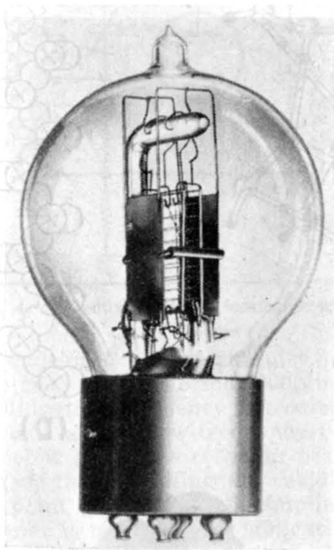


Fig. 113.

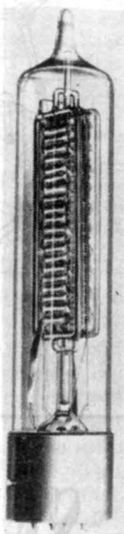


Fig. 114.

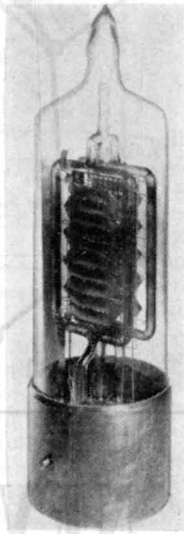


Fig. 115.

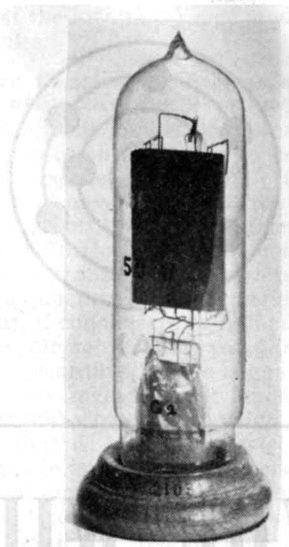


Fig. 116.

THE SAGA OF THE VACUUM TUBE

By GERALD F. J. TYNE

Research Engineer, N. Y.

Part II. Covering a number of the unusual earlier constructed tubes that are of particular interest to many old timers.

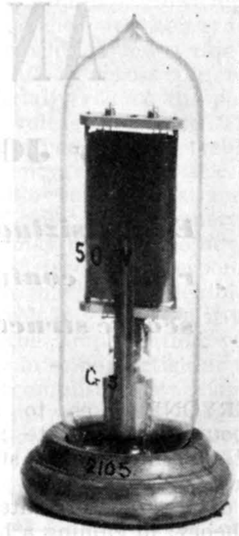


Fig. 117.

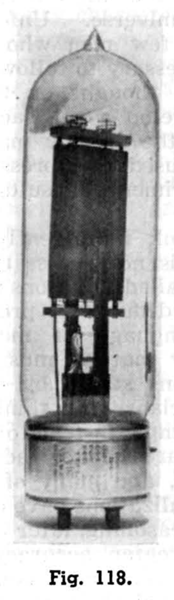


Fig. 118.

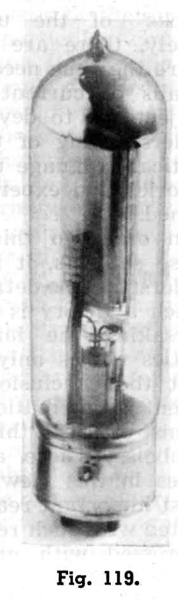


Fig. 119.

UP TO now we have discussed Western Electric vacuum tubes of the telephone repeater type and a few made for the Army and Navy during World War I. There were a number of other early tubes however, and some of these may fall into the hands of the tube collector. Some will bear few marks of identification but may be recognized from their descriptions and photographs, which follow. First let us consider the power tubes.

The low power output tube for telephone applications, type "O," has already been described as well as the so-called "5-watt" tube, type "E."

