The Evolution of the Cathode

By H. W. Kadell*

THE well known radio tube of the three-electrode type contains a cathode, a grid and a plate. The cathode is the heart of the tube because it is the storehouse or reservoir of the electrons which are boiled off when the cathode is sufficiently heated and travel towards the positively charged plate. This electronic current is the well known plate current which, when properly controlled by the grid, makes the tube act as an amplifier or detector.

FILAMENT TYPE CATHODES

In the early days of radio, the cathode consisted of a pure tungsten filament which had to be heated to an intense white heat before enough electrons were boiled out and evaporated from it to make the tube function properly. Because of the poor electron-emitting ability of this type of cathode, considerable power was consumed in heating it and its life was short because of the extremely high temperatures involved. The old 201 amplifier tube requiring 1.0 ampere of filament current at 5.0 volts or 5.0 watts of filament power had such a cathode.

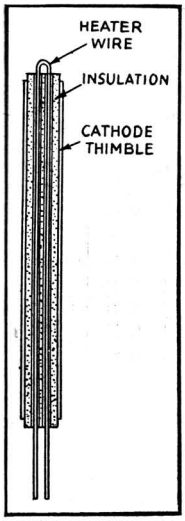

FIG. 1

It was found subsequently that when a small quantity of thorium was added to the tungsten, a cathode could be produced which would emit great quantities of electrons at much lower temperatures. These thoriated tungsten filaments soon replaced the old pure tungsten filaments, and the old 201 tube became the 201-A requiring only 0.25 ampere of filament current or 1.25 watts of filament power.

At about the same time that all this development work was taking place on the thoriated tungsten filament, a great deal of development work was also being done on oxide coatings for filaments. Special coatings were developed consisting of mixtures of barium and strontium oxides which, when properly placed on platinum or nickel filaments, produced very high efficiency cathodes requiring comparatively small heat power for large electronic or plate currents. As an example of the great improvements made in cathodes, it should be noted that the new ER-230 low-drain battery tube will give the same electrical performance as the 201-A but requires only about one tenth as much filament power as the 201-A and only one-fortieth as much as the original 201.

The cathodes of battery operated tubes and of certain a.c. tubes are filaments which are raised to the electron-emitting temperature by the passage of electric current through them. The filament current plays no part in the reception of the radio signals other than affording a convenient way of getting the cathode hot enough to emit the required electrons.

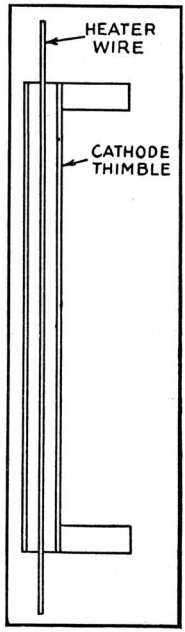

FIG. 2

INDIRECTLY HEATED CATHODES

All of the early attempts to produce a satisfactory "all-electric" a.c. radio receiver were not commercially satisfactory because the filament type cathodes used in all tubes at that time produced entirely too much hum when attempts were made to heat them on raw or unfiltered alternating current. Because of this trouble, a.c. sets did not become commercially feasible until the indirectly heated cathode was conceived along about 1922. Because of the difficulties of manufacture and the attendant cost and operating disadvantages, the indirectly heated cathode type of tube was used only in the detector stage of a.c. receivers until about three years ago. Now it is used in the radio-frequency, detector and audio-frequency stages of practically all makes of radio receivers.

An early type of indirectly heated cathode is shown in Fig. 1. The cathode itself is a hollow nickel cylinder or thimble coated on the outside with a mixture of specially processed barium and strontium oxides capable of emitting great quantities of electrons when heated sufficiently by the a.c. passing through the hairpin loop of wire threaded through the ceramic bushing within the cathode thimble. It will be noted that the a.c. heater is insulated from the cathode. Furthermore, the two heater wires are placed close to one another so that the alternating current fields

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set up around the two wires will largely neutralize one another because the currents in the two wires are of opposite phase, with the result that the external field around the heater will be very weak and the resulting hum therefore low. The great disadvantage of this first cathode is the time required for the tube to begin functioning. Under the operating conditions obtaining in the average radio receiver, it generally takes from 40 to 60 seconds for the set to begin playing after being turned on.

