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A New "All-Glass" Valve Construction*

By F. Prakke, J. L. H. Jonker and M. J. O. Strutt

(Laboratoria der N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland)

SUMMARY.—This article deals with the properties and advantages of a new valve construction, called "all-glass," abolishing the usual valve base. In the first section the general appearance of this new construction is dealt with, including a detailed discussion of the electrodes, their leads and screening, and of the valve pins and valve holder. Section II contains figures on the variation of the capacitances between valve electrodes due to the dielectric isolation between them as a function of the temperature. These figures show a marked improvement over those appertaining to the conventional construction with base for different types of valves, including mixer valves. In Section III the short-wave properties of the new all-glass construction are set forth. As the input and output impedances are dependent on the lengths of the electrode leads, marked improvement is shown by figures for the all-glass valve as compared with the conventional valve construction. An example for the mounting of the all-glass valves in a chassis is shown.

Section I

IN the beginning the development of radio valves made use of the existing glass technique of the manufacture of incandescent lamps. The well-known pinch construction was again employed to bring the connecting wires through the glass envelope and these electrodes were con-

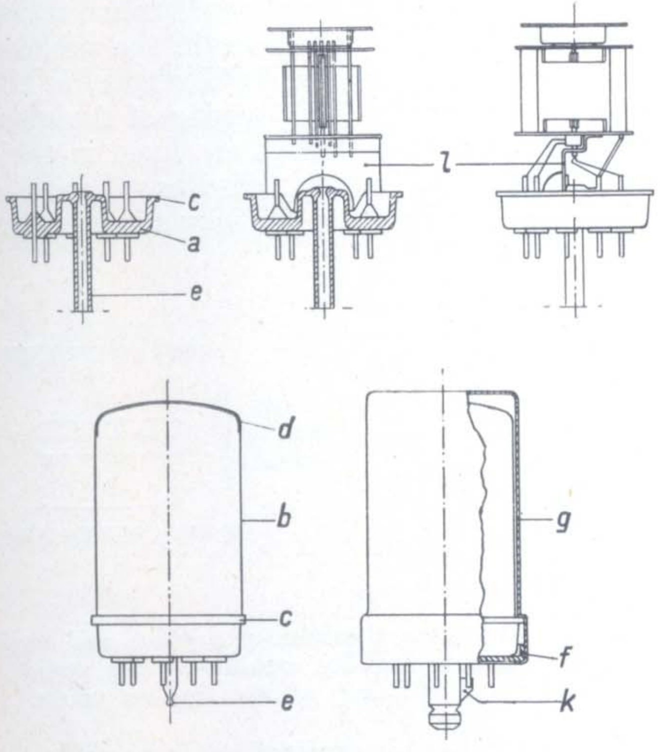

Fig. 1.—*Stages of the assembling of the all-glass valve EF50 showing the construction.*

nected to contacts on a base, which enclosed the pinch tube and protected the exhaust tube against breakage. This construction now proves to be not an ideal solution for radio valves, particularly for short-wave work. The connecting wires between valve electrode and base contact are inevitably rather long, resulting in unwanted inductance. The capacitance of the lead-out wires may give rise to disturbing variations due to temperature changes in the pinch and base. These disadvantages are to a great extent avoided in the new all-glass valve construction, which will be discussed further in this paper.

Fig. 1 gives a sketch and Fig. 2 a photograph of this new valve construction.

The sketch shows the connecting wires leading out directly through a bottom plate *a* which consists of pressed glass. The ends of the lead-out wires, which protrude through this glass bottom plate serve as contact pins of a base. Both functions of vacuum seal for the lead-out wires and base are combined in this bottom plate. Using this bottom plate the length of the connecting wires is considerably shortened. This construction has been made possible by the use of chrome iron for the lead-out wires, which material is known to fuse easily to glass.

