THE SAGA OF THE VACUUM TUBE

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Part 10. Covering the evolution of the vacuum tube through the years 1914 to 1918, as a result of the research work done by Western Electric.

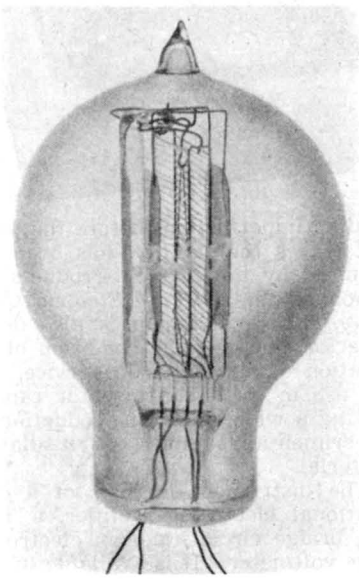

Fig. 92.

THUS far we have considered but one type of Western Electric tube. It has been treated in considerable detail, because of the evolutionary steps through which it passed. These steps show the results which may be attained through painstaking research and careful engineering with but one objective—to produce the most economical and reliable device to fulfill a given function, when operated under expert care and carefully controlled conditions.

Other tubes were evolved in the laboratories and manufacturing plants of the Western Electric Company during the period covered in the preceding articles. Some were for use in the telephone plant, some for the Armed Services of the U. S. Government, and others for divers applications which arose as time went on and wider vistas opened up.

Many of these went through developmental steps paralleling those of the 101 type and will be treated but briefly in what follows. One of the best known of these other tubes is the famous "V" tube. This was probably so called because it was intended for use as a "voltage" amplifier. It was first known as the type "VM"—V for *voltage* and M for *mounted*—but the "M" was soon dropped and it became known as the "V" tube.

The earliest vacuum-tube repeaters, as has been previously stated, used "L" tubes and were single-stage affairs. When the need for higher amplifications than could be obtained in these arrangements arose, two-stage repeaters were developed, and the "V" tube was used in the first stage to provide "voltage" amplification. Its plate-to-filament impedance was too high to permit it to be worked successfully as an output tube, however, and the second stage was an "L" tube with its lower output impedance.

The first experimental "V" tubes

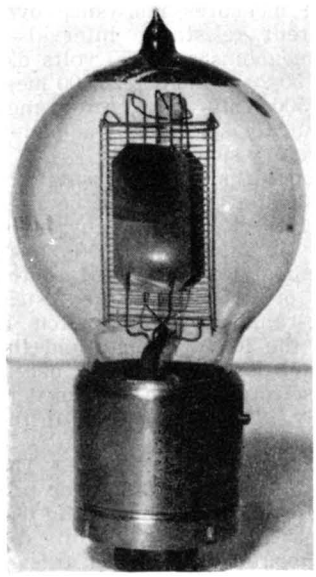

Fig. 93.

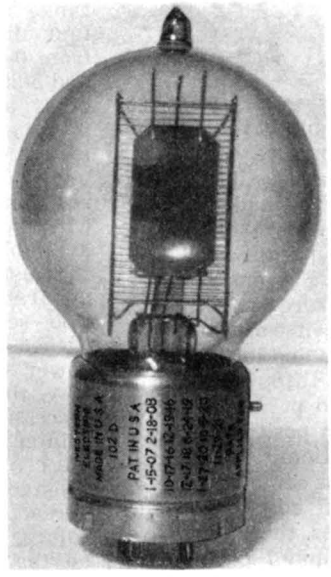

Fig. 94.

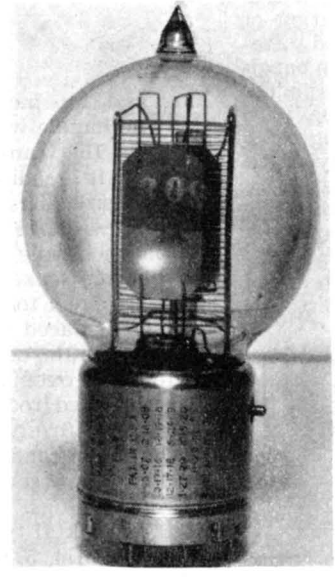

Fig. 95.