The type "E" was preceded by another tube known as the type "K," which is shown in Fig. 113. This was originally intended for application in government equipment as a transmitter tube for aircraft use. It operated at a plate voltage of about 500 volts. This voltage was considered to be a source of serious danger to the operator and the type "K" was abandoned in favor of the type "E" which operated at 300 volts plate. The type "K," to which was assigned the Western Electric code designation "202A" had a machined brass base similar to that used on the early telephone repeater tubes, but of larger size.

Prior to this time the only extensive use of power tubes by the Western Electric Company had been in the famous transatlantic telephone tests conducted in 1915. These were one-way transmissions, the transmitter being at Arlington, Virginia. A bank of some 550 tubes operating in parallel was used in the final amplifier. To fully appreciate such a feat as this and realize the difficulties which had to be overcome by these pioneers, one should hear the stories told by the men who did the job. Problems of division of load, intertube wiring, parasitic oscillations, cooling, and a host of others, which can be fully appreciated only by one who has tried to operate more

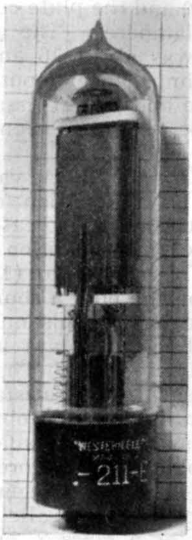


Fig. 120.

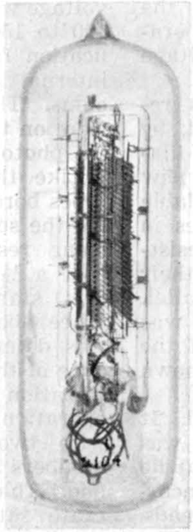


Fig. 121.

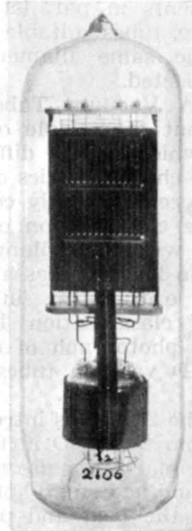


Fig. 122.

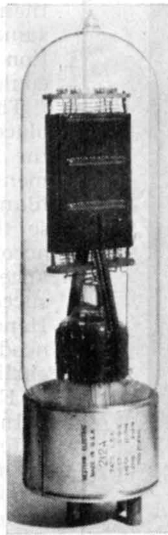


Fig. 123.

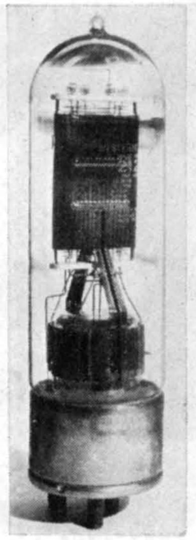


Fig. 124.

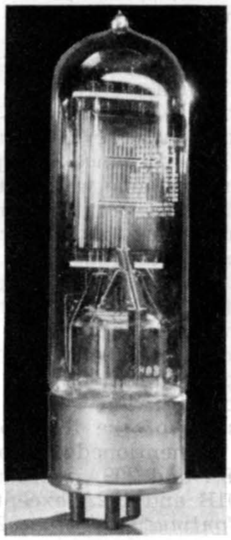


Fig. 125.

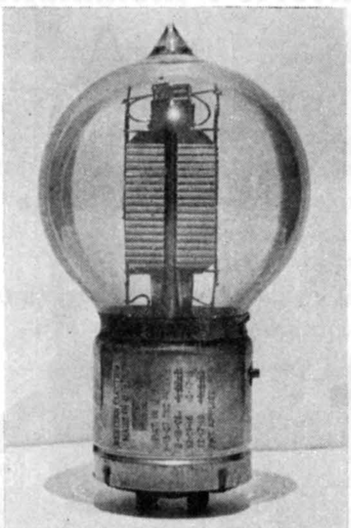


Fig. 126.

than two tubes in parallel, had to be solved. That this was accomplished in a short time is another instance of the results of cooperative effort in an industrial laboratory.

