CHAPTER XVII

Radio Equipment Improvement During Neutrality Period

IMPROVEMENT PROGRAMS

The Bureau of Steam Engineering promptly set about to correct the material deficiencies brought to light by unsatisfactory long-distance communications during the Mexican incident. Despite continued effort to obtain satisfactory equipment, the radio industry could not or would not expend the funds necessary to develop sufficiently rugged equipment for naval use. The superiority of undamped over damped wave transmissions had been conclusively demonstrated but receivers for the latter type were not reliable. In fact such receivers might be described as temperamental and, therefore, not satisfactory for shipboard use. Following an analysis of the situation, two programs were evolved. The first was designed to provide the earliest possible maximum improvement to existent installations by utilizing new components and techniques; the second; a long-range one, was for the eventual replacement of undamped wave by damped wave equipment.

ESTABLISHMENT OF A NAVAL RADIO DESIGN GROUP

It was decided that, insofar as possible, the Bureau would provide the design and rigid specifications for future procurements of radio equipment and, if commercial manufacturers were unable or unwilling to meet the specifications, the Navy would manufacture its own equipment. To carry out this decision additional civilian radio engineers, paid by and responsible only to the Navy, would be required. Six additional civilian aids, each an authority in a particular component of radio apparatus, were employed. They were detailed to various navy yards which were made responsible for the improvement of the components for which the assigned aid was the qualified expert. These assignments were as follows:

Navy Yard	*Expert Radio Aid*	*Responsibility*
Boston, Mass.	Mr. Walter Chadbourne	Keys; condensers.
Philadelphia, Pa.	Mr. E. D. Forbes	Antenna design and construction; rotary spark gaps; radio direction finders.
Brooklyn, N.Y.	Messrs. Guy Hill, George Lewis, and Lester Israel.	Frequency changers.
Washington, D.C.	Messrs. George H. Clark, Lester Israel, W. H. Preiss, and C. Carpenter.	Receivers; detectors; amplifiers; frequency-meters; transformers.
Norfolk, Va.	Mr. H. E. Hallborg	Reactances.
Mare Island, Calif.	Mr. George Hanscom	Transformers; quenched gaps; motor-generators.
Puget Sound, Wash.	Mr. W. H. Marriot	None.[1]

[1] "Radioana," Massachusetts Institute of Technology, Cambridge, Mass., George H. Clark, "Radio in War and Peace," pp. 113–119.

In establishing this group the Bureau of Steam Engineering, in its "Plan for Coordination of Work at Navy Yards," issued 15 June 1915, stated:

The success or failure of the Bureau's project for government manufacture and government development of radio apparatus rests largely upon the personal qualifications of those men as regards both ability and effort, and upon the Bureau's intimate knowledge of the same . . . Recognition of the individual character of the work performed should prove a strong incentive to increased effort.

Before relating the achievements of this organization it is fitting that tribute be paid to its organizer Lt. Commdr. A. J. Hepburn, USN. This can be best done by quoting the writings of George H. Clark, his subordinate and close personal friend:

Design, manufacture, operation! For the smooth building of a military system to handle the first, chief praise goes to Lieutenant Commander A. J. Hepburn, whose clear, incisive thinking led to the building of a smoothly-working technical corps which was operative from its very start.[2]

Hepburn completed his tour of duty in the Bureau at the time these additional civilian experts were employed and was relieved, in April 1915, by Hooper who had returned from his assignment as an observer of radio activities in the European war zone.

With responsibility for the component parts of radio equipment divided among the various navy yards, a standard drawing number system was devised by Mr. Guy Hill.[3] This was approved by Hooper and placed into effect on 15 June 1915. To prevent duplication of effort and to ensure knowledge concerning equipment available, one feature of the system required the provision of copies of each yard's blueprints to all other yards.[4]

[2] Ibid., p. 92.

[3] The details of the standard drawing number system are contained in appendix H.

[4] "Radioana," op. cit., Clark, "Radio in War and Peace", pp. 113–114.