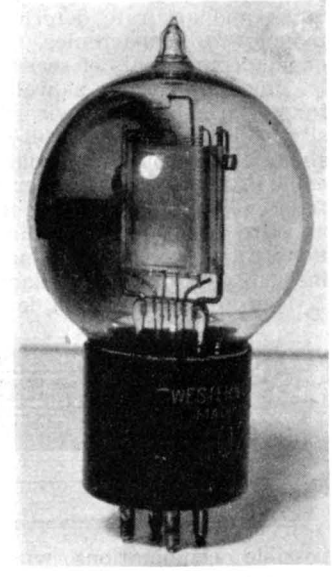

Fig. 96.

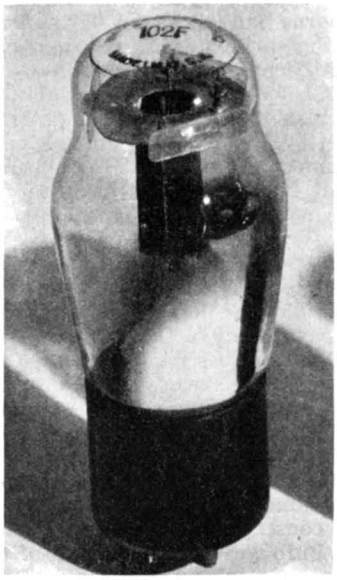

Fig. 97.

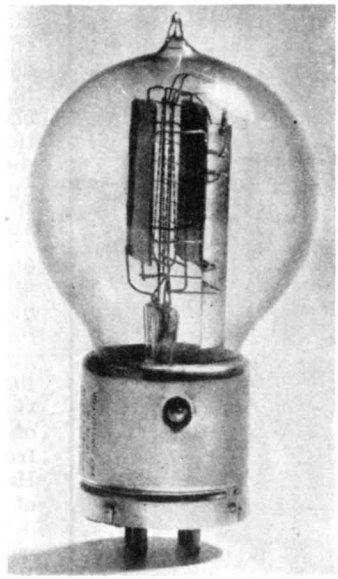

Fig. 98.

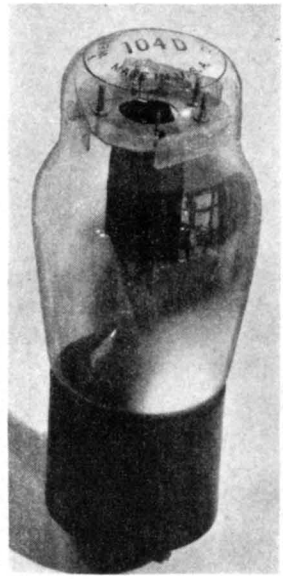

Fig. 99.

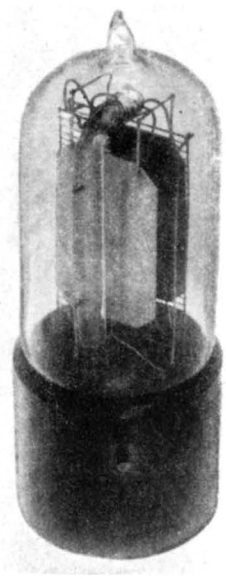

Fig. 100.

were made about the middle of 1914 and the first commercial product appeared early in 1915. Fig. 92 shows one of the earlier tubes before basing.

The "V" tube used the characteristic Western Electric "ladder type" grid and had 31 laterals on each side. The grids were considerably larger in area than the plates, and the filament was Λ shaped. The spacing between grids was about ⅛ inch and between plates about ½ inch. The base used was the same machined brass base used on the "L" tube which has been previously described.

Like the "L" tube, the first of the "V" tubes probably carried no patent markings. Beginning late in 1915 patent markings were applied in a manner similar to that of the "L" tube of that time. In 1916 the code designation "102A Telephone Repeater Element" was assigned to the "V" tube. This was later changed to that of "102A Repeater Bulb."

It is not our purpose to go into further detail concerning the progressive changes made in the "V" tube. However, for the benefit of tube collectors Fig. 93 shows one of the variants of the 102A.

