SAGA OF THE VACUUM TUBE

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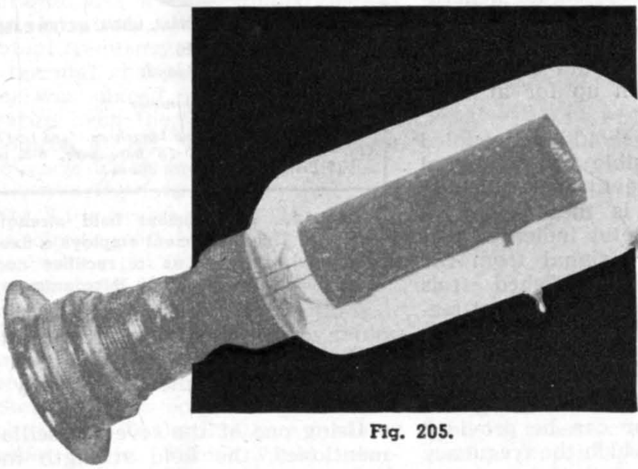


Fig. 205.

Part 19. Covering developments and applications of tubes in England from 1911 through World War I.

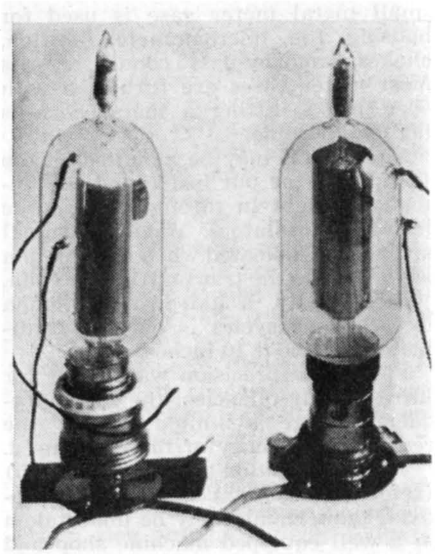


Fig. 206.

WE HAVE considered the evolution of the vacuum tube as a telephone repeater element in Great Britain. The early telephone repeater tubes engineered in Britain apparently were adapted from the radio art and were not developed primarily for telephone use. The early British radio tubes were of the gaseous type and seem to have been inspired largely by the work of von Lieben and Reisz in Germany. True, Fleming had obtained a sample of the de Forest Audion as early as 1907, but we have no records showing that he or any one else in Britain was activated by it immediately.

The first work in tube development in England seems to have been done about 1911 by Captain H. J. Round of the British Marconi Company. It appears to have been done in collaboration with Telefunken, probably as a result of the recently concluded Tele-

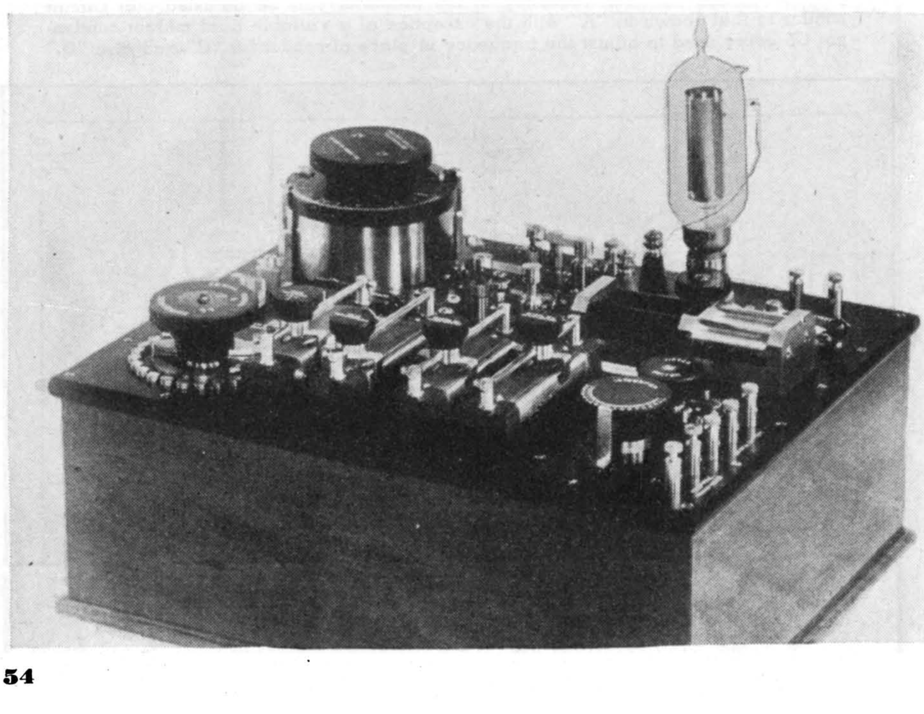


Fig. 207.