OBSTACLES TO NAVY DESIGN OF RADIO EQUIPMENT

In May 1913 the Bureau stated its position concerning radio patents;

. . . it could not take cognizance of patents. It must have certain apparatus and must go on buying it from whomever can or will supply it until it is informed by the Department of Justice or some other authority that we must stop it.[5]

Regardless of this official expression of policy made by the Head of the Radio Division, all Navy contracts for radio equipment continued to carry a clause requiring the supplying firm to guarantee defense against patent infringement actions. The Bureau was fully aware that the manufacture of equipment by the Navy would place it in the position of having to defend itself against any infringement actions which might be brought before the U.S. Court of Claims. The major obstacles standing in the way of manufacture were the Marconi four-circuit tuning and the Fessenden heterodyne patents.[6]

Dr. Louis Cohen who, while associated with the National Electric Signaling Co., had worked with Dr. Austin in the formulation of the Austin-Cohen empirical formula, had devised a new means of coupling, utilizing condensers in lieu of the induction coils used by Marconi. The Navy obtained the right to the use of the Cohen patents and procured his temporary services to assist in the design of receivers.[7]

CIRCUIT DEVELOPMENTS WHICH AFFECTED DESIGN OF NAVY RECEIVERS

Before these receivers were designed, several events occurred which changed the techni-

[5] Letter, dated 20 May 1913, D. W. Todd to Wireless Specialty Apparatus Co., files, Bureau of Steam Engineering, National Archives, Washington, D.C.

[6] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 103.

[7] Annual Report of the Secretary of the Navy, 1915, (Washington Government Printing Office, 1915), p. 267.

ques of and materially improved radio reception. On 29 October 1913 Edwin H. Armstrong filed application for a patent on a regenerative circuit, and on 20 March of the following year De Forest filed application for a patent on a similar circuit. Armstrong was granted Patent No. 1,113,-149 on his circuit on 6 October 1914. De Forest, claiming prior discovery, instituted suit against Armstrong. He was unsuccessful in his early attempts to prove this, and it was not until the case reached the U.S. Supreme Court in 1928 that a decision was rendered in his favor.

Another De Forest development, which was to effect Navy designed receivers, was first exhibited at a meeting of the American Physical Society in April 1914. This was a receiver which utilized a three-element vacuum tube as an oscillator. He called it the Ultraudion. It could be used either as a detector or in lieu of the tiny, expensive, and tempermental arc that Fessenden utilized to produce the local oscillations in his heterodyne receiver. Hepburn immediately requisitioned 34 of them.[8] The "tikkers" provided by the Federal Telegraph Co. for chopping the continouus wave signals generated by the arc transmitters were discarded as rapidly as funds would permit the purchase of additional Ultraudions.

RADIO TELEPHONY DEVELOPMENTS AND THEIR EFFECT ON NAVY DESIGNED RADIO RECEIVERS

A letter, dated 22 May 1915, signed by Rear Adm. Robert Griffin,[9] USN, who had relieved Cone as Chief of the Bureau of Steam Engineering, advised the commandants of the navy yard, Mare Island, Calif.; the naval station, Honolulu, Hawaii; and the radio officer, Canal Zone, of the arrangements for conducting tests of "certain radio apparatus of novel design at the Arlington station about 15 June 1915." No details of these tests were given, the Bureau explaining:

> Without going into details, the point may be sufficiently emphasized by stating that the tests could not be held if it should prematurely transpire that the proprietors of the system are interested in radio matters, or that any test of apparatus made by them is contemplated. The Bureau has taken steps to insure that in the work of preparation for the test, including all correspondence on the subject up to this time, knowledge of the plan in view shall be restricted to the fewest persons possible, and that all such persons may be personally identified.
>
> The Bureau requests that a competent officer at each of the stations mentioned be assigned to supervise the tests and that all necessary facilities for the same be afforded. The Bureau desires not only to provide every convenience for a trial of the apparatus under the most favorable conditons, but also that a positive effort to assist should be made, freely offering such advice. services or use of special naval apparatus as the circumstances may suggest. The commercial representative is in immediate charge of the test and all technical details of the apparatus in question. It will probably be impractical to confine knowledge of the test and of technical details to a single naval representative at each station but every effort should be made to restrict this knowledge to the fewest persons possible.

Proprietor's representatives were authorized, upon producing a copy of the referenced letter, to assist at the cooperating stations as follows: Messrs. R. L. Hartley and B. W. Kendall, Mare Island; Lloyd Espenschied, Honolulu; and R.H. Wilson, Colón.

The instructions contained in this letter paved the way for the first long-distance radio telephony tests. These followed, within a few months, the inauguration on 25 January 1915, of transcontinental wire telephony, made possible by the development of a satisfactory repeater system using the De Forest triode.

The American Telephone and Telegraph Co., the proprietors, constructed a temporary building to house their trans-

[8] Ibid., p. 105.