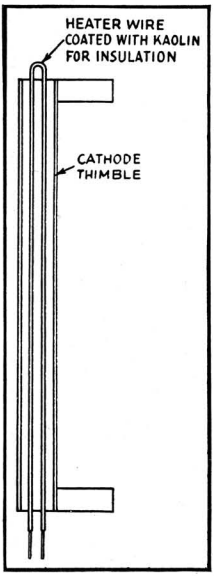

FIG. 3

In an endeavor to reduce this excessive heating time, some tube manufacturers developed the cathode shown in Fig. 2. This type of structure resulted in a quick heating cathode but it introduced many serious disadvantages. In the first place, the a.c. heater is of the "straight through" type in which the a.c. heater current is not made to neutralize itself, with the result that this type of cathode produces entirely too much hum for use in the modern highly sensitive broadcast receiver. It will be evident also that the heater wire must be centered within the cathode thimble by the factory worker; an operation that cannot be accomplished satisfactorily in quantity production. In the second place, the heater wire is supported by long wires in glass beads which are not integral with the cathode. Since the heater wire is not covered with an insulator, the rough handling which a tube gets in shipment and the constant vibration which it receives in use produce short-circuits of the heater to the cathode with resulting greatly increased hum and unsatisfactory operation of the tube.

Fig. 3 shows a type of cathode construction which was developed about two years ago in an endeavor to eliminate the serious limitations of the previous cathode shown in Fig. 2. As will be noted, an insulated hairpin is always centered within the cathode thimble. The kaolin insulation is a very hard and brittle substance, however, with the result that the repeated heating and cooling of the a.c. heater, as the set is turned on and off in use, tends to crack off the insulation from the heater, thereby affording an opportunity for the heater to short circuit against the cathode thimble. It also will be noted that the hairpin heater is hand spaced and supported within the cathode as in the previous construction, and hence is subject to the same trouble.

Fig. 4 shows the Eveready Raytheon quick-heater, low-hum cathode for use in modern high sensitivity receivers. It employs a heater of tungsten wire, coiled into a tight double spiral, which makes it act like a spring. This springy heater is mounted under tension between two insulating plugs in the ends of the cathode. When the wire expands in heating, the springiness of the coiled construction takes up the slack, keeping the heater tight and in the exact center of the cathode. When jolted and jarred, the coil can deflect sideways without breaking, but instantly snaps back into position. The bottom insulating bushing is provided with a short projection which extends up into the heater coil for about two turns. This keeps the end turns from being short circuited against each other as the operator threads the lead-in wires through the two holes in the bushing and thus assures a good rugged construction at this point.

It requires extremely nimble fingers to assemble the tiny cathode parts, and any rough handling during assembly may seriously damage the heater coil. In putting the parts together, the last operation is to stretch the coil tight by pulling on the top supporting rod until the coil stretches slightly, and to weld the collar on the rod to prevent its slipping back through the hole in the bushing. If too much tension is applied to the coil it will be stretched out of shape and some of the turns may become short circuited, thus ruining the cathode and making the tube in which it is placed inoperative. Such defective cathodes are easily detected by the usual inspection methods employed by most tube makers, which is to place the finished tube on test and measure its performance characteristics. With a short-circuited cathode, the tube will not test up to standard and it is rejected.

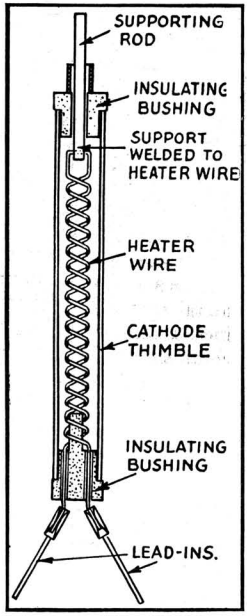

FIG. 4

THE X-RAY SHOWS DEFECTS

But there is a certain percentage of cathodes which are damaged in the assembly but are not inoperative. The turns of the heater coil are almost but not quite short circuited and, while

such a cathode is defective and should not be allowed to leave the factory, none of the usual inspection methods will reveal the damaged condition of the heater coil hidden away inside the metal cathode cylinder.

