A NEW PRINCIPLE OF CONSTRUCTION FOR RADIO VALVES

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A radio valve is described in which the pinch type of lead-in of the connection wires is replaced by a horizontal flat base of pressed glass. In this construction the distance between the leads is greater than in the pinch type, the lengths of the leads in the glass and the lengths from the points of contact outside the valve to the electrodes inside the valve are much shorter. Moreover the construction is much stronger, while it was also possible to lead out the grid connection at the bottom while still retaining the desired value of the capacity between grid and anode. The advantages resulting from these changes are discussed. They are manifested especially clearly when the valve is operated on very short wave lengths. This is due partially to the fact that the cap of insulation material which is ordinarily used may be dispensed with.

Introduction

Consideration of the gradual development of many kinds of new technical products shows that a structural form was at first almost always chosen which had previously served other similar purposes. The first automobile resembled an old-fashioned carriage, the razor, before the transition to safety razors, resembled an ordinary knife, and the oldest electric switch resembled a gas tap.

In the same way the earlier radio valves are similar in many structural details to the electric lamp. As in the case of electric lamps an evacuated glass bulb was necessary in order to raise a wire to a high temperature and maintain it at that temperature without its being attacked. The method of pumping and the leading in of the electrical connections through the wall of the bulb were taken over practically unaltered. Evacuation was through a small glass tube, the exhaust tube, which was originally fused to the top of the bulb. A few wires, with the same coefficient of expansion as the glass which was squeezed around them after heating, served for leads through the pinch. In the same way as with an electric lamp, a cap was cemented to the bulb in order to facilitate connection in radio sets.

The technical requirements which should be met by radio valves were at first not sharply defined, and were indeed still partly unknown. During the steady progress of development, however, a continually better insight was obtained into the specific requirements of radio valves and into the extent to which these requirements were restricted by the prevailing construction of the valves.

What are the requirements which must be satisfied in the construction of a radio valve?

We shall begin by discussing several of these requirements in some detail. It was soon discovered that the mutual insulation of the electrodes, cathode, grid and anode, must satisfy very high standards. In the pinch construction taken over from the manufacture of electric lamps, however, these electrode connections lie close together (from 0.5 to 1 mm apart). The heating up of the pinch during operation of a radio valve therefore sometimes led to electrolysis of the glass, to leakage and breaking of the valve. With the introduction of valves with several grids, such as pentodes, and especially later on in the development of octodes and other mixing valves, the number of leads through a single pinch was increased very much. Since the insulation must be very high, especially between cathode and control grid, and the capacity C_{ag} between anode and control grid must be very low in order to avoid coupling between anode and grid circuits, the lead of the control grid was transferred to the top of the valve. This precaution answered the purpose very well, but for the use of the valves

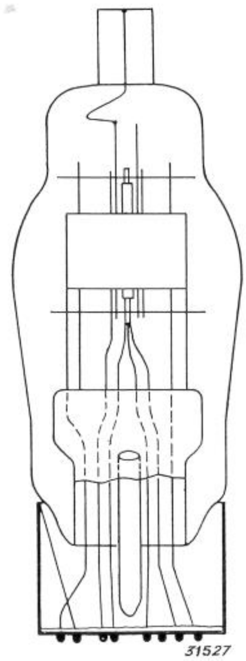

Fig. 1. Radio valve with "pinch" construction. Six wires pass through the glass pinch (broken lines); the connection for the control grid is at the top. The six wires are parallel over a great length and the lengths of the wires in the glass are considerable. The connection of the valve to the cap and the protection of the exhaust tube are shown in the figure. In this recent type of radio valve of the pinch construction already much effort has been made to keep the dimensions small.

in a radio set it would have been preferable to bring out all the leads at the same end of the valve.