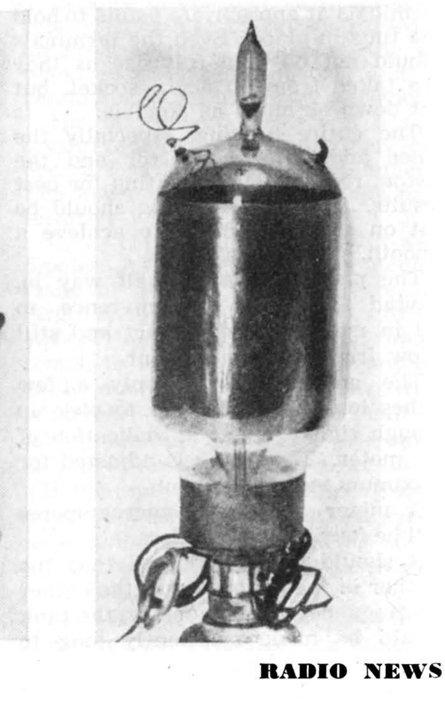


Fig. 208.

funken-Marconi patent agreement. Little has been published concerning Round's early work, hence it is difficult to trace with any degree of authority the evolution of the Round tube. Round speaks intimately of the work of Alexander Meissner of the Telefunken Company in an article on wireless telephone published in 1915,[283] but the article deals chiefly with circuits and applications, and no mention is made of the Round version of the LRS Relay.

The Round tubes differed from the Meissner version of the LRS Relay chiefly in details of design.[284] They were first employed by Round as high-frequency amplifiers, and later as oscillators as well. They were remarkably good amplifiers when operated under optimum conditions. The gain obtainable from the Round type "C" was equivalent to approximately three stages of the best "hard" tube of that time, the so-called "French" tube.[285] The Round type "C" is shown in Fig. 205.

The Round tubes were characterized by coated cathodes, wire mesh grids forming a practically complete enclosure for the filament, a long tubulation containing means for adjusting the vacuum, and cylindrical anodes with a large ratio of anode-filament to grid-filament distance. The filaments were usually of hair-pin shape, with the hottest part at the top. Round considered it necessary for stability of operation that the grid completely enclose the filament. If this were not done the inside of the glass bulb would become charged by bombardment from the filament. If the charge, so accumulated, produced an appreciable electrostatic field at the filament, it would be necessary to readjust the grid potentiometer to compensate. Hence, unless a completely enclosing grid were used this rather critical parameter would require frequent readjustment, an undesirable operating limitation.[286]

There were several types of Round tubes, of which the type "N" and type "T," the latter first produced in 1913,[287] may be taken as representative. Fig. 206 shows two versions of the type "N" and Fig. 207 shows the Marconi Type 27 Receiver with one of these tubes in use as a high-frequency amplifier. The Round type "T" is shown in Fig. 208. Fig. 209 is a view looking down on the type "T" (with the tubulation removed) and shows the internal construction.

The type "N" had a single lime-coated filament which took 3 to 4 amperes at 2 to 2.5 volts. It operated with 40 to 80 volts on the anode, and was used in the famous Marconi No. 16 Circuit, which used a carborundum detector. The tube functioned in this circuit as an r.f. and a.f. amplifier, the circuit being of the reflex type. A variant of the type "N" was the type "CA" shown in Fig. 210, which had an extremely fine mesh grid and operated with filament current of 2.5 amperes and anode voltages up to 200 volts.[288]

The type "T" also had two variants, one with coarse and one with fine mesh grid. One of these was known as the type "TN" and operated at 200 volts on the anode. There were three separate filaments, of the oxide-coated type, which were used in succession. The filament current was 4 to 4.5 amperes at about 6 volts. The type "TN" was used in the "Short Distance Wireless Telephone Transmitter and Receiver" made in 1914 by the British Marconi Company,[289] and shown in Fig. 211. It, like the other Round tubes, was manufactured by the Edison & Swan Electric Company.

