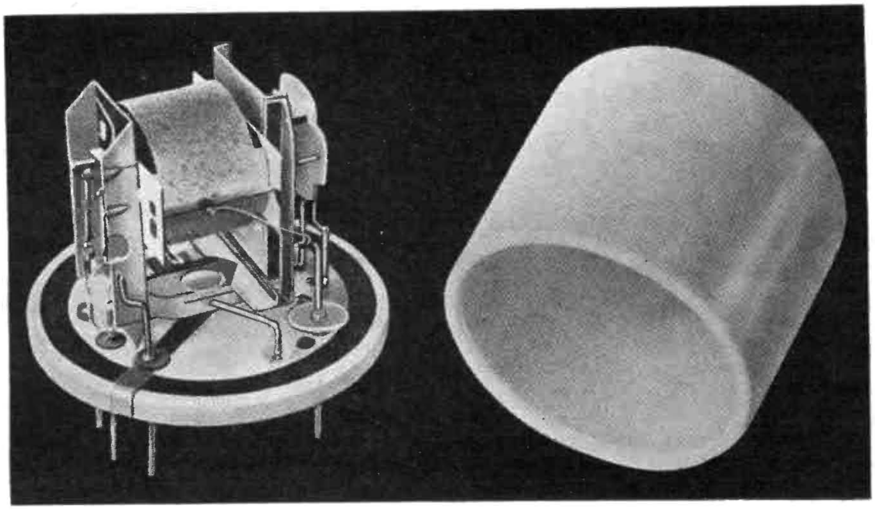
Ceramics in Valve Construction

By R. HOWARD



A ceramic envelope valve of German construction

DURING the development of a U.H.F. generator it was found at frequencies approaching 3,000 Mc/sec. that the losses in the glass of the valve were considerable. The following notes are the result of an investigation into the use of low-loss ceramic material for the seals, with particular reference to the work which has already been done in Germany.

In that country developments have taken place in the manufacture of direct metal-ceramic seals and seals using glass as an intermediate material (Fig. 1). It would seem that the metal-ceramic seal is the better method, since the glass seal tends to reintroduce the losses, the reduction of which is the main object of the use of ceramic material.

A further disadvantage is that metal-glass seals, such as are used for the sealing of leads into ceramic valves, are very prone to cracking. Attempts have been made to overcome this particular difficulty by covering the whole of the base of the tube with a glass melt. It seems, however, that this is impracticable, and again defeats the original object by reintroducing the glass losses.

Nevertheless, the Steatit-Magnesia A.G. of Berlin have specially designed ceramic materials for the purpose of sealing to glass.

On similar lines the Glasswerk Gust. Fischer, a German glass-manufacturing company, have developed glasses for sealing to ceramics, notably "357," for sealing to "Calit" and "Calan," ceramics made by the Hescho Company and "Frequenta," and "Kerafar," made by Steatit-Magnesia A.G., and also "M Glass," for sealing to "Steatite," made also by Steatit-Magnesia A.G.

These glasses are somewhat harder than lead glasses, and have a coefficient of expansion of about 70×10^7* for "M Glass" and 66×10^{7} for "357." The coefficient of thermal expansion for natural steatite is $60-65 \times 10^7$.

These glasses are of some importance, for, while it is possible to do away with glass for sealing the leads into the envelope, the problem of sealing the valves on to a vacuum pump (to be referred to later) is still a large one.

To return to the problem of sealing leads to a ceramic envelope. Consider first the problem of a small tube, when glass is used as a sealing means. In most cases the lead is first wetted, and then jigged into position and sealed to the ceramic (see Fig. 1), in some cases in an atmosphere of hydrogen or other neutral pressure.

Hard glasses are mainly used for these small seals, as the soft glasses of similar coefficients of expansion to the ceramic prevent the effectual heating of all the materials to be interconnected, and create difficulties in the choice of materials to be used for the leads.

* See table on page 376

Where larger metal-ceramic seals have to be made, a more favoured method is that of shrinking the metal part on to the ceramic material and using glass as a means of making the joint vacuum-tight, rather than using it to make the joint itself (see Fig. 2).

