to the Government, said Wallace, the program and appropriation for the Bureau were modest, no more than "comparable to the scientific program of a single large private corporation" (ibid., p. 8).

[54] Hearings * * * 1947, p. 178; NBS Annual Report 1946, p. 172. Discussed at length at the hearings but unreported elsewhere was an appropriation in the budget of $100,000, to provide specifications for consumer goods. Since the 1930's the Bureau's codes and specifications division had maintained a small section called "consumer contacts." Almost certainly at the prompting of Secretary Wallace, funds were inserted in the 1947 budget to expand the section to 32 members in order to extend the work on Federal specifications and the factfinding tests of products for the Federal Trade Commission to the consuming public. As a beginning, the Bureau was to develop at once methods of testing and test machines for determining consumer standards and specifications in leather goods, to "provide simple means of finding out what we get for our money" (Hearings * * * 1947, pp. 205–206, 217–220). It was a short-lived project. Within months, along with most of the simplified practices and trade standards divisions of the Bureau, it was transferred to another agency of Commerce. Its chief, George N. Thompson, went to the Bureau's new building technology division.

[55] Hearings * * * 1947, p. 191; interview with Dr. McPherson, Dec. 5, 1961.

Amid the general apprehension over the unsettled conditions of the postwar world, Condon anticipated what was later to become a commonplace, that any interruption in the flow of new knowledge, or even a slackening of its pace, posed a potential threat to national security. The war demonstrated the necessity of narrowing the leadtime between the discovery of new knowledge and its application, and the Federal Government had come to recognize its responsibility for securing the basic research that made purposeful application possible.

In a lighter moment early in the hearings in 1946, Congressman Rabaut said to Condon: "With this atomic age on our hands we must treat your Bureau with respect, as we do not want to get in wrong with anybody who has anything to do with it." [56] But neither Congress nor the public was quite ready yet to pay for the basic research of the atomic age. A year later when Dr. Condon presented his research program in greater detail, the mood of the subcommittee was economy.

Dr. Condon's original request to the Department of Commerce for 1948 funds totaled $25 million, almost four times the direct appropriation of the previous year. The new Secretary of Commerce, W. Averell Harriman, had whittled it to $17.1, and the Bureau of the Budget had brought it down further to $10.6 by deleting, "without prejudice," the Bureau's proposed research in synthetic rubber, as well as research auxiliary to the atomic energy program (the latter in the amount of $2.5 million), by reducing initial construction funds for a new radio propagation laboratory in Washington by two-thirds ($1.9 to $0.6 million), and refusing most of the proposed cost of rehabilitating the Bureau plant (including $1.5 million for electrical modernization, $2 million for plumbing). Left more or less intact were the new programs planned in building materials, hydraulics, computers, X-ray research for medicine and industrial radiography, fundamentals of metallurgy, fundamental studies in the properties of chemical compounds, electronics, high polymers, and radio propagation.[57]

The kind of industrial research that the Bureau had long carried on, said Dr. Condon, was no longer necessary, except in building. With industry booming, the civilian economy was running at the highest level in its history, about $200 billion a year, and more than 2,400 industrial laboratories were engaged in keeping that production going. As a consequence, the laboratories were making unprecedented demands on the Bureau

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[56] Hearings, ibid.

[57] Hearings * * * 1948 (Mar. 12, 1947), pp. 287–292. Including $1.1 million for equipment and facilities, the final appropriation came to $7.9 million, representing a slight increase over the previous year.

for the fundamental instrumentation they needed and could not do.[58] Some of the new industries, especially those based on electronics, required work on measurements that had never been done before. And the Bureau had to continue to supply basic information to many of the new small businesses that could not afford research laboratories. The funds for this research, on which the Bureau of the Budget had agreed, were approved, but not without a struggle.[59]

Even before final approval, the Bureau began to free itself from considerable industrial-type research, as well as direct research for industry, by abandoning some of its former lines of investigations or shifting to more basic aspects. Research in the rare sugars, for example, turned to wider studies in carbohydrate chemistry and in radioactive carbohydrates. Much of the basic work in plastics, leather, paper, rubber, and other organic materials became centered in the new science of high polymers. In optical glass, production was sharply curtailed and research shifted to the theory and constitution of glass in general. Because of the delay imposed by the Korean war, it was 1957 before all production of optical glass ceased and the plant was dismantled.[60]

Still another Bureau activity, its member participation in the work of the American Standards Association, diminished after 1948 when the association was incorporated under the laws of New York State. As a result, the Department of Commerce and other Federal agencies withdrew from active participation in the administrative affairs of the association, although members of the Bureau continued to serve on the council, boards, and technical committees of the association, as they do to the present day.[61]

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[58] Hearings * * * 1947, p. 203; Hearings * * * 1948, p. 290; Hearings * * * 1950, p. 483.

[59] In final justification of Bureau funds, Dr. Condon found, at the request of the subcommittee, that the estimate of total appropriations for all Federal research and development in the 1948 budget came to $730 million, of which $10 million, including construction, equipment, and facilities, represented the Bureau's share (Hearings * * * 1948, pp. 299–300).

[60] NBS Annual Report 1948, pp. 218, 230–231; Annual Report 1951, p. 36; NBS Consolidated Report on Projects, fiscal year 1958, Project 0902–40–4408; interview with Clarence H. Hahner, May 6, 1964.

[61] NBS Report 6227, "American Standards Association, Inc." (1958), pp. 11–12 and app. 8. The propriety of NBS membership, on the premise that the Bureau was more consumer-directed than ASA, was first raised in memo, Soliciter, Department of Commerce, for Under Secretary of the Department, June 11, 1943. NBS and Federal withdrawal was also urged in memo, EUC for Secretary of Commerce Harriman, Oct. 16, 1946, based on the doubtful legal grounds of the mixed membership and as misleading to the public (correspondence in NARG 40, Secretary of Commerce, file 75388/18). The formal resignation of the NBS and Department of Commerce from ASA was accepted in letter, Secretary ASA to Secretary of Commerce, July 29, 1948 ("General Correspondence Files of the Director, 1945–1955").

One whole division at the Bureau, commodity standards, a recent consolidation of the trade standards and simplified practices division, was transferred with its staff of 30 out of the Bureau to the Office of Technical Services in the Department of Commerce in July 1950. Essentially nontechnical in nature, and with minor justification under Bureau legislation, the division had little relevance to the postwar mission of the Bureau, to provide standards of physical measurement.[62]

Talk of reducing routine testing, as an impediment to the scientific work of the Bureau, met strenuous objections from both inside and outside the Bureau. Some lines, such as clinical thermometer testing, were subsequently discontinued, and the workload in testing electric lamps, cement and other large-scale Federal purchases was somewhat lightened by resorting to statistical analysis test procedures. But while some routine calibrating and testing decreased, that of materials and equipment and the calibration of instruments increased steadily through the 1950's and 1960's.[63] To share the administrative burden on division and section chiefs, responsibility for all testing was subsequently centered in a new Associate Director for Testing.

Plans to increase fundamental research and reduce technological research foundered on a simple economic fact. The military services and the Atomic Energy Commission had vast sums available for research in the new technologies, and the Bureau had the staff, facilities, and knowledge in these fields. As the principal legacy of World War I had been new fields of industrial research, so that of World War II brought to the Bureau the realms of electronics and nuclear energy. Both offered as much opportunity for pure research as for applied research and technical development. For that reason, the technology could not be refused.

Thus in 1947, with many wartime programs still uncompleted, the Bureau reported military research still "a considerable portion" of the total work of the Bureau. By 1951, in the midst of a new emergency, the greater part of Bureau research was again concerned with national defense projects.[64]

For this research the Bureau acquired a great array of new tools: an electron microscope, the first of its kind ever constructed, using energies up

[62] Letter, Secretary of Commerce Sawyer to EUC, May 26, 1950, and attached correspondence ("General Correspondence Files of the Director, 1945–1955," Box 4).

[63] Tests, calibrations, and standard samples in 1946 had an estimated value of $1.2 million. By 1960, test and calibration fees alone amounted to $2.7 million, and by 1963 to $3.4 million (NBS Annual Reports).

[64] NBS Annual Report 1947, p. vii; Annual Report 1951, p. 1. "Three-fourths of the total effort * * * is directed toward meeting vital requirements of the defense program" (NBS BuMemo 52–11, Sept. 17, 1951).

to 1.4 million volts, for research in metallurgy and electron optics; [65] and a magnetic electron spectrometer, for the study of the beta- and gamma-ray spectra of radioactive isotopes and measurement of their disintegration schemes and nuclear energy levels.[66] A mass spectrometer was obtained with the help of the Office of Naval Research, for precise measurement of nuclear masses. It was to be used initially for research in the components of synthetic rubbers.[67] A 50-million-volt betatron was also acquired, for studies in protection and proper shielding against high-energy radiation; [68] and a 1.5-million-volt X-ray tube, for an investigation of the broad X-ray beams used in medical and industrial radiography.[69] Still another new "tool" was the Bureau's ultrasonic laboratory for special studies of the properties of gases and liquids, employing sound waves of extremely high frequency.[70]

In the field of electronics, military and naval ordnance projects predominated, including advanced design work on nonrotating proximity fuzes; development of electronic and servomechanism controls for an advanced guided missile, the Kingfisher series; development of a proximity fuze for guided missiles; and refinement of the toss bombing device, the aircraft bomb director. Important to these projects was the research initiated in the basic elements of electronic computing machines, and the investigation of electronic components in a new electron tube laboratory set up at the Bureau. A secondary purpose of the laboratory was to apply its knowledge of electronic instrumentation and controls to measurement problems in the other divisions of the Bureau.[71]

Apart from the highly classified work on proximity fuzes for guided missiles, the research in electronics centered on electron tubes, printed circuits, and automatic computers. The Bureau designed special equipment

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[65] NBS Annual Report 1948, pp. xv, 214–215. For the Bureau's new microsectioning procedure involving organic materials, in high polymer studies employing the electron microscope, see RP2020 (Newman, Borysko, and Swerdlow, 1949) and Hearings * * * 1950 (Feb. 23, 1950), p. 2169.

[66] NBS Annual Report 1946, p. 183.

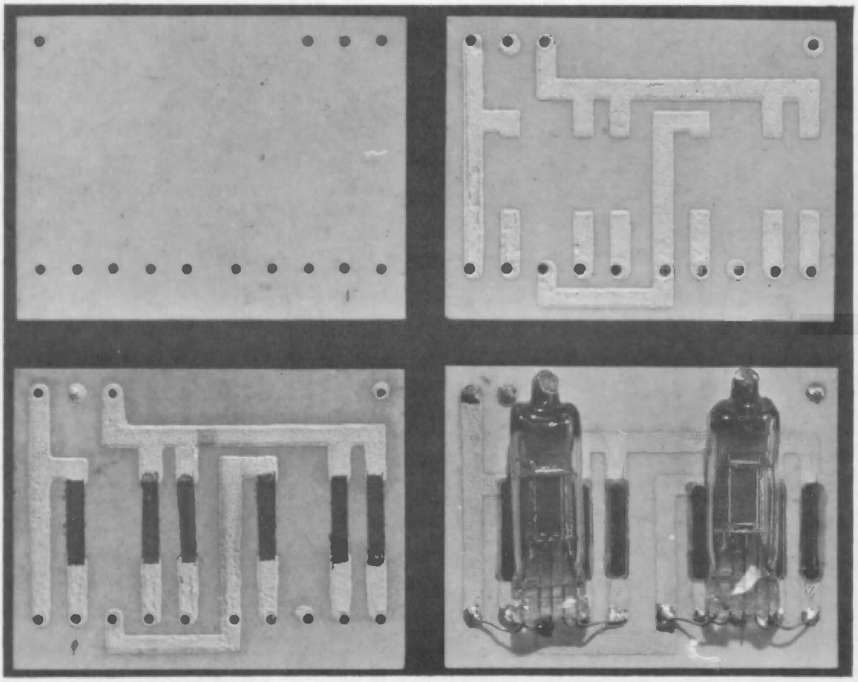
[67] LC791, "The mass spectrometer" (1945) ; NBS Annual Report 1946, p. 193.

[68] NBS Annual Report 1946, p. 184; Hearings * * * 1948, p. 356. With the installation of the first betratron in late 1949, the Bureau ordered a second unit, a 180-million-volt synchrotron (Hearings * * * 1951, p. 217; Science, 105, 230, 1947). Unlike the conventional X-ray machine used in the treatment of most cancer patients, the betatron is used against deepseated cancers, producing high-speed electrons that on striking an internal target produce X rays. Its electron beam can also be used directly to irradiate a tumor. The machines at the Bureau were for studies in basic radiation physics, not medical research or treatment of patients.

[69] NBS Annual Report 1946, p. 184.

[70] NBS Annual Report 1948, p. 221.

[71] NBS Annual Report 1946, pp. 201–203.



The four stages of an early printed electronic circuit: the plate, the circuit wiring, addition of the resistors, and final assembly with miniature tubes.

for measuring the characteristics of the growing family of electron tubes to determine, among other things, the principles by which their life service might be extended.[72] A new field of research was the semiconductors, crystalline materials of high purity, such as germanium and silicon. With their electrical conductivity between that of a metal and an insulator, and their unique ability to change their resistance characteristics, they opened new vistas in the development of communication equipment.[73] They appeared first in the crystal diode developed during the war for radar, and subsequently in the crystal triode or transistor, as replacements for the vacuum tubes in amplifiers. The ubiquitous pocket transistor radio was less than a decade away.

