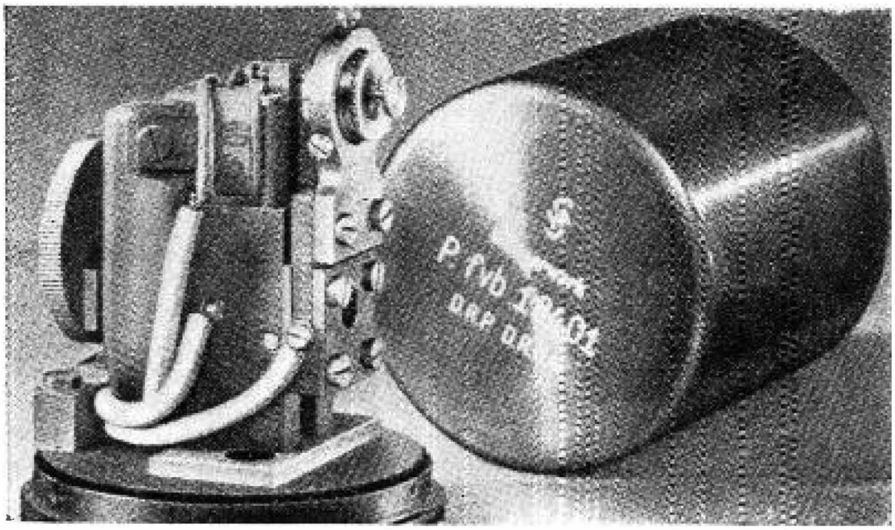


Fig. 196

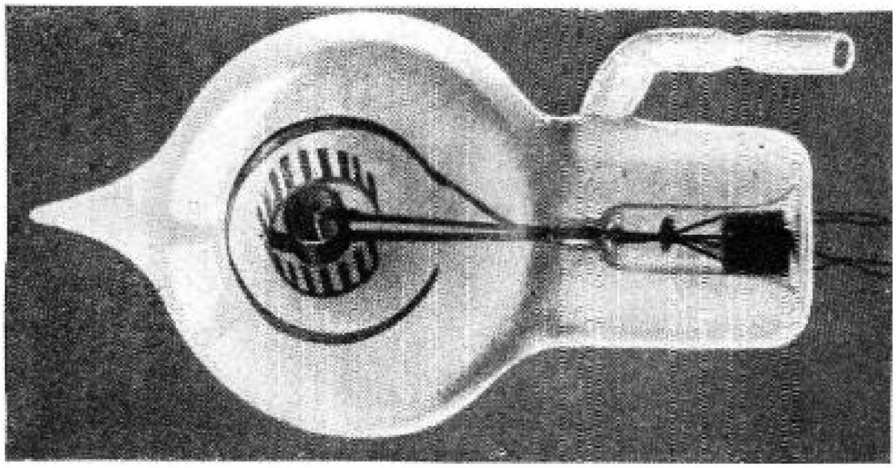
THE SAGA OF THE VACUUM TUBE

By GERALD F. J. TYNE

Research Engineer, N. Y.

Part 18. Continuing our study of telephone repeater-tube developments in this country and abroad and their application during the first World War.

Fig. 197



THE early development of the telephone repeater in Germany followed much the same path as in Great Britain and the United States. Early in 1910 the firm of Siemens & Halske attacked the problem along the line of producing a receiver-microphone type of amplifying device. They had secured the rights to the receiver-microphone repeater which had been developed by S. G. Brown in England. Using this as a basis, they succeeded in producing an improved mechanical repeater which could be adjusted to operate for some months without excessive maintenance.[271] This mechanical repeater is shown in Fig. 196. Its frequency response was not as good as was desired, however, and the search for a better amplifier continued.

In August, 1911, Robert von Lieben demonstrated the von Lieben-Reisz-Strauss tube (the LRS Relay described in a previous installment) to a group of representatives of the leading German electrical manufacturers. The demonstration, which was conducted in the auditorium of the "Institut fur physikalische Chemie der Universitat Berlin" was so impressive that four of these concerns—Allgemeine Elektricitäts Gesellschaft (A.E.G.), Siemens & Halske, Felten & Guilleaume Carlswerk A.G., and the Gesellschaft fur drahtlose Telegraphie (Telefunken)—jointly founded a laboratory, called the "Liebens Konsortium."[272] This laboratory proceeded with the LRS Relay development and studied its applications. In addition, three of the firms undertook development in their own laboratories.

