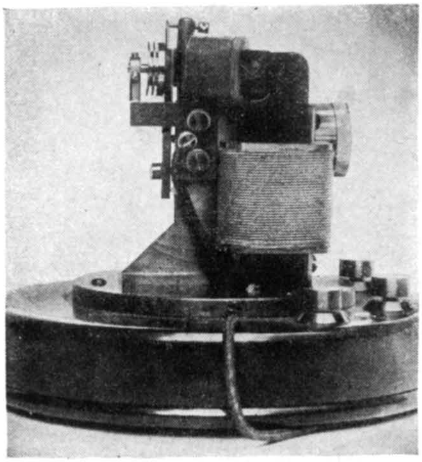


Fig. 185.

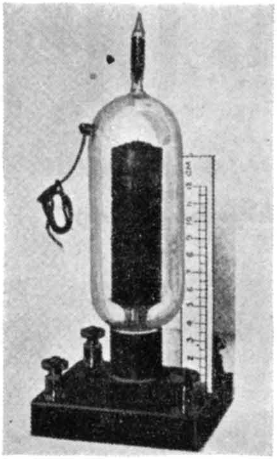


Fig. 186.

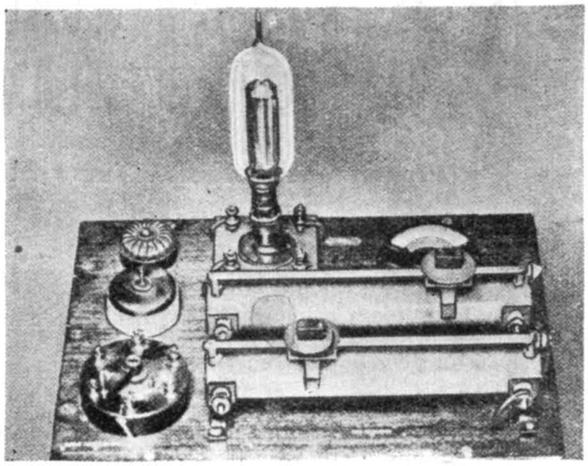


Fig. 187.

THE SAGA OF THE VACUUM TUBE

By GERALD F. J. TYNE
Research Engineer, N. Y.

Part 17. A study of repeater tube developments in local and long-distance telephonic transmissions.

THE problem of telephonic transmission over long distances was not as acute in Great Britain and on the European Continent as it was in the United States. This was due chiefly to the shorter distances involved. Such distances as lay within the borders of any one country, presumably all that would be required at that time to be covered by any one telephone system, could be spanned by the use of heavy gauge conductors and loading. Nevertheless, the advantages from the economic standpoint of a satisfactory repeater were realized and efforts were being made to develop such a device in Great Britain and in Germany.

A study of repeater and repeater-tube developments in Europe brings out the contrasts between the European and American telephone systems. In America the local and long-distance telephone systems are, for the most part, under a single central control, which is a public service corporation, subject to government regulation in the public interest. This corporation, the American Telephone and Telegraph Company, has numerous subsidiaries: operating, developmental, and manufacturing. Such an arrangement is a powerful impetus to systematic development and standardization. Such a connected development procedure is well exemplified in the earlier installments in this series in which the evolution of the American telephone repeater tube has been traced and studied.

In Great Britain and on the continent, on the other hand, the telephone and telegraph systems are, in general, controlled and operated directly by the governments of the respective countries. In these cases, while the earlier steps in new developments may come from either the government research organizations or in-

Fig. 188.