New advances were made in printed circuits, first devised for the proximity fuze, that substitute printed wiring, resistors, and coils for the conventional rigging in electronic devices. Along with subminiature tubes, semiconductors, and circuit design, the printed circuit established a whole

[72] NBS Annual Report 1948, p. 244; Annual Report 1949, p. 80.
[73] NBS Annual Report 1949, p. 21; Annual Report 1951, p. 4.

new field of electronic miniaturization for which the Bureau was to provide useful engineering data.[74]

Problems submitted to the Bureau by the Navy Bureau of Aeronautics included devising reasonably stable and long-lived electronic components capable of withstanding rapid changes in temperatures, and design of miniaturized amplifiers with printed circuits. Within a year the Bureau produced a radar-type amplifier with the same electrical performance but one-quarter the usual size, and a miniature battery-powered radio transceiver, for use as an air-sea rescue device. A miniature radio range receiver, a navigation aid for the Navy, which fitted into a sealed envelope 6 by 5 by 1¾ inches, had the range and power of a conventional 12-tube unit. These amplifiers and receivers were made possible in part by a Bureau-built rotary printer that applied printed circuits on either flat or cylindrical surfaces.[75] A printed resistor, applied by a silk-screen process (later replaced by an adhesive-tape resistor), and a tiny ceramic capacitor, the latter devised at the request of the Signal Corps, contributed to still more rugged and efficient miniaturization.[76]

Much of the work on electronic tubes, printed circuits, and miniaturization saw its most important application in the automatic electronic computing machine project set up at the Bureau for Army Ordnance early in 1946. Two decades earlier, about 1925, the present era of mechanical computation began when Dr. Vannevar Bush and associates at MIT constructed a large-scale computer run by electric motors. This and an improved model completed in 1942, both requiring hand computations as an adjunct to the machines, were extensively used during the war in the computation of artillery firing tables. The modern electronic computer had its genesis in the work of Dr. John W. Mauchly, physicist at the Moore School of Electrical Engineering, University of Pennsylvania. In 1942, convinced that the mechanical calculation of firing tables could be speeded up by the application of electronics, he began the study of such a machine. Four years later, with J. Presper Eckert, Jr., as designer, the Electronic Numerical Integrater and Automatic Computer (ENIAC) was completed, performing 5,000 additions a second, where mechanical calculators handled 10 a second.[77]

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[74] C468, "Printed circuit techniques" (Brunetti and Curtis, 1947); M192, "New advances in printed circuits" (1948), a symposium discussing their application to radio, radar, TV, guided missiles, airborne electronic equipment, computers, and industrial control equipment.

[75] NBS Annual Report 1949, pp. 49, 59, 61; Annual Report 1951, pp. 69–70.

[76] NBS Annual Report 1951, pp. 2, 71; C530, "Printed circuit techniques: an adhesive-tape resistor system" (B. L. Davis, 1952).

[77] Eckert, Mauchly, et al., "Description of ENIAC," Applied Mathematics Panel Report 171.2R (NDRC, November 1945); Jeremy Bernstein, The Analytical Engine: Computers—Past, Present and Future (New York: Random House, 1964), pp. 50, 54–55.

Capable of handling large amounts of statistical data with revolutionary speed, thoroughness, and efficiency, the new machines permitted, among other things, the solution of equations hitherto, from the standpoint of time, impossible to solve, and were to take the guesswork out of problems previously undertaken by constructing costly experimental equipment, such as the wind tunnels used in aerodynamic studies.

The computer project at the Bureau was first assigned to the machines development section of the applied mathematics division. An increasing amount of its component research, however, was carried out by another computer section, that under Dr. Chester H. Page and Samuel Alexander in Dr. Astin's electronics division. In the latter division, utilizing its research in specialized electron tubes, high-speed memory organs, transference means, input and output equipment (a system of electric typewriters and magnetic recording devices derived from standard teletype machines), and transcriber and converter elements, the first Bureau computer was built. A crucial breakthrough was the substitution of the new germanium crystal diodes for electron tubes in all switching and computing elements, with tubes used only for power amplification.[77]

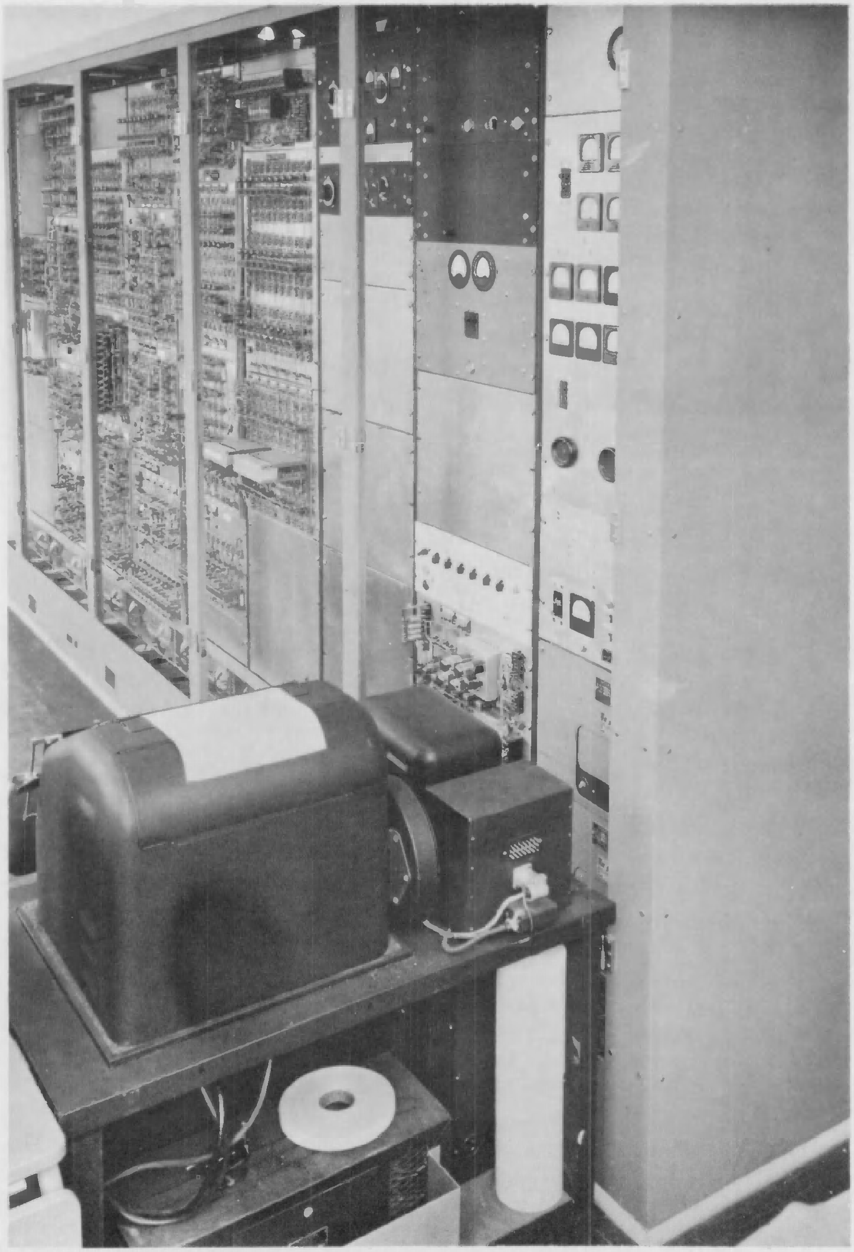
In 1947, a year after the Bureau began its research on computer components, the Bureau of the Census and the Office of Naval Research, with assistance from the Air Force, contracted with the Bureau for the construction of two full-scale computers at an estimated cost of $300,000 each. Their design was assigned to the Eckert and Mauchly Computer Corp., the Raytheon Manufacturing Co., Massachusetts Institute of Technology, and Tufts College. One was to be assembled in the electronics division in Washington, the other at the Bureau's Institute for Numerical Analysis, recently organized at the University of California at Los Angeles.[78]

Presiding over the computer project, Dr. Condon saw the Bureau as "the centralized national computer facility" for the Government, the Washington unit serving the eastern half of the Nation, that at Los Angeles the

[77] NBS Annual Report 1946, p. 202; Annual Report 1948, pp. 240, 256; Annual Report 1950, p. 81.

The germanium or silicon crystal as transistor, first developed by Bardeen, Brattain, and Shockley, physicists at the Bell Telephone Laboratories, in 1948, conducts electrical current in much the same way as a vacuum tube. Unlike the tube, which boils off electrons that flow as directed by an electrical field, the transistor operates without heating and there is nothing to burn out (Bernstein, The Analytical Engine, p. 68).

[78] Negotiations began with memo, Director NBS for Director of the Census, Apr. 26, 1946, sub: Design and construction of electronic tabulation equipment ("General Correspondence Files of the Director, 1945–1955"); NBS Annual Report 1947, p. 187; Hearings * * * 1949, p. 523.



The Standards Eastern Automatic Computer (SEAC), its cover doors removed, with the operator's table in the foreground.

From left to right, the nine racks of the computer include the control unit, the arithmetic unit, the time pulse generator, the clock pulse generator, the magnetic wire and magnetic tape input-output unit, controls and power supplies, and electronic circuitry for the punched tape input-output system. The small panels at the bottom of each rack hold "grasshopper" fuses to protect the circuits above them.

western half. Centralizing in the Bureau the solution of complex mathematical problems confronting Federal agencies in aeronautics, atomic and nuclear physics, ballistics, and guided missiles, as well as analysis of massive data problems, would avoid duplicating computer facilities in other agencies and make maximum use of the Bureau facility, as was being done in radio propagation.[79]

The "central facility" idea was short lived. Other agencies wanted their own computers, and at the request of the Army Map Service and the Air Comptroller, the Bureau entered into additional contracts with Eckert and Mauchly.[80]

While awaiting design results, the Bureau began work on a small-scale unit, the NBS Interim Computer, with which to test components, train operators, and handle computational work in its laboratories. The successful operation of the unit led to its expansion, with Air Comptroller support, as a full-scale machine. In the autumn of 1949, 20 months after beginning construction, it emerged as the National Bureau of Standards Eastern Automatic Computer (SEAC).[81]

The fastest general purpose, automatically sequenced electronic computer then in operation, SEAC was dedicated on June 20, 1950. Failure of a single one of its more than 100,000 connections and components, even for a millionth of a second, would result in computer misfunction. Yet operating often on a 24-hour-a-day, 7-day week, SEAC performed for 4,000 hours in its first 9 months without a malfunction. Besides handling a number of classified problems for the military services and the Atomic Energy Commission, it carried out computations on electronic circuit design, optical lens calculations, statistical sorting and tabulating studies for Social Security

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[79] Hearings * * * 1948, pp. 350–351. The idea persisted, in NBS Annual Report 1950, pp. 71–72, and Annual Report 1951, p. 67.

[80] Discussed in Hearings * * * 1956 (Apr. 18, 1955), p. 29.

[81] NBS Annual Report 1948, p. 239; Annual Report 1949, pp. 64–65; Hearings * * * 1951 (Feb. 23, 1950), p. 2175; Hearings * * * 1952 (Apr. 10, 1951), pp. 502–504; interview with Dr. Edward W. Cannon, July 7, 1964.

In 1950 there were no more than six or eight electronic computers in operation. By 1960 over 10,000 of one type or another had been built. Eckert and Mauchly's Electronic Digital Variable Automatic Computer (EDVAC), for the Ordnance Ballistics Research Laboratory at Aberdeen, was completed in 1950. Between 1951 and 1953 Eckert and Mauchly, at Remington Rand, constructed six Universal Automatic Computers (UNIVAC), the development and assembly of the first of these commercial stored-program computers monitored by NBS for the Bureau of the Census. See Office of Naval Research report, "A survey of automatic digital computers" (Washington, D.C., 1953).

Assembly of the chassis of the Standards Western Automatic Computer (SWAC). SWAC was designed and constructed by the Institute for Numerical Analysis staff to provide a tool for research in numerical analysis. Its relatively high speed resulted from its very rapid cathode-ray-tube type of memory.

and Census, design of supersonic nozzles, and computed data on the crystallography of cement compounds and on the penetration of X rays.[82]

SEAC's high computing speed made it possible to add or subtract pairs of 11-digit numbers 1,100 times a second and multiply or divide them 330 times a second. It completed arithmetical operations of addition or subtraction alone in 50 microseconds, multiplication or division problems in 2,500 microseconds. In a problem of pure mathematics, the machine was directed to compute the factors of any given number up to 100 billion. It rapidly determined that the number 99,999,999,977 has no factors and is therefore a prime number. To do this the machine had to divide 99,999,999,977 by 80,000 different divisors, and solved in 30 minutes a problem that would take a man 2 months working 8 hours a day with a desk calculator.[83]

Dedicated on August 17, 1950, but not fully operative until early in 1952 was the Bureau's second machine, the Western Automatic Computer (SWAC), at the Institute for Numerical Analysis in Los Angeles. It was to handle special problems of the aircraft industry on the west coast for the Navy Department, as well as engineering, physics, and mathematical calculations required by the Bureau institute and by other Federal agencies in the area.[84]

In the course of work on input and output mechanisms for the first Bureau computer, Jacob Rabinow of the electronic division's ordnance development laboratory invented a unique type of electromagnetic clutch. Widely heralded as a new physical principle, the clutch was based on the discovery that frictional forces between solid surfaces and certain types of fluid media (in this case, an oil suspension of iron powder) can be controlled

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[82] NBS Annual Report 1951, pp. 2, 75–76.