In less than a year this development had proceeded to the point where the results were presented for consideration and test to the State Telegraph Administration by the A.E.G., acting for the Konsortium. These tests showed that while the tube was not perfect the defects did not present insurmountable difficulties. The chief difficulty was that of variation in performance with changes in temperature, and it was overcome to a certain extent by operating the tube in a constant-temperature enclosure. In comparison with the de Forest Audion which had also been under consideration, the LRS Relay had a lower output impedance and greater power-handling capabilities. It was used, before World War I broke out, on some long nonloaded open-wire circuits, such as those connecting Koenigsberg (Prussia), Frankfort (Main), Cologne, Danzig, and elsewhere.[273]

After the outbreak of the war there was an urgent demand for reliable, good quality communications between battle areas and the headquarters of the Army and Navy. As early as 1914 circuits using the LRS Relay repeaters were in use to connect the Eastern Front with the Western Front and Berlin. Conversation was successfully transmitted over a distance of about 750 miles between the headquarters at Luxembourg and the Hindenburg Army in East Prussia. This was ac-

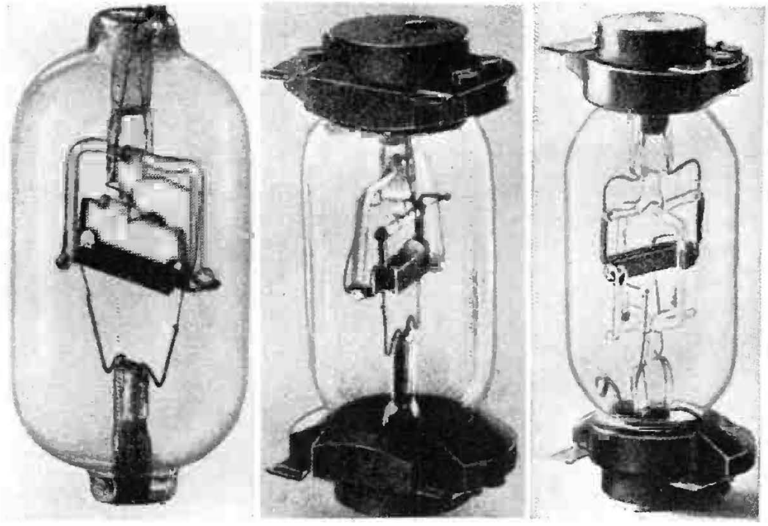


Fig. 198

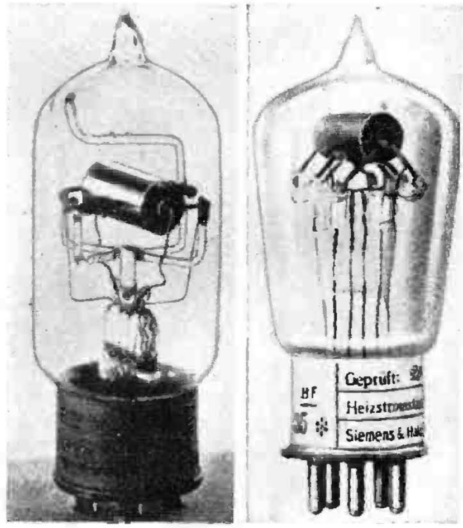


Fig. 199

complished by the use of a single repeater in Berlin. As the fighting fronts advanced this single repeater proved inadequate, and the rapidly increasing length of circuits required the use of several repeaters in tandem. This necessitated the use of the four-wire type of circuit (which was first proposed by the Dutch engineer, Van Kesteren) in which the tubes were used for unidirectional amplification only. By this arrangement good speech transmission was maintained between the Headquarters Staff and Constantinople, and with the armies in Macedonia, Rumania, and Russia. By the end of the war there were about 100 repeaters, of both 2-wire and 4-wire types, in use, which sufficed to take care of the urgent military demands.