[9] Griffin was born in and appointed a cadet engineer from Virginia. He graduated from the Naval Academy in 1847. He became Chief of the Bureau of Steam Engineering in 1915, with the rank of rear admiral, and served in this capacity until his retirement on 27 Sept. 1921. He died 21 Feb. 1933.

mitting equipment close by the transmitter building at Arlington. Switching arrangements were installed in such a manner as to allow the huge Arlington antenna to be shifted to their transmitting equipment whenever it could be spared. This equipment consisted of "a microphone circuit and an oscillating vacuum tube circuit fed into a modulator tube, which in turn was connected to a single stage of amplification supplemented by a second stage with a large number of tubes in parallel. These amplifier tubes were about 50 watts each in power rating." [10] The company representatives carried special receivers to the stations to which accredited. In the tests there were no efforts to establish two-way radio telephone communications, the return circuits from the receiver being by cable and telephone.

Arlington released the antenna to the Telephone Co. whenever possible, which was not often. When the transmitter was in use the most common and monotonous occurrence was the burning out of a tube in the second amplifier stage. Despite all the difficulties and annoyances, long-distance records were established and naval and military officials who observed the tests were highly impressed. The station at Darien, C.Z., distant 2,100 miles, received voice transmissions on 27 August, and both voice and music 2 days later. The Mare Island station, distant 2,500 miles, was able to receive the transmissions on 29 September and on the following night they were received by Espenschied at the Honolulu station.[11]

Following these successes attention was turned to Paris where, with the cooperation of Lt. Col. Ferrie, head of the French Military Communication System, the Eiffel Tower antenna was made available. France being at war, the antenna could only be used for test purposes at rare intervals, which were usually of only a few minutes' duration. This, coupled with the necessity of advising Arlington when to transmit by deferred cable service, made the tests a laborious and tedious procedure. On 23 October transmissions were received at Paris, distant 3,600 miles.[12]

During the tests much information was obtained concerning both radiotelephony and radiotelegraphy. Clark was allowed to trace the Telephone Co. circuits, and in his words:

> . . . there he saw for the first time the arrangement for obtaining "feedback" in a circuit so as to cause an associated vacuum tube to oscillate. Simply described, this consisted of a coil in the plate circuit of the vacuum tube, which coil was coupled to the secondary receiver coil, or other coil in which oscillations were to be produced. Since variation of coupling had a direct bearing on results this at once was seen to provide a positive method for making a tube oscillate, whereas with the De Forest ultraudion scheme, which had no variables, oscillation was a matter of hit or miss.[13]

FIRST NAVY DESIGNED AND MANUFACTURED RECEIVERS

The Washington Navy Yard, responsible for design of receiving equipment, established a radio laboratory in the River Radio station, which had not been used since the establishment of the station at Radio (Arlington), Va. There, Cohen, assisted by Clark and L. G. Butte, took the best portions of the new developments and incorporated them in the designs of the Navy types "A" (60-600 kc.), "B" (30-300 kc.), and "C" (1,200-3,000 kc.) receivers. These were completed in early 1915 and placed in production at the Washington Navy Yard in the same year.[14]

The Cohen method was used. This consisted of coupling and a modified type of feedback circuit, with a coil in the plate circuit for the purpose of making the vacuum tube oscillate. To avoid the use of the term "feed-back," Clark termed it "a 'tickler' because it tickles the audion and

[10] "Radioana," op. cit., Clark, "Radio in War and Peace", p. 247.

[11] Ibid., p. 248.

[12] Ibid.

[13] Ibid., p. 106.

[14] Ibid., p. 103.

makes it quiver." [15] The leads were of solid wire capable of withstanding shipboard vibration and the shock of gunfire. The induction coils were of low resistance as compared with those used in commercial receivers and their values in the two circuits could be varied to provide sharp tuning. Dials were fixed to the shafts of the tuning condensers making it possible to calibrate each receiver so that the operator could tell where to aline it for specific frequencies. Arrangements were incorporated to permit the use of either crystal or vacuum tube detection.