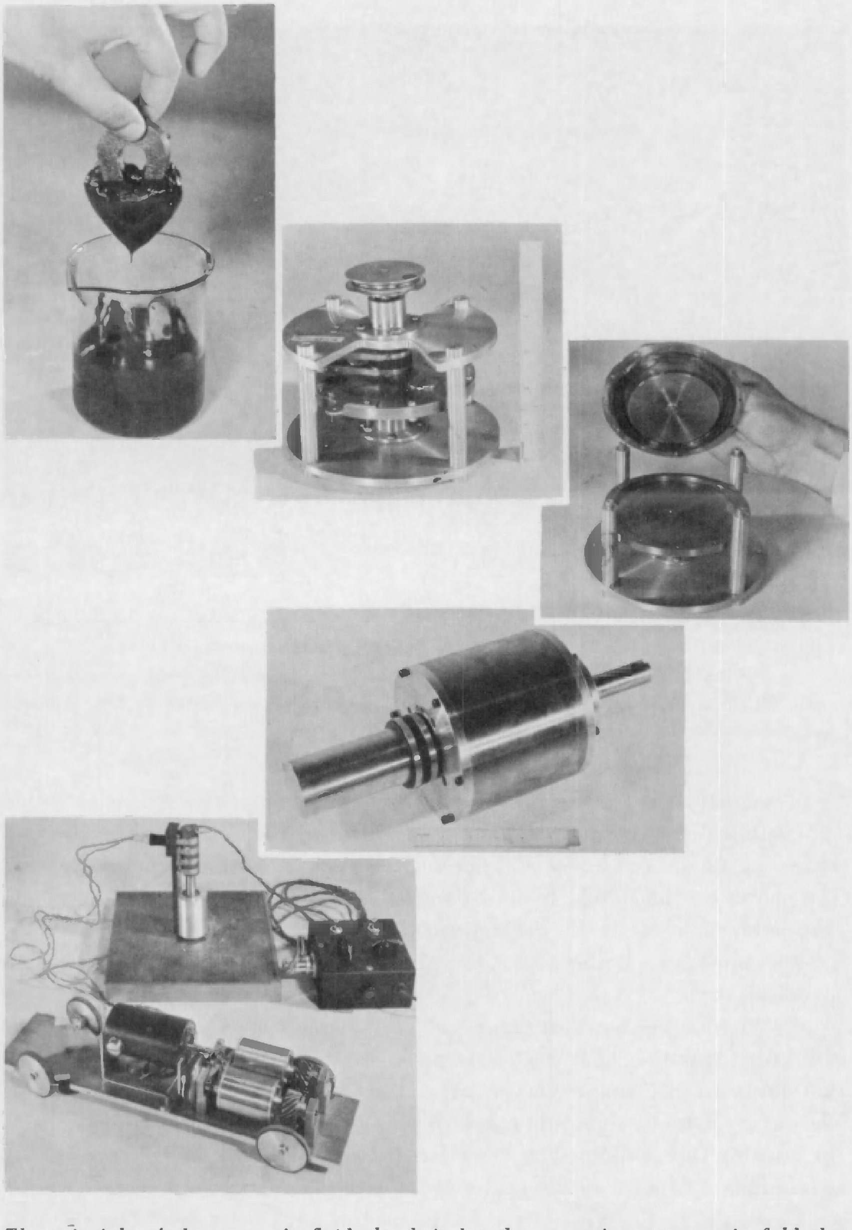
On the use of SEAC to make certain of the calculations for the design of the H-bomb, Edward Teller in "The work of many people," Science, 121, 273 (1955), wrote: "With the help of this facility [a * * * very efficient machine], initial details of the plans were ironed out in a few weeks rather than in tedious months."

[83] NBS Annual Report 1950, pp. 80–81; S. N. Alexander, "The NBSEAC," and Ralph J. Slutz, "Engineering experience with the SEAC," Proc. AIEE–IRE Computer Conference, February 1952, pp. 84, 90.

A second SEAC, DYSEAC, intended for Bureau research alone, was completed in July 1953 but subsequently went to the Signal Corps. See NBS Report 1951, "System specifications for DYSEAC" (Alan L. Leiner, 1952), and C551, "Computer development (SEAC and DYSEAC) at the NBS" (Alexander, Leiner, Slutz, et al., 1955). Other machines based on SEAC were FLAC for the Air Force Missile Test Center at Cocoa, Fla., and MIDAC for the University of Michigan.

[84] NBS Annual Report 1950, pp. 1, 2, 80; Annual Report 1952, p. 2.

SEAC, patterned after EDVAC, employed an acoustic delay line or serial memory. SWAC, patterned after a British computer, had an electrostatic or parallel memory. The two computers were about equally complex, but SEAC had a 512-word memory to SWAC's 256-word memory. Interview with Dr. E. W. Cannon, July 7, 1964.



The principle of the magnetic fluid clutch is based on creating a magnetic field that causes iron particles suspended in oil to become highly viscous and grab together into an almost solid mass.

In the magnetic clutch this oil-and-iron fluid is contained between steel plates. The plates, which operate independently in the absence of electric current, lock together when the current flows into the fluid.

The model car, above, demonstrates the possible use of the principle in automotive vehicles, where two of the magnetic clutches, with suitable gearing, provide the main power transmission.

Dr. Condon of the Bureau and Secretary of the Treasury John F. Snyder, right, demonstrate the NBS electronic currency counter with stacks of worn-out $1 bills.

The assembly on top of the cabinet consists of the turntable and feeding mechanisms and the phototube-light-mirror system. The cabinet houses a binary counter, control circuits, and an air compressor.

by a magnetic field. The principle of Rabinow's magnetic fluid clutch had application not only in computers but, with modifications, in servomechanisms, automatic machines, and possibly even in automobile transmissions.[85] The patent for the clutch, in accordance with Bureau policy, was assigned to "the public interest." So great was that interest that within a year almost 2,000 industrial engineers visited the Bureau to get test data on the invention.[86]

Another device that came out of the electronics division about the same time was the NBS electronic currency counter, a sensing instrument that automatically counted worn paper bills at the rate of 30,000 per hour. The device instantly rejected packets of bills returned by banks to the Treasury for burning that contained more or less than the 100 per packet required by regulations. Since 6 tons of currency are redeemed daily—about $40 million worth, mostly in $1 bills—it was estimated that use of the electronic counter,

[85] NBS Annual Report 1948, pp. vii, 240; Annual Report 1950, p. 78. For the Bureau's high-speed piezoelectric crystal clutch, a nonmagnetic type, also used in computers, see Annual Report 1951, p. 74.

[86] Hearings * * * 1950 (Mar. 9, 1949), p. 490; correspondence with Jacob Rabinow, May 5, 1964.

eliminating hand counting, would save the Government almost a quarter of a million dollars annually.[87]

When planning for the computers first began, the Bureau, with Office of Naval Research and War Department support, established its National Applied Mathematics Laboratories, in order to centralize mathematical research in the Government and begin programming studies for the computers.[88] The laboratories comprised the Institute for Numerical Analysis, at Los Angeles; and in Washington, a computation laboratory, set up with the group brought from the Mathematical Tables Project in New York; a statistical engineering laboratory; and an electronic computing machine development laboratory.

The numerical analysis group, in addition to its preliminary studies for SWAC, undertook solution of linear equations in many unknowns and the representation of complicated functions in terms of simple, easily computable functions. The computation section, besides performing calculations requested by Federal agencies, continued its compilation of highly specialized mathematical tables, particularly those essential to the solution of problems in atomic energy, aerodynamics, radio and radar navigation, and military ordnance.[89]

Allied to the numerical analysis section was the statistical engineering unit, concerned with the application of modern statistical inference to complex engineering experiments, to sampling problems, and analysis of data arising in physical experiments.[90] The computer laboratory sought better

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[87] NBS Annual Report 1950, pp. 2, 4, 73; Hearings * * * 1952 (Apr. 10, 1951), pp. 462–463.

[88] NBS Annual Report 1948, p. 256. See John H. Curtiss, "The NAML: a Prospectus" (February 1947), intended, as Dr. Condon said in the foreword, as "a strong, easily accessible Federal applied mathematics center."

[89] Described in LC777, "Mathematical tables" (1945), superseded by LC884 (1947); NBS Annual Report 1948, pp. 237–238.

[90] NBS Annual Report 1947, pp. xii, 187–188. Early tasks set the statistical engineering section included the preparation of commercial sampling plans for inclusion in Federal specifications and commodity standards. One, made for the Mail Order Association of America, was a study of data gathered by the Bureau of Home Economics, Department of Agriculture, on body measurements of teenage girls. Hip-and-stature and hip-and-maximum chest girth measurements of 70,000 schoolgirls between the ages of 4 and 17 years were analyzed and diagramed to provide statistically efficient coverage from which garments, patterns, and forms could be sized to assure an accurate fit for a large proportion of the teenage population. A year later the Bureau issued a new commercial standard covering model forms for girls' apparel (NBS Annual Report 1948, pp. 238–239; Annual Report 1950, p. 87).

Studies in the field of probability methods centered on stochastic (random) processes, employing random samples of an odd number of observations and a time element. Applying this statistical technique to sample testing of clinical thermometers permitted techniques for numerical computation and their adaptation to machines, as well as better techniques for training mathematicians in the application of numerical methods.[91]

The new age of mathematics, electronics, nuclear physics, tracer research, radio propagation, and high polymer research challenged the Bureau to provide a host of new fundamental physical standards, physical constants, and standard samples. The Bureau also pursued its work on standards in more familiar areas, some whose adoption had waited only for the end of the war. Thus 1948, the year that saw international adoption of absolute values for the electrical units, new photometric units, and adoption of a revised International Temperature Scale,[92] also witnessed, after 30 years of effort, the first real agreement on unification of the screw thread standards of Great Britain, Canada, and the United States. Despite Lend-Lease and the common border to the north, the screw threads produced in these countries all during the war differed sufficiently to prevent their interchangeability, causing severe inconvenience and great economic loss. After 3 years of study, an accord of unification of the American and British standard systems was signed at the Bureau late in 1948 by representatives of the American Standards Association and their British and Canadian counterparts.[93]

The year 1948 also marked the near realization of an atomic basis for the standard of length. Two decades earlier, the Seventh International Conference on Weights and Measures had agreed to seek a definition of the meter in terms of light waves.[94] Great interest was, therefore, aroused in the increased accuracy recently found possible with a new light wave, that of an isotopic mercury in vapor form. The sharp spectral line of this isotope of mass 198 (Hg^{198}) was first observed in 1942 in the Radiation Laboratory at the University of California. In 1945 Dr. Meggers obtained a small quantity of the mercury isotope, distilled from proof gold exposed to neutrons in a chain-reacting pile, from the atomic pile at Oak Ridge.[95]

In precision, reproducibility, and convenience, Meggers found the wavelength of the green radiation from the mercury isotope far superior to either the standard meter or the wavelength of the red line of cadmium.

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inspection testing of five times as many units in a given time by the same staff. Cement testing was put on a similar statistical basis (Annual Report 1948, pp. 238, 251; Annual Report 1949, p. 57).

[91] NBS Annual Report 1951, p. 67.

[92] NBS Annual Report 1948, pp. 201–203; Annual Report 1949, p. 14. For the earlier work, see ch. V, p. 246.

[93] NBS Annual Report 1949, p. 10; Annual Report 1951, p. 101; Fortune, 38, 86 (1948).

[94] See ch. VI, pp. 335–336.

[95] No attempt at the reverse process, changing mercury to gold, as the alchemists of the Middle Ages and as a group sponsored by Scientific American in the 1920's tried, was considered. See Sci. Am. 132, 80 (1925), and issues of December 1924 and March 1925.

He announced it the ultimate in a length standard.[96] Three years later the tentative standard was made available to science and industry in the form of the NBS-Meggers Mercury 198 Lamp.

The 13 Meggers lamps initially distributed in 1951 were capable of calibration to a precision of 1 part in 100 million, as opposed to the 1 part in 10 million possible with the standard meter. With further refinement—in particular, the use of an atomic beam of Hg^{198} instead of the vapor, to narrow the line and overcome the slight effect of temperature on the Meggers lamp—the Bureau looked forward to extending that accuracy to one part in a billion.[97]

Funds for a program to try the atomic beam method were not then available and it was 1959 before the work was completed. Meanwhile, the Bureau urged adoption of the mercury 198 lamp as the international standard, considering it a simple and excellent working standard for length measurements. Although the Russian standards laboratories favored the cadmium lamp, the other laboratories abroad settled on the krypton 86 lamp, proposed originally by the Physikalisch-Technische Bundesanstalt (the West

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[96] Meggers, in J. Opt. Soc. Am. 38, 7 (1948), and Sci. Mo. 68, 3 (1949).

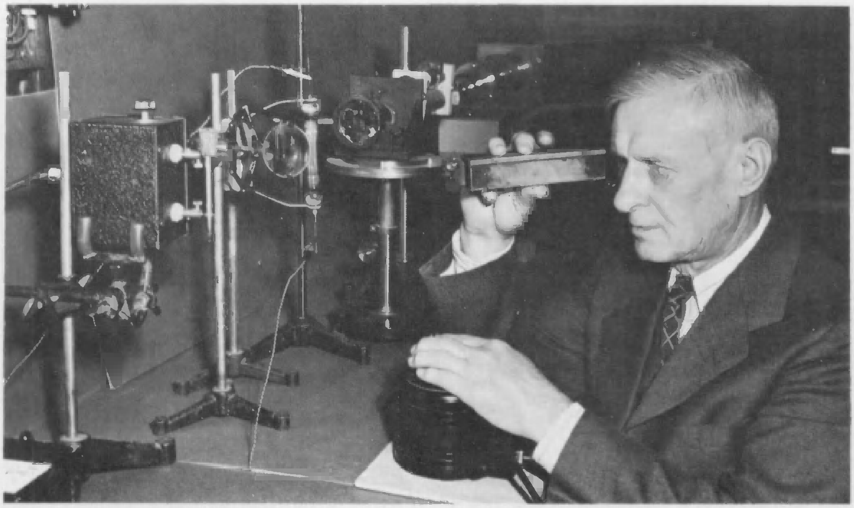
The standard meter, etched on a platinum-iridium bar maintained at the International Bureau, had been the world's standard of length since 1889 (see ch. I, p. 30). The cadmium line, first proposed by Michelson in 1893, had never been adopted. Though widely used, its structure limited the precision attainable. Time, however, and superior radiations witnessed notable improvements in the measurement of light waves.

Wavelengths of light are still measured with a Michelson-type interferometer. By splitting a beam of light, the interferometer permits its speed and wavelength to be measured with extraordinary accuracy. Each normal element or isotope of an atomic element, when made incandescent with high-frequency radio waves, emits a light with a characteristic and unchanging wavelength of its own. The wavelengths are measured in terms of the angstrom, named for A. J. Ångström who introduced the scale of wavelengths in 1868, his unit representing the ten-millionth part of a millimeter or 10^{-10} meter.

The light waves from some elements and isotopes can be measured more accurately than others, among them the red line of cadmium vapor, the orange line of krypton gas, the green light of mercury vapor, and, sharper than these, the green light of the unidirectional mercury atomic beam. Under excitation, the radiation of the atoms of these elements or isotopes is seen as measurable fringes of light between the parallel metallic-coated plates of the interferometer.

In establishing a standard of length, a gage block, meter bar or similar known quantity is measured directly against the wavelength seen in the interferometer, the spectroscopist measuring the half-width of the wave under observation and from that deriving precise values, in terms of angstroms, for the length standard. See NBS M248 (1962), pp. 9–11.

[97] NBS Annual Report 1947, p. 197; RP2091, "Lamps and wavelengths of mercury 198" (Meggers and Westfall, 1950); NBS Annual Report 1951, pp. 6, 29.



Dr. Meggers observing the spectral line of the mercury isotope of mass 198, a potential basis for an atomic standard of length.

German successor to the PTR), and in October 1960 the krypton lamp was adopted as a new international standard of length.[98]

Other developments in the postwar period, discussed later in the section on nuclear physics, included a standard of time, determined by an atomic clock; a primary neutron standard; and a fundamental nuclear constant, the gyromagnetic ratio of the proton.