The tubes used in this amplifier were known as type "W" and the official designation was "204B Vacuum Tube." The type "W" operated with a filament current of 4 to 4.5 amperes, plate voltage of 600 volts, and plate current of 150 to 200 milliamperes. Most of the type "W" tubes used at Arlington were unbased although some based tubes, similar to that shown in Fig. 114, were also used.

The most noticeable feature of the type "W" was the plate. Since a solid sheet metal plate of the requisite size would contain much occluded gas which would have been difficult to remove with the evacuation technique of that day, the construction shown in the photograph was adopted. The plate was made from a strip of metal tape bent back and forth as shown. The material used was a high resistance alloy and leads were brought out from both ends of the strip. The tape could thus be heated by the passage of current from an external source, during the evacuation process, and the occluded gases thus expelled.

Another similarly constructed tube, used chiefly as a modulator in the long distance tests preceding the transatlantic tests, was known as the type "S" and had the code designation "204A." This tube is illustrated in Fig. 115. Although this tube was smaller in size, the similarity in construction to the type "W" will be noted. It was the experience and knowledge gained in the development of these tubes which enabled the Western Electric Company to produce the other types of power tubes urgently requested by the U. S. Government for radio communication in World War I.

After the war there grew up a demand for higher powered tubes for radio transmitters and public address systems. This need motivated the development of two series of tubes which are familiar to those acquainted with the early days of broadcasting. One was known during its development as the type "G" and the other as the type "I."

The type "G" was one variety of the size which later became commonly known as the "50-watter" and was the progenitor of the Western Electric 211A and others of the 211 series. As in all such developments, problems were encountered in the process and various structures were tried before one suitable for commercial service was attained. Figs. 116 and 117 show some of the element assemblies tried out during this process. The construction finally adopted, which was given the code designation "211A Vacuum Tube" is shown in Fig. 118.

This tube operated with a filament current of 3.4 amperes at 9 to 10 volts. The plate voltage was usually about 750 and plate current 40 to 80 milliamperes. The amplification factor was about 12 and the internal plate impedance 3000 to 4000 ohms. The operating life was about 300 hours. The base was the same size as that originally brought out by the Western Electric engineers for the type "K" tube, and eventually adopted as standard for all 50-watters, by other manufacturers as well.

The 211 type tubes were intended for operation at a fixed value of filament current, and the value of filament voltage was determined by the filament resistance. They were usually operated, however, from a constant voltage source. Hence, they were classified at the time of manufacture into five groups, and the classification was indicated by a letter etched on the bulb at the end of the serial number. The letters used were A, B, C, D, and E.

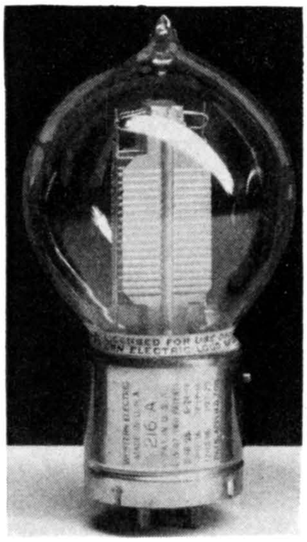


Fig. 127.

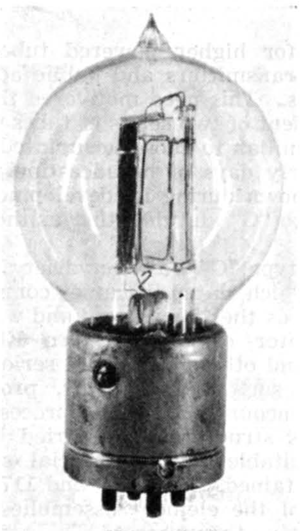


Fig. 128.

This was done so that when two or more were required to operate with their filaments in parallel from the same source, tubes suitable for operation at the same filament voltage could be selected.

