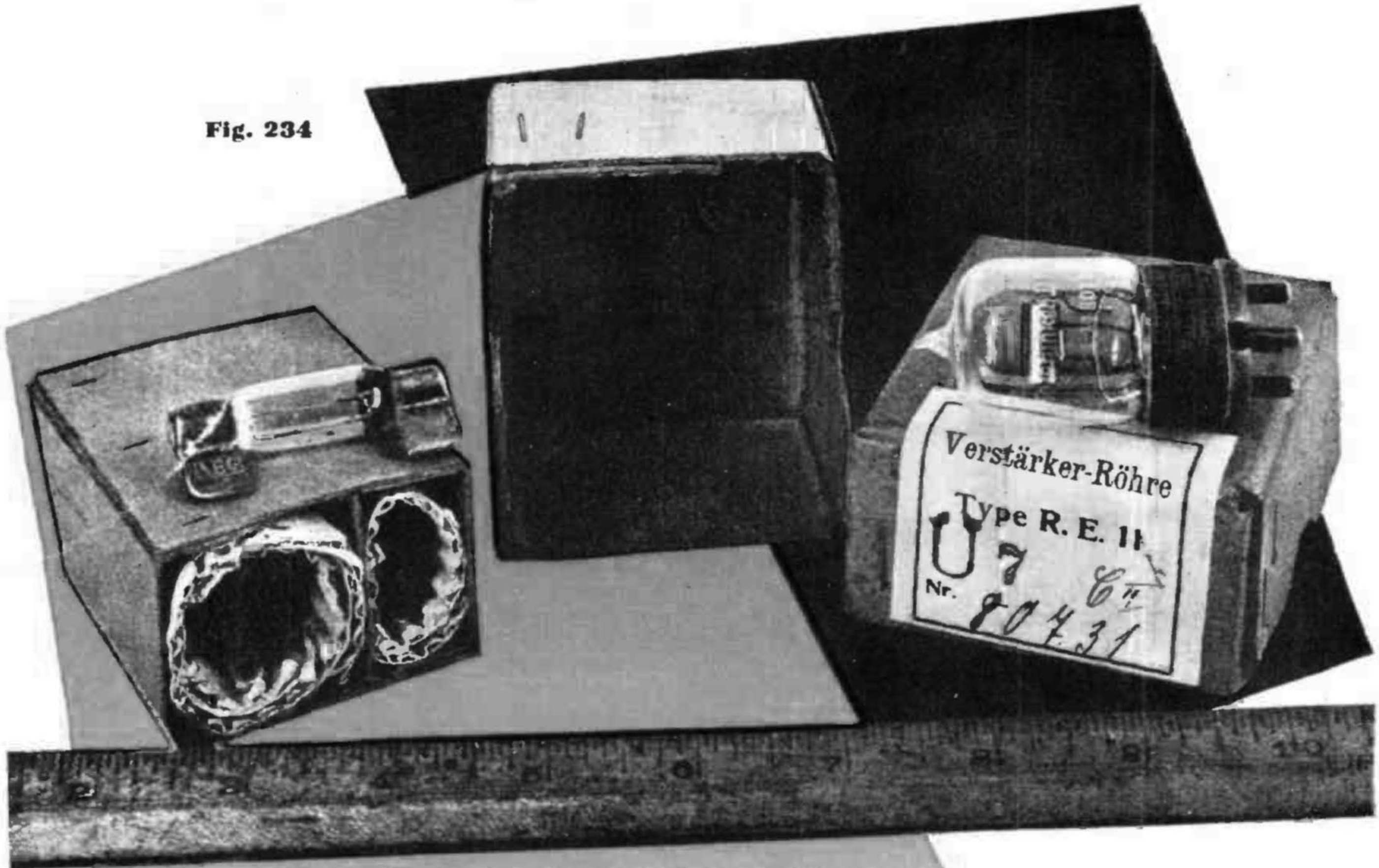
Fig. 234



Saga of the VACUUM TUBE

By
GERALD F. J. TYNE
Research Eng.