These receivers were placed in service at the shore stations and on the more important combatant ships as fast as they could be manufactured. However, economy dictated the continued use of the crystal detector, and the heterodyne feature was used only for the reception of the continuous wave signals.[16]

AMPLIFIER AS AID TO RECEPTION

From the beginning of radio, engineers and operators recognized the desirability of amplifying the received signal and of improving the signal-to-noise ratio. Late in 1912, the Federal Telegraph Co., for which De Forest was then working, had delivered the Navy a crude "bread board" model of an amplifier which increased the intensity of the signal without introducing additional noises of its own. It provided sufficient amplification to allow the first daylight reception of a west coast transmission at Arlington. De Forest left the employ of the Federal Co. in 1913 and reorganized his defunct Radio Telephone Co., changing its name to the Radio Telephone and Telegraph Co. In November of that year he submitted the first sample of a commercial amplifier to the Navy for test. The following month 10 were purchased, and the use of the amplifier in radio receiving began. They were not at that time included as components of radio receivers and were used only for audiofrequency amplification. Economy necessitated limiting the supply of amplifiers to one for each ship and shore station. A switching arrangement was provided so that the amplifier could be connected to the particular receiver most in need of it. During 1914 the Navy continued to purchase them from De Forest, but they were not a completely satisfactory device and were later redesigned to meet service requirements.[17]

IMPROVEMENT OF VACUUM TUBE

Equipment utilizing the three-element vacuum tube possessed one serious weakness, the tube itself, as manufactured by the Radio Telephone and Telegraph Co. They were expensive, short lived, and lacked uniformity due to De Forest's persistent belief that some residual gas should be left in the tube. It was impossible to gage the exact amount of gas left with the result that some of the tubes were better amplifiers, and others better detectors. To limit the number carried, it was essential that each tube function equally well for all purposes. Dr. H. D. Arnold of the American Telephone and Telegraph Co. held the opinion that the instability of De Forest's tubes "was caused by gas ionization, and that this defect could be removed by increasing the vacuum." He also believed that the tube could be improved by the use of an oxide coated cathode in lieu of one of tantalum. By the end of 1913 the Telephone Co. had developed a tube with a laboratory life of 1,000 hours which could be uniformly produced. Dr. Irving Langmuir of the General Electric Co. arrived at the same conclusion held by Arnold in respect to the necessity for a high vacuum. The Bureau of Steam Engineering considered that De Forest, as the inventor of the three-element tube, should be favored in the purchase of tubes, provided

[15] Ibid.

[16] Ibid., p. 103.

[17] Ibid., p. 107.

he could deliver a product comparable in quality and cost. Despite persistent effort to convince De Forest that his theory was erroneous, he continued to deliver nonuniform tubes with high residual gas content.

At this time the Bureau took the first of many successful actions destined to improve the quality and life of tubes by making it financially feasible for industry to expend funds for research. A requisition was prepared for vacuum tubes in which the specifications called for uniform, high vacuum tubes, guaranteed for a life of 5,000 hours at a cost of $10 each. In addition to De Forest, both the General Electric and the Western Electric Cos. were urged to meet the specifications. De Forest merely laughed at the requirements. The Western Electric Co. stated that the 5,000-hour requirement could be met but that a more practical tube could be built if the life guarantee was reduced to 2,000 hours and the cost reduced to approximately $4.50 per tube. The specifications were modified accordingly, the Western Electric Co. was awarded the contract and produced satisfactory tubes. This action on the part of the Navy in placing a seemingly impossible requirement on American industry resulted in advancing the radio art in this country by at least 2 years, saved the Government thousands of dollars, and made the general naval use of tubes economically feasible.[18] De Forest continued to attempt to compete with other tube manufacturers but was never able to produce comparable tubes.[19]

IMPROVEMENT OF CONDENSERS

The high capacity condensers required for radio transmitters had necessitated the use of Leyden jars. In the earlier days these were made of glass covered with tinfoil. Later types were made of glass plated with copper. Those utilizing Bohemian glass were the best. During World War I the supply of this glass was cut off, and manufacturers were forced to resort to jars of American manufacture. In December 1914 the Wireless Specialty Apparatus Co. delivered a shipment which failed to meet Navy specifications but urgent requirements necessitated their acceptance. Jars of Bohemian glass had been a constant source of trouble but the wartime inferior product caused even more annoyance.

Early in 1916 Mr. William Dubilier submitted a mica condenser for test. It failed to meet the requirements of the Navy or to fulfil the claims of its inventor. Hill, Radio Aide at the New York Navy Yard, believed Dubilier's idea possessed merit and drew up specifications for such a device requiring, among other things, that they be in metal containers so that the generated heat could be radiated faster. By December of the same year, with Hill's advice, Dubilier had improved his product and the Bureau purchased 1,000 of them. In the meantime Firth, of the Wireless Specialty Apparatus Co., not at all happy at the prospect of losing the lucrative Leyden jar business, entered the mica condenser field and sold the Navy 750 condensers in the same month. During the next several years both manufacturers sold large numbers of these condensers. Following the war Dubilier brought an infringement action against the Wireless Specialty Co., but the suit was settled prior to court decision.[20]

NAVY RADIO TYPE NUMBER SYSTEM

By 1916 so many component parts of naval radio equipment were in stock that it became difficult to identify any specific item without long descriptive discourse. To simplify the situation, a type number system

[18] U.S. Naval Communications Division Memorandum, 10 February, 1937.