The use of shorter and shorter wave lengths makes it essential to keep all the capacities between the different electrodes, the self-inductions of the different leads and their mutual inductions as low as possible. With the pinch type of construction a limit is soon reached, since the leading-in wires, run parallel and close to each other in the pinch and pinch tube for some little distance, have quite high capacities and self-inductions. In the pinch these wires are separated by glass with a fairly large dielectric constant which further increases the capacities. The width of the pinch is being continually increased (see *fig. 1*), but since the leads in such a pinch lie in a single plane, and the pinch must not touch the walls of the bulb and must be able to pass through the neck of the bulb, the distance between the outermost wires in the pinch is usually not much more than half the diameter of the neck of the bulb.

It is, however, not only desirable that the capacities between the electrodes of a valve should be small, but they must also be as constant as possible. Upon switching on a radio set, the temperature of the valves increases gradually. The capacities between the electrodes therefore will only be sufficiently constant when the temperature coefficient of the dielectrics in the valve is low. This condition is fairly well satisfied by the glass of the pinch, it is much less nearly satisfied by the press material of the cap. The result is that the resonance frequencies of the two tuned circuits change to a certain extent after switching on. Furthermore it is desirable to have the value of the capacities equal in different valves of the same type, so that the set need not be readjusted when a valve is changed.

The position of the wires in one plane parallel to the flat part of the pinch is capable of being improved upon from the mechanical point of view also. The inside assembly of the radio valve, *i.e.* the grids and the anode, is mounted on the pinch by welding, and the strength of such a construction is too low for shocks perpendicular to the plane of the pinch. The inside assembly of the valve is therefore often supported against the upper part of the tube wall by mica plates.

These and similar considerations have led to the search for a different type of construction from the traditional one. We shall discuss in this article a new type of glass construction worked out by Philips, and the results achieved with it.

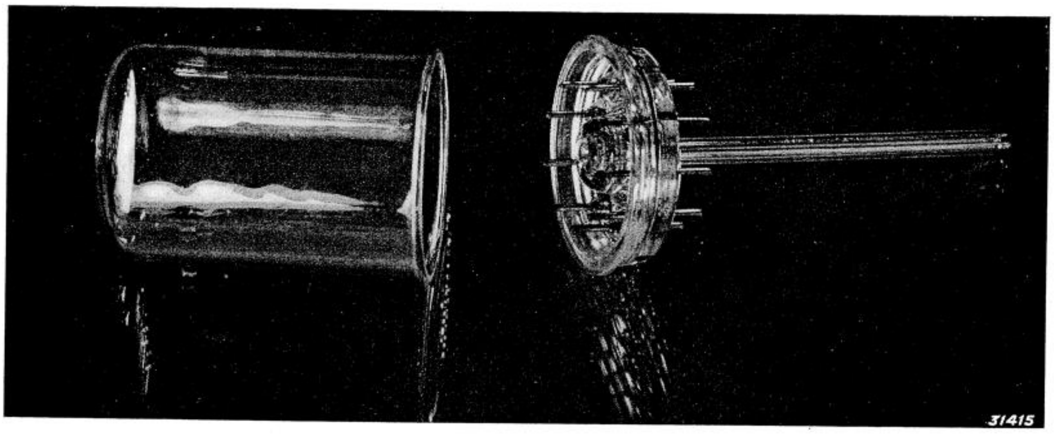

Fig. 2. Photograph of the bulb and the circular base of moulded glass which are fused together along the flange. At the centre of the base is a depression where the exhaust tube is fused on. The chrome iron pins pressed into the glass are clearly visible. Contact is made in the socket through the projecting ends of these pins. The inside assembly is mounted in the valve on these pins (see Fig. 4).