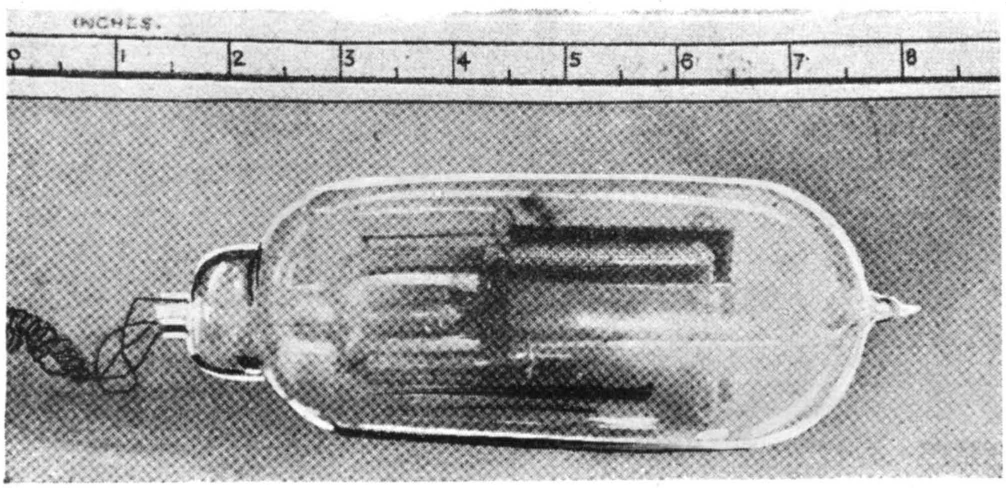
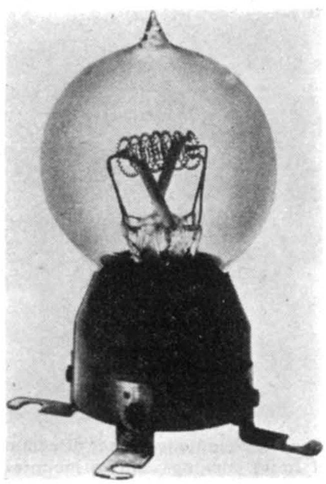


Fig. 189.



dustry, the providing of the actual equipment for use is by competitive manufacturing organizations. When a new installation, such as a long-distance cable, is to be made, the requirements which this installation is to meet are laid down by the authorities and bids for the installation are invited from various manufacturers. Hence, while a suitable system for the project may be installed by the successful bidder, it may differ considerably in equipment from previously installed systems, meeting similar requirements, but purchased from some other manufacturer. This delays standardization of equipment in the early stages of development and hence we find different repeaters and different repeater tubes in use simultaneously in various parts of a country.

The method of attack on the repeater problem in Great Britain was similar to that used in the United States in that efforts for a time were confined to attempts to develop a satisfactory receiver-microphone device. In America the so-called "Shreeve Repeater" came in for attention; in Great Britain a "telephone relay" along these same lines was devised by S. G. Brown. There were several varieties of this relay, one of which, known as "Type G," is shown in Fig. 185.

In this relay the received currents flowed through an electromagnet which actuated a steel reed. The vibration of this reed was applied to the carbon granules of a microphone unit and caused telephonic variations in the microphone current. Since in the carbon microphone the electrical output can be greater than the acoustical or mechanical input, such a device can be made to function as an amplifier or telephone repeater. It is claimed that the Brown "Type G" Relay gave a gain of about 20 times. Under favorable conditions as many as three of these devices could be used in tandem on a one-way circuit but at the expense of some distortion. The inherent disadvantages of the device were that the frequency range which could be repeated was limited by the mechanical characteristics of the moving element, and that there were difficulties in getting and maintaining the proper mechanical adjustments. Nevertheless, some installations were made, and the first of these was in Leeds in 1914, on a London-Glasgow circuit.[253] This was a one-way repeater, and was used in connection with a so-called "jumping switch." This "jumping switch" was a voice-operated relay which automatically made the necessary changes in connections to permit of two-way operation. Its use caused undesirable "clipping" of the conversation.

The engineers of the British Post Office were well aware of the limitations of the mechanical repeater, and in 1908 a small group of research workers, who were studying cathode-ray phenomena in the Post Office Research Laboratory, conceived the idea of developing a telephone relay of the cathode-ray type.[254] Possibly their thinking had been stimulated by the issuance, in 1906, of the von Lieben patent on just such a device. The necessary machinery for making and evacuating such tubes was purchased and installed. Unfortunately the group was broken up by staff changes shortly thereafter, and the work was overshadowed by the possibilities of the mechanical amplifier which promised quicker results, even though of less satisfactory quality.

