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A NEW SERIES OF SMALL RADIO VALVES

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The development of radio valves having flat bases and of either all-glass construction or with metal envelopes made it possible to reduce the dimensions appreciably, and particularly the overall length, while at the same time maintaining good performance at very high frequencies. The downward trend of dimensions was halted, in the case of metal valves, at the point where further reductions in size resulted in excessive mutual capacitances and dielectric losses between internal leads, and, in the case of all-glass valves, at the point where the proximity of the electrode assembly to the seal between base and envelope exposed the cathode to excessive temperature during the sealing operation. In a new series of valves now developed by Philips, and known as the "A" series or "Rimlock" valves, over-heating of the cathode is avoided by joining bulb to base with a glaze or cement which becomes plastic at a comparatively low temperature. Further substantial reductions in bulb diameter have been achieved. A diameter of 22 mm has been adopted to permit the use of eight contact pins in the base, thus providing the maximum number of connections required in normal receiving valves, and to ensure that there shall be no over-heating of the bulb in the case of valves of the highest dissipation (*i.e.* 14 W for an output pentode). This article describes in some detail the construction and manufacture of these valves.

Over a considerable period the general internal structure and form of envelope (bulb and lead-in wires) had become stabilised, the so-called "pinch" construction being considered normal practice. But certain new requirements in radio engineering called for new developments — developments which would satisfy, for example, the needs of the manufacturers of small, inexpensive sets for which there is a demand in most countries, and the requirements for short-wave and very-short wave reception including television reception.

Small, compact receiving sets call for the production of valves and other components of the smallest possible dimensions, and in this connection the past seven or eight years have seen remarkable developments, the first stages of which have already been the subject of articles in this periodical [1][2]. In the new series of valves about to be described, further reduction in size is once more a prominent feature but, as will be explained, this reduction has been made possible by a new manufacturing technique which has at the same time resulted in improved performance in short-wave operation.

[1]) Philips Techn. Rev. 4, 162, 1939.
[2]) Philips Techn. Rev. 6, 318, 1941.

Glass and metal valves with flat bases

In valves which are to be used for short-wave (and, when required, for ultra-short-wave) reception it is essential, amongst other requirements, that capacitances between the leads to the various electrodes, and the dielectric losses in the insulating material between these leads should be very small.

An important advance in this direction was made when the original "pinch" construction was abandoned in favour of a bulb with a flat base [1]). In these valves the lead-in wires were much shorter; they were enclosed in the glass for a short distance only; and they were spaced well apart. These leads could also be made to serve as the contact pins, thus avoiding the necessity of fitting a base cap of plastic material, which has been the source of large and variable losses. Moreover, the short overall length of the leads resulted in proportionally smaller self-induction and opened up new possibilities for the use of valves of this type for very high frequencies (metre waves) [3]).

At this stage, the wished-for reduction in valve dimensions and the equally desirable improvement in performance on short-waves were being attained

[3]) See for example Philips Techn. Rev. 3, 103, 1938.

by one and the same means. But when further development was attempted on the same lines the two requirements came into conflict. Any considerable decrease in size of receiving sets demanded a reduction in the diameter of the valves, since this dimension largely determines the area of the receiver chassis. But reduction of valve diameter involves a closer spacing of contact pins in the flat valve base, and this results in increased mutual capacitances and dielectric losses.

This difficulty was most pronounced in those valves which employed both bulb and flat base made entirely of metal, with the contact pins fused into the base with glass beads, and this construction gave little prospect of further reductions in valve diameter. It had, however, one important advantage over the all-glass construction, in that the sealing of the metal bulb to the base is achieved by only very slight increase of temperature in the electrode system, since the heavy welding machine employed for this operation generates, in a single current impulse of short duration, an accurately calculated amount of heat which is quickly dissipated to the welding electrodes and surrounding material due to the high thermal conductivity of the metal parts. In the all-glass construction, however, bulb and glass base had to be raised to a temperature of some 800 °C to 900 °C, and in proportion as the diameter of the valve and the length of the leads are reduced, the distance between the parts of the electrode system and the seal also becomes smaller, and the temperature to which they are exposed during the sealing operation becomes greater. The smaller the valve, therefore, the greater the risk that, during sealing, parts of the electrode system may be oxidised and that the cathode may have its emission impaired by the chemical action known as "poisoning". Excessive manufacturing rejects can, in these circumstances, be avoided only by passing an inert gas such as nitrogen through the valve during the sealing operation — a manufacturing complication which cannot be contemplated with equanimity.