Part 22. Concluding article of a historical series which has covered the development of the vacuum tube from its conception to the end of World War I.

NOT long after the EVE173 tube was put into production the system of nomenclature was changed and German receiving tubes were denoted by the prefix RE (= Rohre Empfanger), transmitting tubes by RS (= Rohre Sende), and two new prefixes came into being RG (= Rohre Gleichrichter) for rectifiers and RV (= Rohre Endverstarker) for output tubes.[312]

Probably the first of these tubes to be made in any quantity, 250 per day in 1918,[313] was the RE11, shown in Fig. 234. This tube like most of its predecessors was used with an iron wire ballast resistor in the filament circuit and one of these ballast resistors is also shown in the figure. This tube had a tungsten filament of about the same characteristics as the EVE173 (.55 ampere at 2.8 volts), but operated at an anode voltage of 40 to 70 volts and had an amplification factor of 8 and mutual conductance of 120-150 micromhos, slightly higher than that of the EVE173.[314] It was a general purpose tube.

Another general purpose tube, bearing a closer resemblance to the EVE173, was the RE16 shown in Fig. 244. This was used chiefly as a detector for c.w. work.[315] The extent of its use may be gauged by the fact that in the summer of 1918 *Telefunken* was producing them at the rate of 1000 per day.[313] It had a filament which took 0.5-0.6 ampere at 4.0 volts. The usual anode voltage was 65 and the mutual conductance about 200 micromhos, the internal resistance being about 24,000 ohms. This tube had about the same anode characteristics as the French tube described in the preceding installment although it required less filament power. The normal anode current was about 1 milliampere.

Triode tubes were also made during this period by other German manufacturers, among them *Huth*,[316] *Seddig*,[317] and *Auer*.[318] Some of these tubes are shown in Figs. 238 and 239. It will be observed that the *Huth* tube shown was of plane parallel electrode construction. Earlier *Huth* tubes used a cylindrical element assembly but *Huth* was compelled to change to the plane electrodes because of patent difficulties. The earlier *Huth* tubes bore RE numbers similar to those of *Telefunken*, but those with plane electrode systems were designated by LE numbers.[319]

It is during this period also that we find considerable research effort being expended in Germany on the multiple electrode tube. It was early realized by Dr. Walter Schottky[320] of the *Siemens & Halske Company* that there were limits to the amplification which could be attained by the use of a triode and he set out to devise a tube which would be capable of high amplification with the low anode potentials available in Army field equipment.

Accordingly he investigated the possibility of modifying the high vacuum triode by the insertion of additional electrodes. He patented the space charge principle in 1915[321] and the "protective network" type in 1916.[322] His first patent on a multiple electrode tube was German patent D.R P. 300617, issued June 1, 1916, and covered a tube designated by Schottky as a "protective network" (Schutznetz) type. Another patent, D.R.P. 300192 issued June 21, 1916, covered another double grid arrangement. Patent D.R.P. 300191 for a tube having a space charge grid in which both grids were characterized by being composed of strips of sheet metal placed with edges toward the cathode was issued on January 24, 1917.

The first production of the multiple electrode Schottky tubes were tetrodes of the protective network type, known as the SSI, SSII, and SSIII. While the protective network was a grid inserted between the control grid and the anode these tubes differed from the modern "screen-grid" type in that no attempt was made to use the additional grid to minimize the electrostatic capacitance between the anode and the control grid. This difference is relatively unimportant for low-frequency work, but is of great importance in high-frequency applications. As Schottky himself pointed out, his tubes were not suitable for use at high frequencies.[323]

The early model and later quantity-production type of the SS tubes are shown in Fig. 241. Fig. 241 (left) shows the earliest construction of this type. The electrode assembly was cylindrical, the grids were of the "squirrel cage" type, and a double press was used. The electrodes were slotted so that it was possible to insert the filament assembly into the electrode assembly after fabricating the two separately. Fig. 241 (right) shows a single-ended production type tube with glass "star" as the support of the electrode system.