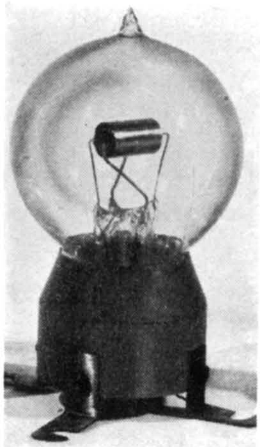


Fig. 190.

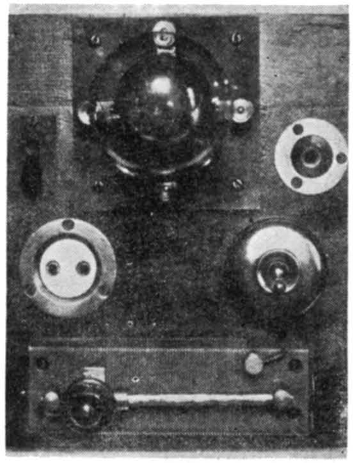


Fig. 191.

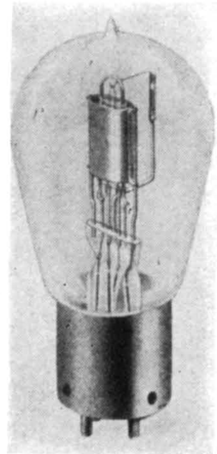


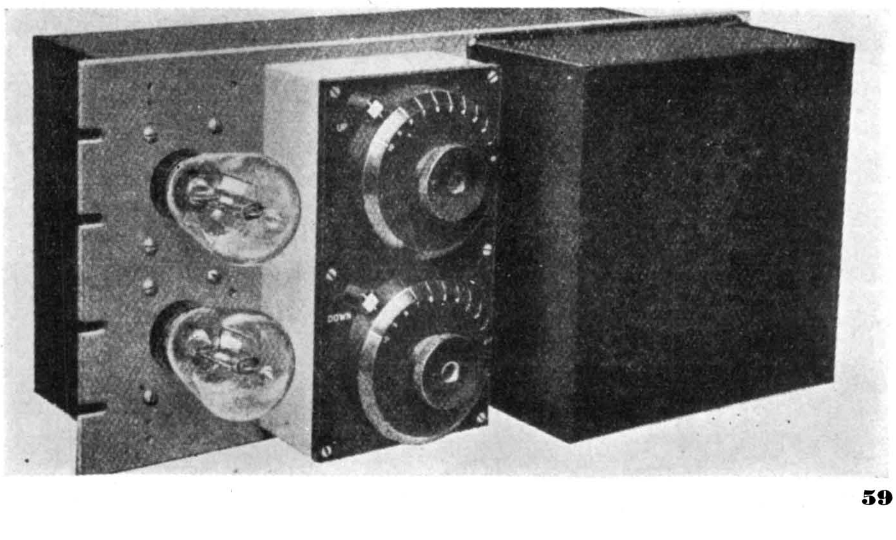
Fig. 192.

Interest in the thermionic repeater was reawakened in 1913, however, when the work of de Forest, Lieben and Reisz, Round, and others had brought the thermionic amplifier out of the research laboratory into the realm of commercial practicability. Fortunately, one of that small group dispersed in 1908 returned to the research laboratory about that time and resumed the suspended experiments. Samples of tubes were obtained from de Forest, Lieben and Reisz, and Round, and examined to see if they could meet the requirements of telephone work. New experimental tubes were constructed, incorporating such special features as might adapt them to telephone requirements.

The Round type of "soft" tube at first seemed to be the best and a number of these were produced in the laboratory. They were somewhat larger than the original Round tubes, in order to handle the necessary power. Fig. 186 is a photograph of one of these tubes, the first type to be used in telephone service in England. Fig. 187 shows the repeater unit in which it was used. The essential features of this type of tube are (1) the cathode is of the Wehnelt, or oxide-coated, type; (2) the grid is a fine mesh completely surrounding the filament; (3) the anode is a cylinder surrounding the grid; and (4) there is a tubulation containing a wad of asbestos extending upward from the top of the bulb. This grid construction was adopted to prevent electrification of the inner surface of the glass bulb by electrons expelled from the filament, and the asbestos in the tubulation was used as a source of gas to restore the pressure when the tube became hard. The asbestos gave off small quantities of gas when heat was applied externally to the tubulation.