In 1917, a program of research was instituted with a view to adapting repeaters to general civilian use, particularly on cable circuits. After making a study of the action of the Lieben tube, the elements were re-arranged and a concentric cylindrical element assembly, shown in Fig. 197, was adopted.[274] The mercury vapor filling was still retained, however. This means that the difficulties of operation caused by variations in atmospheric temperature were still to be overcome. These difficulties indicated

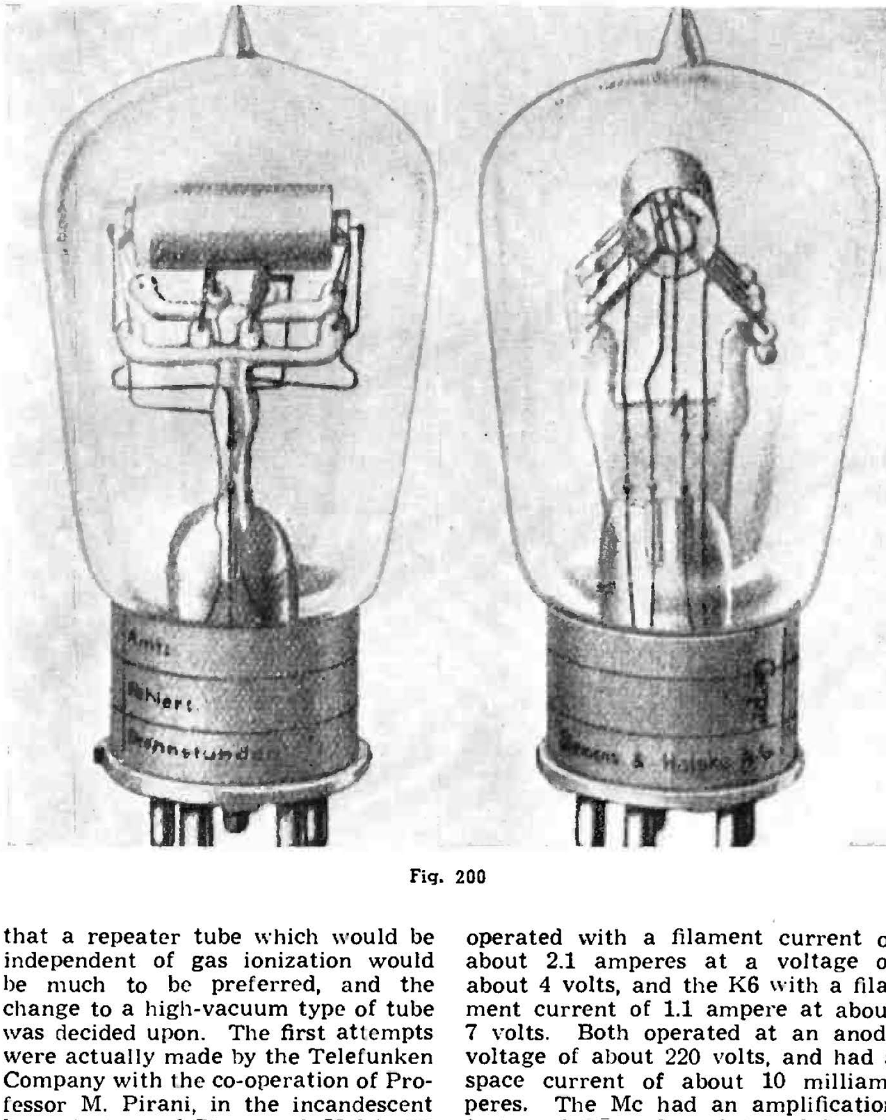
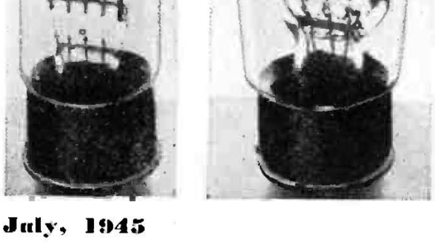


Fig. 200

Fig. 201



that a repeater tube which would be independent of gas ionization would be much to be preferred, and the change to a high-vacuum type of tube was decided upon. The first attempts were actually made by the Telefunken Company with the co-operation of Professor M. Pirani, in the incandescent lamp factory of Siemens & Halske.[275]