The SSI was first manufactured in 1917. It had a filament which operated with 0.4 ampere at 2.4 volts. The anode potential was 35 volts and the potential of the protective network was 15 volts. When so operated it gave an amplification of about 50 and had a mutual conductance of 250 micromhos.

The SSII, also known as the RE97,[324] was a lower powered, lower gain tube, operating with a filament current of 0.24 ampere at 1.9 to 2.2 volts, and with 10.5 volts on both the anode and the protective network. It had an amplification factor of 30 and mutual conductance of 30 micromhos.

The SSIII, also known as the RE114, drew a filament current of 0.55 ampere at 3.2 volts and operated with 120 volts on the anode and 45 volts on the protective network. It had an amplification factor of about 100 and a mutual conductance of 250 micromhos. The internal resistance was about 250,000 ohms.

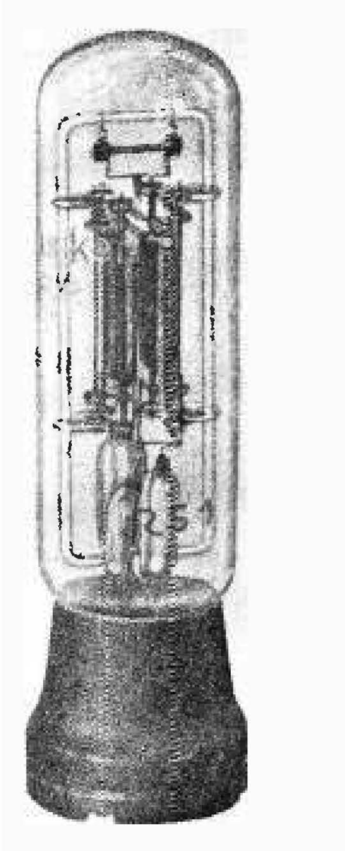


Fig. 235

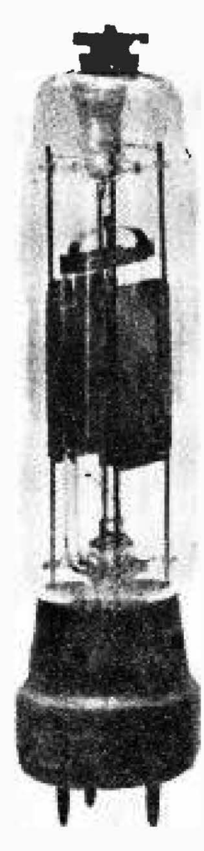


Fig. 236

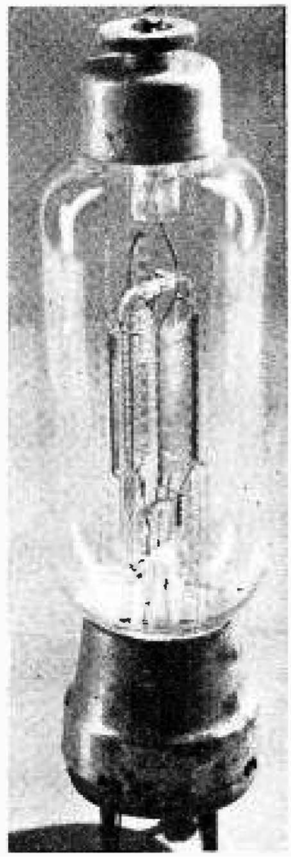


Fig. 237

Tubes of the space-charge grid type were also manufactured during this period. Typical examples of the smaller ones are the *Telefunken* RE20 and RE26, shown in Fig. 242. Both these tubes had tungsten filaments operating at 0.5 ampere at 2.8 and 4.0 volts respectively. They operated at 12 to 18 volts on the anode and space charge grid, had an amplification factor of about 8 and mutual conductance of about 350. Since they had 5 prong bases they required special sockets.