For many different types of valves having the pinch construction it was necessary to have the signal grid brought out at the top of the valve, because the capacity of this electrode to others has to be exceedingly small. In receiving sets it proved to be more economical to have all electrodes brought out to one end of the valve. The usual pinch construction offered almost insur-

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mountable difficulties in this respect, for the reason that all the connections in the pinch are very close to one another with resulting excessive capacitances between them. In the case of high-frequency pentodes this would lead to instability due to feed-back.

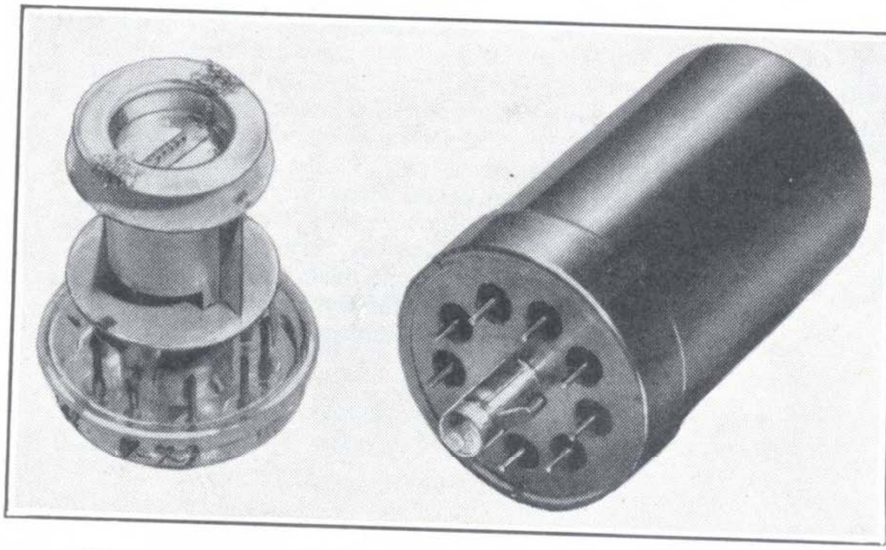

Fig. 2.—*The exterior and interior of an all-glass valve.*

The all-glass construction is ideal for bringing all lead-out connections at the one end. Fig. 3 shows that the distance between the lead-out wires in the bottom plate is much bigger than in the pinch and in addition a screen *l* of special form has been fitted between the base plate and the electrode assembly, which together with the screen *f* outside the valve divides the base electrostatically in two parts; the signal grid lead-out is located in the one part, the anode and heater lead-out wires in the other. If the valve holder has a corresponding screen, the capacity between the electrodes is comparable with the same in old type valves with grid to the top. The metallic enclosure *f*, *g* provides mechanical protection for the glass bulb *b* and the exhaust tube *e*, besides the electrostatic screening. The metal bottom plate *f* can also easily be fitted with a spigot *k*.

The advantages of the all-glass construction above the pinch construction will now be discussed in more detail.

(*a*) *Short connecting wires from valve electrode to soldering point of the valve holder*

Fig. 4 shows the connecting wires of the Mullard high-frequency pentode valve EF9. Their paths run in parallel over about 35 mm whereas in an all-glass construction this value would be only 15 mm. To compare both constructions Fig. 5 shows the total length of a connecting wire from an electrode to the soldering point of the valve holder. This comparison has been made for a normal EF9 valve and an all-glass television - amplifier pentode EF50.

Section III deals with the influence of these long connecting wires on the short-wave performance of the valve.

(*b*) *Small capacitance tolerances*

It is desirable for easy replacement of defective valves, and for convenient trimming of wireless sets in the manufacturing process that the capacitances of several samples of the same valve type are as nearly equal as possible. It has been proved that the differences which occur between the capacitances of valves of the pinch construction are chiefly due to variations in the position of the connecting wires, for instance, in the pinch. During the hot pressing of the glass bottom the lead-out wires are fixed in their exact position, which ensures that the capacitance differences are very small. Now