It is said that these tubes were rather stable in operation and gave a good quality of reproduction. When new they would start up from cold in about three seconds, but when older and as the internal pressure decreased they sometimes required some time to

Fig. 193.



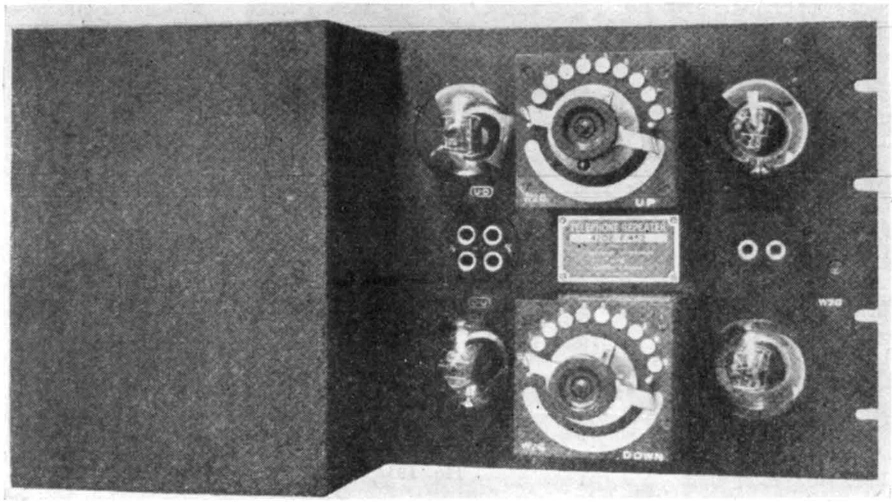


Fig. 194.

reach their full amplification. The pressure could be restored by heating the tubulation, in most cases. The life, when only moderate gains were required, was on the average about 600 hours.[255]

These soft tubes were difficult to manufacture with any degree of uniformity and were soon replaced by a "hard," or high-vacuum tube, the earliest form of which is shown in Fig. 188. In this tube the cathode was either tungsten or the oxide-coated type and was supported on a U-shaped glass frame. The grid was of nickel gauze, similar to that used in the soft tubes, and was fitted over the glass frame which carried the cathode. The anode consisted of two plates of nickel, supported by glass arbors, one on either side of the grid-cathode assembly. This tube was exhausted to such a vacuum that it showed no indication of ionization when worked at an anode voltage of 400 volts.