The "glazing" technique

The problem outlined above has now been solved in the case of all-glass valves by adopting an entirely new method for joining the bulb to the flat base. Instead of direct fusion, a "glaze" or cement is used, the material selected having a melting point much below that of the glass.

When the glass base with its moulded-in contact pins has been made, a moulded ring of the powdered cement is placed round the upper edge of the base. The whole is then raised to the temperature at which the "glaze" melts and becomes firmly bonded to the glass base (see *Fig. 1*), and is then slowly cooled to relieve the mechanical stresses in the glass.

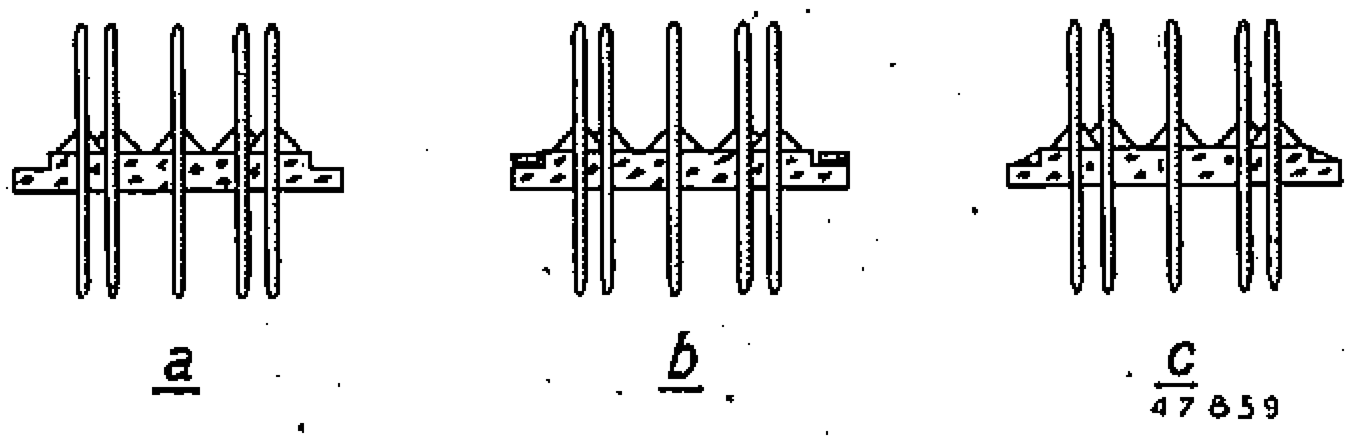


Fig. 1. *a*) Base plate of a radio valve of A series with moulded-in contact pins. Actual size.
b) Same base plate with ring of glaze laid upon it.
c) The ring of glaze is fused on the glass.

The electrodes are then assembled to the supports, the base-plate, complete with electrode assembly, is placed over the inverted bulb in a special sealing machine, and heat is applied until the cement softens, when the base sinks by its own weight far enough to allow the rim of the glass bulb to penetrate the layer of cement. On cooling, the cement sets and adheres to the edge of the bulb to form a vacuum-tight seal (see *Fig. 2*). During the whole of this process it is only the cement and not the glass which is softened, and for the material used in the valves now in production the temperature employed is only some 450 °C. The electrodes, and particularly the cathode, attain a temperature not exceeding 230 °C as compared with 500 °C to 600 °C in the previous method of sealing.