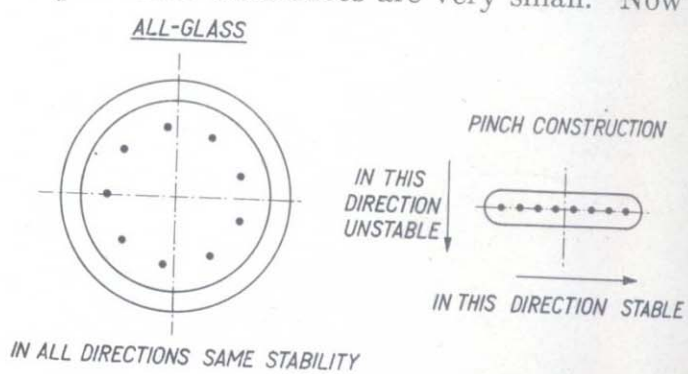

Fig. 3.—*Transversal section of a pinch and an all-glass bottom showing stability of the valve assembly and distance of the lead-out wires.*

that the top lead is omitted, it is possible to locate the getter mirror at the top of the bulb. This is important because the metallic deposit of the getter may cause unequal additional capacitances to the lead-out wires and so give rise to differences in the capacitances between similar valves. It proved to be possible to lessen the capacitance tolerances of valves of the pinch construction from $\pm 0.6\ \mu\mu F$ to $\pm 0.2\ \mu\mu F$ for all-glass valves.

(c) Sturdy assembly

In the pinch construction all leads and supporting rods are in one line on the pinch. Due to this the stability of many valves was in-

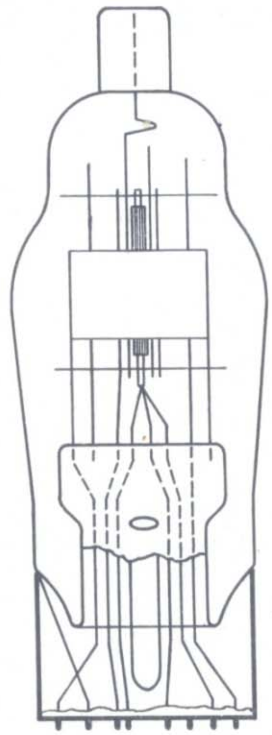

Fig. 4.—*Longitudinal section of a Mullard EF9 valve showing the connecting wires from electrode to base contact running in parallel over a considerable length.*

sufficient and the system had to be supported in the dome by dome micas.

In the new construction the supporting rods are placed in a circle (Fig. 3) which method has increased the mechanical stability of the system to such an extent that supporting the system in the dome of the bulb is no longer necessary.

(d) Good screening

As discussed above, it is possible in the all-glass construction to keep the inter-electrode capacitances very low by using the internal screen together with a specially shaped external screen, in spite of the fact that all the lead-out wires are placed in one thick glass bottom-plate. It is important that the capacitances between the signal grid and the anode, and between the signal grid and the heater, should be low to avoid, on the one hand, excessive feed-back and, on the other, hum induction on the signal grid.

These capacitances are $0.002\ \mu\mu F$ in the EF9 valve with grid to the top and 0.002 and $0.003\ \mu\mu F$ respectively for the all-glass valve EF50, measured with the valve in the valve holder. It is clear from these values that although it seemed hardly possible, comparable capacitances have been achieved by the careful application of screens and a favourable location of the lead-out wires in respect to each other.

(e) Valve holder

The diameter of the pins of the all-glass base is smaller than those of other bases and without suitable precautions there is a danger that valves will drop out of their holders as a result of shocks, for instance, during transport. To prevent this, the spigot of the all-glass base has been supplied with means to keep the valves firmly in the holder (Fig. 6).