Much new work was done in the field of physical constants. The Bureau made available comprehensive data on the infrared absorption spectra of chemical compounds for use in research analysis. It compiled tables of selected values of chemical thermodynamic properties for the simple sulfur compounds and the compounds found in liquefied petroleum gases.

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[98] R. L. Barger and K. G. Kessler, "Kr^{86} and atomic-beam-emitted Hg^{198} wavelengths," J. Opt. Soc. Am. 51, 827 (1961).

In possible extenuation of the European adoption of the krypton lamp was the fact that at that time only the United States had reactors to supply mercury 198 (interview with Dr. Condon, Oct. 29, 1963).

Objective comparisons made in neutral laboratories reportedly agreed in general that krypton provided the highest precision. Despite the krypton lamp standard, metrology and spectroscopy laboratories both here and abroad use the Meggers lamp for its combination of accuracy and simplicity. Laser sources may yet supersede the atomic beam principle as the ultimate in sharpness in a spectral line standard. Interviews with Dr. Meggers, Mar. 13, 1962, and July 7, 1964; A. G. McNish, "Lasers for length measurement," Science, 146, 177 (1964).

And science and industry also needed the tabulations made by the Bureau of the dielectric constants of liquids, both inorganic and organic.[99]

Equally extensive work was done in standard samples, the array of materials maintained by the Bureau and certified as to their chemical composition or certain physical or chemical properties. Begun in 1905 with the preparation of four types of cast iron, by 1911 the Bureau stock comprised 37 samples of steels, brasses, ores, limestone, and sugars, and 100 standard combustion samples used to standardize calorimeters.[100] In 1951 the Bureau listed more than 500 distinct materials, of which 225 were certified for chemical composition and some 90 of these prepared specifically for spectrographic analysis. Others certified such properties as acidity, viscosity, melting point, density, index of refraction, and heat of combustion. Over 25,000 samples were prepared and distributed that year, for the use of Federal agencies and industry in checking tests, controlling manufacturing operations, and settling disputes between producers and consumers.[101]

Among the newest samples were a tin-bearing steel, a tungsten steel, and two nickel-chromium-molybdenum steels. An additional 32 standard samples of hydrocarbons brought the total of these compounds to 92, and 15 new standards for color or tint made 28 color standards available. Other samples included radioactive iodine and phosphorus for use in tracer micrography, radium gamma-ray standards, radioactive carbon and radon standards, and a series of pH standards.

Work on the pH samples had begun back in 1940 at the urging of the National Canners Association, of dairymen, dry cleaners, textile manufacturers and other groups. The control of acidity was also a problem in manufacturing pharmaceuticals, paper, leather, dyes, sugar refining, and biological materials. Lack of a universally accepted definition of the pH scale, or hydrogen ion concentration, by which the degree of acidity was measured, resulted in frequent confusion and disagreement.[102] After almost 8 years of study and consultation with industry, the Bureau established four standardized substances, representing pH 2, 3.5, 10, and

[99] NBS Annual Report 1950, p. 50; Annual Report 1951, p. 42; R. D. Huntoon and A. G. McNish, "Present status of research on the physical constants * * *," Nuovo Cimento (Rome), 6, 146 (1957).

[100] See ch. II, p. 93; NBS Annual Report 1911, p. 80.

[101] Harry A. Bright, "Standard samples program of the NBS," Anal. Chem. 23, 1544 (1951); C398 "Standard samples" (1932) and Supplement (1946); NBS Annual Report 1951, p. 85; C552 "Standard samples" (1954), second ed. (1957); James I. Hoffman, "The evolution of certified reference materials," Anal. Chem. 31, 1934 (1959).

[102] Hearings * * * 1940 (Apr. 21, 1939), pp. 162, 379; Hearings * * * 1946 (Dec. 9, 1939), pp. 136–139; RP1495 "Provisional pH values for certain standard buffer solutions" (R. G. Bates, W. J. Hamer, et al., 1942); LC993, "Standardization of pH measurements" (1950).

11.7, as the basis for a new pH scale. With certified samples of these substances, laboratories were at last provided with means for checking their own scales and maintaining uniformity of procedure.[103]

A series of important postwar projects began shortly after an Army plane, the XS–1, exceeded the speed of sound (760 miles per hour at sea level) for the first time on October 14, 1947. At the request of the National Advisory Committee on Aeronautics and the Navy Department, search was made for engineering and operational data on air turbulence and its effects at supersonic speeds.

The inauguration of supersonic flight also led to new work at the Bureau in high temperature ceramics and the development of a new high temperature ceramic coating, for the turbine blades of jet engines and the liners of rocket motors. Significant studies were conducted on combustion at high altitudes in jet, turbojet, and ramjet engines and thrust augmenters. With special instruments devised for the tests, new measurements were made on rubber and metal reactions at extremely high and low temperatures. But much remained to be done. Jet propulsion and supersonic flight called for almost total revision of data on fuels and the extension of many measurements to higher temperatures, pressures, and velocities.[104]

At the other extreme was a new phase of the Bureau's low temperature work, begun with the acquisition of an improved helium liquefier in 1948 for a program of basic research in superconductivity.[105]

The phenomenon of superconductivity—the disappearance in certain materials of resistance to an electrical current at very low temperatures—seemed a particularly challenging field in low-temperature physics, its spectacular effects giving promise of a basic insight into some of the fundamental properties of matter. Several lines of investigation were started, including studies of the anomalous properties of liquid helium II, an analogue of

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[103] NBS Annual Report 1948, pp. 219–220: Annual Report 1950, pp. 46–47.

An interesting standard sample was the 15 gallons of very pure isooctane (2,2,4-trimethylpentane) and normal heptane prepared by the Bureau in the late 1940's and put up in ampoules for the American Petroleum Institute as ultimate primary standards for the octane rating of gasolines sold throughout the country. Subsequently the Phillips Petroleum Co. prepared good batches of both isooctane and heptane as working standards, but the Bureau ampoules, known as "the gold-plated standards," are still maintained at the API research laboratory at Carnegie Institute of Technology to settle disputes. Interview with Thomas Mears, Sept. 15, 1964.

[104] NBS Annual Report 1948, pp. 221, 223; Annual Report 1949, pp. 15–16, 18, 49; Annual Report 1950, pp. 8, 58, 64, 66; Annual Report 1951, pp. 24, 43. See also LC832, "Bibliography on gas turbines, jet propulsion, and rocket power plants" (1946); LC872, "Gas turbines and jet propulsion" (1947); C482 (1949), superseded by C509 (1951), on the same subjects.

[105] For earlier note on superconductivity, see ch. V, p. 247.

helium I, its normal liquid form. Liquid helium II, cooled to 2.19 °K or lower, acquires properties so unique that it is often described as a fourth state of matter.[106]

The studies in superconductivity led to the almost simultaneous discovery at the Bureau and at Rutgers University of a new and wholly unexpected relationship, called the isotope effect in superconductivity. A connection was observed between loss of electrical resistance at very low temperatures and the mass of the atomic nucleus. The pure mercury isotope Hg^{198}, it was found, becomes superconducting at a temperature about 0.02 °K higher than natural mercury. From the discovery that heavier mercury isotopes react at lower temperatures than the lighter ones, it was inferred that the nucleus must exert an important effect on the superconducting properties of the metal.[107] The finding appeared to offer a key to a basic understanding of how superconductivity comes about.

Still other lines of research in cryogenics were to be explored after a new laboratory was erected in Boulder, Colo., in 1951.

NUCLEAR PHYSICS AND RADIO PROPAGATION

The postwar research program of the Bureau's atomic physics division ranged widely, from investigations of intense neutron sources and of artificial radioactive isotopes to safety precautions at atomic plants and measurement techniques. The wartime studies in radiation hazards, atomic metallurgy, and atomic energy levels continued when their administration was transferred from the Manhattan District to the Atomic Energy Commission. The AEC also undertook support of a number of studies at the Bureau in atomic and molecular spectra, radiometry, electron optics, mass spectrometry, X rays, radioactivity, and determination of atomic and nuclear constants.[108]

An early achievement was construction of a national primary neutron standard, to serve as a reference unit of neutron intensity for the quantitative measurement of the strength of neutron sources and fluxes. In the absence of the standard, such measurements had previously been possible with an accuracy of only about 20 percent. The new standard, consisting of a beryllium sphere with a radium bromide center, made possible intercomparison of neutron measurements in other laboratories and later proved in-

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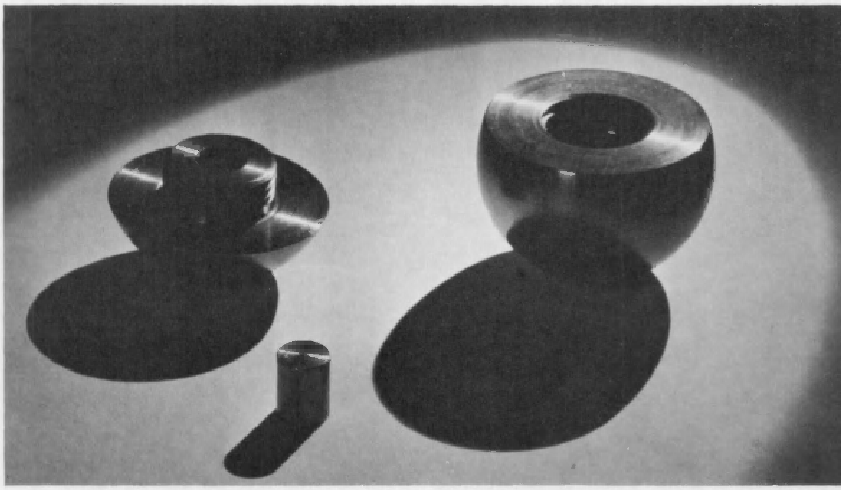
[106] On the Kelvin scale of absolute temperatures, zero is equivalent to −273.15° C or −459.7° F.

[107] E. Maxwell, "Isotopic effect in the superconductivity of mercury," Phys. Rev. 78, 477 (1950); NBS Annual Report 1950, pp. 7–8, 32–33; Annual Report 1951, pp. 16, 26.

[108] NBS Annual Report 1948, p. 216; Annual Report 1951, p. 36.



The NBS standard of neutron intensity, a solid beryllium sphere, 4 centimeters in diameter, enclosing a capsule of platinum-iridium containing a gram of radium bromide compressed to maximum density.

Neutrons are emitted in the sphere by the action of the gamma rays from the radium at a constant rate of 1.1 million per second.

The establishment of a national neutron standard was made imperative by the increasing importance of neutrons as bombarding particles in physical and biological research.

valuable both in the operation of nuclear reactors and in neutron irradiation research.[109]

Accurate determination was first made at the Bureau of a fundamental nuclear constant, the gyromagnetic ratio of the proton, in absolute units, which previously had been made in terms of relative values of other physical constants. An important contribution to the knowledge of nuclear phenomena, it provided a simple and convenient standard for measuring the absolute value of magnetic fields, knowledge necessary in the use of such scientific apparatus as cyclotrons, mass spectrographs, and beta-ray spectrometers, and in such industrial equipment as servomechanisms and electromagnets.[110] Refinement of application of this constant led to a more precise knowledge of such other important atomic constants as the magnetic moment of the

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[109] L. F. Curtiss and A. Carson, "Reproducibility of photoneutron standards," Phys. Rev. 76, 1412 (1949); NBS Annual Report 1948, pp. ix, 213. A refinement of the standard, based on a new determination of its emission rate, was reported in NBS Annual Report 1956, p. 36.

[110] NBS Annual Report 1948, pp. ix, 214.

proton, the charge-to-mass ratio of the electron, and the first precise determination of the proton moment in absolute units.[111]

A new instrument, the omegatron, also came out of the atomic physics division. Basically a miniature cyclotron about the size of a pack of cigarettes, the omegatron made possible determination of the values of several important atomic constants with much higher precision than heretofore. In addition, the faraday, previously determined solely by electrochemical measurements, was for the first time evaluated directly by physical methods, the preliminary value obtained representing a slight but significant degree of greater precision over that obtained with either the silver or iodine voltameter. The omegatron also facilitated sharper determination of the magnetic moment of the hydrogen proton.[112]

The formulation within a year or two of three proposed basic standards—length, determined by the green line of mercury 198; the gyromagnetic ratio of the proton, a constant to which the standard of mass might be referred; and time, in the constant natural frequency of the Bureau's atomic clock (see below, pp. 476–477)—led some at the Bureau to hope that "a complete set of primary atomic standards" might not be far off. They saw an increasing number of primary references for physical measurements—the independent and arbitrarily defined units of the last century—replaced by a set of working definitions comprising an atomic meter, atomic second, atomic ampere, atomic newton, atomic coulomb, and atomic kilogram.[113]

The year 1946 saw the inception of Bureau research in tracer micrography, that is, the tracking of the movement of radioactive atoms through organic systems, and later through inorganic systems as well. With radioactive isotopes made available by the Atomic Energy Commission (iodine 131, cobalt 60, phosphorus 32, sodium 22), tracers rapidly became an important tool of research in chemistry, biology, medicine, and industry.

A comparison check made by the Bureau disclosed discrepânices in medical and other research laboratories of several hundred percent in the determinations of amounts of radioactive material in samples of substances being used for medical treatment. The Bureau at once began work on standards for quantitative measurement of each of the tracer elements. Before

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[111] H. A. Thomas, R. L. Driscoll, and J. A. Hipple, "Measurement of the proton movement in absolute units," Phys. Rev. 75, 902 (1949), and Phys. Rev. 78, 787 (1950); Driscoll, Thomas, and Hipple, "The absolute value of the gyromagnetic ratio of the proton," Phys. Rev. 79, 339 (1950); NBS Annual Report 1949, pp. 19–20; Annual Report 1951, p. 29.

[112] J. A. Hipple, H. Sommer, and H. A. Thomas, "A precise method of determining the faraday by magnetic resonance," Phys. Rev. 76, 1877 (1949); NBS Annual Report 1950, pp. 6, 34.