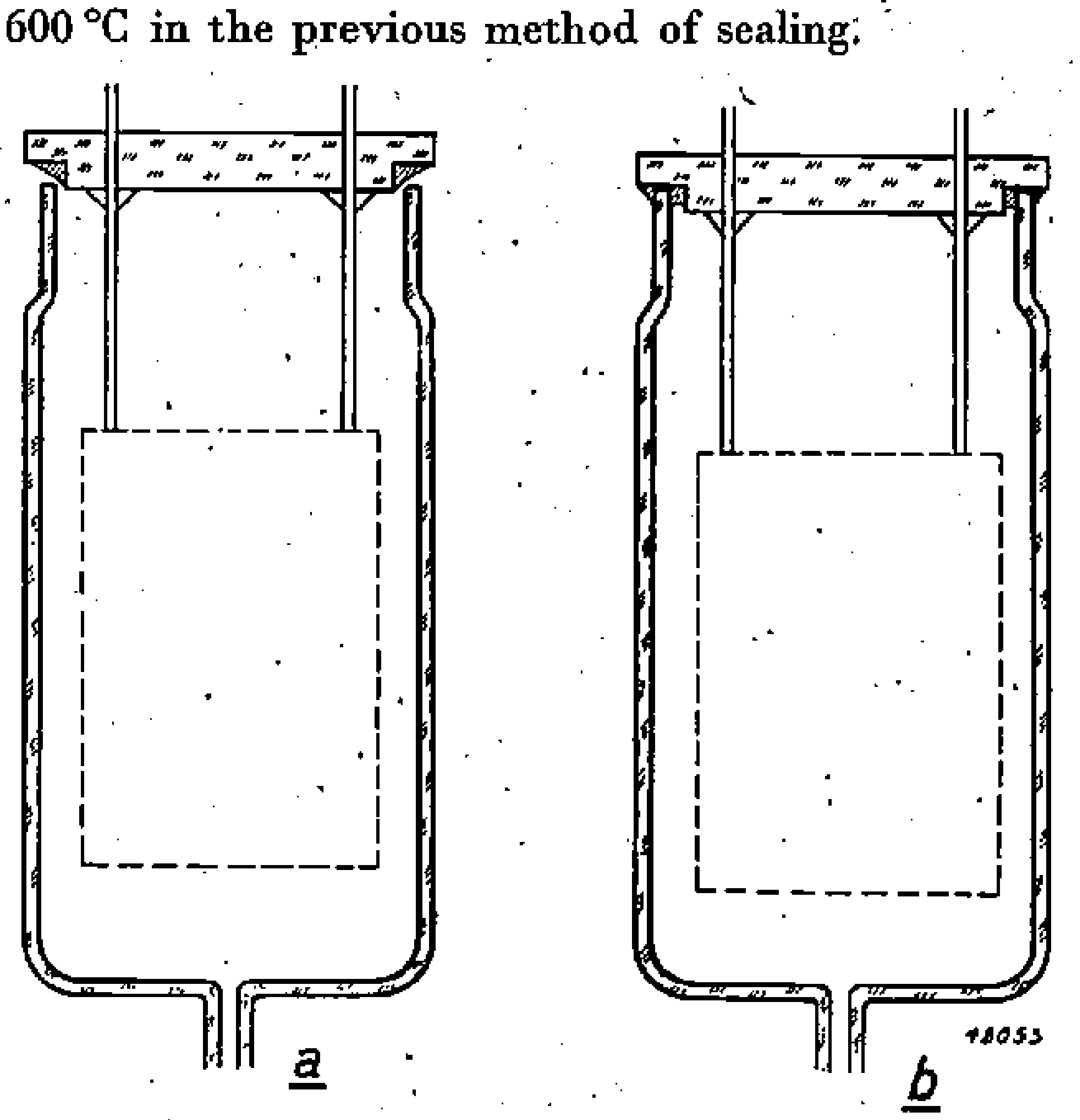


Fig. 2. The joining of bulb and base plate by the glazing technique. 1.5 times actual size.
a) The base plate with the fused ring of glaze is laid loosely on the edge of the bulb.
b) As the glaze melts the edge of the bulb penetrates into the layer of glaze and after the latter has set the bulb and base are securely joined and vacuum-tight.

In order to avoid risk of dangerous mechanical stresses being set up in the valve while cooling after sealing, it has been necessary to find a glaze or cement having a coefficient of thermal expansion practically equal to that of the glass used for the bulb and base. Moreover, the material had to have a suitable surface tension, so that the meniscus of the layer of glaze is slightly concave (see Fig. 1*c*) to prevent the base from becoming displaced to one side when placed on the bulb as shown in Fig.2*a*.

Fig. 3. Detail of the sealing machine on which bulb and base plate are joined. A metal cap is placed on the base plate (left). The whole passes between two rows of gas flames, the layer of glaze being heated to about 450° C, necessary for fusing.

Fig. 3 shows in detail the machine used in sealing the bulb to the base. A metal cap is suspended over the upward-projecting contact pins of the base. The whole passes between two rows of flat flames directed towards the cap. The edge of the bulb and the base are thus heated uniformly, so that no mechanical stresses are set up in the glass. The weight of the cap assists the rim of the bulb to penetrate well into the layer of cement.