Construction

In the new type of construction the valve consists mainly of a circular glass base upon which the inside assembly is mounted and a glass cylinder which is fused to this base along a flange. These two parts are shown in *fig. 2. The base plate is completely moulded out of glass.* This pressing of the glass can easily be done mechanically. During the process of moulding the base plate the chrome iron leads can be included in the mould and the joint between glass and leads is airtight. It was found possible to choose the leads thick enough to serve directly as contact points without danger of leakage or breakage of the glass. The construction of the socket must of course for good contact be adapted to the diameter of the pressed-in chrome iron contact pins, The chrome iron pins are placed in the moulding in a circle with a fairly large diameter (21 mm). The distance between them is therefore great (with 9 pins it is 7 mm) and very good insulation is thus guaranteed. At the centre of the base there is a depression in which a stem is fused (*fig. 3*). Because of this depression the length of the stem to the point of sealing off, even when the distance from the sealing off point to the base is short, is not so small that the glass will break at the joint between base and stem upon sealing off.

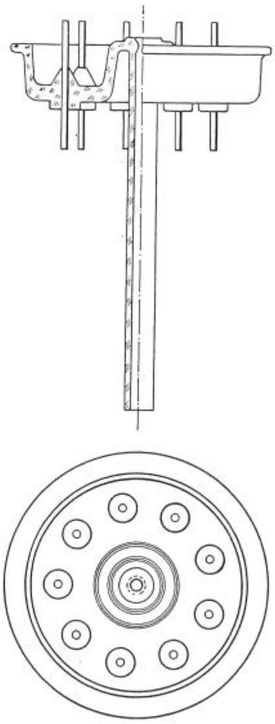

Fig. 3. Drawing showing the details of the circular pressed glass base with exhaust tube and leading-in wires of chrome iron. There is a depression in the base for attaching the exhaust tube. The length of the wires in the glass is considerably less than in the case of the pinch.

The inside assembly of the valve is strongly mounted on the leading-in pins (*fig. 4*), its base is broad and there is plenty of room between the different wires. All the connections including that of the modulation grid are led out at the bottom. The shortening of the length of the connections from the base to the electrodes in this type of construction is shown in *fig. 5*.

The very small value of the anode-grid capacity C_{ag}, which is necessary to prevent a capacitative coupling between the anode and grid circuits, is obtained by choosing for the grid and anode connections two lead-in pins which are far enough apart. In addition some of the electrodes are screened from each other by vertical shields placed inside the tube on the base. Several separate sectors are thus formed through which different wires are led in without their being able to influence each other. In the photograph (fig. 4) these can be seen quite easily. The shielding is finally completed by a metal cap which is described below.

After assembly the glass cylinder is placed over the electrodes and fused to the base along the flange. The evacuation of the valve, the outgassing of the metal parts and the improvement of the vacuum by the evaporation of a getter is carried out in the usual way. After the stem is sealed off the valve is practically complete, but must still be finished off. A cemented cap of moulded material with contact pins is unnecessary, since the chrome iron pins may serve as contacts. Some protection is, however, necessary for the sealed-off exhaust tube which might easily be broken by a knock. A flat metal shield is therefore fastened to the underside of the valve. All the connections project through holes in this shield and can make contact in the socket. At the centre of the shield is a metal