Larger tubes of the space-charge grid type were also developed and Fig. 243 shows the development series of one such tube Figs. 243(A) and 243(B) show the early models. The grids are of wire netting. The space charge grid is small in diameter while the control grid is very close to the anode. Fig. 243(C) shows a production type tube of the vintage of 1919, still with the double press, Fig. 243(D) illustrates the final construction which was put into production about 1920.

Combination space charge and protective network tubes with three grids were also developed and some of these are shown in Fig. 245. The tube at the left is an experimental type with three grids using a double press and slotted electrodes. That at the right is a production type similar to the SS series.

In parallel with the work on receiving tubes *Telefunken* and the other German concerns had also been carrying on the development of transmitting tubes. The first of these to be made in quantities was the RS1, shown

Fig. 238

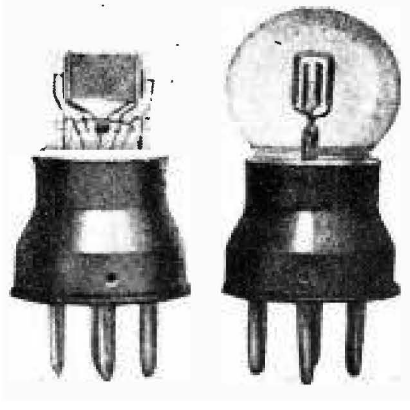
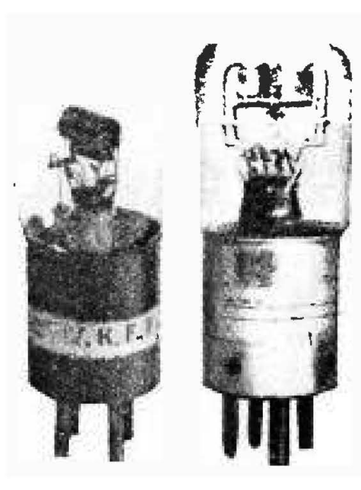