This "glazing" technique has made possible the new series of valves known as the "A" series or "Rimlock" valves, having a diameter of only 22 mm. For the sake of comparision it may be mentioned that the "B" series described previously have a diameter of 32 mm., and the "C" series, which included the short-wave push-pull pentode type EFF 50, a diameter of 36 mm [4]).

Some of the types in the "B" and "C" series are not suitable for inclusion in the "A" series for, reasons which are explained later.

Fig. 4a shows a number of valves in the "A" series; Fig. 4*b* a valve in the "A" series compared with valves in the "B" and "C" series; while the reduction in dimensions is best illustrated in *Fig. 5*, where four successive models of two different valve types, namely an I.F. pentode and an output pentode of similar performance, are shown side by side.

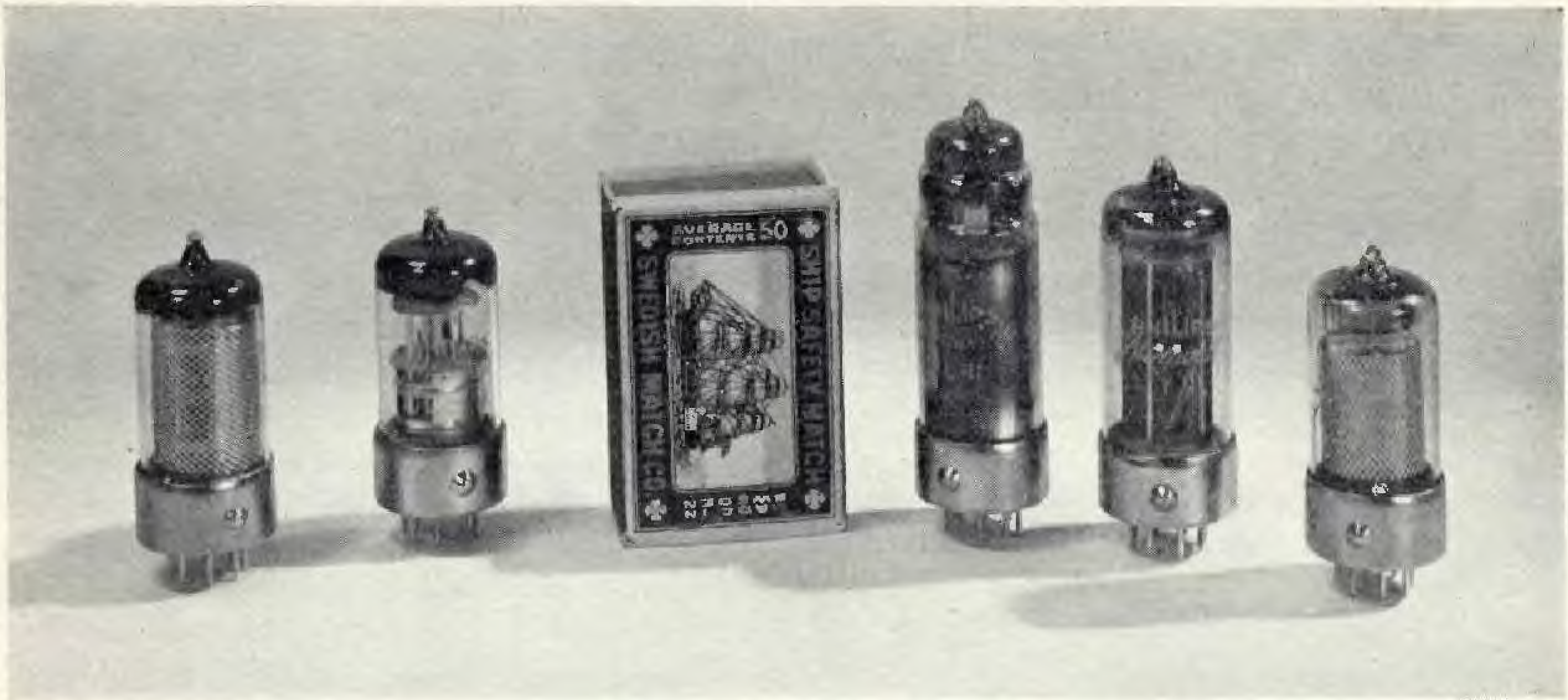
In addition to making possible valves of more compact dimensions, the "glazing" technique confers the general advantage that the bulb can be made to any desired shape, accurate to within 0.1 mm., and that this shape will be maintained during the sealing operation. As examples, *Fig. 6* shows two bulbs without electrode systems. That on the left has a constriction of the envelope close to the base — required for a definite purpose to be explained later. Only by the "glazing" technique can such small details be maintained in the finished product — they would be entirely lost owing to the softening of the glass if exposed to the high temperatures employed in the earlier method of sealing.