Another type of seal, which again does not use glass as an actual sealing means, but more as a method for rendering the seal vacuum tight, can be seen in Fig. 3, in which the metal and the ceramic, or the two ceramics, form a butt joint around which a glass melt is formed, thus making the seal vacuum-tight.

A joint in which the glass actually does form the seal is shown in Fig. 4. The glass is used to join the ring of ceramic, which forms a ring seal, to the ceramic tube comprising the envelope.

While there are numerous disadvantages to the metal-glass-ceramic construction, such as fabricating problems, annealing difficulties, unreliability of seals, and, above all, greater losses at ultra-high frequencies, there is very little to be gained, except possibly in reduction of cost.

Now consider the other aspect of the problem, that of direct metal-ceramic seals. Metal-ceramic seals are in the main more expensive to manufacture, but they are not open to criticism on the same grounds as the glass seals. There is no increase in dielectric loss at ultra-high frequencies, they are not sensitive to critical temperature changes, and are therefore easier to de-gas, and are not prone to cracking or seepage and subsequent loss of vacuum.

There are two main types of metal-ceramic seals, the first being a coaxial type of seal very similar to the lead-in seals using glass, previously described, except that the actual sealing metal (in most cases silver) does not extend the whole length of the lead in the ceramic but is melted into a conical depression on the outside of the seal (see Fig. 5).

This method would seem to be rather a crude adaptation of prior metal-glass-ceramic seals.

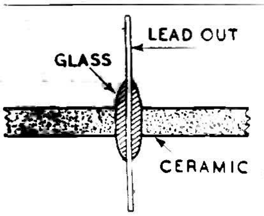


Fig. 1.

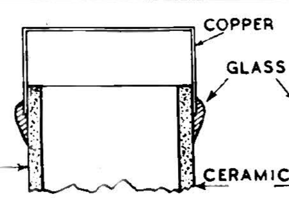


Fig. 2.

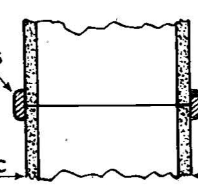


Fig. 3.

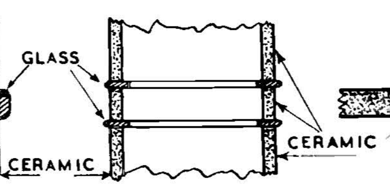


Fig. 4.

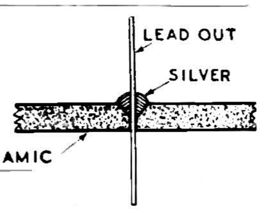


Fig. 5.

The other type of seal is more highly developed, and it is best to describe it in greater detail.

Dealing first with the problem of joining two surfaces of ceramic, a major consideration is that the two surfaces should fit as precisely as possible at the point of contact. A considerable improvement can be made in this respect by grinding the parts in.

An adherent layer of metal is then applied to the two faces, either by sputtering on in vacuum, by electroylisis, or by sintering powdered tungsten or molybdenum on to the surface of the ceramic.

Carbonyl iron has been suggested as an alternative to tungsten or molybdenum.

In the cases where the metal has been sputtered on in vacuum or applied by electrolysis, the mechanical stress of the joint between the metal and the ceramic may be too great if the thickness of the metal exceeds 0.1 mm. The layer must not, however, be so thin as not to fill the spaces which may be left, even after grinding.

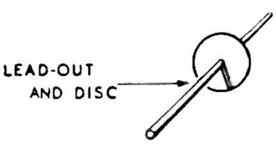


Fig. 6

The ground and metallized faces are now pressed together and raised to the melting-point of the metal used, thus forming a vacuum-tight joint. Alternatively, if it is not desired to heat the joint to a high temperature, a metal or solder with a much lower melting-point can be used to join the metallized faces. It is obvious that in the case of the tungsten or molybdenum surfaces it would be extremely difficult to use the first method.

It has been suggested that the actual metallic layer be used as the lead out, but this presents a number of difficulties.

A logical development of this method of sealing flat surfaces together is the following method of sealing a metal lead through the wall of a ceramic envelope, utilizing an annular disc attached to the conductor as the actual sealing means (see Fig. 6). A bush is formed at the place where it is desired to seal the lead through, with a hole through the centre of the bush of somewhat larger diameter than that of the lead-in.