Fig. 239



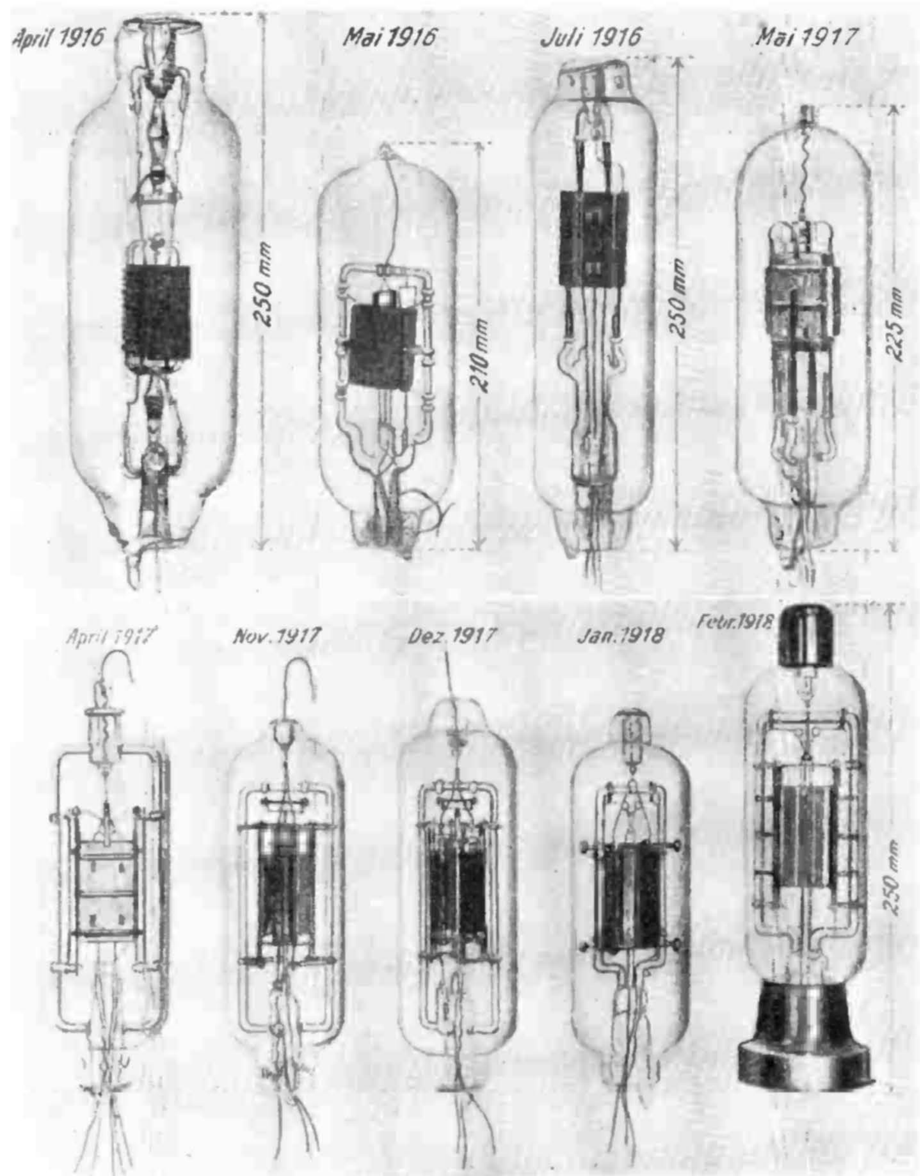


Fig. 240

in Fig. 235. It gave about three watts output when operated with 400 volts on the anode, in the apparatus in which it was first used, an Army trench transmitter. It was capable of operation at higher anode voltages, and at 600 to 800 volts would put out 10 to 20 watts.[325] The RS2 and RS3 were of no particular importance. The RS4 was a higher powered tube giving 50 to 75 watts output at 1000 to 2000 volts on the anode, and had a filament which took 3 amperes at 9 volts. The RS5, shown in Fig. 236, was an RS4 with improved characteristics. It took a filament current of 3 amperes at about 8 volts. The successor to the RS4 was the RS17, the evolution of which is shown graphically in Fig. 240.

All these transmitting tubes were characterized by the excellent glass work shown in their internal construction. This construction was common to all of the small transmitter tubes of early German manufacture, and is again exemplified in the TKD ST-12 shown in Fig. 237.[326] This tube again shows the effect of metal shortages. The interior portion of the base, in which the connecting pins are mounted, is of wood and the shell is of iron, with a poor nickel plate.

This series of articles has been presented to trace the development which took place up to the end of World War I along a particular branch of the network of roads which led to the modern radio tube. It has attempted to trace the evolution from studies of the interactions between heat and electricity as pursued by the early philosophers and by the physicists who followed them. These limitations have been adopted in an attempt to report the work done in the years where there is a dearth of readily available published material.

In any field of human activity books and periodicals are published by and for those interested. Such was the case in the early days of radio, with which the vacuum tube is so inextricably bound up. Much of the widespread interest in radio in the United States may be traced to the band of eager enthusiasts who made up the amateur fraternity in the days before World War I. The ham of those days spent his spare, and often not-so-spare, cash, burned his midnight electricity, and experimented unceasingly to fathom the mysteries of transmission and reception. Much progress came from interchange of ideas and experiences with others of like inclination. But unlike the situation existing today the facilities for such interchange were very limited. Books and periodicals dealing with such matters were few

(*Continued on page* 132)