The Siemens & Halske Company evolved a high-vacuum tube with a tungsten filament, known as the type "Mc," and the A.E.G. produced the "K6" tube. Both these tubes were used during the latter part of the war for special telephone circuits for military use. The Mc tube, shown in Fig. 198, operated with a filament current of about 2.1 amperes at a voltage of about 4 volts, and the K6 with a filament current of 1.1 ampere at about 7 volts. Both operated at an anode voltage of about 220 volts, and had a space current of about 10 milliamperes. The Mc had an amplification factor of 6.7 and an internal impedance of about 10,000 ohms. The output was about 60 milliwatts.[276] The U-shaped electrode assembly of the Mc tube was adopted in order to obviate the necessity of centering the filament. At that time it was considered impossible to accomplish this centering by the application of tension to the

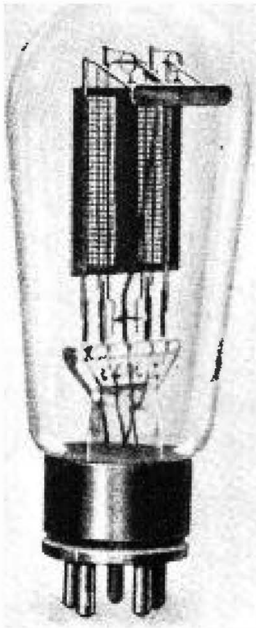


Fig. 202

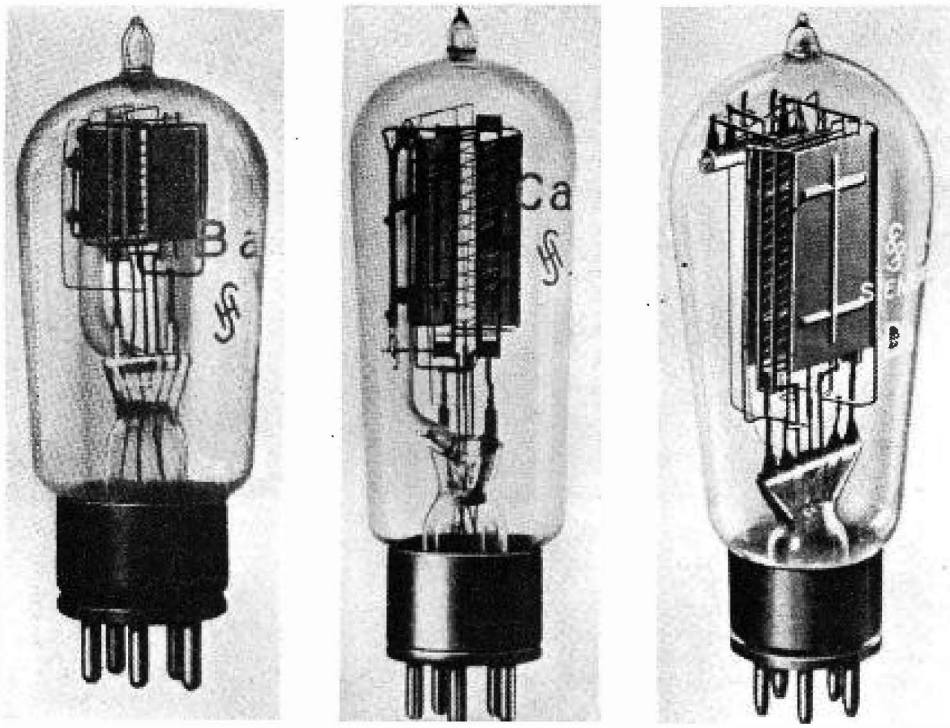


Fig. 203

ends of the straight filament wire. The K6 tube employed an assembly of plane parallel electrodes.[277]