The 211A Vacuum Tube was replaced, about the middle of 1924, by the 211D which used a different filament. The characteristics of this new filament were sufficiently controllable so that the classification of tubes in accordance with their filament resistance was no longer necessary to their successful operation in parallel. Hence, no classification letter was needed. A photograph of one of the earlier 211D vacuum tubes is shown in Fig. 119.

In 1926 the 211E was introduced. It differed from the 211D in that it was intended primarily for use as an audio amplifier, and had small spirals incorporated in the grid and plate leads, which may be seen in Fig. 120. The effect of these small radio frequency chokes was to discourage the tendency to set up high-frequency parasitic oscillations in the circuit in which such tubes were operated in parallel.

The code and patent markings were at first placed on the metal base of the 211 types in depressed characters, but later were applied to the bulb by the use of baked enamel lettering. Still later tubes used molded plastic bases. The 211 series of tubes have not been made since 1938, having been replaced by later designs.

The type "I" tube was the forerunner of the 212 series of Western Electric tubes, and was rated at 250 watts. Figs. 121 and 122 show two of the experimental tubes of this type and Fig. 123 shows the early commercial type which carried the code designation "212A." This tube had an over-all height of about 13⅝ inches and a diameter of 3⅝ inches. It was intended for both oscillator and modulator use. The filament current was 6.25 amperes at 12.5 to 14 volts. The nominal plate voltage was 1500 and the plate current 100 to 150 milliamperes. The amplification factor was about 16 and the internal plate impedance about 2000 ohms. The code and patent markings were on the base, as will be seen from the photograph.

Like the 211A, the 212A vacuum tubes bore a letter designation following the serial number, to indicate filament resistance. In addition they bore a ½ inch high numeral (1, 2, 3, or 4) stamped on the bulb a short distance above the base. This numeral was determined by the plate impedance of the particular tube. The classification was such that satisfactory operation in parallel could be obtained with two tubes whose classification numbers did not differ by more than one. That is, a class 1 tube would operate satisfactorily in parallel with another class 1 or a class 2, but not with class 3 or 4. A class 2 tube would operate satisfactorily in parallel with either class 1, 2, or 3, but not with class 4, and so on.

The 212A Vacuum Tube was replaced in 1924 by the 212D, photographs of which are given in Figs. 124 and 125, and somewhat later the 212E was brought out. The 212D tubes were classified in accordance with plate impedance in the same way as the 212A, but because of a new filament did not require classification in accordance with filament resistance.

In addition to the power tubes described, the Western Electric Company also made a number of small tubes during this time for non-telephone applications. Since, for the most part, these were similar in structure to some of the telephone tubes they will be mentioned only briefly.

The 208A and 209A were the same as the 101B and 102A except for the

(Continued on page 92)

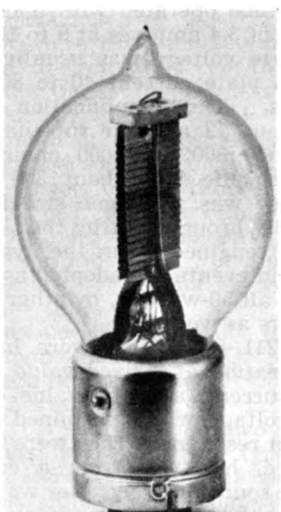


Fig. 129.

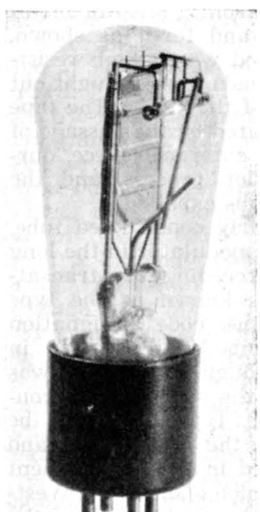


Fig. 130.