Up to the end of 1918 all of the "V" tubes and some of the other tubes made by the Western Electric Company had been manufactured in the shops of the Engineering Department of the Company in New York. This was done because of the need for close engineering supervision in the early manufacture of a new device. By the end of 1918 progress was considered sufficient to permit their manufacture in the regular factory, and accordingly, production of some of them, among which was the 102A, was begun at the Hawthorne plant of the Company in Chicago.

All of the early Western Electric tubes had a serial number etched or sandblasted on the bulb. In order to distinguish between tubes made in New York and in Hawthorne the tele-

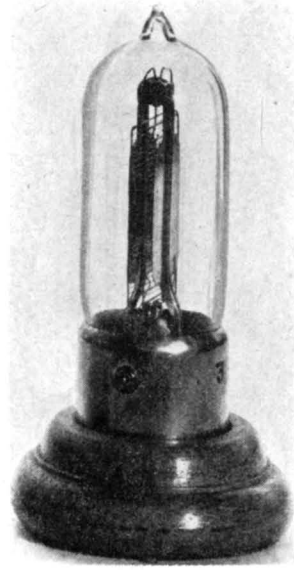

Fig. 101

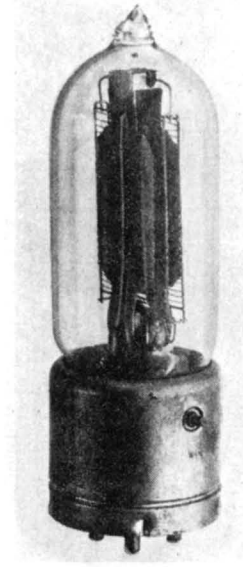

Fig. 102.

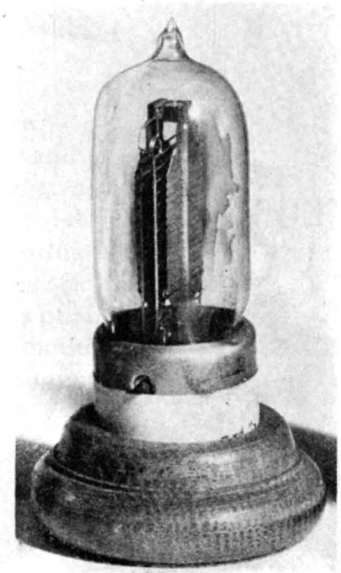

Fig. 103.

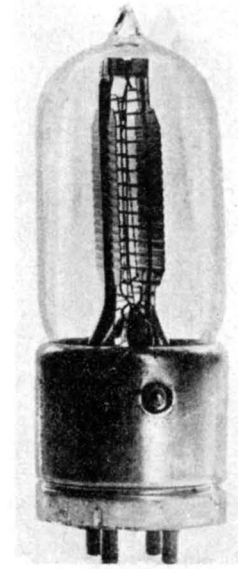

Fig. 104.

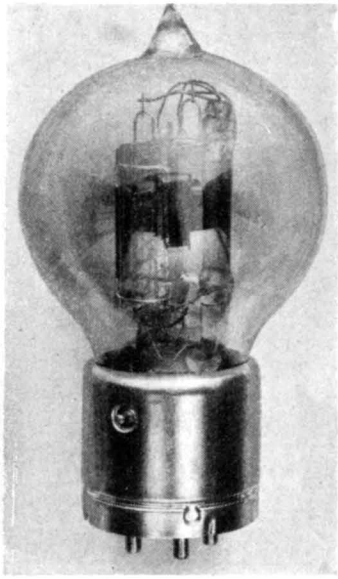

Fig. 105.

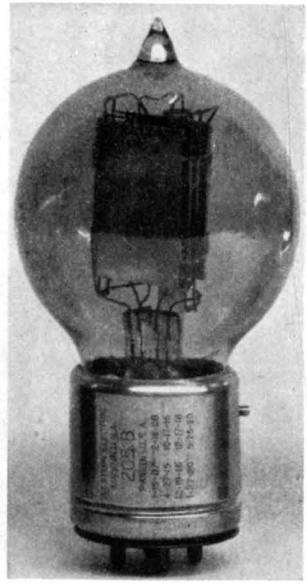

Fig. 106.