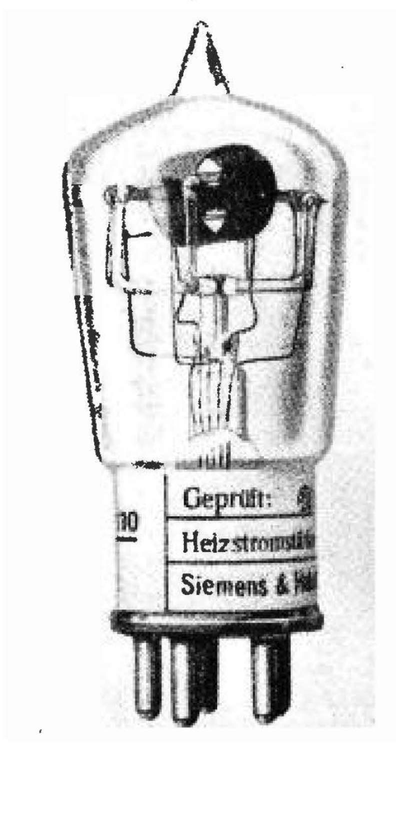
Since the power output required in ordinary repeater work is less than the output of these tubes, they were replaced, after the war, with smaller ones designed especially for telephone-repeater work. For this purpose equivalent tubes were made by several manufacturers, among them Siemens & Halske, A.E.G., Suddeutsche Telefon-, Kabel-, und Draht Werke (Nurnberg), C. Lorenz A.G., and Dr. Erich F. Huth Gesellschaft. With the exception of those made by Huth, which used plane parallel electrodes, all these tubes had a cylindrical electrode system.

The Siemens & Halske tube designated as type "BF" may be taken as an example of these tubes. It is shown in Fig. 199. This tube had a tungsten filament operating with a current of 1.1 amperes at 3.6 volts, thus consuming only half the filament power of the Mc. The anode voltage was 220 volts, and the saturation current about 8 milliamperes.[278] The amplification factor was about 12, internal impedance about 25,000 ohms, it had a mutual conductance of about 500 micromhos when operated at −6 volts on the grid, and it gave an output of about 30 milliwatts. The average life initially was about 600 hours, but was later raised to 1000 hours.

The BF tube was the first tube to be designed from the ground up with a view to meeting the rigid requirements of a telephone repeater tube, and it was the standard tube for use in all the Reichspost amplifiers from its introduction in 1920 until 1925. The cylindrical electrode system and glass supporting structure for the electrodes were carefully worked out to secure exact maintenance of the relative electrode spacings, and it was found to have a low sensitivity to microphonic disturbances.[279]

Meantime, the advantages offered for telephone repeater work by an oxide-coated cathode of the Wehnelt type, particularly as to constancy of filament operating characteristics during the useful life of the tubes, were appreciated. Siemens & Halske had begun work on this type of cathode (which was used in the LRS Relay) in 1912 and developed a tube with plate

Fig. 204



characteristics and power-handling capabilities similar to the BF, but using a Wehnelt cathode with a platinum-iridium core. This tube was designated as the type "BO" and was first introduced on a trial basis in the Post Office Amplifiers in 1923.[280] It is shown in Fig. 200.

The BO operated with a filament current of 1.1 amperes at 1.8 volts, thus requiring only about one-half the filament power of its predecessor, the BF. It operated at an anode voltage of 220 volts, and had a mutual conductance of 700 micromhos and an amplification factor of about 15. It was superior to the BF in that it was not nearly so sensitive to changes in the filament current. The BF required that the filament current be held to within plus or minus 5% of the nominal value, whereas the BO would function satisfactorily with variations as high as plus or minus 15%. The BO was also an improvement on the BF in the matter of useful life, which was at least 3,000 hours, an increase of 200%. Similar tubes were made by the other manufacturers noted above.

These tubes were satisfactory until the need arose for amplifiers of higher power output for use in connection with submarine cable work. For this application the Siemens & Halske type "OCK" tube, shown in Fig. 201, was developed in 1926. It had an output power of about four times that of the BO tube. In obtaining this output the amplification factor was reduced to about 6, the internal impedance to about 5,000 ohms, and the mutual conductance was increased. The filament was longer, and the filament power required (1.1 amperes at 2.4 volts) was greater than that of the BO. In this tube a new grid construction was adopted, which involved the use of grid wires of very small diameter. Difficulties were encountered in the process of welding these grid wires to the supporting rings. The difficulties were overcome by eliminating the welding operation and pressing the hard tungsten grid wires into the relatively soft nickel supporting rings. The cylindrical anode was of wire mesh, and was blackened to increase its radiating ability, and to lessen the chances of grid emission. This tube was later superseded by the type "Ca," shown in Fig. 203, which had greater reliability.

The next telephone tube to make its appearance was the type "CO" shown in Fig. 202. It had an amplification factor of 4 and an internal impedance of 1400 ohms. It gave an output of about 1 watt and was used chiefly as an oscillator output tube. It was similar in construction to the OCK tube, and was later replaced by the type "Da," shown in Fig. 203, which had a longer life.