The flat surface of the bush is metallized by any of the methods described.

The disc on the lead-in fits flush with the flat metallized face of the bush and is soldered to it, thus forming a vacuum-tight joint (see Fig. 7).

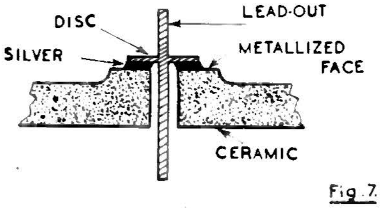


Fig. 7

The disc need not be an integral part of the lead, but may be soldered to it at the same time as the soldered joint to the ceramic is made.

In most cases this type of seal has been made, using a metal of similar coefficient of expansion as the ceramic itself, such as nickel-iron, using silver as the soldering means.

Usually, the soldering operation takes place in a non-oxidizing atmosphere.

There is no apparent reason why, for U.H.F. work, the annular disc should not be made of copper, provided that it is kept thin in cross-section. The whole lead, including the integral disc, could then be machined from a copper rod.

As a matter of interest it is worth while mentioning a method, primarily intended for use in large mercury-arc rectifiers, for sealing a metal lead insulated by a ceramic inset to a metal envelope. In this case the metal is soldered direct to the ceramic, without any prior metallizing whatsoever.

A metal tube is fixed projecting from the envelope (see Fig. 8), and a ceramic tube with an annular groove is fitted to the inside of the projecting metal tube. In a similar manner, a cap carrying the lead-in is fitted to the other end of the ceramic tube. The annular rings are filled with a solder such as silver, in a powder or wire form. The whole is then heated in a reducing atmosphere or vacuum, the solder taking to the metal and the ceramic, thus forming a vacuum-tight joint.

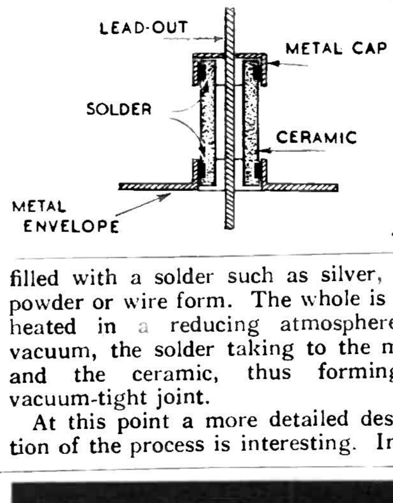


Fig. 8

At this point a more detailed description of the process is interesting. In the first place, the solder is melted in a vacuum (thus the ceramic part is degassed considerably). Bubbles of gas try to rise through the solder, but as soon as it is fully melted a neutral gas, such as hydrogen, is let into the furnace at a pressure of several atmospheres, thus increasing the surface pressure on the solder, which is immediately cooled. As soon as the solder is set the furnace is again evacuated, air only being admitted after the seal is quite cool.

In this way a seal is formed in which the gas bubbles in the solder itself are compressed to a very small volume at the point of contact between the solder and the ceramic, and the seal itself is thoroughly degassed.

Although the technique of sealing leads through the ceramic envelope has progressed considerably, there is still room for a great deal more development.

A further problem which has to be tackled is that of the exhaust tube. This problem can be approached in several ways. The most simple is to seal a tube of one of the specially designed glasses, to a bush on the envelope of the valve (see Fig. 9). This again, however, reintroduces certain undesirable factors into the manufacture of the valve.

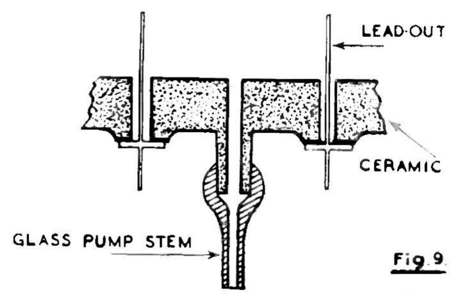


Fig. 9

Another method is that of placing the valve bodily in a container which is attached to the vacuum pump. The valve itself is then evacuated, either through an aperture which is covered by a mesh, or through the actual place where the seal will eventually be made.