First, this purpose may be served by the projecting part *a* of the spigot. This key turns behind the pertinax plate of the valve holder *b* when the valve is rotated after the

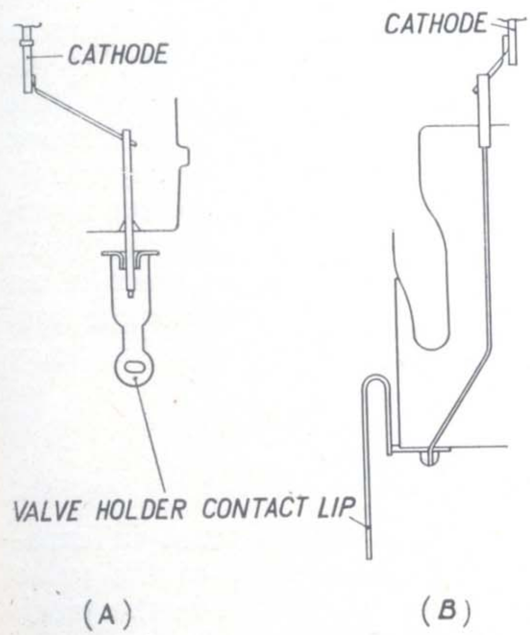

Fig. 5.—*Showing the total length of the connecting wires from valve electrode to the soldering point of the valve holder. A, EF50; B, EF9.*

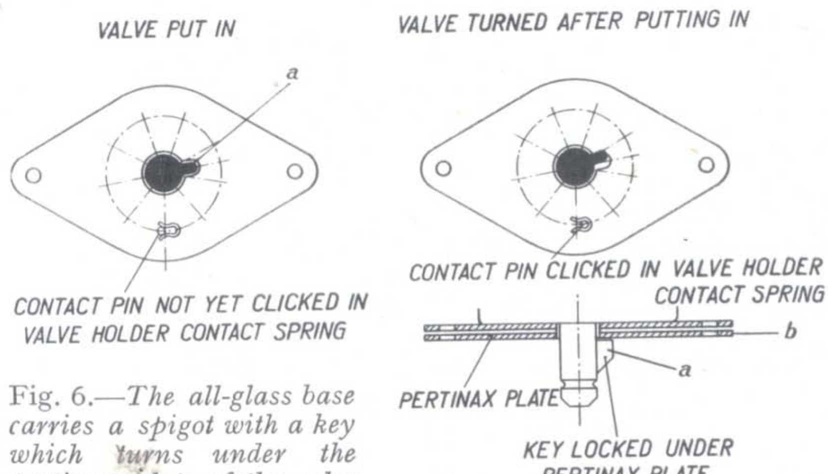

Fig. 6.—*The all-glass base carries a spigot with a key which turns under the pertinax plate of the valve holder. The contact pins are gripped firmly by the contact springs.*

spigot is inserted in its hole. Then the contact pins are gripped firmly by the contact springs. Insertion and withdrawal of the valve from the valve holder may be accomplished by a slight pressure.

When desired the constriction *a* of the spigot may be used to keep the valve in a valve holder, as shown in Fig. 7, but insertion and withdrawal requires considerable force. When the space in the set is too small to permit a strong pull, the first construction is more desirable.

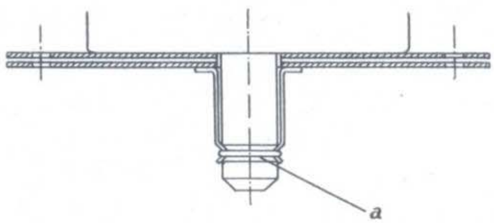

Fig. 7.—*In this valve holder the valve is kept firmly on the base by a constriction on the spigot.*

(f) Temperature effects

The temperature of several parts of the valve may attain a rather high value, especially in rectifiers and output valves, owing to the energy which is dissipated within the bulb. This may have very undesirable results for the glass parts. For instance, the appearance of lead trees in the pinch, due to electrolysis of the glass which may lead to gas leakage in the pinch.

Carefully constructed valves have such dimensions that the cooling is sufficient to avoid this trouble, but the all-glass construction has distinct advantages in this respect over the pinch construction. With this latter construction the lead-out wires are confined in the pinch, inside the bulb. Cooling by convection is practically impossible, and radiation is diminished by the surrounding bulb. The all-glass valve on the contrary, has the lead-out wires on the exterior of the valve, distributed over a much larger radiating surface. Also the conduction of heat by the short pins to the valve holder proves to be very efficient.