[19] U.S. Navy Contract 980, 8 May 1918, was awarded De Forest for 2,000 tubes. Because of lack of uniformity 1802 of these were rejected.

[20] "Radioana," op. cit., Clark, "Radio in War and Peace", pp. 109–110.

devised by Clark was placed in effect. In this, a modification of which is still in effect, a specific consecutive number was assigned each device and to collective components. Preceding the type number was a letter designation indicating the design source: SE if designed by the Navy, or C if of commercial design, followed by one or two additional letters indicating the particular originating company.[21] Mr. A. M. Trogner, then the chief draftsman for the Bureau, worked out the details and made the assignments.[22]

STATUS OF NAVY DESIGN AT TIME WE ENTERED THE WAR

The rapidity with which the Navy radio engineers designed the various components of radio transmitters and receivers is astounding. By the time we entered the war, 25 percent of the components of radio equipment to which type numbers had been issued were of Navy design. Nor does this present the complete picture because the percentage of commercial design was largely made up of standard electrical instruments, insulators, motor generators, condensers, etc., while those contained in the Navy's portion included many complete transmitters and receivers, and in most cases the component parts of these were mostly of Navy design. As an example, SE 720, a 5-kw. spark transmitter of Navy design, was made up of 14 Navy and 3 commercial components. CM 301, another 5-kw. spark transmitter of American Marconi design, was made up of five Navy, seven Marconi, two Dubilier and one Crocker-Wheeler components.[23]

[21] Appendix I contains a list of manufacturers designations.

[22] "Radioana," op. cit., Clark, "Radio in War and Peace", pp. 115–116.

[23] "Model Letter and Type Number Book, 1923," (RE 15A 101F), Navy Department, Washington, D.C.

INCREASED EQUIPMENT REQUIREMENTS

In August 1916 Congress authorized a $600 million program for the construction of 10 battleships, 6 battle cruisers, and 140 miscellaneous naval vessels during the next 3 years.[24] The manufacturing facilities of the various navy yards were not sufficient to provide radio apparatus in the quantities required by this preparedness program and this necessitated dependence upon commercial production. A court decision of the previous year had made the acceptance of Government contracts for radio equipment more attractive to commercial manufacturers. Judge Hough, presiding over the U.S. District Court for the Southern District of New York, had held that owners of patents infringed in the manufacture of equipment under Government contracts were limited to the recovery of damages from the United States. Manufacturers, many of them just entering the field, believing themselves secure from litigation, sought Government contracts. Competition became so intense that all were willing to provide equipment based on Navy design and meeting Navy specifications.

STANDARDIZATION OF SHIPBOARD INSTALLATIONS

Prior to the beginning of World War I shipboard installations had been made primarily on a space available basis without regard to space best meeting the particular requirements of radio. Following the authorized increase in the Navy, the Bureau, in 1916, prepared standard equipment allowances and installation plans for each type of naval vessel.[25]

[24] David Saville Muzzey, "A History of Our Country," (Ginn and Co., Boston, 1943), p. 653.

[25] "Radioana," op. cit., Clark, "Radio in War and Peace," p. 120.

COMPARISON WITH OTHER NAVIES

At the time of the outbreak of hostilities in Europe, Germany was as well advanced in the radio field as any nation. Due to the widespread activities of the Marconi Cos. she had not been too successful in commercial exploitation, but her military equipment was superior to that of France and England. The German Navy was equipped with quenched-gap spark transmitters and Germany also had an ample number of shore stations to serve the requirements of her fleet. France had made little use of radio, but her navy was equipped. England, because of the Marconi interests, had a source of trained designers and manufacturers but, due to the nature of the envisioned operations of the Home Fleet, continued to use broadly tuned and less sensitive equipments. By the time the United States entered the war, we had better radio equipment than any other navy. The quenched-gap component of our spark transmitters, built on Navy specifications, was superior to that of Germany; Navy-designed power control units permitted limiting the output of transmitters; Navy-designed frequency changers allowed a transmitter to be quickly shifted from one frequency to any of several others; the rotary spark and the arc transmitter provided reliable communications over much greater distances; and our Navy-designed and constructed receivers were the best in the world.