The heater coil is actually inspected after it has been assembled in the cathode by taking an X-ray picture of every cathode before it is assembled in the tube. The finished cathodes are assembled in shallow wooden trays, one hundred to the tray. An X-ray photograph of the one hundred cathodes is made, and with the developed film, the inspector picks out of the tray all the cathodes having imperfect heaters.

Fig. 5 shows an enlarged X-ray picture of a good cathode and a defective one. In B the heater coil has been pulled or twisted out of shape until several of the turns are almost, but not quite, short circuited. If this cathode were assembled into a tube, it would heat up correctly, it would emit; the tube would have mutual conductance and amplification, and in all ways give evidence of being a good tube. But it wouldn't last long. It would be an unsuspected cripple. The jolts and jars of transportation might complete the short circuiting of the heater, in which case the apparently good tube would be dead when put into use.

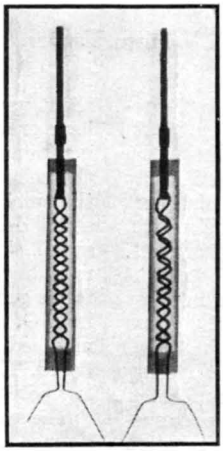

FIG. 5.—THE X-RAY SHOWS UP A DEFECTIVE CATHODE

Although the left cathode might not prove defective on test at the factory it is none the less defective and would give trouble in time. The cathode at the right is perfectly normal.

Even with the most painstaking care exercised in the making of cathodes, the all seeing X-ray reveals four or five out of every hundred that could not be allowed to go into finished tubes.

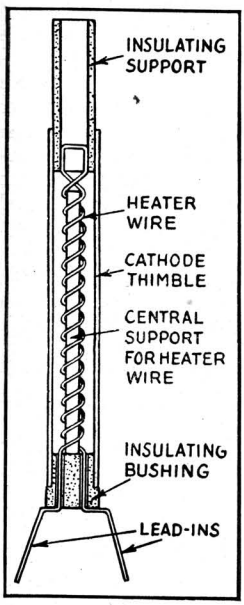

FIG. 6

AN IMPROVED CATHODE

Fig. 6 illustrates an improved type of cathode construction as now used in type ER-224 and ER-227 tubes, designed to reduce the possible defects of the previous type. The projection on the bottom insulating bushing has been lengthened until it now extends for the full length of the heater coil. The advantages of this construction are that the stiff, hard rod, running the full length of the coil, will make it impossible for the operator to twist or pull the coil out of shape when inserting it in the cathode. Further, because of this central support, it no longer becomes necessary to put a strain on the coil to keep it stretched when it heats up. The top bushing centers the free end of the coil in the cathode and holds it accurately in place without imparting any strain to the wire, leaving the coil free to expand and contract as it pleases without danger of harm. This new construction will not make the tube operate any better; it is simply an example of good engineering principles applied to the design of the tube to speed up production and to reduce scrap, and, what is of importance to the buyer of tubes, to add a certain measure of strength, ruggedness and dependability.

Strays

Wonder what some people think when they see a ham transmitter for the first time? W2BOE's landlord complimented him on the fine-looking dashboard in his shack!

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We've often seen r.f. chokes smoke, and W8ADJ gives his every chance to do it. It's wound on a cigarette!

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SWEEPSTAKES REPORT POSTPONED

The story on the Sweepstakes Contest, originally scheduled for this issue, is still in the process of preparation as we go to press. We have been forced to hold the story over until the July issue so that the task of checking the hundreds of logs may be completed. Scores run much higher than in last year's contest, several topping 20,000.

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W5BTL picked this one out of the "Exchange" columns of the local newspaper: "6-tube Atwater-Kent radio with attachments for good milch cow."

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I. R. E. CONVENTION

The Sixth Annual Convention of the Institute of Radio Engineers is scheduled for June 4th, 5th and 6th at the Hotel Sherman in Chicago. A number of important technical papers are to be presented during the program. In addition to several inspection trips, an exhibition of component parts for broadcast receivers, measuring and laboratory equipment and other material of interest to engineers will be held.