The type "Ba," also shown in Fig. 203, began to replace the BO about 1933. It operated at a filament current of .5 ampere, and with 220 volts anode potential. It required the same heating energy as the BO, however. For some applications a similar tube, designated as the "Be," which operated at 130 volts anode potential was also used. The advantage of these tubes lay in the reduced filament current, even though the filament power was the same. The lower current resulted in economies in the power supply and wiring of the repeater stations. These tubes also had a longer life than the BO, their life being considerably above 5,000 hours.

In addition to the telephone repeater tubes discussed above, there was another type of tube used during World War I by the German Postal Administration for terminal amplifiers. This was a double grid type of tube developed by Schottky.[231] Two varieties were used, one made by Siemens & Halske and designated type "110" (shown in Fig. 204) and the other by A.E.G. and denoted "K26." The filament current was .55 ampere at 3.2 volts for the 110, and it operated at 12-24 volts on both the anode and auxiliary grid.[282] The amplification factor was about 6 and the internal impedance about 9,000 ohms. The output was small but the tube was particularly adapted to the producing of the desired gains at low anode potentials. This was essential for their use in military work, since the terminal amplifiers were self-contained portable devices operated from their own batteries. After the war these fell into disuse, since there was no further need for the gains which they produced. In fact, high gain would have been a distinct disadvantage, because of the difficulties involved in making full use of it. It still survived for applications where low anode voltages were necessary, as in some types of measuring apparatus.

All the tubes subsequent to the CO

having an oxide-coated cathode used a platinum-nickel alloy wire for the filament core, in place of the platinum-iridium alloy formerly used. The change was introduced about 1935 and the new alloy core had several advantages. The oxide coating of the old core presented a large and variable resistance to the flow of the space current, in the case of the BO tube the resistance being of the order of 1,000 ohms, depending on the temperature and the condition of the cathode surface. The use of platinum-nickel in the core facilitated the application of new coating processes and resulted in a thinner and more uniform coating with greatly reduced transverse resistance. It also tended toward stabilizing the resistance of the filament during its operating life.

It will also be noted that the later tubes used a system of plane parallel electrodes. This permits the use of a W-shaped filament with consequent increase in the cathode emitting area. The cylindrical construction with axial filament previously used limited the filament to a single length. Increasing the length of the element structure was the only satisfactory way of increasing the emission. This involved mechanical difficulties particularly in tubes where the grid was placed close to the filament. An example of this is the OCK tube which had a filament length of about 1½ inches, which had to be kept accurately centered in a spiral grid only .118 inch in diameter. The plane parallel electrode system has the disadvantage that more power is required to maintain the cathode at the proper temperature since the radiation losses are greater. The open construction, however, facilitates the cooling of the grid and thus reduces the chance of grid emission.

With the introduction of the new cathode there was instituted a new method of nomenclature, suggested by the Postal Administration, and exemplified in the tubes shown in Fig. 203. It involved a designation composed of a capital or upper case letter, followed by a small or lower case letter. The capital letter indicates the output rating of the tube and the small letter indicates the place of the tube in the series of that output. Thus the "Aa" tube is the first of the "A" or lowest output series. The "Ba" is the first of the series with the next higher output rating. The "Ca," "Da," and "Ea" have respectively greater outputs, the last mentioned being a 5-watt tube.

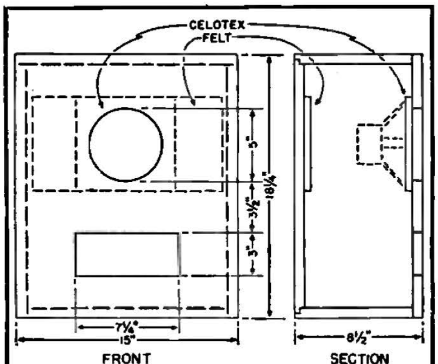
It is interesting to compare German and American repeater-tube development. Both started at about the same time (1911) utilizing gaseous devices; the Arnold arc in America and the LRS Relay in Germany. In 1913 the American development of the high-vacuum tube with oxide-coated cathode got well under way, whereas the decision to use high-vacuum tubes was not made in Germany until 1917. The early German high-vacuum tubes used

(*Continued on page* 150)

Speaker Enclosures
(Continued from page 49)

with hair felt if possible. This can be obtained from auto supply houses as it is used under car floor mats, or may be the felt pad intended for ironing boards. In the absence of these, a blanket can be made with rock wool insulation and a piece of cloth or, as a last resort, a piece of celotex could be used. The idea is to absorb the high frequency radiations from the back of the speaker so they will not be able to reflect from the back of the baffle and, being out of phase with the speaker cone, cancel out some wanted frequencies therefrom.