A particularly troublesome result of glass softening occurs in small diameter valves, the plastic condition of the glass allowing the contact pins to depart from their vertical alignment, or even to shift their location slightly, with the result that the pins have to be straightened by force. To avoid risk of cracking the glass during this adjustment, the pins must be made of soft metal. This, in turn, introduces the risk that the pins may become bent in service, so that the valve will no longer fit the holder. Using the "glazing" technique, however, the base retains its shape throughout the sealing process, the need for bending the pins disappears, and it is possible to employ pins made of hard metal, not only for the new small diameter "A" series, but also for the valves of larger diameter in the "B" and "C" series.

Apart from the practical advantages already indicated, the "glazing" technique results in a simplification of manufacture and a speeding up of production, the latter being due not only to the

[4]) The development of the B and C series, the so-called "key valves", is described in full in the article referred to in footnote [2]).

a)



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b)

47941

EFF 50 ECH 21 UCH 41

Fig. 4. *a*) Five valves of the new A series ("Rimlock" valves) diameter 22 mm designed for a normal receiving set. The types shown from left to right are: UCH 41, a triode-hexode; UF 41 an intermediate-frequency pentode; UAF 41, a diode-pentode; UY 41 a rectifier valve and UL 41, a 9 W output pentode. These valves are suitable for A.C. and D.C. sets.

b) For the sake of comparison the following are shown side by side: UCH 41; ECH 21, a triode-heptode which because it requires 9 contacts is made in the previously described B-technique (32 mm diameter); and the short-wave push-pull amplifier valve EFF 50 in the C technique (36 mm diameter).

general simplification, but also to the fact that the lower sealing temperature can be attained more quickly than the higher one.

The new valves

Choice of diameter

Had the cathode temperature during the sealing operation been the sole consideration, a diameter considerably smaller than 22 mm could have been selected. But it is the capacitances and other losses between leads which are now the limiting factors, and the extent to which the diameter can be reduced therefore largely depends upon the number of contact pins it is necessary to set in the base. A further factor is the amount of heat generated in the valve which, in conjunction with the valve diameter, determines the working temperature of the envelope and thus affects to a large degree the dielectric losses and electrolysis of the glass between the pins.

The number of pins required and the amount of heat generated vary widely between valves of different types. Thus, a rectifier valve for a radio receiver needs only four pins, while an indirectly-

Fig. 5. Successive models, with about the same performance, of an intermediate-frequency pentode (front row) and a 9 W output pentode (back row). Front row, left to right: AF 7 (1937), EF 9 (1937), EF 22 (1941), EF 41 (1946); back row: EBL 21 (1941), EL 41 (1947).

heated frequency changer of the triode-hexode type (which is to be preferred owing to its inherent constancy of tuning on short waves) requires at least eight pins — six for the electrodes (the cathode being common to the triode and hexode sections and two pairs of grids can be interconnected) and two for the cathode heating.

Thus, in principal, different minimum diameters could be selected for each valve type. But this would be very impracticable from the standpoints of both the valve-maker and the set-designer, both of whom desire the greatest possible degree of standardisation of components.

One diameter only has therefore been chosen for the whole of the "A" series — a diameter large enough to accommodate the maximum number of eight pins and one which does not introduce the risk of excessive bulb temperatures being developed at the maximum total dissipation in any valve designed for a normal receiving set — namely the 14 watts dissipated in a 9 W output pentode which, in order to obtain a high mutual conductance, is provided with a long cathode consuming $4^1/_2$ W. The few special valves which require nine contacts are made in the "B" or "C" series.