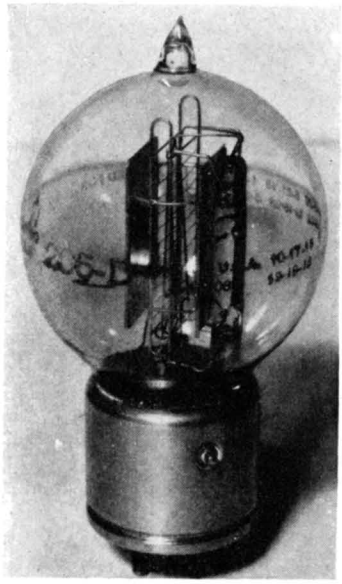

Fig. 107.

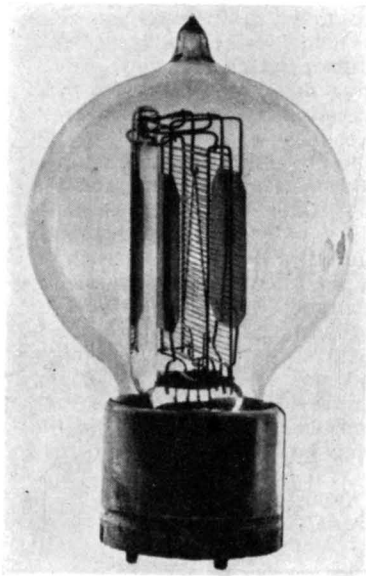

Fig. 108.

phone repeater type tubes made at Hawthorne had the letter "H" appended to the serial number. When production became great enough so that the number of digits in the serial number increased beyond five, the designation letter was changed to "A" and the numbering repeated. The tubes made at New York had no letter included in the serial designation.

There were also some minor details of construction in which tubes made at Hawthorne differed from those made at New York. One of these was in the positioning of the laterals of the grid. In the tubes made at New York the grid laterals were welded to the vertical support wires on the outside of the frame; that is, the side away from the filament. Tubes made at Hawthorne had the laterals on the side of the frame nearer the filament.

The construction of the 102A Repeater Bulb was similar to that of the 101B in that the elements were supported by a glass arbor welded to the edge of the press. Early in 1922 the 102A was replaced by the 102D which had an improved filament, operating at the same filament current as the 101D. The construction was soon changed so that the arbor was attached to the stem below the press, in a manner analagous to that of the later type 101B and the 101D. The single Λ filament was retained since the normal plate current of the 102 types was much lower than that of the 101 types and the electron emission from the smaller surface was adequate.

From this time on the changes in the 102 series, such as location and type of markings, substitution of molded for metal base shells, etc., in general followed those of the 101 series and will not be detailed here. Again for the benefit of the tube collector photographs of some of the variants

(*Continued on page* 90)

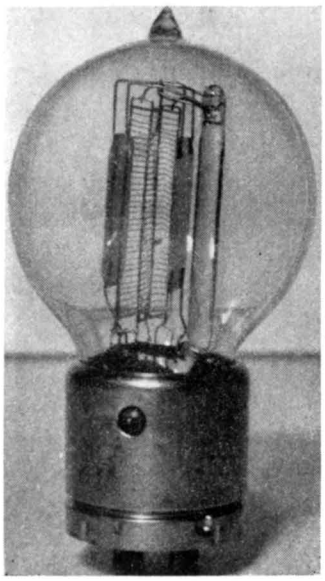

Fig. 109.

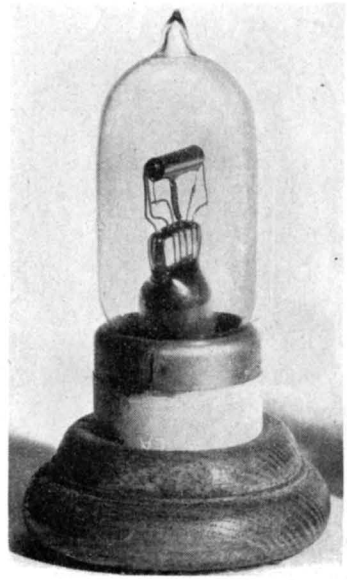

Fig. 110.