[113] R. D. Huntoon and U. Fano, "Atomic definition of primary standards," Nature, 166. 167 (1950).

long, standard samples of these isotopic elements were made available, assuring uniformity in the tracers in use.[114]

One of the first tracers produced for industrial research was chromium 51, a quantity of which the Bureau metallurgists acquired for study from the AEC. Preliminary work with this isotope promised to shed new light on the mechanism of electrodeposition, by identifying the type of chromium ions actually reduced to metal.[115] Perhaps the widest publicity on the new tracers, making them generally known to the public, was that given to carbon 14, the radioactive atom found in normal carbon 12.

As a constituent of the atmosphere—about one in a millon carbon atoms is radioactive—C^{14} is present in every living or once living thing. Made only during the life-cycle, production of C^{14} ceases at death and begins its slow but measurable decay, disintegrating at a constant rate. With a "half-life" on the order of 5,700 years, the time required for a given quantity of C^{14} to decay to one-half its original amount, the measurement of the remaining radiocarbon in bone, horn, shells, seeds, wood, charcoal, peat, or any organic matter in history, makes it possible to establish a method of absolute dating. By amplifying the exceedingly faint radioactive pulse or discharge with an ultrasensitive Geiger counter and measuring it against a calibrated scale, the age of the substance, up to 20,000 to 30,000 years, can be determined with considerable precision.[116]

Bureau interest in C^{14} was less in its proficiency as a kind of "atomic clock" than as a tracer in carbohydrate research. The Bureau turned after the war from sugar research to fundamental work in carbohydrates in general, especially in the molecular structure of sugars and associated compounds. By 1951, under AEC sponsorship, glucose, mannose, galactose, and lactose were prepared for the first time with an atom of C^{14} in their carbon chain for chemical and biological research.

How tracer research proceeded was seen not long after in a Bureau investigation for the Army Surgeon General's Office. Before the medical laboratories of the Surgeon General could determine the possibility of using the commercial sugar compound, Dextran, as a blood plasma extender or even plasma substitute it had to be tagged, in order to track it through its physiological life cycle. The Bureau found a way to label the carbonyl group in the compound and patented the method. The technique of inserting C^{14} in

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[114] NBS Annual Report 1948, pp. ix, 211; Annual Report 1949, p. 22.

[115] F. Ogburn and A. Brenner, "Experiments in chromium electro-deposition with radioactive chromium," J. Electrochem. Soc. 96, 347 (1949); NBS Annual Report 1949, p. 31.

[116] NBS Annual Report 1949, pp. 22–23; Frederick E. Zeuner, Dating the Past: an Introduction to Geochronology (London: Methuen, 1952), p. 341, reports the pioneer work of Willard F. Libby of the Enrico Fermi Nuclear Institute at Chicago who worked out the theory and technique of radiocarbon dating in 1947. See also L. J. Briggs and K. F. Weaver, "How old is it?" Natl. Geo. 114, 235 (1958).

a sugar compound was subsequently applied also to Inulin, a levulose polysaccharide used in the study of kidney functions.[117]

Elsewhere at the Bureau, after almost 5 years' work, the first volume of "Atomic Energy Levels" was completed in 1949. Designed for the use of workers in nuclear and atomic physics, astrophysics, chemistry, and industry, it was a compendium of all energy states for the first 23 elements, from hydrogen to vanadium, as derived from analyses of their optical spectra. Similar data for the next 19 elements, chromium through niobium (No. 41), comprised the second volume in 1952, and from molybdenum to plutonium (No. 94), a third volume in 1958.[118]

Another compilation made with AEC support was that of the experimental values of nuclear physical constants and properties, greatly needed by nuclear physicists, reactor engineers, and industrial and medical users of radioactive tracer materials. The first edition of "Nuclear Data," containing tables of experimental values found for the half-lives of radioactive materials, radiation energies, relative isotopic abundances, nuclear moments, cross sections, and nuclear decay systems, was issued in September 1950. A supplement appeared in April 1951 and two more late that year and early the next.[119]

Yet another AEC project at the Bureau was the sponsorship of a program of measurement of some previously undetermined properties of hydrogen. Using the helium liquefier acquired for its program in superconductivity, the Bureau made a series of studies over a period of 8 years focused on three isotopic modificiations of hydrogen, the normal hydrogen molecule, (H_2), hydrogen deuteride (HD), and deuterium (D_2), under a wide range of pressures. The report by Woolley, Scott, and Brickwedde on the thermal properties of hydrogen became a classic and established the Bureau as the Federal expert on cryogenic engineering.[120]

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[117] NBS Annual Report 1948, p. 218; Isbell in Science, 113, 532 (1951); Hearings * * * 1953 (Jan. 18, 1952), p. 441; Chem. Eng. News 30, 1112 (1952); RP2886, "Carbon-14 carboxy-labeled polysaccharides" (J. D. Moyer and H. S. Isbell, 1958).

[118] NBS Annual Report 1950, p. 44; C467, compiled by Charlotte E. Moore.

[119] NBS Annual Report 1951, pp. 35–36; C499, compiled by Katharine Way, Lilla Fano, et al.

[120] RP1932, "Compilation of thermal properties of hydrogen in its various isotopic and ortho-para modifications" (1948); NBS Annual Report 1948, p. 207. Subsequent research by the cryogenic group made at the request of the AEC early in 1951 included the measurement of the vapor pressures, dew points, and critical constants of hydrogen, deuterium, and hydrogen deuteride (NBS Annual Report 1951, p. 27).

Bureau interest in cryogenics dates back to the turn of the century, when a plant for making and maintaining liquid and solid hydrogen, the invention in 1898 of Prof., later Sir, James Dewar, British physicist, was exhibited at the St. Louis Fair in 1903 and purchased by the Bureau (see ch. II, pp. 83–84). In 1923 Clarence W. Kanolt of the

The Bureau had long since outgrown the facilities for cryogenic research in its small low temperature laboratory in Washington when in April 1951, with the cooperation and financial support of the AEC, ground was broken at Boulder, Colo., for the construction of the world's largest liquid hydrogen plant and cryogenic laboratory. The plant at Boulder was completed that summer and the staff to man the plant and laboratory buildings moved in. The hydrogen liquefiers, the units producing liquid nitrogen to precool the hydrogen, and the purifiers, all in duplicate to insure continuous operation, were designed and their construction supervised by the Bureau. Both the plants and laboratories incorporated elaborate safety and anti-explosion features to minimize the hazards of working with liquid hydrogen in large quantities.[121]

Engineering research and production at Boulder accelerated when in 1956 the Air Force became interested in liquid hydrogen as an aircraft and rocket fuel.[122] Large-scale operations were established after 1957, when the National Aeronautics and Space Administration (NASA) began negotiations for all the liquid hydrogen the Boulder plant could supply, as a missile and satellite fuel. It followed the announcement by the U.S.S.R. in August 1957 of its first successful test of an intercontinental ballistics missile (ICBM). Two months later Russia's 184-pound satellite, Sputnik I, was launched and began orbiting the earth. A new race, to span continents and send men and machines into space, was on.

The cryogenic plant at Boulder shared the 220-acre tract with the Central Radio Propagation Laboratory (CRPL), the new Bureau division evolved from the wartime Interservice Radio Propagation Laboratory (IRPL) that had operated out of the Far West building at the Bureau.[123] Established on May 1, 1946, under Bureau operation and administration, CRPL came under the direction of an executive council representing the Army, Air Force, Navy, Federal Communications Commission, Civil Aeronautics Administration, Coast Guard, the Bureau itself, the Weather Bureau,

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Bureau devised a standard and precise method of producing liquid and solid hydrogen at a temperature 25° above —459.7° F or absolute zero (Sci. Am. 129, 106, 1923). In 1931, with the same apparatus, Dickinson and Brickwedde, by precooling with solid hydrogen, produced liquified helium for the first time in this country, at a temperature of —456° F. (Science News, 73, 12, 1931; Time, 17, 58, 1931; NBS Annual Report 1931, p. 8).

[121] NBS Annual Report 1952, p. 14.

[122] Russell B. Scott, "Liquid hydrogen for chemical and nuclear rockets," Discovery, 21, 74 (1960).

[123] While the cryogenic plant began operations at Boulder in the fall of 1951, not until completion of CRPL were the Boulder Laboratories formally dedicated, on Sept. 8, 1954.

The NBS Boulder Laboratories in Colorado, housing the radio propagation, radio astronomy, and radio standards laboratories. In the background, on the first rise of the foothills of the Rockies, are the Bureau's cryogenic laboratories.

and commercial radio, as the central agency of the Nation for basic research in the propagation of radio waves.[124]

Besides continuing operation of the worldwide chain of stations—the total number was 58, of which 14 were directly operated or supported by the Bureau—to provide prediction services for long-distance radio, CRPL took over the research functions of the radio section of the Bureau's electrical division. It at once undertook extension of the research in lower frequencies into the ultrahigh frequency and microwave region (3000 megacycles or more) for the new fields of television, of frequency modulation (FM) broadcasting, and military and commercial radar.

Severely limiting the range and minimum usable signals in FM broadcasting, television, and other very-high-frequency services, the Bureau found, was the noise associated with cosmic and solar radio waves reaching earth from outer space. To study these phenomena, the Bureau instituted a program in radio astronomy, setting up at Boulder two solar radiometers with mirrors 25 feet in diameter, operating at different frequencies, to track the sun and observe its outbursts of radio energy.[125]

While outer space phenomena produced measurable limitations on very-high-frequency transmission, the major influences on propagation at microwave frequencies proved to be nearer to earth. Studies in tropospheric meteorology and terrain geometry—that is, the effects of rain and trees and hills—first begun several decades earlier for ordinary radio transmission, were resumed in order to learn the causes of attenuation of very short microwaves, particularly those used in radio relay operations.[126] Both the radio astronomy program and that on the troposphere became long-range projects.

An innovation in the radio services of the Bureau, begun on October 3, 1945, shortly before setting up CRPL, was the shortwave broadcast of standard time signals each 5 minutes around the clock. It augmented the standard radio frequencies, standard time intervals or pulses, standard audio frequen-

[124] Hearings * * * 1948 (Mar. 12, 1947), p. 339. Establishment of CRPL was authorized in letter, Secretary of Commerce Wallace to Secretary of the Treasury, Jan. 9, 1946 (copy in NBS Historical File), and activated as a division of the Bureau by memo, Director, for Division and Section Chiefs, NBS, Apr. 19, 1946 ("General Correspondence Files of the Director, 1945–1955").

[125] NBS Annual Report 1948, p. 247. The new branch of science, radio astronomy, had its beginnings in 1932 when Karl G. Jansky of the Bell Telephone Laboratories described the reception of extraterrestrial radio waves and from their diurnal variation in direction tentatively identified their source in the Milky Way. See Proc. IRE, 20, 1920 (1932); Nature, 132, 66 (1933). Grote Reber, both before and after he came to the Bureau in the 1940's, and the Bureau's chief of radio research, Dellinger, were to extend these observations. See F. T. Haddock, "Introduction to radio astronomy," Proc. IRE, 46, 3 (1958).

[126] NBS Annual Report 1949, p. 71.

cies, and standard musical pitch (middle A at 440 cycles per second), which the Bureau radio station, WWV, had broadcast since 1935.[127] As supplementary to the time signals of the Naval Observatory, the signals are widely used by such industries as mining, shipping, railroads, power, air transport, and communications, among many others.[128]

Within a year after beginning its new time signal service, improved standards resulted in achieving a maximum change of 0.001 second per 24 hours and deviations of as little as 0.009 to a maximum of 0.031 second from corrected Naval Observatory time.[129] Extending reception of the frequency and time signals of WWV, on November 22, 1948, the Bureau established a new experimental broadcast station, WWVH, on the island of Maui in Hawaii. Soon after it began operations, reports confirmed the expected success of the station in reaching with consistency a far greater range of areas in the Arctic and the Pacific than had been possible from Maryland.[130]

CRPL's extension of the primary frequency standard to 40,000 megacycles in 1948 helped to open research in a field of physical science first explored during the war, that of microwave spectroscopy. Of immediate importance to the Bureau work on guided missiles, the new methods devised for measuring electrical quantities at microwave frequencies made possible the use of sharp microwave beams on systems where high resolution was needed, as in short-range target-seeking rockets and missiles.[131]

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[127] NBS Annual Report 1946, p. 206; NBS TNB 31, 21 (1947); Radio News, 38, 118 (1947).

[128] Long concerned with time as a factor in all measurement, and with clocks, watches, and sundials (on which it issued many Letter Circulars), the Bureau began testing timepieces shortly after its founding. See C51 (1914) and the current C432 (1941) on the testing of timepieces.

The propagation of standard time signals has been by tradition the prerogative of the Naval Observatory at Washington. The Bureau has also had an interest in standard timekeeping, dating back to World War I. Under an act of March 19, 1918, authorizing the establishment of daylight saving time and standard time zones in the United States, Congress appointed the Interstate Commerce Commission to define the limits of each time zone for the Nation. As a matter involving "standards," the ICC requested the Bureau to prepare the map from data that ICC supplied. The map was first published in 1925, in an NBS circular on standard times throughout the world (C280, currently C496, 1950), and a "standard time conversion chart" appeared in 1928 (M84). In 1930, over objections from the Department of Commerce that such a map was no function of the department, the Bureau replied that it was part of its information service to the Nation's commerce. It appeared in a separate publication that year as M111, currently M190, 1948. See Department of Commerce correspondence of August–September 1930 in NARG 40, Box 120, 67009/93.

[129] NBS Annual Report 1947, p. 223.

[130] NBS Annual Report 1949, p. 81.

[131] NBS Annual Report 1948, p. xiv.

Dr. Condon and Dr. Harold Lyons with the first atomic beam clock. It operated with an ammonia-regulated quartz crystal and ran with a constancy of one part in 20 million.

The Bureau atomic clock program sought to provide a spectroscopic standard capable of being used as a new atomic standard of time and frequency to replace the mean solar day and so change the arbitrary units of time to atomic ones. With such a clock, new precise values might be found for the velocity of light; new measurements of the rotation of the earth would provide a new tool for geophysicists; and new measurements of the mean sidereal year might test whether Newtonian and atomic time are the same, yielding important results for the theory of relativity and for cosmology.

The new microwave measurement technique, by overcoming the limitations of conventional optical and infrared equipment, also promised to extend spectroscopic analysis methods to high polymer research, that is, to the investigation of organic substances such as paper, leather, and plastics which are made up of very large molecules.[132] An immediate and dramatic application of the microwave technique, however, was in the Bureau's construction of an atomic clock.

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[132] NBS Annual Report 1948, pp. xiv, 249.