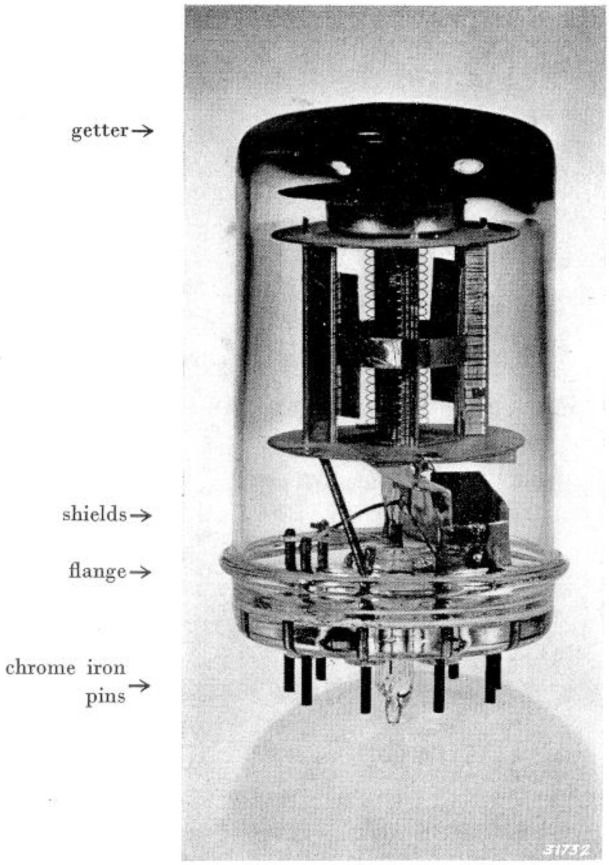

Fig. 4. Photograph of the exhausted and sealed-off valve. Directly above the flange along which the base and bulb are fused together may be seen the two mutually perpendicular shields which separate grid and anode leads from each other, making it possible to keep the grid-anode capacity C_{ag} low. The length from the sealing-off point of the exhaust tube to the base is short. The getter is deposited at the black spot in the upper part of the bulb.

tube which protects the exhaust tube (*fig. 6*). This metal tube fulfils another purpose at the same time. In inserting the radio valve in a suitable socket in which the pins make contact, there is only one permissible relative position of valve and socket. In order to find this position the shielding tube is provided with a pointed cam which fits into a slit in the socket. When the tube is pressed far enough into the socket the cam locks. This can be done in two ways. After the valve is pressed down in the socket it is turned slightly: the upper edge of the cam is then held against the lower side of the bottom of the socket so that the valve cannot be pulled out. During this turning the contact pins in the bottom are pressed in the springs of the socket and good contact is obtained. The ring-shaped groove at the end of the metal tube may also be used to lock the valve; it must then be caught by an appropriate fastening in the socket.

The shielding of the inside assembly of the valve against inductive or capacitative interferences from the outside can be accomplished in different ways. We shall not go into that here, however, but call attention to the fact that the metal shield provided sufficient protection at the lower side.

Properties of the valve

We shall deal one at the time with the results obtained with valves of this construction.

Temperatures of the glass at the sealing-in points

In the pinch type of construction the pinch reaches temperatures which in unfavourable cases may amount to 200 °C or even higher. The new construction reduces the temperature at the sealing-in points to 90° C. Since the conductivity of the glass varies exponentially with the temperature, this reduction results in better insulation and less chance of electrolysis of the glass. The probability of breakage of the glass is also reduced.

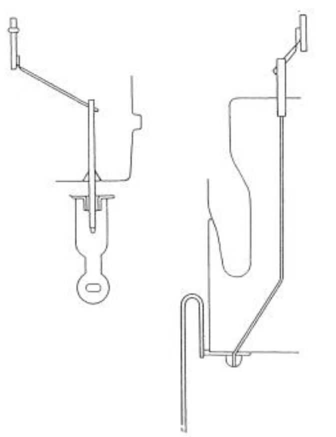

Fig. 5. Detail drawing of the length of the connection wire from the cathode to the contact strip of the valve socket in the new design (left) and in the pinch construction (right).

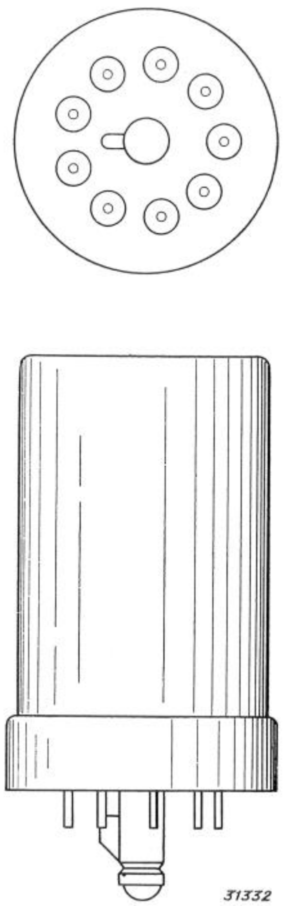

Fig. 6. Drawing of the finished valve with protecting tube and pointed cam.