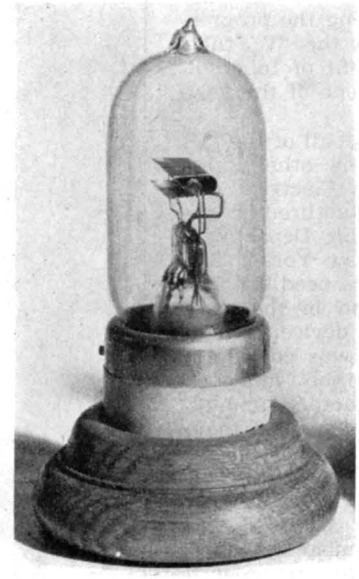

Fig. 111.

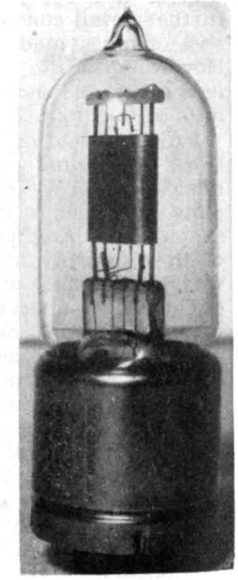

Fig. 112.

It would be highly desirable if the automatic air traffic control equipment for aircraft could be light enough and cheap enough so that all aircraft flying under instrument flight rules would be equipped with these devices. However, it is expected that at least for a long time only the larger aircraft will be so equipped. The most optimistic estimate would place not more than 50% of the aircraft flying in instrument weather by 1950 in the category of those having full automatic air traffic control equipment. This means that the air traffic control system would have to continue to be capable of controlling a substantial amount of air traffic involving aircraft having only the minimum air traffic control equipment such as is required at the present time.

However, the automatic devices for aircraft and the ground aids for air traffic control previously described point to the possibility of obtaining the ultimate objective of permitting the flow of air traffic under instrument weather conditions in the same volume and with the same frequency as is possible under contact weather conditions. This means that at an airport properly designed and adequately served by navigational air traffic control facilities, landings under instrument weather conditions would be possible at extremely short intervals. Thus, future planning seems to indicate that it will be possible for the air traffic control system within the United States to reach the level of safety and efficiency which ultimately will be required by mature air transportation.

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Saga of Vacuum Tube

(*Continued from page* 52)

of the 102 series will be found in Figs. 94 to 97, inclusive.

The 102 type vacuum tube was an extremely long-lived device, because of the conservative engineering behind it and the low plate current required. The writer recently saw a 102A Repeater Bulb which had been removed from service in a laboratory device only two years ago. It had been in daily use for almost 20 years and was still functioning satisfactorily.

Another tube which was used in telephone equipment, but to a lesser extent than the "L" and "V" tubes, was the 104 type, which started life under the appellation of type "O". It was probably so designated because of its original use as an "output" tube. It had a lower plate impedance than either the "L" or "V" types. The "O" tube was first made commercially in the shops of the New York Engineering Department late in 1917. As originally made, it consisted of two plates ¾ inch wide and 1¼ inches high, spaced 5/16 inch apart, and two grids of the ladder type, the same size as the plates and spaced ⅛ inch apart. Each grid had nine laterals. The filament was M shaped. The structural difference between the "L" and "O" tubes was chiefly in the spacing of the elements. The type "O" originally had two glass arbors, one for each plate-grid assembly. Late in 1918 the use of the second arbor was abandoned and the stem thus became similar to that of the type "L". The code designation "104A" was applied to this tube, which was later replaced by the "104D" Figs. 98 and 99 show some of the variants of these types.

All the Western Electric tubes thus far considered were engineered for use under the carefully controlled conditions existing in the telephone plant. But at the time of World War I the engineering skill and manufacturing experience which produced them were invaluable in providing background for the production of tubes for sorely needed military equipment.

Vacuum tubes for military and naval use are a "different breed of cat" from the telephone repeater. They must be capable of giving a reasonable service life under conditions which may vary widely at different times and in different places. In much equipment considerations of weight and space are paramount. Ambient temperatures vary from the cold of the radio cabin in the arctic to the broiling heat of a destroyer engine room in the tropics. Filament and plate voltages may vary widely and rapidly. Mechanical shocks are inevitable.