The first actual use of the three-electrode tube in the British armed services was by Round, in December 1914, in a Marconi Direction Finder.[290] Many of the Round tubes were used by the Royal Flying Corps (later the Royal Air Force) in the earlier wireless sets for plane-to-ground communication during World War I. Discussing their use shortly after the War, one of the R.A.F. officers said:[291]

"The soft valves used in the early days were provided with a regulating device in the form of a pip containing a crystal of asbestos or other mineral. This when heated reduced the vacuum in the valve. It was the custom to heat the pip before a flight took place but it often happened that when in the air one found that the valve had become too hard to oscillate. In order to overcome the danger of applying a naked flame, a small electric heater was devised which could be placed over the regulating pip."

The Round tubes were used to a considerable extent because of their high gain and power handling capabilities in British communications equipment during the war. They were difficult to manufacture and required highly trained operators to utilize their capabilities. Concerning their

Fig. 209.

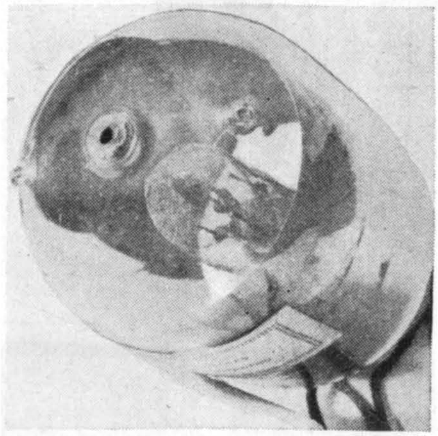


Fig. 210.

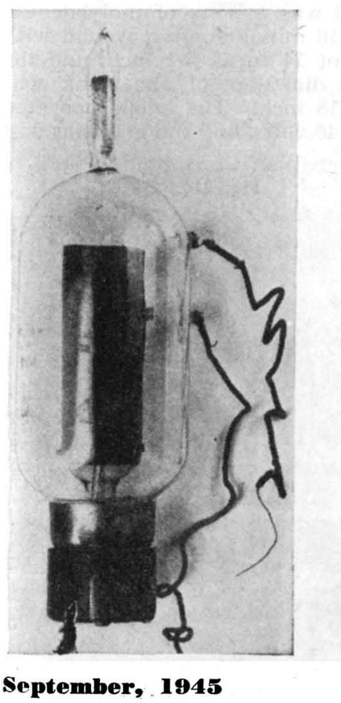
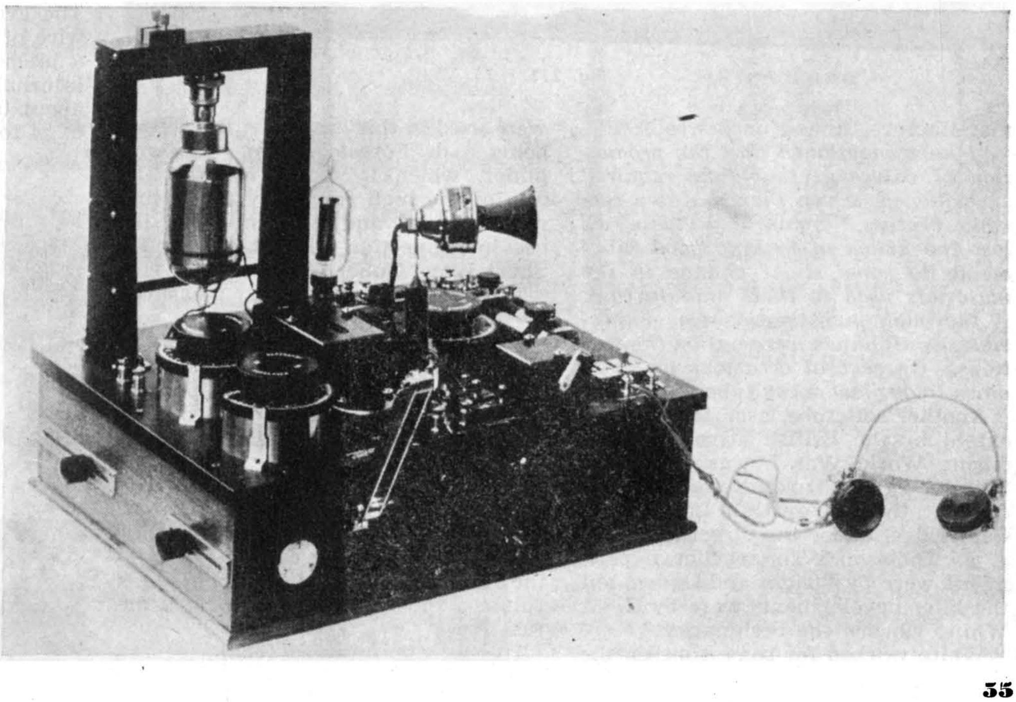