Some of the first microwave measurements of the spectrum lines of ammonia gas against the NBS primary frequency standard suggested that they might serve as an invariable secondary frequency standard. A year later, in 1949, the Bureau devised means for utilizing the vibrations of atoms in the ammonia molecule, derived from the microwave region of ammonia gas, to control an oscillator with which to drive a clock.

The result was the first atomic clock ever built. While its magnitude of accuracy was only a little better than that of the 24-hour rotation of the earth, and not as good as time based on the annual rotation of the earth around the sun, a breakthrough had been achieved. With further refinement, using the cesium rather than ammonia atom, and with precise control of the radio frequency, much higher accuracy became possible. A time accuracy of at least 1 part in 10 billion, representing an error of 1 second in 300 years, was thus achieved, without reference to the earth's rotation or the planetary motions.[133] Such timing is not possible with the 2,000-year-old solar time system. And on an earth gradually slowing down, millionths of a second become vital in projecting such feats as timing rocket launches to meet in orbit hundreds of miles above the earth where a space platform might be assembled.

Of special importance to astronomy, both the clock and the method of construction represented new tools of research in technical fields where precise measurement of time and frequency are crucial, from long-range radio navigation systems and tracking of satellites to basic research in microwave spectroscopy and in molecular structures.[134]

HIGH POLYMERS AND BUILDING RESEARCH

In 1944 Dr. Robert Simha, an Austrian chemist teaching at Howard University in Washington, came to the Bureau to give a series of lectures in a new field of science, that of the high polymers. The word "polymers" or "high polymers" was then less than 5 years old, and the study of the molecular

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[133] H. Lyons, "Microwave spectroscopy frequency and time standards," Elec. Eng. 68, 251 (1949); NBS Annual Report 1951, pp. 13–14; H. Lyons, "Atomic clocks," Sci. Am. 196, 71 (1957). The achievement represented an outgrowth of work started at Westinghouse by Dr. Condon. See William E. Good, "The inversion spectrum of ammonia," Phys. Rev. 69, 539 (1946).

[134] With continued refinement of the cesium atomic beam apparatus, the accuracy of time measurements increased to 1 part in 100 billion, or 200 times greater than that achieved by astronomical means. Subsequent use of atomic hydrogen masers promised to increase the order of accuracy still further. Meanwhile, on Oct. 8, 1964, the 12th General Conference of Weights and Measures, meeting in Paris, authorized a temporary atomic definition of the second, derived from the cesium clock, as the international unit of time. NBS TNB 48, 209 (1964).

properties of these systems little older. The science deals with the chainlike molecules of relatively very high molecular weight that make up substances as different as rubber, textiles, paper, leather, and plastics, all of which owe their strength, elasticity, durability and plasticity to the long chainlike structure of their molecules. Dr. Simha's lecture-seminars led the Bureau to invite him to join the staff, and he remained for 2 years organizing high polymer research at the Bureau.[135]

The growth of the synthetic rubber and plastics industries in this country during the war raised the problem of new standards based on accurate determination of the structures and properties of polymer substances. Awareness of the problem was accentuated by the discovery of German advances made in plastics and textiles, learned from the search of their laboratories in the last months of the war in Europe.[136] Particularly pressing was the need for more basic research in the rubber industry, both in natural rubber, flowing freely once again, and in synthetic rubber, as insurance "in the event of any future emergency." [137]

Apart from the Bureau program, rubber research in industry and in the universities on behalf of the Federal Government was then running over

[135] R. Simha, "Preliminary Proposal for a Plan of Research on Molecular Properties of High Polymers," Aug. 1, 1945 (NBS Historical File); Science, 104, 572 (1946).

Important in the history of the Bureau have been the guest lecturers from industry and the universities who have become temporary consultants or staff members in order to initiate new lines of research or even whole new programs at the Bureau. In many instances they have subsequently sent their graduate students or laboratory assistants to join the Bureau staff.

The guest lecturer policy was introduced by Dr. Stratton, who even after leaving the Bureau continued to invite leading scientists, among them Niels Bohr, to lecture there. In 1923 Prof. Arnold Sommerfeld of the Institute of Theoretical Physics in Munich, early pioneer in the quantum theory and quantum interpretation of spectra, spent 2 weeks at the Bureau as consultant and lecturer. The practice continued in the 1930's when, among others, Wojciech Swietoslawski and his pupil Mieczyslaw Wojciechowski of the Polytechnic Institute of Warsaw brought the technique of ebulliometry to the Bureau (ch. VI, see p. 343), and Prof. John D. Ferry of the University of Wisconsin came to lecture on rheology, the science of the flow and deformation of materials.

Dr. Herman F. Mark, who fled Nazi Germany and started polymer science in this country, came as a consultant to the Bureau in 1941–42. Another lecturer on high polymers, Dr. Paul J. Flory of Stanford University, later sent his prize student, Dr. Leo Mandelkern, who did some of the first work in this country on the crystallization of polymers. Similarly, Dr. Herbert P. Broida came to the Bureau in 1949 to work in flame spectroscopy, and stayed to direct a research program on free radicals. The policy continues to the present day. Interviews with Dr. Lawrence A. Wood, June 30, 1964; Dr. Meggers, July 7, 1964; and Dr. Samuel G. Weissberg, Sept. 8, 1964. On the free radicals program, see NBS AdminBul 56–66, Oct. 29, 1956.

[136] NBS Annual Report 1946, pp. 190–192.

[137] NBS Annual Report 1947, p. xv; LC871, "Bibliography of recent research in the field of high polymers" (Simha, 1947); LC922, ibid., 1948; C498, ibid., 1950.

$5 million a year. As Federal activity in this field was in danger of being stopped through termination of the war agency which handled it, Dr. Condon proposed that the Bureau assume direction over the major programs in progress and, "as in the fields of mathematics and radio propagation," become "the centralizing and coordinating agency" in rubber research for the Government.[138] Instead, the whole of the Federal research program was curtailed as operations in its synthetic plants were cut back and a number of the plants were put in standby status. Bureau research in rubber continued as part of the investigation of high polymer substances.

The investigation centered on the constants and properties of the high polymer compounds that are formed chemically in nature by the process known as polymerization. Using X-ray diffraction, infrared spectroscopy, and electron microscopy, along with standard chemical, optical, and thermodynamic techniques, the Bureau sought better knowledge of the fundamental properties of both natural and synthetic polymers. On the basis of early results, the Bureau explored the incorporation of rubber into sole leather to improve wearing qualities, obtained new tire and tube evaluations, standardized fading tests in textiles, and improved leather hides by impregnating them with resins or rubber. Related studies were concerned with the nature of adhesion in polymers, with adhesives among the synthetic resins, and the use of resins in the fabrication of aircraft, housing, and containers.[139]

Research into the molecular dimensions of the polymers provided the standards necessary for the utilization of Dextran as a blood-plasma substitute and the control tests for its manufacture and maintenance in storage.[140] For the Office of Rubber Reserve, important studies were made in the degradation of rubbers and on the rheological (flow and deformation) properties of various rubbers and rubber solutions.[141] And in 1950, with the procedures it had devised for measuring molecular weights by osmotic pressure, viscosity, and light scattering (ultracentrifuge) techniques, the Bureau started its standard sample program of high polymers.[142]

When an examination of the high-polymer characteristics of paper and paper materials offered no immediate solution to a filter problem, the Bureau, with the cooperation of the Naval Research Laboratory, produced from commercial "glass wool" a new kind of paper composed entirely of glass fibers. Originally sought for use in gas mask filters, its excellent in-

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[138] Hearings * * * 1948 (Mar. 12, 1947), p. 322; NBS Annual Report 1947, p. xv.

[139] NBS Annual Report 1947, p. 209; Annual Report 1948, pp. 224–225.

[140] NBS Report 1713 (Weissberg and Isbell, June 13, 1952). Although the current availability of whole blood from donors reduced the necessity of Dextran except in an emergency, 10 million pints were made and stored against that contingency.

[141] NBS Annual Report 1951, p. 51; Annual Report 1952, p. 34; Annual Report 1953–54, p. 51.

[142] See RP2257 (Weissberg, Simha, and Rothman, 1951).

sulating properties and high resistance to heat readily suggested that glass paper might have extensive use in electronic and other electrical equipment.[143]

An area of research that had become scattered over many divisions at the Bureau was reorganized in 1947 to form a new division, that of building technology. For the first time a unified approach was made to the problems of the construction industry as the Bureau coordinated its investigations of properties of building materials, studies in structural strength, fire resistance, acoustics and sound insulation, heating, ventilation, air conditioning, and building and electrical equipment.[144]

As after every war, the construction industry turned its attention first to conventional housing, of which there was an estimated shortage of 5 million units.[145] The Bureau made home construction its immediate target. With building materials approaching the cost of labor, the Bureau aimed at new structural designs based on engineering principles tested in the wartime construction of ships and planes—something of an innovation itself—and on maximum use of nonconventional building materials that provided structural strength with the minimum of materials and labor. Bureau reports went out to the industry on the properties of materials unknown a decade before, such as some of the new plastics, laminated woods, lightweight concretes, and slag aggregates. New and better masonry paints and asphalts were also reported.[146]

In order to formulate standards of heating, the Bureau built a test bungalow 25 feet square with an 8-foot ceiling. One after another, commercial heating devices including stoves, furnaces, and panel heating were installed and the detailed data gathered on temperature gradients attained inside were correlated with outside temperatures.[147] A long series of fire tests of building structures and materials were carried out in search of better means of reducing the direct annual loss from fire, currently estimated at 8,000 lives and $700 million in property damage.[148]

The next decade witnessed a steady rise in private and public housing, in construction of office buildings and Federal buildings. Aided by the new Swedish-invented hydraulic self-lifting Linden crane, high-rise apartment houses went up as fast, and in some cities, faster than homes. Bureau research figured to some extent in much of the high-rise construction, but could

[143] NBS Annual Report 1951, p. 48; M. J. O'Leary, B. W. Scribner, et al., "Manufacture of paper from glass fibers," Tappi, 35, 289 (1952).
[144] NBS Annual Report 1947, pp. xiii–xiv.
[145] Hearings * * * 1947 (Jan. 29, 1946), p. 203.
[146] BMS107, "Building code requirements for new dwelling construction * * *" (Thompson, 1947); BMS109, "Strength of houses: application of engineering principles to structural design" (Whittemore et al., 1948).
[147] NBS Annual Report 1947, pp. 202–203, 208; Hearings * * * 1950, p. 492.
[148] NBS Annual Report 1948, pp. 234–235.

In this test of house wall fire resistance, the fire took 27 minutes to come through the Douglas fir siding as gas flames were applied to the other side. An instrument on the pole measures the bulge of the wall. (Picture by courtesy of the National Geographic Society.)

take no blame for a major flaw in many of the new buildings, their woeful failure in soundproofing. As it only added to the comfort of tenants, acceptance of Bureau studies in the acoustic properties of materials had little appeal. But as they saved time or money or material, Bureau reports on asphalt stabilizers, vapor-barrier materials, thermal conduction, and heat transfer found ready acceptance in the industry.[149]

As a service to new homeowners and old, the Bureau revised and reissued its publication, "Care and repair of the house." On its first appearance in 1931, "Care" went through 12 printings, selling 175,000 copies at 20 cents each.[150] In the 5 years after 1949 that the 209-page revision, Circular 489, was available to the public it sold 253,000 additional copies, at 50 cents each. Undergoing a second revision in 1955, the Bureau's best-

[149] NBS Annual Report 1949, p. 36; Annual Report 1951, p. 61.

[150] See ch. V, pp. 251–253.

seller was suddenly withdrawn from further publication, with the official explanation that it was both an inappropriate publication for a scientific agency of the Government and was competitive with private industry.[151]

Bureau services such as "Care" represented, whether to homeowners or to the public in general, have sometimes been unwelcome to private industry, as well as to the friends of industry on Capitol Hill. One such public effort in the postwar period came close to spelling disaster for the Bureau.

Ever since its founding, the Bureau, alone or in conjunction with the Federal Trade Commission or some other watchdog agency, has from time to time impinged on one aspect or another of rugged individualism or the principle of laissez faire. It was the Bureau that led the first crusade against fraudulent weights and measures in the marketplace, against faulty railroad scales, mine scales, and truck scales. It aroused the ire of the public utilities by pointing out the hazards of electrolysis, of poor gas appliances, and by insisting on electrical safety codes.

It angered the building industry with many of its codes and specifications and some of its assessments of building materials. It repeatedly warned the public against so-called gas-savers on kitchen stoves, against gasoline additives, gasoline "dopes," destructive antifreeze solutions, and useless antileak compounds. It exposed the fraud in proprietary radium and radioactive nostrums. It reported the inferiority of reclaimed rubber for automobile tires. Its research on photographic emulsions was stopped. Attempts were made to suppress a number of its reports, including those on the quality of heating and illuminating gas, on gypsum and certain other building materials, and on chemical glassware. And from time to time the Department of Commerce itself considered it necessary to suppress Bureau releases, as it did one in 1926 describing the quality of dental amalgams.

Every Director of the Bureau has come under fire from business interests or industry, entrepreneurs, or legislators as a result of some Bureau investigation or other. Dr. Condon had been at the Bureau only a matter of months when the "Aquella" incident occurred.

In January 1946 a popular magazine published the story of a fabulous new paint formula for waterproofing masonry, with the claim that it had been tested by the National Bureau of Standards and won an unqualified "Excellent" rating.[152] It was being made at home and sold from door to door by a family of French refugees who had arrived in New York in 1941 with no possessions but the secret formula for their paint. They claimed that their waterproof paint called "Aquella" had been used throughout the Maginot Line.

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[151] "New York Times," May 15, 1955, p. 68; correspondence with Vincent B. Phelan, March 9–May 27, 1963 (NBS Historical File).

[152] Kurt Steel, "Water, stay away from my wall," Reader's Digest, 48, 45 (1946).

The story with its testimonials drew thousands of inquiries about "Aquella" and hundreds of requests seeking licenses for "Aquella" agencies. On the strength of the mail, the family obtained capital and began selling manufacturing rights to distributors.

The Better Business Bureau of New York asked the Bureau to test the waterproofing paint. The Bureau already had. At the request of the military services it had obtained samples and reported its findings in December 1942. Six months later it had made a second report. The new tests confirmed the earlier ones. Judged "excellent" immediately after application, "Aquella" on the outer face of masonry after 10 months offered no more than "good" protection against water seepage. The inner face rated "poor." "Aquella," at $3 to $4 a quart was judged a fair waterproof paint but no better than a Bureau recipe made with 10 cents' worth of material. The Bureau also learned that "Aquella" had been used in the Maginot Line, but only for decorative purposes, as a blue calcimine.