Change of the capacities between the electrodes due to changes in temperature

The capacity between two contact pins in a radio valve cap of the old construction is about 0.3 μμF. During heating up the increase in temperature of the cap is about 10° C. Since the temperature coefficient of the dielectric constant of the artificial resins is about 50×10^{-4} per degree, the capacity changes by 0.015 μμF. This change in capacity gives in a circuit oscillating on a wave length of 13 m and with a tuning capacity of 50 μμF a change in frequency of 3.4 kilocycles. Even greater than this is the change of capacity between leading-in wires in a glass pinch during the warming up. The temperature coefficient of the dielectric constant of glass is 5×10^{-4} per degree, thus lower than for artificial resins. The increase in temperature is here, however, greater, as we have seen, namely 150 °C. The capacity between the leads is 1 to 1.5 μμF in the cold state, and the change due to heating may amount to 0.09 μμF. As a result of this a change in frequency of 20 kilocyles may occur under the same conditions as above, and the reception is appreciably disturbed.

Under these circumstances the omission of the cap and the maintenance of a low temperature of sealing-in points, such as are possible with the new construction are a great advantage. It was found that in the new design on a wave length of 20 m and with a tuning capacity of 75 μμF with a room temperature of 25 °C the frequency change did not exceed 2.7 kilocycles, while with the same tube with the pinch type of lead-in connection wires it amounts to 4.4 kilocycles.

Tolerances in the capacities

When a defective radio valve is replaced by a new one, the new valve must have the same capacities between the different electrodes. The set is adjusted by means of trimmers to an average capacity, and the actual values of the capacities in different radio valves of the same type must therefore have only slight tolerances. In radio valves with the pinch construction these tolerances for the different capacities, with the exception of that between anode and control grid which has a much smaller value, had a value of about 0.6 μμF. In the new construction on the other hand the value is only about 0.2 μμF.

Capacity between control grid and anode

In screen grid valves, in order to avoid reaction of the anode circuit on the grid circuit, the capacity between anode and control grid must be very small. Therefore, as already mentioned, the grid connection is led out at the top of the valve in many types, and the grid and anode circuits are screened from each other inside the valve. In this way it is possible to reduce the capacity to 0.002 μμF. This point necessitated much care in the new construction, since the anode and grid connections are now led out on the same side, they both pass through the base. By the precautions discussed it was also found possible in the all-glass construction described to reach values of from 0.002 to 0.003 μμF or even less if necessary.

Properties for operation on short wavelengths

Due to the shortening of the leading-in wires and the greater distances between them, it was to be expected that for operation on very short wavelengths, 5 m for example, the all-glass valve would prove more satisfactory than that with the pinch construction. The input as well as the output resistances of the new construction were actually found to have values which give the all-glass valve advantages over valves with pinch construction for operation on very short wavelengths.

The following table illustrates the difference. Since the input resistance of a valve of the earlier form of construction was always five to ten times as small as the output resistance, the value of the input resistance restricted the value which could be chosen for the impedance of the coupling circuit between two valves. In the table values of the input resistance in the cold state and in the working state are given for two wavelengths, three and ten meters, for the same type, EF 9, in the old and new form of construction. In the old form the valve was provided with a P-cap (see fig. 1).

Table

Wave length	Cold resistance (10^3 ohms)		Working resistance (10^3 ohms)	
	old	new	old	new
3 m	36	28	2	4
10 m	460	360	27	66

When in operation, *i.e.* when the valve is warm, the input resistance of the new type of construction is thus more than twice as great as in the old construction. The impedance of the coupling circuit between two valves may therefore be increased, and a greater gain per stage of amplification is possible.

It may be seen from the values given that the differences become smaller at longer wavelengths. In many respects, however, the other advantages mentioned are still of importance.

Compiled by P. G. CATH.