Fig. 241

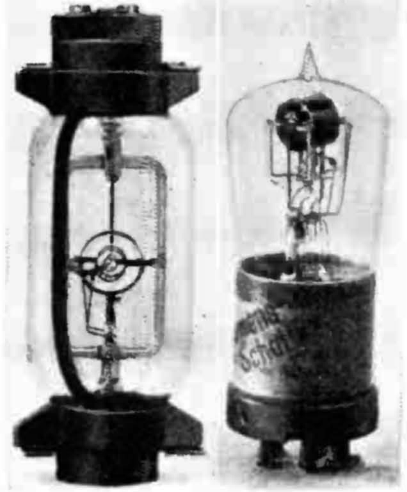


Fig. 242

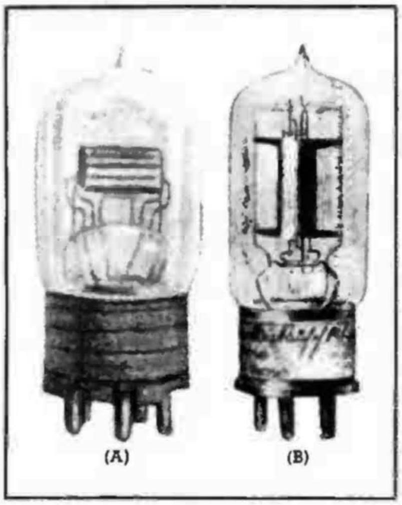
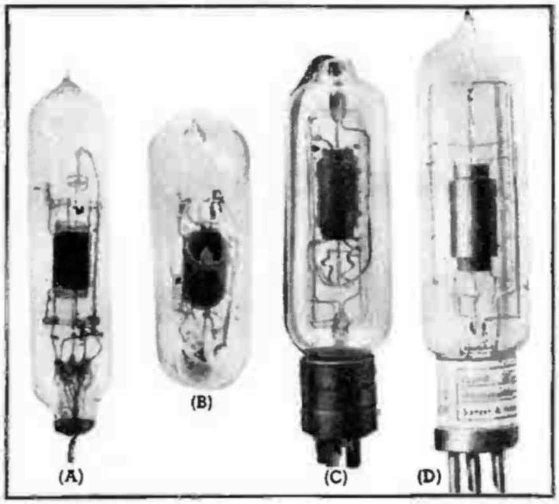


Fig. 243



Saga of the Vacuum Tube

(Continued from page 54)

and far between. Periodicals in particular were of limited circulation, aimed at the experimenter of high-school age and pocketbook and, except in a few cases, were not deemed of sufficient importance to be included in the permanent files of public libraries. Few books were written, since the men who were doing the work were too busy doing it to write about it.

With the advent of broadcasting and the great increase in adult popular interest in radio there came into being a number of widely circulated periodicals, technical and popular, both here and abroad, which published large quantities of information on current radio and vacuum tube development. These were preserved in most libraries of any size and are usually available to the earnest student of vacuum tube history.

For this reason little space has been devoted to cold-cathode, cathode ray, multi-grid, and higher powered transmitting tubes, such as the silica envelope type made by *Philips-Mullard*, the water-cooled copper-to-glass seal type developed by *Housekeeper*, and the larger radiation cooled types. Information on these phases of development can be obtained from these sources by the student or collector who seeks information on a specific type, and its collation and republication here is considered unjustified.

Fig. 244

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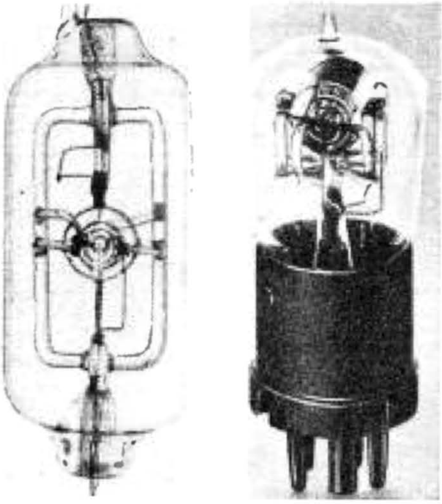