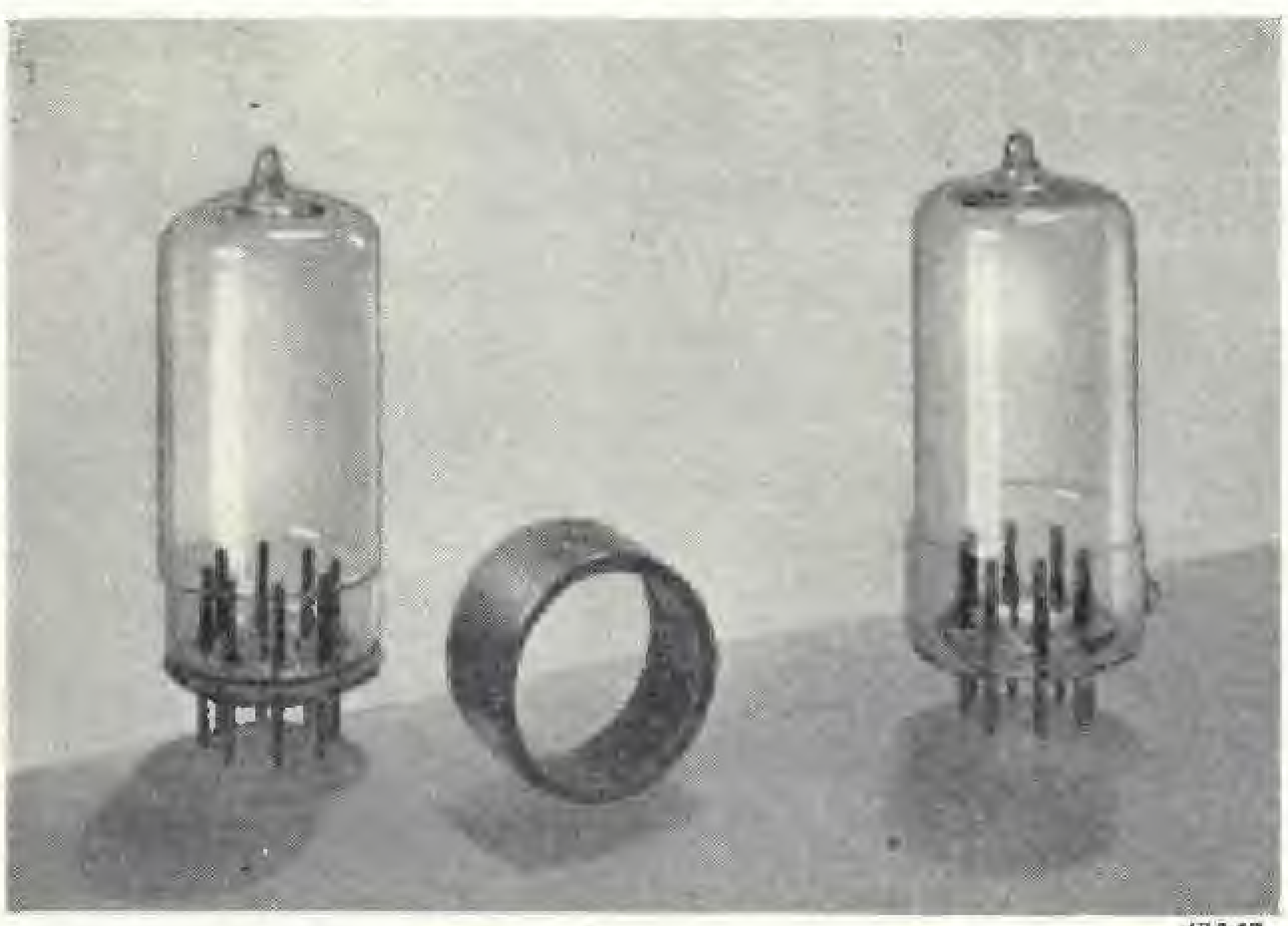


Fig. 6. Photograph of the envelope of the A valves without electrode system. Evacuation and sealing off take place at the top of the valve. The sealed off point is reinforced by moulding it into a compact conical form immediately after sealing off. The two envelopes shown have different forms of guiding mechanism for mounting the valve in the holder (see the final paragraph of this article).

The diameter of 22 mm. selected for the "A" series provides ample security so far as insulation at high voltage is concerned. It has even been found that a special television valve designed for a peak voltage of 4 000 volts could be operated with that voltage applied between two diametrically opposite pins without risk of electrolysis of the glass or of breakdown. This valve is illustrated in *Fig. 7*.