Fig. 5. Mechanical dimensions for an enclosure employing a 6" speaker. Table shows cabinet size for other speaker sizes.



12" (or two 8") speakers	12" x 22" x 31"
15" (or two 10") speakers	13" x 25" x 33"
18" (or two 12") speakers	14" x 27" x 35"

All dimensions are o.d., assuming ¾" plywood.

If a less elaborate enclosure is desired, the dimensions for a smaller, simpler model are given in Fig. 5. This houses a single heavy duty six-inch speaker. The author has been using this identical speaker system as a monitor speaker on a 15-watt, 2A3 amplifier, and the results are very good.

The approximate dimensions for bass reflex enclosures for different size speakers are given in Fig. 5, and you will see that even the largest enclosures are not too big for an average living room. Of course, an enclosure might be concealed in a bookcase or closet. The variations are practically limitless. You can arrange it to suit your own personal needs.

(Ed. Note: For further information on phasing of loud speakers, we refer you to an article appearing in the April, 1945 issue of Radio News, entitled "Phasing of Loud Speakers.")

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Saga of the Vacuum Tube
(Continued from page 62)

a cylindrical element assembly with axial tungsten filament and having a life of 600-1,000 hours, whereas the American tubes were of plane parallel electrode construction, using oxide-coated cathodes with platinum-iridium cores, and with an operating life of 1,500 hours.

The first German oxide-coated cathode tubes using platinum-iridium cores appeared about 1923, with a life of 3,000 hours, and were not in full use until 1925. By 1922, however, the American tubes had been equipped with platinum-nickel cores, with a life of 20,000 hours. The use of platinum-nickel filament cores and plane parallel electrode systems was introduced into German practice about 1933, by which time the American practice had abandoned the open construction and was using a completely enclosed electrode system, of oval section to permit the utilization of a W-shaped filament. The filament current in the standard American repeater tubes was reduced to .5 ampere in 1927, with the same performance, whereas this did not take place in German practice until 1933.

The corresponding development in Germany of the vacuum tube as applied to radio, as distinct from wire practice, will be covered in a subsequent installment in this series.

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CAPTIONS FOR ILLUSTRATIONS

Fig. 196. Siemens & Halske Mechanical Repeater. Reproduced from Siemens Zeitschrift—1941.

Fig. 197. Modified von Lieben tube with concentric element assembly. Reproduced from Archiv fur Geschichte der Mathematik, der Naturwissenschaften und der Technik—1930-31.

Fig. 198. Siemens & Halske type "Mc" telephone repeater tube. Left—Experimental model. Center and Right—Production type tubes. Reproduced from S. & H. Veröffentlichungen, 1935.

Fig. 199. Siemens & Halske type "BF" tube. Left—Experimental model (1920) using glass star. Right—Production type tube. Reproduced from S. & H. Veröffentlichungen, 1935.

Fig. 200. Siemens & Halske type "BO" tube. Reproduced from Elektrische Nachtichtentechnik—1925.

Fig. 201. Siemens & Halske type "OCK" tube. Left—Early construction with glass bracket for cathode attachment. The grid is unsupported at the upper end. Right—Later construction with better reinforcement. Reproduced from Siemens & Halske Veröffentlichungen—1935.

Fig. 202. Siemens & Halske type "CO" tube. Reproduced from S. & H. Veröffentlichungen, 1935.

Fig. 203. Latest developments (1935) in telephone amplifier tubes made by Siemens & Halske. Left—Type "Ba," which replaced "BO." Center—Type "Ca," which replaced "OCK." Right—Type "Da," which replaced "CO." Reproduced from S. & H. Veröffentlichungen—1935.

Fig. 204. Siemens & Halske type "110" tube. Reproduced from "Taschenbuch der drahtlosen Telegraphie und Telephonie" edited by Banneitz, published by Springer, Berlin, 1927.

(To be continued)

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