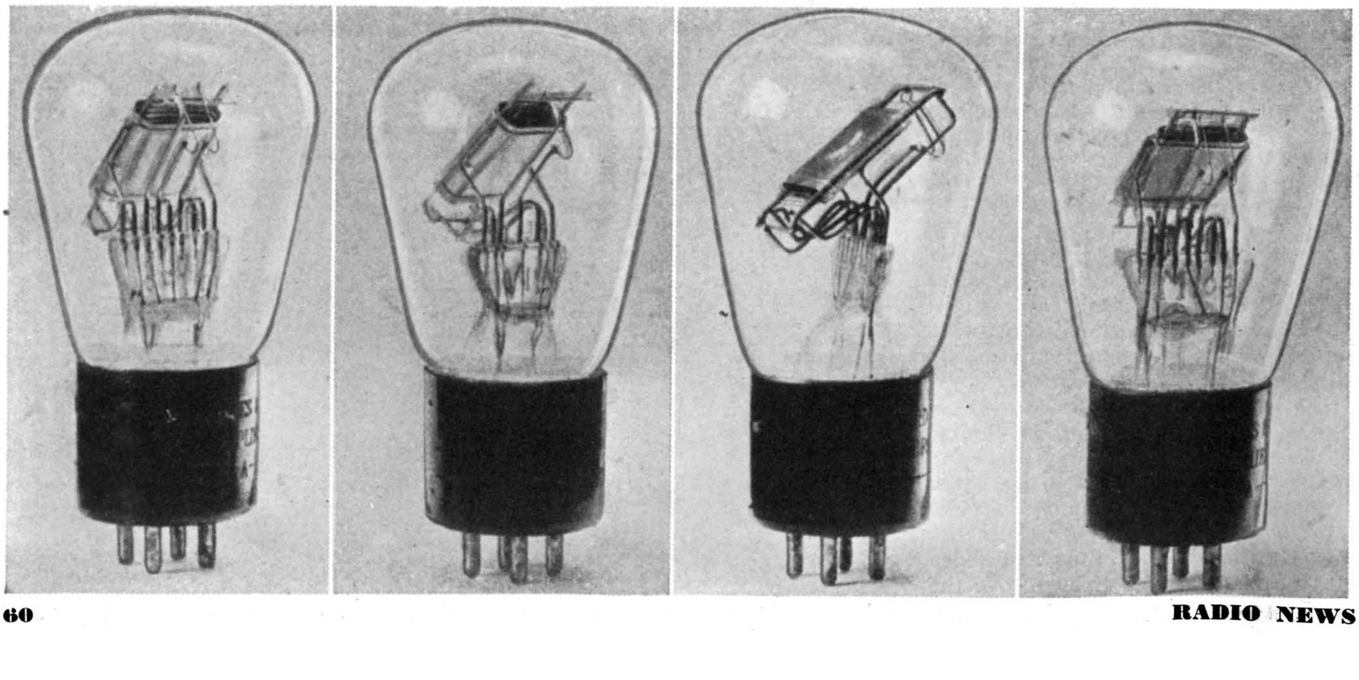
The glass work of this tube was rather troublesome to make[256] and subsequently the Post Office engineers inclined toward the use of a tube similar to that developed by the French Military Telegraphic Service under General Ferrie, and commonly known as the "French" tube. The version of this tube which was arrived at by the Post Office became the first "Standard Repeater Valve," and was officially known as "Valve, Amplifying, No. 1." It is shown in Fig. 189.

The filament of this tube was a fine spiral of tungsten wire. The grid was a somewhat more open spiral, at first of tungsten and later of alloy wire, mounted concentrically with the filament and about ¼ inch in diameter. The anode was a spiralled helix of tungsten wire mounted concentrically with the grid and filament, and with a radial spacing of 1/16 to ⅛ inch. Later (1919) models of this tube had the anode made of sheet nickel, and one of these later tubes is shown in Fig. 190. The bulb, spherical in shape, was mounted on a red fibre base which carried the four terminal connections. These were flat strips of brass, arranged to be clamped under binding posts on the repeater unit. This method of mounting was used in preference to the four-pin base used on the "French" tube because of the necessity of keeping contact resistance to a minimum. The anode terminal strip was painted red "for reasons that will be appreciated by anyone who touches it while the valve is in operation."[257] The repeater in which this tube was used was known as "Repeater, Telephonic, No. 2," and is shown in Fig. 191.

The filament of this tube was designed to give a total space current of not less than 10 milliamperes when a potential of 150 volts was applied between filament and grid-anode connected together. The normal operating value of the anode current was 1 to 2 milliamperes. The working temperature of the filament was chosen to give a working life of about 2000 hours.[258] The tube had a mutual conductance of 450 micromhos and an internal impedance of about 20,000 ohms In order to insure obtaining a reasonably straight-line plate current-grid voltage curve, one of the requirements of this tube was that between grid voltages of —8 and zero, the mutual conductance must not vary more than 20% from the value at —4.5 volts, the grid bias existing in Repeater No. 2.

In order to insure meeting the other requirements, the proper filament current for each of these tubes was determined for the individual tube.[259] This was done by putting the tube into a test circuit and increasing the filament current until the mutual conductance reached a predetermined value. At this point the filament voltage was noted and thereafter the filament was operated at that voltage. The usual value of heating current was between the limits of .7 and .8 ampere, and the filament voltage was about 4.7 volts. Under these conditions the filament resistance was about 10 times its resistance when cold. The usual anode voltage was 200-220 volts.