Fig. 211.



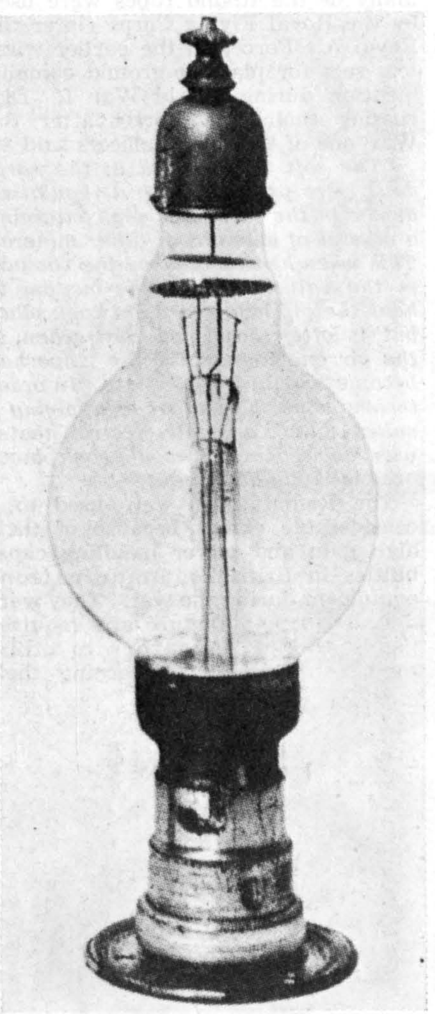


Fig. 212.

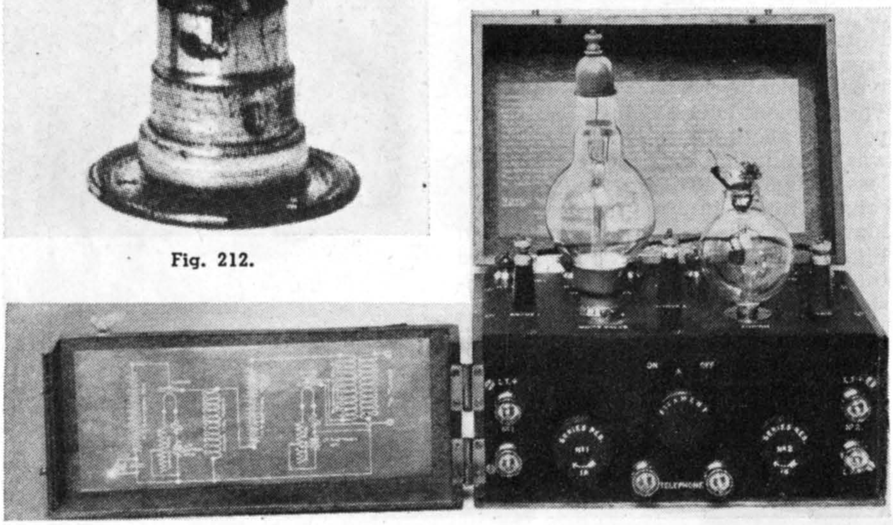


Fig. 213.

manufacture, Round once wrote:[292]

"I have mentioned that the production of valves at that time required special men. Even then it was a terrible process. Again and again we lost the knack of making good tubes owing to some slight change in the materials used in their manufacture. A thorough investigation was impossible, as all hands were out on the stations. On several occasions we were down to our last dozen tubes."