In the U.S.A. very small all-glass valves known as miniature valves with a diameter of 17 mm. have been developed in recent years. These valves, however, have a maximum of seven contact pins. As a consequence, an indirectly-heated frequency changer of the triode-hexode type cannot be made in that series, and only output pentodes of low mutual conductance or small output, unless a high working temperature of the bulb is accepted.

Construction of the electrode system

It is generally desirable to construct the electrode system of a radio valve in such a way that it can be mounted on two or three support rods and that it stands free from the walls of the envelope. This construction is not only simpler than that in which the electrode system is supported from the walls by rings or discs, but it also reduces the risk of the assembly being distorted while being inserted into the bulb. The free-standing construction is not, however, easy to achieve in bulbs of small diameter owing to the risk of the electrode system striking the walls of the envelope under conditions of mechanical shock or vibration, thus giving rise to noises when the set is in operation.

The selected diameter of 22 mm is, however, sufficiently great to permit free-standing construction to be adopted for most types, including the triode-hexode, pentode and diode-pentode, each of which has a length of 43 mm.

Only for the 9 W output pentode and the rectifier in the new series has it been necessary to support the electrode system from the walls, these valves having comparatively long electrode assemblies and bulb lengths of 61 mm and 52 mm respectively (see Fig. 4*a*).

The multiple valves in the "A" series, such as the triode-hexode and diode-pentode, differ from earlier valves of similar type in that the more complex of the two electrode systems is mounted below the simpler. This simplifies the construction of the support rods and the mica discs employed to give the whole assembly the necessary rigidity. At the same time it confers advantages in connection with the effect of the conduction of heat through the current leads at the bottom of the cathode. A short axial extension of the cathode serves for the simpler system, and the remaining, and longer portion of the cathode for the more complex system. The average temperature of the longer section will obviously be less affected by heat conduction at one end than that of the shorter section.

Fig. 7

Fig. 8

Fig. 7. Diode for television purposes. The highest voltage that may come to lie between 4 diametrically opposite contact pins amounts to 8000 volts.

Fig. 8. Double diode (mixing diode) for ultra short waves, with glass guiding stud on the bulb.

The "glazing" technique has special advantages in the case of battery valves, in which it is important to keep to a minimum the power required to heat the cathode. A directly heated cathode consisting of the thinnest practicable wire with a very thin coating of a highly emissive oxide is thus indicated [5]). Using the normal nickel filament, wire diameters below 20 microns are not practicable because of the low tensile strength of the material. It was for this reason that for many years Philips have used tungsten filaments which have much higher tensile strength and can therefore be made much thinner. Tungsten wire is, however, more susceptible to oxidation than nickel, and it is in this connection that the low sealing temperature employed in the "glazing" technique confers a great advantage, permitting the use of a filament wire only 8 microns in diameter, for which a heating current of only 12.5 mA is needed.

Valve holders

A radio valve and its holder should be so constructed that when fitting the valve in the holder there is no risk that the pins can enter the wrong sockets.