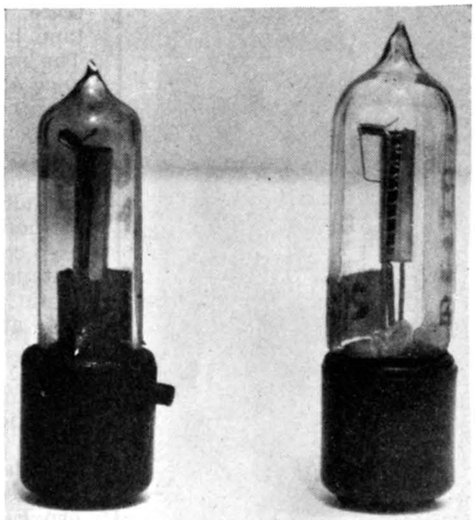
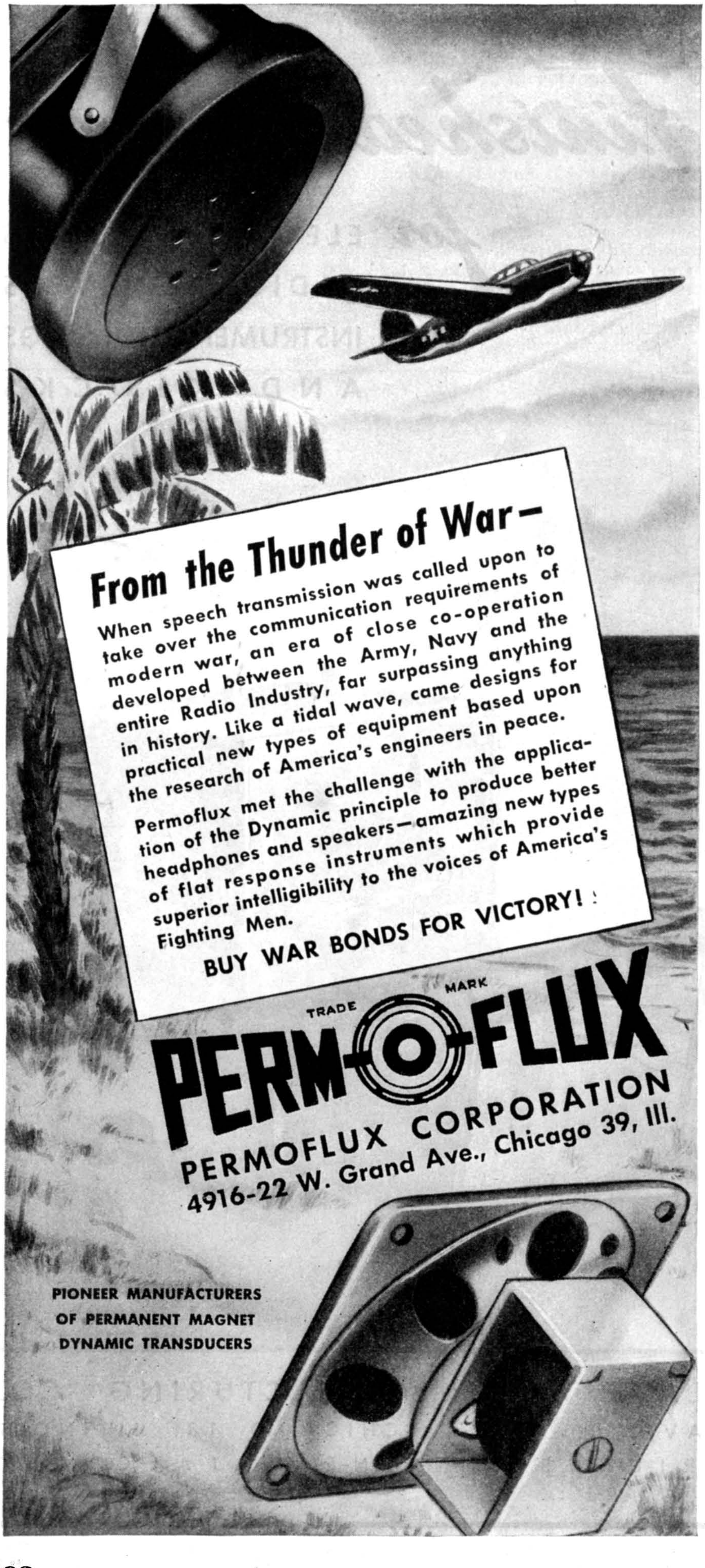


Fig. 131.