To compare both constructions temperature measurements have been taken on similar valve types (see Table below).

TABLE.

Valve types	Temperature of the glass near the lead-out wires
EL6 18W pentode	200° C. above ambient tem-
EL6 (all-glass) ..	90° C. ,, ,, perature
AZ1 rectifier ..	150° C. ,, ,, ,,
AZ (all-glass) ..	83° C. ,, ,, ,,

The large difference in temperature of both constructions is obvious.

Besides the above-mentioned advantages, the low temperature has also electrical benefits, which apply specially to short-wave and band-spread receivers and will be discussed in Section II.

Section II

Variation of the capacitances of the valve owing to temperature effects

For oscillator and convertor valves the constancy of the oscillator frequency depends on the constancy of the capacitance and inductance of the oscillator circuit elements. The oscillator anode and grid form part of this circuit, and so their capacitances have to be constant. These capacitances are composed of the capacitance of the electrode assembly, pinch and base, or bottom plate.

The valve base consists of an artificial resin product and this material has rather unfavourable high-frequency losses. Another disadvantage is the variation of the dielectric constant with temperature. This means that the capacitance of the lead-out wires varies during the heating-up period of the valves, or when the ambient temperature varies. We will investigate to what extent the reception may be affected by this variation.

The capacitance between two contacts in a valve base is about 0.3 $\mu\mu$F. During the heating-up period the increase in temperature of the base is about 10° C. As the increase of the dielectric constant ϵ for synthetic resins is about 50×10^{-4} per degree centigrade, the capacitance increases by 0.015$\mu\mu$F. This variation in capacitance causes in an oscillator-circuit on 13 m wavelength and with 50 $\mu\mu$F tuning capacitance a frequency drift of

$$df = -\frac{dc}{2C}f = 3.4 \text{ kc/s}.$$

More serious than the increase in capacitance during the heating-up of the valve base is the capacitance change in the pinch of normal radio valves. The increase of ϵ for glass is smaller than for synthetic resin and about 5×10^{-4} per degree centigrade. In normal cases the capacitance between two lead-out wires in the pinch is larger than in the valve base and 1–1.5 μμF. The increase of temperature of the pinch is in most cases 100–200°C. Under these circumstances the variation of capacitance easily amounts to 0.09 μμF or in the case above mentioned a frequency drift of 20 kc/s. It is clear that this frequency drift may disturb the reception considerably.

The case is somewhat different when we consider the variation in capacitance for a change in ambient temperature.

We can suppose, approximately, that the pinch loses all its heat by radiation and that the valve base traces the temperature of its surroundings. If this temperature increases 10°C, the pinch will not follow the rise, but increase its temperature only a fraction $\left(\frac{\text{ambient temperature}}{\text{pinch temperature}}\right)^4$. For an ambient temperature of 300° K and a pinch temperature of 425° K the increase will be only 2.6° C corresponding to a variation of capacitance of 0.0015 μμF.

The benefit of the omission of the valve base which gives for the same 10° C rise of ambient temperature an increase in capacitance of 0.015 μμF, is clear.

Also the change from the pinch to the bottom plate construction has its advantages. For instance, the lead-out wires have a lower temperature than in a usual pinch giving together with the lower capacitances between them (0.8 μμF against 1.2 μμF) a smaller variation in capacitance.

Above that, because the temperature of

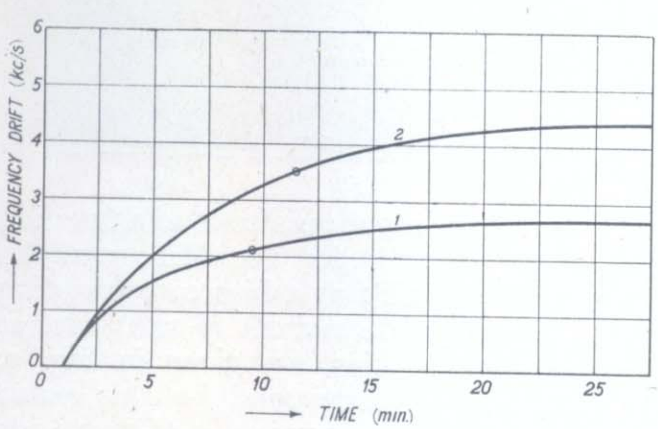

Fig. 8.—*Curves showing the frequency drift during the heating-up period of an all-glass convertor valve* (1) *and the same type of valves on pinch and all-metal construction* (2).