Nevertheless the Western Electric engineers, at the urgent request of the Armed Services, set about the development of vacuum tubes of stable and rugged construction to meet these new but no less exacting requirements. From their labors emerged a number of reliable tubes, probably the best known of which were the "VT1" and "VT2."

"VT1" was the U. S. Signal Corps designation for the tube, which in its inception was known to Western Electric engineers as the type "J". This same tube was also used by the U. S. Navy under the designation "CW933." The Western Electric code numbers assigned to this type were in the 203 series, the first being the 203A."

The "J" tube was a general purpose tube, being used as detector, amplifier, or low power oscillator. Fig. 100 is a photograph of one of the early "J" tubes. A cylindrical bulb was used instead of the spherical bulb common to the other Western Electric tubes up to that time. The element assembly used the same glass arbor construction as the telephone repeater tubes, and the earliest models had machined brass bases. The grids were of the ladder type and the plates were of flat sheet.

The glass arbor construction proved to be too fragile to withstand the severe vibration conditions imposed on the equipment in which the tube was used. In order to insure permanent alignment of the elements under the severest conditions there was developed a form of element assembly which became known as the "iron-clad" conconstruction, in which the plate formed the support for the grid and

filament. This structure was the result of an evolutionary process which can be traced through the steps shown in Figs. 101 to 104 inclusive.

The first change was in the base. The machined brass base was replaced by a lighter sheet metal base similar to that used in the standard telephone repeater tubes. The next construction was that shown in Fig. 101. Here the glass arbor has been eliminated and a new plate structure used. The plates are supported from the stem, and a stiffening rib provided. Ladder type grids with wire laterals are still used. Fig. 102 shows the next modification, which was the substitution of a corrugated plate for the flat plate in the preceding version. Fig. 103 shows a later modification, in which grids of punched sheet metal replaced those of the wire type. The final version, which was manufactured in large numbers as the VT1, is shown in Fig. 104. After the close of World War I many of these VT1s found their way into the general market, via sales of surplus Army equipment, and were used by amateur radio enthusiasts.

The VT1 operated with a filament current of 1.15 amperes at a voltage of 2 to 2.5 volts. The plate voltage used varied from 20 to 100 volts, and the plate current from 0.5 to 2 milliamperes, depending on the purpose for which the tube was used. The amplification factor was about 6 and the internal plate impedance 10,000 to 25,000 ohms.

The other widely known and used tube was the VT2. This was developed as a result of a request from the U. S. Signal Corps in 1917. The request was for a small transmitting tube to operate at a plate voltage of 300 volts. The VT2, which was also used by the U. S. Navy under the designation "CW931," was originally designated by Western Electric Company as the type "E", and later code numbers in the 205 series were assigned.

Fig. 105 shows one of the earlier "E" tubes. The construction was somewhat similar to the type "L" except that the plates had turned-up edges and different bracing wires. This difference in construction was necessitated by the higher plate dissipation of the "E" tube which tended to warp flat plates. The base first used was of the wax-filled type which was standard for use on telephone repeater tubes. This was later found unsatisfactory because of the higher temperature at which the "E" tubes operated, and was replaced by a base using a phenolic insert.

The VT2 operated with a filament current of 1.35 amperes at a voltage of 6 to 7.5 volts. The operating plate voltage was 250 to 350 volts, the plate current 30 to 45 milliamperes, amplification factor approximately 7 and internal plate impedence 3,000 to 4,500 ohms. It was rated at 5 watts continuous output as an oscillator.

Other uses were found for this series of tubes after the war, and the manufacture of the 205B was continued until about 1924, when it was replaced by the 205D. The chief improvement was in the filament. The new filament was better electrically, and differed in appearance in that it was plain instead of being twisted. Since that time the "E" tube has undergone other changes which may be seen in Figs. 106 and 107.

There were, in addition to these tubes, several others made in somewhat smaller quantities for the U. S. Government during World War I. One of these bore the Western Electric code designation "201A," and was known to the Navy as the "CW186." This tube, with its three contact base, is shown in Fig. 108. It was similar to the type "V" except for the grid, which had 37 laterals on each side instead of 31. The 201A, as will be noted from Fig. 108, was made with a base which had three contact studs, the fourth terminal being the metal base shell. This was made in accordance with Navy requirements. This tube in the standard telephone repeater base had been known as the type "D" tube to the Western Electric engineers.