Saga of Vacuum Tube

(*Continued from page* 56)

code and property markings. The 210A was similar to the 104A. The marking "Property of the American Tel. & Tel. Company" was omitted and the marking "Western Electric Company" was applied instead. The 223A was similar to the 104D except that a heavier filament was used.

Probably one of the best known of the Western Electric small tubes of this period was the 216A, which was intended for use in the amplifiers of small public address systems and similar low power applications. It was somewhat similar in characteristics to the 101D but with a plate structure resembling that of the VT1. Figs. 126 and 127 show several variants of this tube.

There were also a series of rectifier tubes using the same general construction as the corresponding amplifier tubes. The 214A and 217A shown in Figs. 128 to 130, were similar to the 211A and 216A respectively, with the grid omitted. The 219A and 219D were the rectifier counterparts of the 212A and 212D.

In the low filament power field there were the 230D and 231 D. These were used in the same applications as the well known RCA UV199 and UX199 types. The 221D and 235D were general purpose tubes similar to the RCA UV201A.

The only other early Western Electric tube which the collector is likely to acquire is the 215A, also known as the Signal Corps VT5, and the Navy CW-1344. It was first known as the type "N" vacuum tube. This is the

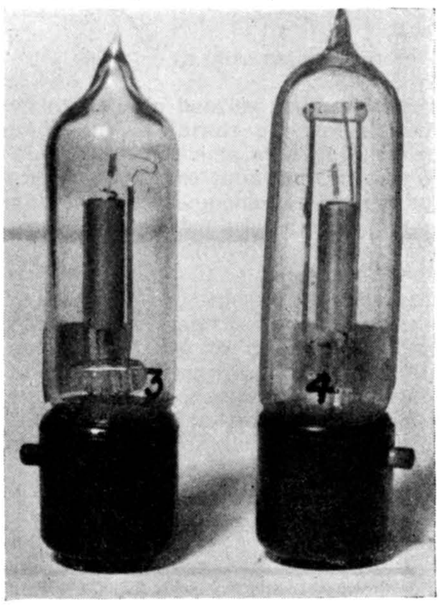


Fig. 132.

original "peanut" tube, so called because of its size. It was the only early Western Electric tube to utilize a concentric element assembly.

The filament was a single strand mounted vertically, the grid a spiral wire, and the plate a cylinder. Fig. 131 shows two of the early variants of this tube, the difference being chiefly in the bulb size. The tube shown at the left in Fig. 132 is the next variant, in which the spirally coiled filament tension spring has been replaced by a single bent wire. These early "N" tubes were very sensitive to mechanical disturbances. This was to some extent overcome by modification of the element structure to include a glass re-enforcing bead as shown in the tube at the right in Fig. 132. All of these earlier "N" tubes had metal bayonet locking pins inserted in the molded plastic base. Subsequently, a new base with a molded bayonet pin was developed and may be seen on the tube whose element structure is shown at the right in Fig. 133. This variant, in which the glass re-enforcing bead has been increased in size, utilized magnesium flashing and was the final development of the 215A.

Somewhat later, for applications which required less sensitivity to microphonic disturbances, and yet low filament power and approximately the same electrical characteristics as the 215A the tube shown in Fig. 134 was developed. This was designated 239A. Earlier tubes of this code had tips but the later ones were of the tipless variety.

With this we bring to a close our consideration of the earlier Western Electric tubes. Very little information has been published concerning the contributions to tube development made by this organization. For this reason these tubes have been treated in as much detail as space will permit. In our next article we shall return to the consideration of this work as carried on by de Forest and his co-workers, with the aid of funds received from the sale of rights to the Audion.