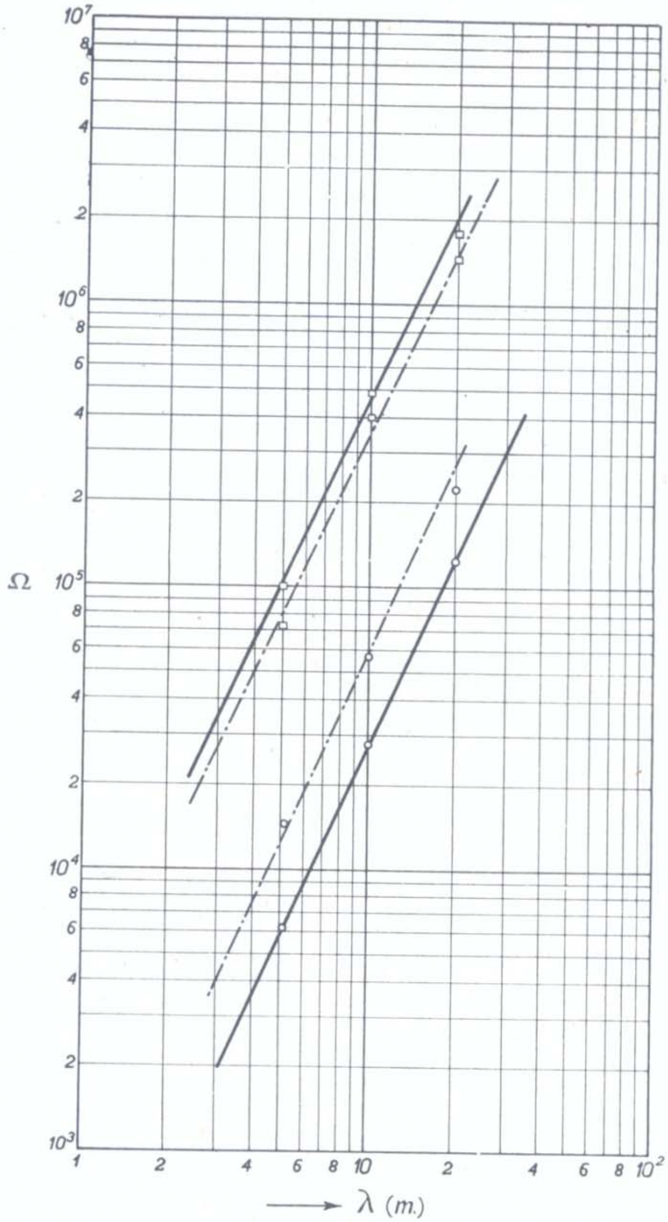

Fig. 9.—*Curves of the input resistance as a function of the wavelength for a H.F. pentode system EF9 at a bias corresponding at maximum anode current and at cut off for a valve with pinch and P-base* (*full line*) *and the all-glass valve* (*dotted line*).

the glass bottom is always high compared with the ambient temperature, variations in this temperature will not have much influence on the bottom plate temperature.

Due to the above-mentioned circumstances, the frequency drift during heating-up of the oscillator of an all-glass octode EK2 is only 2.7 kc/s, while for the same valve with pinch construction or all-metal construction, this amounts to 4.4 kc/s. These measurements are obtained at a wavelength of 20 m, the tuning capacitance was 75 μμF and the ambient temperature

25° C. These frequency drifts correspond to changes in capacitance of 0.044 and 0.027 $\mu\mu$F respectively.