One of the difficulties encountered in the use of this tube by the Navy was microphonic trouble caused by imperfect contact between the metal base shell and its socket. To eliminate this condition the design was changed to use the four contact base, originally used on this type. In this form it was known as the Western Electric 201B, and is shown in Fig. 109. Few were made, however, since it was soon replaced in Navy equipment by the all-purpose "J" tube.

Early in 1918, at the request of the Signal Corps, the work of developing a tube similar to the VT1, except suitable for operation in portable equipment, was undertaken. The chief problem was that of obtaining a filament which would operate with a current of the order of 0.2 to 0.25 ampere from a single storage cell. The tube which fulfilled these requirements was designated "VT3" by the Signal Corps and was known to the Western Electric engineers as the type "P." Figs. 110, 111 and 112 show three of the structures used for this tube, that of Fig. 112 being the final one. The designation "VT-3" was etched on the bulb, in block letters, but the etching is too faint to show in the photograph. Only a few of these tubes were made since the necessity for them was reduced by the cessation of hostilities. The work was not lost, however, since the knowledge gained was used to good advantage in the development of the famous "peanut" tube, which will be discussed in our next article.

CAPTIONS FOR ILLUSTRATIONS

Fig. 92. Western Electric Type "V" Telephone Repeater Element, before basing. 1915. Photograph courtesy Bell Telephone Laboratories.

Fig. 93. Western Electric 102A Repeater Bulb. This is the first variant using the formed sheet metal base.

The code marking appears only in the wax filling of the base. Note colored lacquer—black—applied to tip.

Fig. 94. Western Electric 102D Vacuum Tube, showing Western Electric name, code, and patent marking on base in $\frac{1}{16}$ inch characters.

Fig. 95. Western Electric 102D Vacuum Tube, showing Western Electric name, code, and patent marking on base in $\frac{3}{64}$ inch characters.

Fig. 96. Western Electric 102F Vacuum Tube with code marking on base in depressed characters.

Fig. 97. Western Electric 102F Vacuum Tube of current construction. New element assembly and domed bulb.

Fig. 98. Western Electric Type "O" or 104A Vacuum Tube — early construction.

Fig. 99. Western Electric 104D Vacuum Tube—current construction. New element assembly and domed bulb.

Fig. 100. Early Western Electric Type "J" or 203A Vacuum Tube with machined brass base and glass arbor construction. Photograph courtesy Bell Telephone Laboratories.

Fig. 101. Western Electric 203A Vacuum Tube—third type—with element assembly supported by collar on stem of tube. Wire ladder type grid and flat plate with stiffening rib. Photograph courtesy Bell Telephone Laboratories.

Fig. 102. Western Electric 203A Vacuum Tube—later type with corrugated plate and wire grid. Photograph courtesy Bell Telephone Laboratories.

Fig. 103. Western Electric VT1 with early type punched grid. Photograph courtesy Bell Telephone Laboratories.

Fig. 104. Western Electric VT1—final version. Photograph courtesy Bell Telephone Laboratories.

Fig. 105. Early Western Electric Type "E" or 205A Vacuum Tube. Sheet metal base, wax filled. Photograph courtesy Bell Telephone Laboratories.

Fig. 106. Western Electric 205B Vacuum Tube—still later type with later patent markings.

Fig. 107. Early Western Electric 205D Vacuum Tube—with metal base and markings on bulb.

Fig. 108. Western Electric Type "D" or 201A Vacuum Tube. This was made for the U. S. Navy under the designation "CW186." Note the three contact base. Photograph courtesy Bell Telephone Laboratories.

Fig. 109. Western Electric 201B Vacuum Tube. Same as 201A shown in Figure 108 except for use of standard four-prong base.

Fig. 110. Western Electric Type "P" Vacuum Tube — first construction. Photograph courtesy Bell Telephone Laboratories.

Fig. 111. Western Electric Type "P" Vacuum Tube — second construction. Photograph courtesy Bell Telephone Laboratories.

Fig. 112. Western Electric VT3 — final form of type "P" vacuum tube. The "VT-3" marking is etched on the bulb in block letters but the etching is too faint to show up in the photograph.

(To be continued)