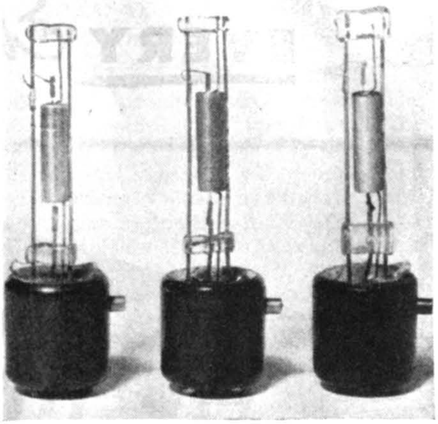


Fig. 133.

CAPTIONS FOR ILLUSTRATIONS

Figure 113. Western Electric Type "K" or 202A Vacuum Tube. The machined brass base is the size of that used by the Western Electric Company, and later by others, for the "50-watt" type tubes. Photograph courtesy Bell Telephone Laboratories.

Figure 114. Western Electric Type "W" or 204B Vacuum Tube. This is a based tube of the type used in the Arlington-Paris tests of 1915. Both based and unbased tubes were used in the transmitter. Photograph courtesy Bell Telephone Laboratories.

Figure 115. Western Electric Type "S" or 204A Vacuum Tube. This is a based tube of the type used as a modulator in the tests which preceded the Arlington-Paris transmissions. Photograph courtesy Bell Telephone Laboratories.

Figure 116. Western Electric Type "G"—second embodiment of the 50-watt type tube. Made in 1919. Photograph courtesy Bell Telephone Laboratories.

Figure 117. Western Electric Type "G"—final version—coded 211A Vacuum Tube—1919. Photograph courtesy Bell Telephone Laboratories.

Figure 118. Western Electric 211A Vacuum Tube—commercial version of the Western Electric Type "G."

Figure 119. Western Electric 211D Vacuum Tube.—Replaced 211A Vacuum Tube. This tube has an improved filament and has the code and patent marking on the bulb in baked enamel lettering. Photograph courtesy Bell Telephone Laboratories.

Figure 120. Western Electric 211E Vacuum Tube—similar to the 211D except for the inclusion of spiral coils in the grid and plate leads.

Figure 121. Western Electric Type "I" Power Tube—first attempt at 250 watt air cooled tube and forerunner of the 212 series of tubes. Made in 1919. Photograph courtesy Bell Telephone Laboratories.

Figure 122. Western Electric Type "I" Power Tube—second version. Made in 1919. Photograph courtesy Bell Telephone Laboratories.

Figure 123. Western Electric 212A Vacuum Tube—sample of the early commercial tubes of this series.

Figure 124. Western Electric 212D Vacuum Tube—improved 250 watt tube which replaced the 212A—front lighted to show construction.

Figure 125. Western Electric 212D Vacuum Tube—same tube as Figure 124 except back lighted.

Figure 126. Western Electric 216A Vacuum Tube—early model. The base has been made from that of the 208A by cancelling the former code marking and those of the patent markings which did not apply to the 216A. The new code number and license notice are carried on a paper band around the neck of the tube.

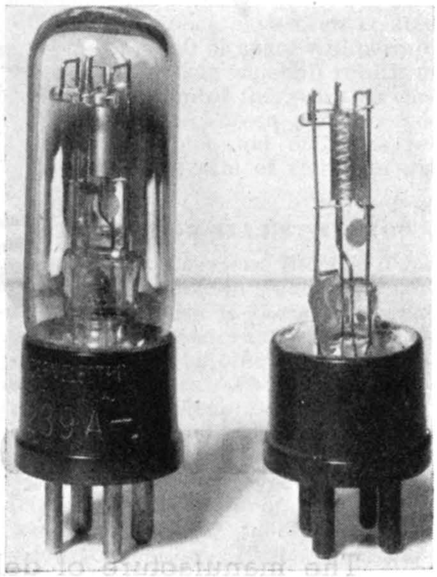


Fig. 134.