It is also interesting to note how the course of the frequency drift curve will be in the period after switching on the valve. If, for instance, 80 per cent. of the frequency drift would occur in one minute after switching on a receiver, the effect would be rather unimportant because the tuning operation would not yet be finished. Fig. 8 gives the curves of the frequency drift as a function of the time after switching on, obtained for the above-mentioned valve types. The drawn curves give the average values for several samples.

80 per cent. of the frequency drift is obtained for the different types in the following periods.

Normal EK2 with pinch and valve base of synthetic resin	11.5 min.
All-glass EK2	9.5 ,,
All-metal EK2	11.5 ,,

It is clear that the figures do not differ widely but again the all-glass construction has an advantage over the other two.

Section III

Short wave performance

As we have seen in Section I (a) the all-glass valve construction affords possibilities for shortening the length of electrode leads inside and outside the valve. Recent investigations[1] have shown that the length of these leads is of primary importance for the short wave applications of valves. The output parallel resistance of H.F. valves is for the major part dependent on the mutual and self-inductances and the capacitances of the valve electrodes and their leads inside and outside the bulb, and the input parallel resistance also for an important part as far as short waves (e.g. shorter than 30 m wavelength) are concerned. Considering a number of H.F. valve stages in series, the output resistance of one valve as well as the input resistance of the next valve are parallel to the tuned interstage circuit (if a resonant circuit and no band pass filter circuit acts as interstage coupling element). With all valves hitherto measured, the output resistance was always considerably higher than the input resistance, say 5 to 10 times. Hence the most important limitation for the interstage circuit impedance and for the stage gain arises from the input resistance. The impedance of the resonant circuits themselves can be made much higher than the input impedance of practically any valve type. Because the input impedance is always much higher when measured at cut-off bias than at normal anode current, the major part of this damping cannot be attributed to bad insulation or dielectric losses.

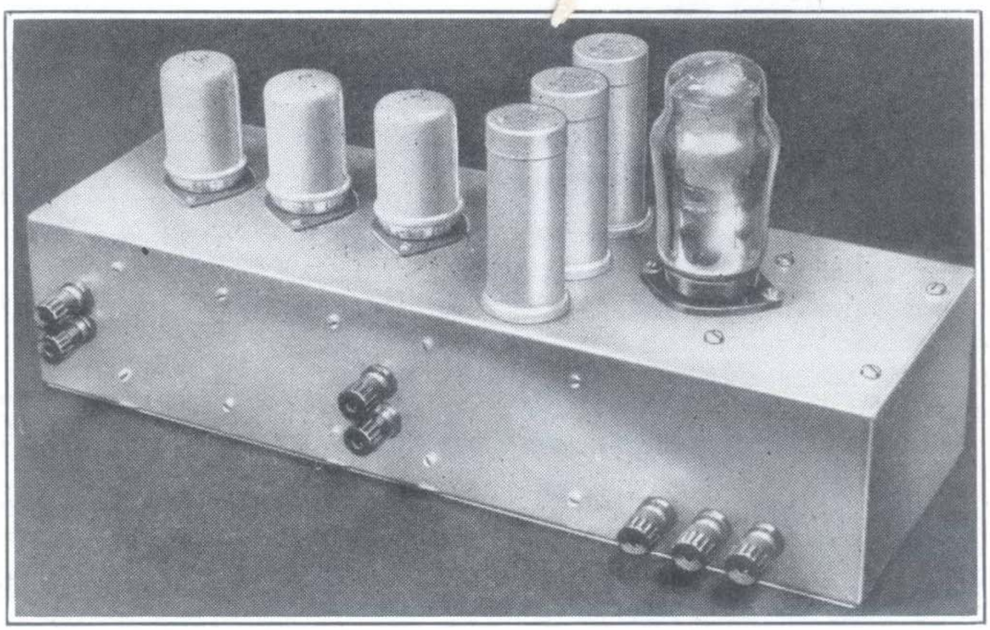

Fig. 10.—*Mounting of all-glass valves in a three-stage 7 m television amplifier.*