Newspaper accounts of the Bureau reports, following publication of the magazine story, resulted in almost 20,000 inquiries about the Bureau tests. They were answered with a mimeographed letter summarizing the findings on "Aquella." The mail also brought numerous protests of Government interference with private enterprise, notably the intercession of Gov. Ellis Arnall of Georgia with Secretary Wallace on behalf of prospective "Aquella" distributors in his State. Wallace "recalled and retracted" the Bureau's mimeographed letter.[153]

No such simple détente marked the results of Bureau tests of a battery additive called "Protecto-Charge," later known as AD–X2. Its history went back to the years immediately after World War I when the resurgence of the automobile industry brought on the market a freshet of battery additives, substances whose makers claimed would restore vitality to dying batteries. Through the next three decades the Bureau, at the request of the Federal Trade Commission, the Post Office Department, and various Government agencies with fleets of cars and trucks, tested these additives as they appeared on the market. By the early thirties almost a hundred of the preparations had come to the Bureau, but whether based on epsom salts or other substances, none showed any notable effect on either battery life or performance.[154]

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[153] "NBS Report of water permeability tests on coating of 'Aquella' paint applied to masonry walls," Dec. 8, 1942; ibid., June 4, 1943; mimeo letter, "Summary of water-permeability tests of 'Aquella' * * *, Aug. 9, 1946; report on "Aquella," Consumers' Res. Bull. 17, 20 (May 1946); letter, H. A. Wallace to President, Prima Products, Inc., New York City, June 3, 1946 ("General Correspondence Files of the Director, 1945–1955"); interview with Dr. E. U. Condon, Oct. 29, 1963.

[154] See ch. V, p. 281. The correspondence on battery additives in the early thirties is in NBS Box 369, TE.

The appearance of new gasoline "dopes," antifreeze compounds, and battery additives continued through the forties. Routine tests to determine the validity of their advertised claims turned up nothing new.[155] Then in the spring of 1948, Jess M. Ritchie, whose firm, Pioneers, Inc., of Oakland, Calif., made the battery additive AD–X2, wrote to the Bureau asking for special tests of his product, on the grounds that it was an exception to the negative findings of the Bureau's Letter Circular 302 on battery additives, published in 1931, but still current and available to the public.[156] Since the Bureau does not make tests for private individuals or firms, it refused.

In January 1949, in connection with a current program of research on the properties of batteries, the Bureau undertook a reinvestigation of battery additives, in preparation for a revision of the 20-year-old LC302. Among the additives tested, but as in all such cases unidentified except by a number, was AD–X2, samples of which had been recently received from the Better Business Bureau of Oakland. Essentially compounded of common epsom and glauber salts (magnesium and sodium sulfates), AD–X2 was found by the Bureau to have no special merits. Where these salts ordinarily sell for about 22 cents a pound, when packaged as a proprietary battery additive, at $3 per packet, they came to almost $20 a pound.

Dr. George W. Vinal of the electrochemistry section, coauthor with Paul L. Howard of the Bureau circular in preparation, reported the test results on AD–X2 to the Better Business Bureau in Oakland in April 1950, identifying AD–X2 by name. This was admittedly a deviation from the usual practice, but was intended as a reply to proponents of AD–X2 that prior statements of the Bureau on battery additives did not apply to that particular product.[157] Four months later the national office made the report public.

Pioneers, Inc., directed its distributors to write to their Congressmen in protest.[158] Before the end of 1951, 28 Senators and 1 Congressman had sent queries to the Bureau on behalf of AD–X2. The issue smoldered for more than a year, arousing public interest for the first time when in December 1952 a national magazine reported that laboratory tests of AD–X2 made at the Massachusetts Institute of Technology were at variance with those of

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[155] NBS Annual Report 1947, p. 221; Annual Report 1948, p. 251.

[156] Particularly objectionable to Pioneers, Inc., was the fact that the National Better Business Bureau had reprinted LC302 in its own circular of June 19, 1931, as the authoritative statement on the subject.

[157] [Senate] Hearings before the Select Committee on Small Business * * * on investigation of Battery Additive AD–X2, 83d Cong., 1st sess., March 31–June 26, 1953, p. 220.

[158] The findings on AD–X2, unidentified as such, were also reported in the reissue of LC302 in 1949 and in C504, "Battery additives" (Jan. 10, 1951), the latter including confirming tests of AD–X2 made for the Federal Trade Commission in March 1950. The NBBB letter is reprinted in Senate Hearings, above, p. 549.

the National Bureau of Standards. The issue ignited soon after the Eisenhower administration took office in 1953.

In the controversy over AD–X2 that erupted in the Department of Commerce, the Director of the Bureau was temporarily relieved of his post.[159] Under press attack for an act of dismissal without a hearing, and confronted with the reaction of scientists and scientific organizations, Secretary Weeks rescinded his dismissal order pending a congressional hearing and called upon the National Academy of Sciences to appoint a committee "to evaluate the present functions and operations of the Bureau of Standards

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[159] In the Eisenhower administration, Sinclair Weeks, a manufacturer from Newton, Mass., became Secretary of Commerce. The new Secretary appointed Craig R. Sheaffer, president of the Sheaffer Pen Co. in Fort Madison, Iowa, his Assistant Secretary for Domestic Affairs.

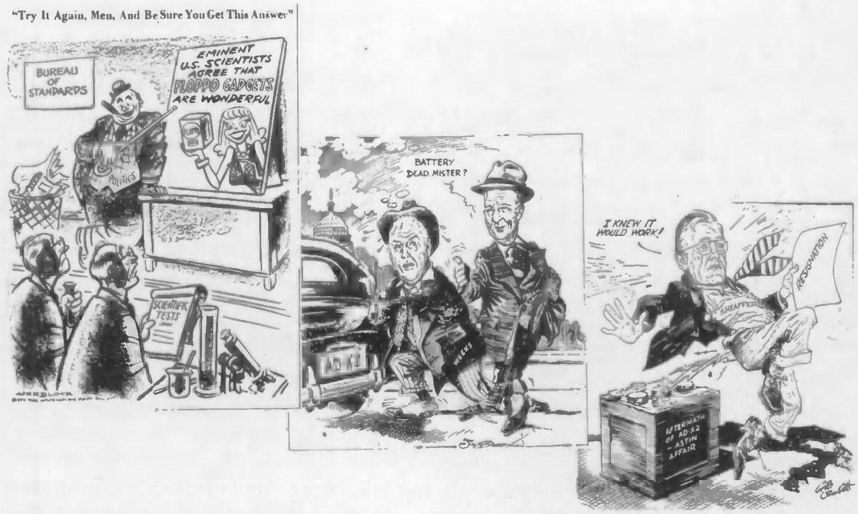
Both the Secretary and his assistant were concerned over Federal agencies that in their view often hampered the efforts of small business to get ahead. Both seem to have thought the Bureau was one of those agencies. The Federal Trade Commission not long before had forced the Sheaffer company to discontinue advertising its ballpoint pen as a lifetime pen. (Senate Hearings, above, pp. 272, 511). He now found the Bureau, long closely associated with the FTC, under his immediate supervision.

More than a year prior to the Eisenhower election, in August 1951, Dr. Condon, who was Director when Circular 504 on battery additives appeared, resigned from the Bureau to become director of research for the Corning Glass Works. Dr. Allen V. Astin, electronic and ordnance physicist and a guiding hand in the development of the Bureau's proximity fuze, became Acting Director until his appointment as Director was confirmed by the Senate on May 30, 1952 (see Hearings * * * 1954, Jan. 11, 1954, p. 76). During that period, Pioneers, Inc., its distributors, and supporters continued pressure on the Bureau to reverse its findings on AD–X2. At the request of the Post Office Department in September 1951, the Bureau retested AD–X2. Six months later it was again tested for the House and Senate Committees on Small Business, and again, almost a year after, much more extensively, for the House Interstate and Foreign Commerce Committee.

On Feb. 24, 1953, the new Postmaster General, Arthur E. Summerfield, as a consequence of the latest Bureau findings, put AD–X2 on the mail fraud list. Six days later, the fraud order was suspended. Assistant Secretary Sheaffer instructed Dr. Astin to impound all copies of Circular 504 and all other reports, pamphlets, and data on battery additives, including AD–X2.

On Mar. 24, 1953, Secretary Weeks forced the resignation of Dr. Astin "for a number of reasons," none of which was specified, except that "the National Bureau of Standards has not been sufficiently objective because they discount entirely the play of the market place" ("Washington Post," Apr. 1, 1953, p. 1).

The action raised a basic question: whether Government through its regulatory and scientific agencies was to judge the merits of new products offered to the public, or whether this function was to be left to the test of the market place. The integrity of the Government's primary scientific research body had been impugned. The Bureau was being subjected to pressure, and to reorganization in accordance with an outside concept of scientific objectivity. The attack on the Bureau implied a radical reversal in the role of Government as the regulator of commerce.



The Washington, D.C., newspaper cartoonists capture the fervor of the AD–X2 case. (1953 © cartoon by Herblock in the "Washington Post"; other cartoons by courtesy of Berryman and Crocket, "Washington Evening Star.")

in relation to the present national needs." [160] (The report of this committee is considered in the envoi of the present history.) A second committee of the National Academy of Sciences was appointed specifically to appraise the work of the Bureau on AD–X2.

A Department of Commerce press release on August 23, 1953, announced the resumption of his duties by the Director of the Bureau. It also disclosed that on the basis of Senate hearings, the merits of AD–X2 remained controversial but "there [was] insufficient proof of an actual intent * * * to deceive." [161]

On November 13 the committee of 10 scientists named by Dr. Detlev W. Bronk, president of the National Academy of Sciences, to study the claims made for AD–X2, reported that the MIT tests "were not well designed for old batteries differing markedly in the characteristics of the cells." The committee found the Bureau staff fully competent, the quality of its work

[160] "Washington Post," Apr. 18, 1953, p. 1. The Director of the Bureau had recommended early in March that the Secretary call upon the Academy and his Visiting Committee to the Bureau to review Bureau operations, including its testing of battery additives. See "Washington Post," Apr. 2, 1953, p. 1.

[161] The Secretary's press release also announced the transfer of direct supervision of NBS from the Assistant Secretary for Domestic Affairs to the Assistant Secretary for Administration. Soon after, Mr. Sheaffer resigned and returned to his business.

The Senate Hearings * * * on * * * Battery Additive AD–X2 comprised 511 pages of testimony and exhibits and 274 pages of appendices.

on storage batteries "excellent * * * without reservations," and supported "the position of the Bureau of Standards that the material is without merit." [162]

GOLDEN ANNIVERSARY

Dr. Condon could have had no inkling of the tempest to be visited upon the Bureau when he approved the letter circular and formal circular on AD–X2. They were routine test reports, as had been that on "Aquella" and hundreds of other commercial products since the founding of the Bureau. Of greater concern to him were the new lines of research he had set going, the reorganization of the Bureau laboratories, the establishment of new facilities at Corona and Boulder, and, not least, the preparation of a new and comprehensive handbook on physics, to be written by the Bureau staff. The handbook, with worldwide distribution, would not only be scientifically important and prestigious but would set a capstone on 50 years of modern physics.

Precedent for the encyclopedic work planned by Dr. Condon was the Dictionary of Applied Physics, the five-volume work edited by Sir Richard T. Glazebrook, first director of the National Physical Laboratory in England and published in 1922–23.[163] The idea of the handbook was preceded in March 1946 by plans for another comprehensive work, a Bureau proposal to the Commerce Science Committee to prepare 50 or more publications designed especially to aid small business. Bureau circulars, letter circulars, and other publications in print were to be revised and new ones prepared by recognized authorities at the Bureau, describing products, methods of manufacture, and processes developed in this country and abroad during the war that might serve as a basis of new enterprises. At the time, the estimated cost of the project, $250,000, was considered by Congress to outweigh the merits of the enterprise.[164]

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[162] Report of the Committee on Battery Additives of the National Academy of Sciences, Oct. 30, 1953, pp. 1, 31, 33–34 (NBS Historical File); "Washington Post," Nov. 14, 1953, p. 1; Hearings * * * 1955 (Jan. 11, 1954), pp. 105–107.

The AD–X2 affair is presented as a case history in public administration and policy formation, for teaching purposes, in Samuel A. Lawrence's The Battery Additive Controversy, Study No. 68 (University of Alabama Press, 1962).

[163] NBS contributors to the Glazebrook dictionary included Silsbee on superconductivity, McCollum on electrolysis, Coblentz on radiation and radiometry, Gibson on spectrophotometry, and Meggers on the measurement of wavelengths.

[164] The 13-page outline, "Proposed technological services to business, industry, and the public, in collaboration with the Office of Declassification and Technical Services," Mar. 1, 1946, is in NBS Historical File.

The outline for the first project, the "NBS Handbook of Physical Measurements," as it was originally entitled, appeared in a 117-page mimeographed study in December 1946. It called for eight volumes, on metrology, mechanics, heat, electricity, optics, atomic and chemical physics, and physical chemistry, each volume and its chapters and sections assigned to Bureau authorities in the field. In March 1947, Dr. Condon asked the House Appropriations Subcommittee for $30,000 to initiate the project.[165] No demur was made and the work was launched.

Progress on the handbook was slow. Besides their reorganization and some shifting around of laboratories, the divisions were clearing up backlogs of paper work, completing reports on wartime research, and planning new programs of research. Since the handbook was to be a formal Bureau publication, Dr. Condon directed that it might be done on Bureau time. The working day simply wasn't long enough, and the only writing accomplished was that done on nights and weekends, on individual initiative.