Fig. 245

316. Dr Erich F. Huth Gesellschaft fur Funkentelegraphie.
317. (R.I.W.) Seddig, Wurzburg.
318. Auer Studiengesellschaft fur elektrische Leuchtrohren.
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320. Schottky, W.—"Uber Hochvakuum Verstarker III Teil; Mehrgitterrohren" Archiv fur Elektrotechnik, Vol. 8, No. 9, December 8, 1919, pp. 299-328.
321. D.R.P. 310605, issued March 19, 1915.
322. D.R.P. 87745, issued May 31, 1916.
323. See reference 323, p. 320.
324. Pohlmann, B. and Gehrts, A.—"Werdegang einer Verstarkerrohre" Elektrische Nachrichten-Technik, Vol. 2, No. 3, March 1925, pp. 65-74.
325. See reference 316, p. 142.
326. "TKD" is the trade mark of Suddeutsche Telefon-, Apparate-, Kabel-, und Draht-Werke, Nurnberg.

CAPTIONS FOR ILLUSTRATIONS

Fig. 234. RE11 tube with ballast resistor. Photograph courtesy Bell Telephone Laboratories.

Fig. 235. Telefunken RS1. Reproduced from Telefunken Festschrift—1928.

Fig. 236. Telefunken RS5. Photograph courtesy R. McV. Weston and Electrical Communication.

Fig. 237. TKD ST-12 tube.

Fig. 238. Huth LE219 tube, front and side views. Reproduced from Nespers' "Der Radio Amateur"—1924.

Fig. 239. Left—Seddig tube. Filament 0.56 ampere at 2.8 volts. Right—Auer receiving tube.

Fig. 240. Development of Telefunken RS17. Reproduced from Niemann's "Funkentelegraphie fur Flugzeuge"—1921.

Fig. 241. Development of the SS (Siemens-Schottky) type tube. Reproduced from "Veroffentlichungen aus dem Gebiete der Nachrichtentechnik"—1935.

Fig. 242. Left RE20 tube. Right—RE26 tube. Reproduced from Banneitz "Taschenbuch der drahtlosen Telegraphie"—1927.

Fig. 243. Development of the space charge grid tube. Reproduced from "Veroffentlichungen aus dem Gebiete der Nachrichtentechnik"—1935.

Fig. 244. RE16 tube. The top is painted red. Reproduced from Nespers "Der Radio Amateur"—1924.

Fig. 245. Development of the Schottky three grid tube. Reproduced from "Veroffentlichungen aus dem Gebiete der Nachrichtentechnik"—1935.

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Direct-Wire Television

(*Continued from page* 40)

apart from the oscillographs which translate light and power values to moving graph-like lines, three monitoring screens. Two show the image being picked up by the cameras. The third is the "output" image being fed to the other receivers or monitors attached to the direct-wire installation.

Switching relays, three simple pushbuttons, at the console permit the operator to select which of the two camera's pick-up images is to be fed to the line amplifier, or he may choose a combination of both. To effect fades, he slowly cuts the gain, rides it all the way down to the light image and then, when the image is virtually imperceptible, he switches images. Lap dissolves and ghost images may also be accomplished by shifting the light levels.

From the engineer's control console, the signal is fed to a line amplifier and distribution panel. The line amplifier's function is to build the video signal to sufficient volume to feed the various monitors plugged into the distribution panel. In the department stores which will be equipped with many of the monitors, it may be desirable to have more than one line amplifier and distribution panel on other floors to intensify the signal and send it elsewhere to feed other monitor units or distribution panels. Such a system permits considerable saving in cable required and leaves distribution of monitors more flexible.

In operation, the monitors to receive the program at any one time can be selected at will. In the evening, after hours, the store may prefer to feed the program to monitors on the windows. Or it might prefer to concentrate its television appeal to audiences on different floors at different hours of the day.

It will be possible for the store to arrange to pick up the programs broadcast by local television stations by use of a receiver in the studio or by tapping a network line to bring selected programs to the store monitors or to relieve the store's programming staff at intervals.

The sound system for this television arrangement is entirely independent of the video system. It can be built into the video unit or handled as an autonomous public address installation with outlets adjacent to the monitors. It is important, though, whichever type of sound system is used, that the appearance of the sound coming from the characters speaking on the monitor be retained lest the whole illusion of television broadcasting be lost.