Another soft tube, used to a limited extent by the British armed services during World War I, was called the "White" valve. It resulted from work done at the Cavendish Laboratory, Cambridge, under the direction of Sir J. J. Thomson. The earlier experiments were by Wright and Ogden, but the later developments were by G. W. White, whence the designation.[293]

White worked for some time on the use of cold-cathode tubes and succeeded in making some which operated satisfactorily in wireless work.[294] These tubes were not as sensitive as those of the hot-cathode type although they did possess some advantages. No filament heating battery was required, and their action was not sensitive to small changes in the internal pressure.

Probably because of the increased sensitivity obtainable, White eventually abandoned the cold cathode and went to an incandescent cathode construction. A White tube of the type which came into practical use in 1916 is shown in Fig. 212. The filament is of oxide-coated platinum, operating with 2.8 amperes at 6 volts. The grid is a disc of perforated copper and the anode is of iron amalgamated with mercury. It operated at anode potentials from 25 to 75 volts. The base is of the bayonet type and the grid connection is made through the base shell. The anode connection is made to the knurled nut at the top of the tube. This tube was used in the Mark III Amplifier, which was designed by the British Signals Experimental Establishment for field use, and was first manufactured in 1917.[295] Two tubes were used in this amplifier, the second being a de Forest Audion. The amplifier, which is shown in Fig. 213, was of the high frequency type using regeneration, and was intended for use in connection with the Mark III Short Wave Tuner.

It will be observed that, measured by present day standards, the soft tubes made by Round and White were of comparatively large physical size, as was the original LRS Relay. This was necessary in the interest of stability of operation. Any attempt to reduce the volume of the tube meant an increase in the ratio of electrode area to the volume of the gas present, so that the variations in electrode temperature had a greater effect on the residual gas. The smaller the gas volume, the more erratic was the tube.[296]

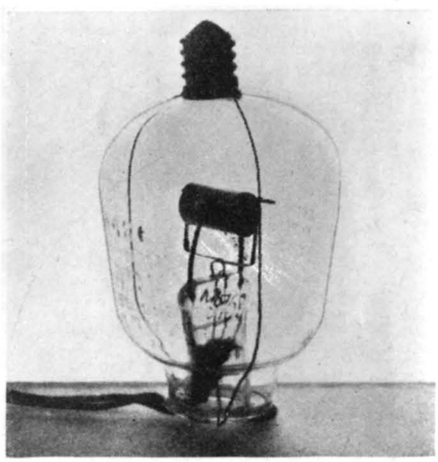
It was appreciated, even as these developments were carried out, that the high vacuum tube had great advantages in military work, because of the stability of its characteristics and the uniformity of the manufactured product. Yet the soft tube possessed such a high sensitivity that much development effort was expended in an attempt to make of it a stable, reliable device, which could be applied in military work, where the skill of the operator could not be guaranteed.

The manufacture of soft tubes was undertaken by the British Thomson-Houston Company at Rugby during the summer of 1916 and the first production was of the Audion type, but with much better life expectancy. Serious difficulties were experienced early in 1917, and as a result of investigation the Audion structure was abandoned and a soft tube similar in construction to the hard "R" tube was developed. This tube was known as the "R2 valve" and at first was nitrogen filled to a pressure of 0.06 mm. mercury. The pressure was measured during manufacture by measuring the width of the dark space in an auxiliary cold cathode tube. After development the specifications on this tube were released to several manufacturers, and the first quantity production was achieved by the Osram-Robertson Works of the General Electric Company, Ltd., in June of 1917.

Difficulties were encountered in maintaining the gas pressure, because of the absorption of nitrogen by the electrodes. Later R2 tubes were helium-filled to a higher pressure, about 0.6 mm. mercury. The manufacture of the helium-filled R2 was begun in September 1917.

The filament of the R2 tube was of drawn tungsten wire. It was 0.79 inch long and 3.3 mils in diameter. It operated at 1.1 amperes with a potential drop of about 3.3 volts. The anode was of sheet nickel, bent into the form of a complete cylinder, approximately 0.6 inch long and 0.35 inch in diameter. The grid was a helix of molybdenum wire of 16 mils diameter, wound with a pitch of 14 turns per inch, and the internal diameter of the helix was about 0.18 inch. The anode operated at 24 to 40 volts, and the grid bias was

Fig. 214.



adjusted by means of a potentiometer to the optimum operating value while in use. An R2 tube is shown in Fig. 214. This tube was made by General Electric (Osram), British Thomson-Houston, and Edison & Swan.