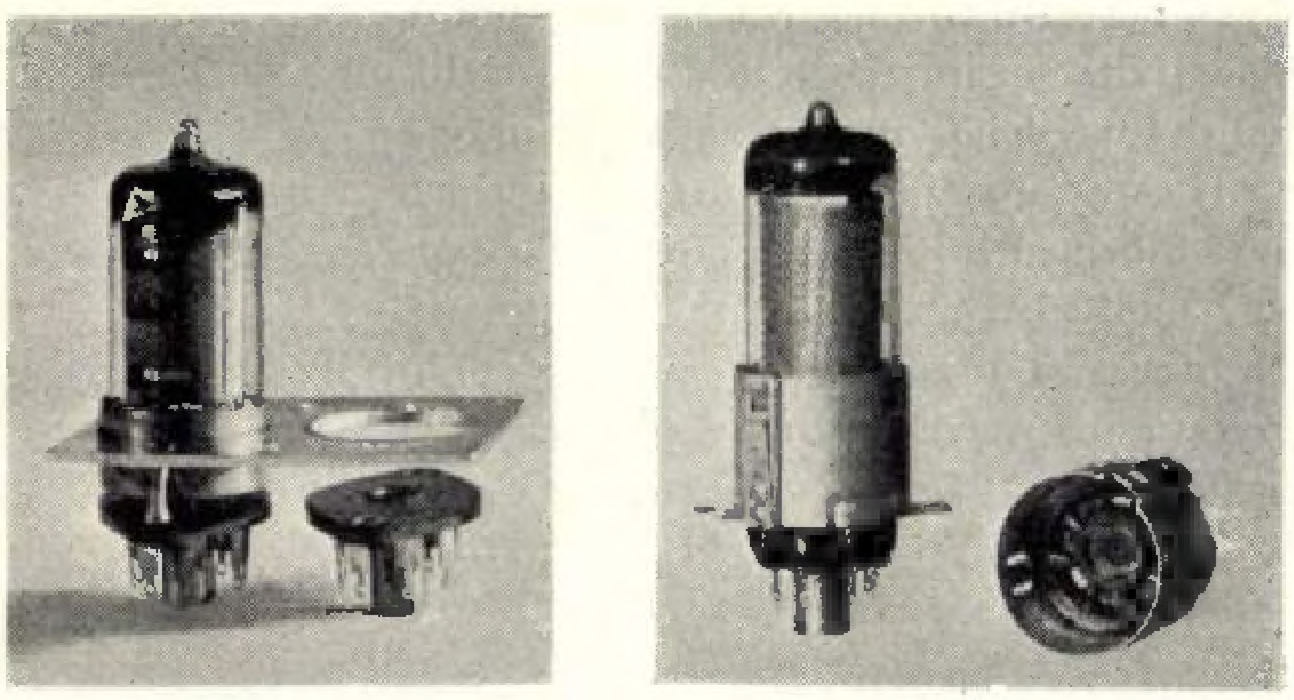
The earliest method of ensuring this was to space the contact pins non-uniformly in the valve base, but it was then difficult to insert the valve correctly into a holder, especially when the latter was located in a more or less inaccessible position in the receiver. Furthermore, in the small all-glass valves where the old sealing technique necessitated the use of soft metal pins there was considerable risk that valves would be forced into the holder, and this introduced the danger of the glass base being cracked.

The method adopted for the "A" series and also for the "B" and "C" series is to space the contact pins uniformly around a pitch circle and to provide some form of locating device to ensure that the valve is inserted in the correct position.

In the "B" and "C" series the locating device consists of a stud at the centre of the base. In the "A" series a metal ring is cemented to the lower portion of the bulb, where the diameter is slightly reduced. This ring carries a small rounded projection or boss which fits into a corresponding groove in the edge of the valve-holder — hence the name

[5]) In these valves the proportionately smaller cathode surface of the thinner wire has practically no effect on the valve characteristic.

"Rimlock". As already explained, the possibility of fitting this ring closely round the bulb within very small dimensional tolerances is entirely due to the low sealing temperatures required by the "glazing" technique.



a) 47943 *b)* 47944

Fig. 9. *a)* Simple valve holder for the A series. The stud on the rim of the bulb falls in a groove in the edge of the holder. The valves are therefore called "Rimlock" valves.

b) Valve holder with locking device. The valve is held fast by means of a spring which locks over the stud when the valve is inserted. The small can in the middle of the holder provides a screen between the contact pins right up to close under the base plate.

Further, owing to the complete absence of bulb distortion, the metal ring can be dispensed with and the locating boss can be formed on the glass wall itself, as is shown in the empty bulb illustrated in *Fig. 6*. *Fig. 8* shows a double diode (mixing diode) for ultra short-wave operation. This solution is particularly advantageous in ultra short-wave valves as the metal ring would substantially increase the capacitances of the leads.

The locating device described above makes possible great simplification in the design of valve-holders. In *Fig. 9a*, for example, a holder is shown consisting of a flat plate carrying the contacts and suspended by two bolts about 8 mm below the top deck of the chassis. A circular hole in the chassis permits the valve to be inserted, and a notch at the correct point on the circumference of this opening serves to accommodate the locating boss of the valve.

It is often desirable, particularly when a receiver has to be transported with the valves in position, to combine a locking device with the locating arrangement. A holder incorporating a locking device is illustrated in Fig. 9*b*.

In Figs. 9*a* and 9*b* can be seen a small metal can at the centre of the holder. When the valve is in position the can reaches just below the underside of the valve base and serves as an electrostatic screen between the contact pins, especially between the anode and control grid pins. In the "B" and "C" series valves this function was, of course, performed by the central spigot.