Curves of the input resistance as a function of the wavelength for the H.F. pentode system of type EF9 at a bias corresponding to maximum anode current (6 mA) and at a large negative bias, are given in Fig. 9. The full curves correspond to this valve with the pinch construction, a P-base (side contact) valve and the other curves to the same valve in all-glass. For the input impedance at maximum anode current these

[1] *Wireless Engineer*, Sept., 1937, Vol. 14, pp. 478–488 and *Proc. Inst. Rad. Eng.*, Aug., 1938, Vol. 26, pp. 1011–1032.

curves show a marked improvement for the all-glass valve as compared with the P-base valve. At 5 m wavelength the figures are 13,000 ohms and 6,000 ohms respectively. Hence we owe this important improvement to the short connecting wires.

On the other hand, the input resistance for the P-base valve is higher at large bias values than the resistance of the all-glass valve. This results from the fact that the dielectric path between the grid connection (at the top) and earth (cathode) is much longer for the P-base valve than for the all-glass valve. Curves similar to those shown in Fig. 9 have been measured for other valve systems, always with similar results. Hence, preference ought to be given to the all-glass valve for short-wave work.

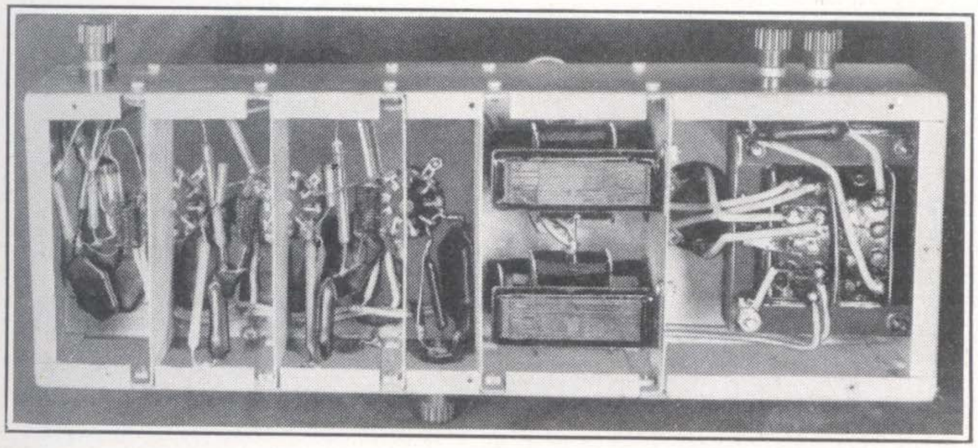

Fig. 11.—*The short connections between valves and circuit elements when using all-glass valves are clearly shown.*

The single-ended construction of the all-glass valve gives even more benefit in this respect.

It was found theoretically[2] that a mutual inductance between the input grid lead and the cathode lead may tend to increase the input parallel resistance at full anode current. Whereas the valves having a top connection to the input grid afford no practical possibilities to realise this feature, it may be easily incorporated in all-glass valves. Referring to the EF50 valve, an increase of 30 per cent. was found at 7 m wavelength for the input resistance at full anode current (10 mA) by constructing the grid lead close to the cathode lead inside the valve.

Figs. 10 and 11 show the mounting of all-glass tubes in a three stage 7 m television amplifier. In Fig. 11 the very short connections between the valve holder electrodes and the interstage coupling elements, such as circuit coils, are clearly shown. The separation between two successive stages runs right across the bottom side of the valve holder, separating the grid side from the anode side. Measurements have shown that a sufficiently small feed back value may be obtained at 7 m wavelength. With the EF50 the effective feed-back capacitance at 7 m was about 0.001 $\mu\mu$F in this chassis.

[2] M. J. O. Strutt, "Moderne Mehrgitter-Elektronenröhren," Vol. II, p. 76, Springer, Berlin, 1938.

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