A modification of this tube, known as the R2A, manufactured chiefly by Marconi-Osram, was used in the British naval installations during the last years of World War I. It marked the final development of the soft tube in England. It operated under the same conditions as the R2 except that it had a somewhat narrower range of anode voltage, 28 to 38 volts.

Another soft tube used to a limited extent for aircraft work was known as the "Air Force Type D," and will be touched upon in a later installment.

Before leaving the consideration of soft tubes of British origin, mention should be made of one other. This is the so-called "NPL" valve, described by Stanley in 1919, in the following words:

"In this valve the plate was a thin sheet of circular metal; above this was the grid consisting of a perforated sheet of metal, beyond which was the bowed tungsten filament. This was a bad design; the grid was too heavy and the flow of electrons from the filament was not uniform along its length but was concentrated at the center. The design is now out of date.—"

Apparently this was a soft tube, since the characteristics given by Stanley show kinks ascribed by him to the presence of mercury vapor, and he records the presence of an amalgam of mercury on the anode. The author has never seen any mention of this tube except that referred to above. It may be possible the "NPL" was another designation for the White valve previously described. If the reader compares the description given by Stanley with the White valve shown in Fig. 212, he will see that if the White valve be mounted with its base uppermost Stanley's description reads rather well on it.

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(Continued on page 124)

flected by water surrounding a sea-borne radar set.

Spark gap—An arrangement of two fixed electrodes between which a high-voltage arc discharge takes place.

Squaring amplifier—See Overdriven amplifier.

Squegging oscillator—An extreme form of grid blocking in an r.f. tuned-grid tuned-plate circuit.

Synchronism—The relationship between two or more periodic or recurrent wave forms, when the phase difference between them is zero.

Synchronizer—See Electronic timer.

Tail—Attenuated decay of an r.f. pulse.

Target—Any object which produces a radar echo.

Time base—The trace produced on the screen of a cathode ray tube by deflection of the electron beam.

Time constant—An indication of the speed with which a circuit can be charged or discharged.

Timer—See Electronic timer.

Transmitter pulse—Burst of r.f. energy radiated by the radar transmitter. The pulse appears as a strong signal at the left end of the oscilloscope time base. —30—

Saga of the Vacuum Tube

(*Continued from page 58*)

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296. *See reference 284, page 165.*

CAPTIONS FOR ILLUSTRATIONS

Fig. 205. Round type "C" Valve. Photograph courtesy R. McV. Weston.

Fig. 206. Left—Round type "N" Valve with screw base. Right—Round type "N" Valve with Ediswan bayonet base. Photograph courtesy Marconi's Wireless Telegraph Co., Ltd.

Fig. 207. Marconi type "27" Receiver, 1914-1918, using Round type "N" Valve. Photograph courtesy Marconi's Wireless Telegraph Co., Ltd.

Fig. 208. Round type "T" with multiple cathodes. Photograph courtesy R. McV. Weston.

Fig. 209. Top view of Round type "T" with tubulation removed, showing characteristic Round mesh type grid.

Fig. 210. Round type "CA" Valve. Photograph courtesy Radio Corporation of America.

Fig. 211. Marconi Short Distance Wireless Telephone Transmitter and Receiver. The tube in the gallows frame is the Round type "TN" used for transmitting. The tube at the right rear is the Round type "C" used for receiving. Photograph courtesy Marconi's Wireless Telegraph Co., Ltd.

Fig. 212. White Valve. Photograph courtesy R. McV. Weston.

Fig. 213. Mark III Amplifier using White Valve and de Forest Audion. Photograph copyright by H. M. Stationery Office.

Fig. 214. Osram R2A Valve, fitted with candelabra base for use in naval apparatus designed for de Forest Audion. This valve was usually supplied unbased, the user applying whatever base he saw fit. Photograph courtesy Bell Telephone Laboratories.

(*To be continued*)

William P. Lear, President of Lear, Inc., holding the "magazine" of a radio and wire recorder combination shown recently at a special preview given to the press and science writers. The "magazine" does away with threading the wire; it can be changed as easily as slipping a pack of cigarettes into your pocket. Wire recorders will become a part of many postwar home receivers and they will also be offered as a separate unit, to be attached to present sets, as well as for other commercial entertainment, educational, and industrial uses.