Fig. 195.



By 1926 there were 26 repeater stations in Great Britain with a total of about 670 repeaters in service.[260] One of the "standard" amplifying tubes used in such repeaters was designated by the Post Office as "Valve, Thermionic, No. 25" and is shown in Fig. 192. It was made by the General Electric Co., Ltd. of London,[1] and was a further development of the "R" type tube used for radio applications. It was also used as an output tube in radio receivers under the designation "L.S. 5." It operated with a filament current of .82 ampere at a voltage of 4.5 volts in telephone equipment, and had a life of 1000-2000 hours.[261] This tube was used in both 2-wire and 4-wire repeaters, one of the 2-wire type being shown in Fig. 193.

Another type of repeater of about this same vintage is that installed on the London-Glasgow cable, which was placed in service about 1926. The repeater equipment of this cable was furnished and installed by Standard Telephones and Cables, Ltd., and one of the repeaters is shown in Fig. 194.[264] The tubes used were the Standard Telephones and Cables types 4101D and 4102D, designated by the Post Office as "V.T. No. 31" and "V.T. No. 32" respectively, which are essentially the same as the Western Electric (U.S.A.) 101D and 102D tubes previously described, using oxide-coated filaments. This similarity came about because the Standard Telephones and Cables, Ltd. had originally been the Western Electric Company, Ltd., an affiliate of the Western Electric Company of the United States, and the British product thus closely paralleled the American practice, and reflected the progress of American development.

Subsequently, other repeater tubes which operated at lower filament currents, permitting economies in repeater-station power plant and station wiring, were developed by Standard Telephones and Cables.[263] A group of these repeater tubes, which became available about 1932, is shown in Fig. 195.

The 4019A had plate characteristics in general similar to those of the 4101D, and could be used to replace it in existing equipment, with a slight increase in gain. The 4020A was intended to replace the 4102D. The 4021A replaced the 4104D with, again, some increase in gain. The 4022A was really a higher gain 4019A. The filament and plate voltages for the new tubes were about the same as for the replaced tubes. The 4019A, 4020A, and 4022A had a life exceeding 10,000 hours, while the life of the 4021A was in excess of 3000 hours.

The need for telephone repeaters did not arise as early in France as in other countries. This was partly at least due to the limited use of the telephone in that country. The attitude of the French might be typified as that of one Frenchman who, in 1915, when an at-

[1] The General Electric Co. Ltd. of London is not affiliated with the General Electric Co. of U.S.A.

tempt was made to explain to him the American telephone system and its slogan "Universal Service," is reported to have replied that he couldn't see any sense in telephones anyhow, all the people he wanted to talk to in a hurry lived with him, the others didn't matter, and a letter was quick enough in any case.

There was little standardization of equipment. The subscriber supplied his own equipment, which resulted in a diversity of station sets, chosen according to the whims of the individual. Its electrical characteristics were the last thing he considered. No two central offices were alike in construction or operated in the same way. [264] Long-distance telephony was practically nonexistent until late in World War I. Even as late as 1921 distances of the order of 500 miles were spanned only with difficulty and under the most favorable conditions.[265]

The first repeater used in France was installed and operated on an experimental basis at Lyons on a Paris-Marseille circuit in 1917. It was a two-stage affair, using tubes of the type previously denoted as "French" tubes, developed primarily for military use in radio work.[266] Following the success of this experimental installation an increase in the use of repeaters was proposed with the suggestion that the first step be taken by the installation of cord-circuit repeaters in Paris.[267]

By 1920, however, there were only 30 repeaters available. Of these, three were of the French type, using French tubes, eight were British repeaters installed at Abbeville and Lyon by the British Army during World War I, and the other 19 (of which 7 were of the cord-circuit type) were American repeaters of Western Electric manufacture. These last had been obtained from the stocks of the American Army in France.[268] The increase in the number of repeaters was slow, since early in 1923 there were but 38 in use. Of these 26 were cut in on specific circuits, while 12 were of the cord-circuit type.[269]