When the tube has been exhausted, in the case of the tube with the meshed

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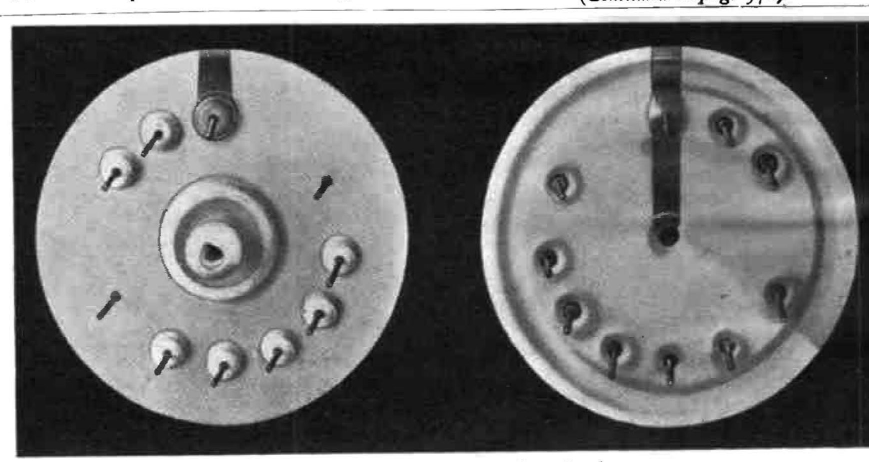
Examples of seals in ceramic valve base

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(*Continued from page 344*)

aperture, some form of solder is melted, thus filling the holes in the mesh and forming a vacuum-tight seal. In the other case, the seal is moved into position and soldered in a similar manner.

The latter method of pumping the valve appears to be the most satisfactory, and a similar method of pumping all-metal valves is at present being production-tested in the United States.

In general, while great strides have been made since the original attempts to use glass as sealing means, development has by no means reached an optimum.

It is noticeable that very little work has been published other than in Germany, workers in this country and the United States having left the field almost entirely to the Germans.

Although great strides have been made in the generation of ultra-high frequencies, in most cases a more or less conventional glass construction has so far been used, and it is hoped that this article will stimulate the development of a more specialized method of construction for these frequencies.

TABLE I.

Material.	Coefficient of Thermal Expansion.
Copper	165×10^{-7}
Lava	90×10^{-7}
Platinum	90×10^{-7}
" M-Glass "	79×10^{-7}
" 357 " Glass	66×10^{-7}
Commercial Steatite	60 to 70×10^{-7}
Low Loss Steatite	60 to 65×10^{-7}
Molybdenum	48 to 52×10^{-7}
Tungsten	40 to 45×10^{-7}
Porcelain	30 to 60×10^{-7}

All figures for 20°C. to 100°C. approximately.

A Method of Detecting Metallic Foreign Bodies

Recently a speaker on the German Radio described a new device by which, he claimed, bullets, shell splinters, needles and other metal objects can be readily located.

This metal finder developed by Siemens and their medical advisers depends on the use of a high frequency oscillator of small intensity. The tuning coil of a small short-wave transmitter is fitted into a sterilisable porcelain probe, 10 cm. long and 10 mm. in diameter. If this coil approaches a metallic substance, such as a splinter in the operation area, the inductance of the coil will change and hence so will the frequency of the transmitter. The change of frequency which may be very minute, can be made audible by combining these oscillators with those of a second short wave transmitter, oscillating at a slightly different frequency and so obtaining oscillations at the beat frequency, amplifying them and passing them to a loudspeaker.

The apparatus is extremely sensitive and can trace the minutest particles, but all metal instruments within a 10 cm. radius must be removed while the probe is in use.—*Lancet*, May 31, 1941, p. 699.

G.E.C. " Microgram "

A modified and improved version of their " Microgram " amplifying equipment is announced by the General Electric Co., Magnet House, Kingsway.

It embodies a three-stage amplifier with microphone and gramophone input, transverse current microphone, turntable, and 50 ft. of cable, contained in a portable oak cabinet 20½ in. by 17 in. by 13½ in. Both inputs can be independently controlled.

The maximum power output is 14 watts, and the equipment is particularly suitable for use in factories where it may be subjected to rough usage. Inquirers should ask for Leaflet BC. 9330.