Four years later, when Dr. Condon left the Bureau, some 10 or 12 chapters out of the 57 projected had been completed. No longer to be a Bureau enterprise, the handbook was modified in scope and the aid of authorities in industry and the universities was enlisted. A progress report and new outline late in 1952 described a more extensive work. It was to comprise 88 chapters, of which 40 were completed or in the first draft form. The published book, Condon and Odishaw's Handbook of Physics, appeared in 1958. Of the contributors to "what every physicist should know," as the editor described the volume, 13 were members of the Bureau staff.[166] Dr. Condon himself wrote 17 of the final 90 chapters in the 1,459-page handbook.[167]

An accomplishment of importance to the Bureau that Dr. Condon saw achieved in somewhat less time than the handbook was amendment of the Bureau's organic act of 1901. Even before Congressman Stefan raised the question in 1947 of the Bureau's spending millions of dollars "on the basis of a two-page law," Dr. Condon had already initiated final preparation of the draft legislation for submission to Congress in order, as he said, to "remove some of [the] ambiguities and try to state more explicitly and in

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[165] Hearings * * * 1948 (Mar. 12, 1947), p. 367.

[166] In addition to their articles and books published under Government imprint, members of the Bureau staff have produced almost a hundred books and textbooks, including two autobiographies. See app. N.

[167] New York: McGraw-Hill Book Co. The progress report of 1952, with instructions for authors and a sample section, is in NBS Historical File.

Some of the material prepared by Bureau members for the handbook subsequently appeared as NBS publications: C476, "Measurements of radioactivity" (Curtiss, 1949); C478, "Colorimetry" (Judd, 1950); C484, "Spectrophotometry" (Gibson, 1949); C544, 'Formulas for computing capacitance and inductance" (Snow, 1954).

more up to date language what the exact functions of the Bureau of Standards are." [168]

The reformulation of functions that the Science Advisory Board recommended in 1934, to cut the depression suit of the Bureau to its cloth, had been filed at the time and all but forgotten.[169] The burst of scientific accomplishment in World War II had since changed the course of Bureau research. Its orientation was to science rather than, as in the original act and in 1934, to industry.

The new statement of Bureau functions, as an amendment to the organic act, became official with the enactment of Public Law 619 in 1950. The restatement included a significant change in direction. In the original act, the basic authority for the functions of the Bureau resided in the Bureau itself. Relieving it of this sometimes onerous responsibility, the amendment transferred the authority to the Secretary of Commerce.[170] The amendment consolidated the broad range of special Bureau activities that had been granted piecemeal in appropriation legislation through the years. Finally, it made specific in the scientific research and testing activities of the Bureau its responsibilities in the new fields of science opened in the past decade.

As in the organic act, the Bureau still had six basic functions, but they included nothing quite like Dr. Stratton's wonderful catchall, "the solution of problems which arise in connection with standards." [171] It was the Secretary of Commerce, rather than the Bureau, that was responsible for:

> The custody, maintenance, and development of the national standards of measurement, and the provision of means and methods for making measurements consistent with those standards, including the comparison of standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the Government.

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[168] Hearings * * * 1948 (Mar. 12, 1947), p. 352; Hearings * * * 1951 (Feb. 23, 1950), p. 2179.

Secretary of Commerce Wallace recommended amendment of the organic act to Congress in 1945, in order to incorporate authority for such Bureau activities as were covered only by supplemental legislation, Executive orders, and customary procedures. The drafting of the amendment was almost entirely the work of Dr. Crittenden. See Report of the Visiting Committee, Oct. 31, 1945, and attached correspondence ("General Correspondence Files of the Director, 1945–1955," Box 6); interview with Dr. Condon, Oct. 28, 1963.

[169] See ch. VI, p. 323n.

[170] For the general reorganization of executive departments, in line with the recommendations of the Hoover Commission, that was the immediate occasion for enactment of the Bureau amendment, see "New York Times," Mar. 14, 1950, p. 1, and May 24, 1950, p. 1.

[171] See ch. I, p. 43.

> The determination of physical constants and properties of materials when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere.
>
> The development of methods for testing materials, mechanisms, and structures, and the testing of materials, supplies, and equipment, including items purchased for use of Government departments and independent establishments.
>
> Cooperation with other governmental agencies and with private organizations in the establishment of standard practices, incorporated in codes and specifications.
>
> Advisory service to Government agencies on scientific and technical problems.
>
> Invention and development of devices to serve special needs of the Government.

The first two functions encompassed the original organic act and were virtually identical with the statements of responsibilities. The next two confirmed the responsibilities acquired through the special appropriations that Congress had made to the Bureau over the years. The last two functions represented Bureau responsibilities accrued under transferred funds from other Federal agencies, as established by acts of 1920 and 1932 (see app. C) and, affirming its advisory capacity, gave a firm legal basis to what had become the dominant direction of the Bureau.

Spelled out in the amendment were 19 specific activities of the Bureau which the Secretary of Commerce was authorized to undertake in carrying out these functions.[172]

Public Law 619 was approved on July 22, 1950, 4 months before the Korean incident became a full-fledged conflict and put the Nation on a wartime footing once again. In the national emergency, the Federal Government reopened its synthetic rubber plants that had been on a standby basis, and ordered stepped up production at the Bureau of optical glass for use in large optical elements. Proximity fuze and guided missile development was at once greatly intensified, as were other defense projects at the Bureau, including some scheduled for termination.[173]

Anticipating the acceleration in scientific research, a program of research in basic instrumentation was initiated, in cooperation with the Depart-

[172] The complete amendment appears in app. C. See also "Bureau of Standards Functions," H. Rept. 2349, to accompany S. 2201, 81st Cong., 2d sess. [July 22, 1950]; NBS BuMemo 50–7, Apr. 24, 1950; BuOrd 51–12, Aug. 11, 1950.

[173] NBS Annual Report 1951, pp. 2, 8, 9, 59, 84.

ment of Defense and the Atomic Energy Commission.[174] As the conflict began, the Bureau established its North Pacific Radio Warning Service for the Arctic region, operating 24 hours a day, 7 days a week, to insure reliable radio communications in the war zone. Yet, even with almost half the staff engaged once more in classified defense programs, the Bureau reported a total of 630 unclassified projects going on in its laboratories.[175]

As it braced itself for the national emergency, the Bureau marked the approach of March 3, 1951, the 50th anniversary of its founding. The publications staff prepared a number of designs for a commemorative stamp for the semicentennial but efforts to interest the Post Office were unsuccessful.[176] In celebration of the anniversary, some 30 scientific and technical societies of the country elected to hold their meetings that year in Washington.[177] In addition, the Bureau, with the special cooperation of the Office of Naval Research, sponsored 12 special symposia on subjects of current importance to the Bureau and the Department of Defense.[178]

The symposia were in mid-career when on August 10, 1951, Dr. Condon announced his resignation as Director of the Bureau. For more than 4 years he had been under intermittent attack by a subcommittee of the House Committee on Un-American Activities, headed by Congressman J. Parnell Thomas of New Jersey, as an alleged security risk in high public office.[179]

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[174] Projected in Condon's "Is there a science of instrumentation?" Science, 110, 339 (1949).

[175] NBS Annual Report 1952, pp. 1, 2

[176] It has been stated that as a rule it is not Post Office policy to so honor Federal bureaus or agencies.

[177] Also marking the semicentennial were companion articles by Dr. Briggs on the early work of the Bureau and by Dr. Condon on its current program, in Sci. Mo. 73, 166 (1951). See also Condon, "NBS: a Semicentennial," Science, 114, suppl. 3 (Aug. 17, 1951).

[178] NBS Annual Report 1951, p. 100, and file, "NBS Semicentennial, 1951," in the Office of Technical Information and Publications, NBS. The subjects of the symposia were low temperature physics (subsequently published as C519, 1952), mechanical properties of metals at low temperatures (C520, 1952), gravity waves (C521, 1952), the solution of systems of linear equations and the determination of eigenvalues (AMS39, 1954), mass spectroscopy in physics research (C522, 1953), energy transfer in hot gases (C523, 1954), electrochemical constants (C524, 1953), polymer degradation mechanisms (C525, 1953), optical image evaluation (C526, 1954), electron physics (C527, 1954), characteristics and applications of resistance strain gages (C528, 1954), and electrodeposition research (C529, 1953).

[179] The trouble began on July 17, 1947, when the press reported that Thomas' Special Subcommittee on National Security was investigating Dr. Condon because his acquaintances included Russian scientists and alleged Communist sympathizers in this country.

In the uneasy years after the war, resentment arose against the scientists who worked on the atomic bomb, and over transfer of control of atomic energy from the Army to

Despite the failure of the subcommittee to prove its charges, despite vindication in the press and by the security procedures of the Departments of Commerce and Defense and the Atomic Energy Commission, and the wide support of his fellow scientists, Dr. Condon came to feel that he might best serve Bureau interests by resigning.

Accepting an appointment as director of research at Corning Glass Works, Dr. Condon submitted his resignation to President Truman, effective September 30. The resignation was regretfully accepted.

> You have served [said the President] in a most critical position with continued and loyal attention to your duties as director, and by reason of your standing among scientists and the supervision you have given to the bureau's activities, you have made of it a more important agency than it ever has been before.[180]

After presiding over the semicentennial symposia that month on mass spectroscopy, on electrochemical constants, and on polymer degradation mechanisms, Dr. Condon left the Bureau. Confronting the new Acting Direc-

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the civilian Atomic Energy Commission. Also, rumor were widespread of domestic Communist activities in connection with the development of the bomb.

Dr. Condon had been at Los Alamos, and was scientific adviser to the McMahon committee that had obtained enactment of the law for civilian control of atomic energy. He now directed, according to Mr. Thomas, "one of the most important national defense research organizations in the United States, the target of espionage agents of numerous foreign powers."

Then in a statement handed to the press on Mar. 1, 1948, the Thomas subcommittee charged that "the Soviet Union and her satellite nations have been desperately attempting to * * * secure our complete atomic knowledge. * * * From the evidence at hand, it appears that Dr. Condon is one of the weakest links in our atomic security." He had, Thomas said, "knowingly or unknowingly, entertained and associated with persons who are alleged Soviet espionage agents."

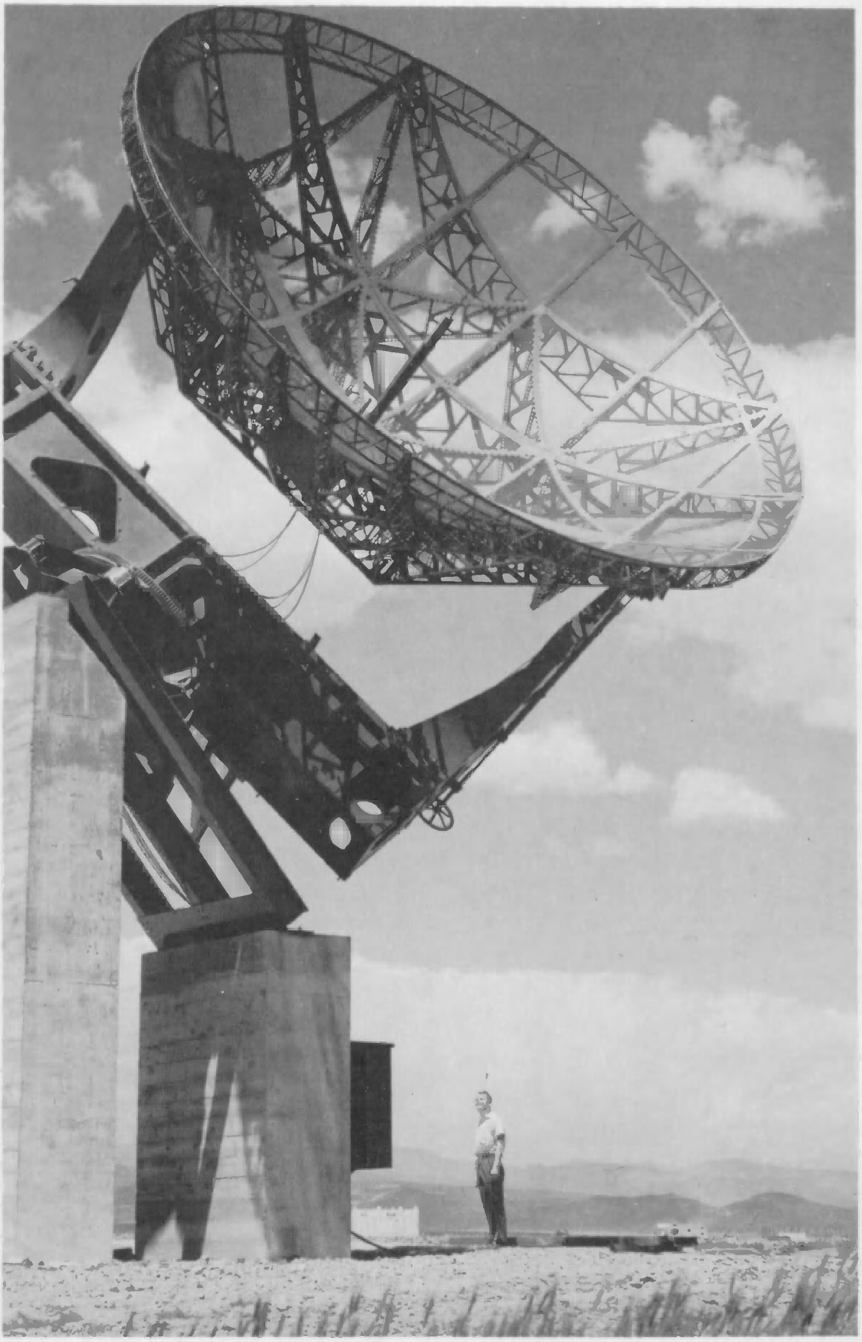
From the first, Dr. Condon expressed his willingness to appear for a hearing but was ignored. Almost unanimously the press, the world of science, and other members of Congress questioned the charges and the procedure of the House Committee. Although he was cleared by the Loyalty Board of the Department of Commerce and by W. Averell Harriman and Charles Sawyer, the Secretaries under whom he served, the criticism of the Director of the Bureau by this committee of Congress continued.

See Stephen K. Bailey and Howard D. Samuel, Congress at Work (New York: Henry Holt, 1952), pp. 321–336, 487; "Trial by Newspaper," Sci. Am. 180, 16 (1949); and congressional documents and newspaper accounts in NBS Historical File.

[180] "New York Times," Aug. 11, 1951, p. 1.

tor was the trouble, already warming up, over AD–X2. But that too would pass, and with time adjustment to the new world of science would be made.

The standard troy pound of Queen Elizabeth, formed of 8-ounce and 4-ounce nesting weights.



One of the three giant Wurtsburg antennas at the Bureau's Gun Barrel Hill, Colorado, field station. Used in radio propagation research, a dipole at the focal point of the paraboloid reflector receives radio energy from the sun.