At the end of 1923, however, the French Administration contracted for a loaded and repeatered cable between Paris and Strasbourg. This cable was completely in service late in 1926. The repeaters used on this installation were supplied by Standard Telephones and Cables, Ltd. through their French subsidiary, the "Société Anonyme, Lignes Télégraphiques et Téléphoniques." These repeaters were of the type previously mentioned in connection with the London-Glasgow cable and were equipped with S. T. & C. tubes of the 4101D and 4102D types.[270]

Hence it may be said that, up to this time, no vacuum tubes designed especially to meet the requirements of telephone repeater service, and of French development and manufacture, had been used in France. This is not to say, however, that the French lagged behind other nations in the

(*Continued on page* 128)

Saga of the Vacuum Tube

(*Continued from page 64*)

development of vacuum tubes for other applications. In fact, development of the "French" tube by the French Military Telegraphic service early in World War I was one of the outstanding communications achievements of the War.

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CAPTIONS FOR ILLUSTRATIONS

Fig. 185. S. G. Brown's "Type G" Telephone Relay. Photograph courtesy Bell Telephone Laboratories.

Fig. 186. Original Post Office Amplifying Valve (Round's Type). Reproduced from Post Office Electrical Engineers Journal—1919.

Fig. 187. Post Office Repeater using Round's Valve. Reproduced from Paper No. 76 of the Institution of Post Office Electrical Engineers.

Fig. 188. Earliest type of high-vacuum telephone repeater tube used by

British Post Office. Reproduced from Paper No. 76 of the Institution of Post Office Electrical Engineers.

Fig. 189. Original form of "Valve, Amplifying, No. 1," Photograph courtesy R. McV. Weston.

Fig. 190. Later form of "Valve Amplifying, No. 1" Photograph courtesy Bell Telephone Laboratories.

Fig. 191. "Repeater, Telephonic, No. 2" Reproduced from Post Office Electrical Engineers Journal—1919.

Fig. 192. "Valve, Thermionic, No. 25" made by General Electric Co. Ltd. of London. Reproduced from J. A. Fleming's "The Thermionic Valve and its Developments in Radiotelegraphy and Telephony"—2nd edition.

Fig. 193. Two-wire repeater using "V.T. No. 25" Amplifying Valves. Reproduced from Paper No. 99 of the Institution of Post Office Electrical Engineers.

Fig. 194. Standard Telephones and Cables Type 4202F Repeater using 4101D and 4102D tubes. Reproduced from Post Office Electrical Engineers Journal—1926.

Fig. 195. Quarter Ampere Repeater Tubes made by Standard Telephones and Cables, Ltd. from 1932. Reproduced from Electrical Communication—1932.

(To be continued)

Television Antennas

(Continued from page 42)

only .1 to .15 wavelength behind the dipole. However, for television this would mean a sharp reduction in antenna resistance and consequent loss of wide-band response. The length of the reflector for various bands is shown in the dimension chart, and is approximately 5% longer than the dipole. Thus, in the above example, our quarter-wave spacing would be three feet seven inches, and the length of the reflector seven feet two inches.

2. *Folded Dipole.*

The folded dipole, Fig. 4A, has a higher surge impedance and a lower rate of reactance increase as the frequency departs from resonance. Surge impedance of the folded dipole, four times larger than the impedance of a single dipole, is approximately 300 ohms and can be conveniently matched with a parallel coaxial line, each coaxial line having an impedance of approximately 150 ohms. In this case, if we use a one-inch outer conductor, from our coaxial line chart, our inner conductor should be made of #12 wire. Center-to-center spacing is not critical and is approximately two to three inches. Spacing between the legs of the dipole is approximately r/8 or less. The flat frequency characteristic of the folded dipole permits both use of a reflector and director with improved sensitivity, plus the use of smaller size tubing for the dipole itself. The parasitic elements must not be folded; actual construction is shown in Fig. 4B.

3. *Stacked Array.*

The stacked array, consisting of various elements stacked vertically, is a more efficient antenna, for it more ef-

Fig. 8. Mechanical requirements of 60-mc. rhombic antenna (A) and long-wire antenna (B).