Figure 127. Western Electric 216A Vacuum Tube—later version than that shown in Figure 126. The code and correct patent marking are on the base but the license notice is still carried on the paper band around the neck of the tube.

Figure 128. Western Electric 217A Vacuum Tube—early form—rectifier with structure based on that of the 101D. Photograph courtesy Bell Telephone Laboratories.

Figure 129. Western Electric 217A Vacuum Tube—later type—rectifier version of the 216A. Photograph courtesy Bell Telephone Laboratories.

Figure 130. Western Electric 217A Vacuum Tube—still later version in pear shaped bulb. Photograph courtesy Bell Telephone Laboratories.

Figure 131. Left—Early model of Western Electric Type "N" tube. Right—later model using larger bulb diameter.

Figure 132. Left—Western Electric Type "N" Vacuum Tube—redesign showing new filament tension spring.

Right—Later model with small diameter glass beads for stiffening element assembly and reducing response to mechanical shock.

Figure 133. Western Electric 215A Vacuum Tube—commercial production of type "N"—element assemblies. The one at the right with the heavier glass reinforcing beads is the later construction.

Figure 134. Western Electric 239A Vacuum Tube.

Left—Complete tube of late type. Earlier tubes had the code marking on the glass.

Right—Element assembly of this tube with plate opened up to show spiral grid and axial filament.

(To be continued)

Fundamental Optics

(Continued from page 26)

ment automatically. Probably the most widely publicized of these is the Hardy color analyzer. This instrument will accomplish in minutes what formerly took a trained technician hours.

Refraction

As far back as the tenth century the Arab Alhazen demonstrated the true behavior of light as it passes from one medium into another. It remained for Willebrord Snell, over six centuries later, however, to determine the mathematical law relating the angles of incidence and refraction. Snell's law, the law of refraction, states that the sines of the angles of incidence and refraction are in a constant ratio to each other for any given medium. Its proof, based upon the concept of wave fronts, is relatively simple.

Consider, as shown in Fig. 3, the boundary between two materials, one less dense than the other, like air and glass. The plane wave fronts incident upon this surface are brought closer together after entering the denser medium because the velocity of the propagation of light is directly proportional to the density of the material in which it is traveling. If, too, the wave fronts are incident upon this boundary at an angle ABC, as shown, then the wave fronts will suffer a turning action because part of the wave will be slowed down sooner than the remainder. The wave fronts will then leave the boundary at an angle BCD. It can be seen, also, that in the time that point A takes to travel to point C, point B would have traveled to point D. The distances AC and BD, therefore, are proportional to the velocities of the light in the two mediums, or

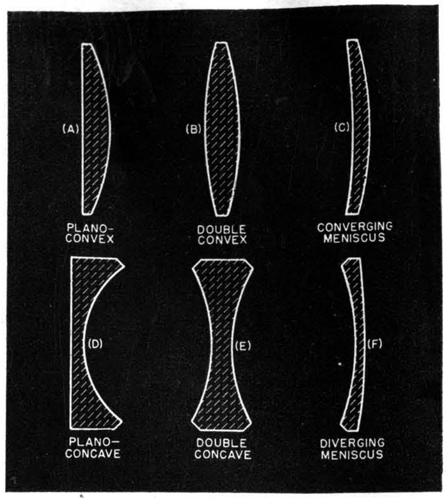


Fig. 11. A number of common lenses having spherical surfaces.

$$\frac{AC}{BD} = \frac{\text{velocity of light in air}}{\text{velocity of light in glass}} = \frac{Va}{Vg}$$

Mathematically, we can divide both numerator and denominator of a fraction by the same quantity without changing that fraction, hence

$$\frac{AC/CB}{BD/CB} = \frac{Va}{Vg}$$

But it is soon evident that

$$AC/CB = \text{sine } \angle ABC$$
$$BD/CB = \text{sine } \angle BCD$$