June 5, 1962 G. D. O'NEILL 3,038,098

ELECTRON TUBE

Filed July 14, 1959

Fig. 1

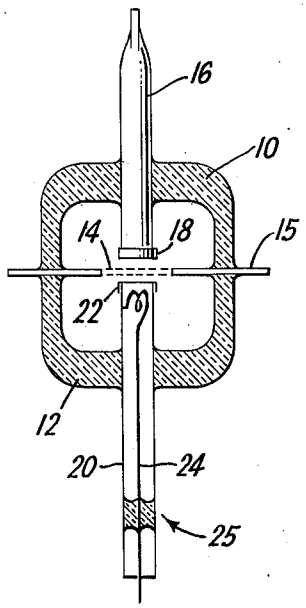
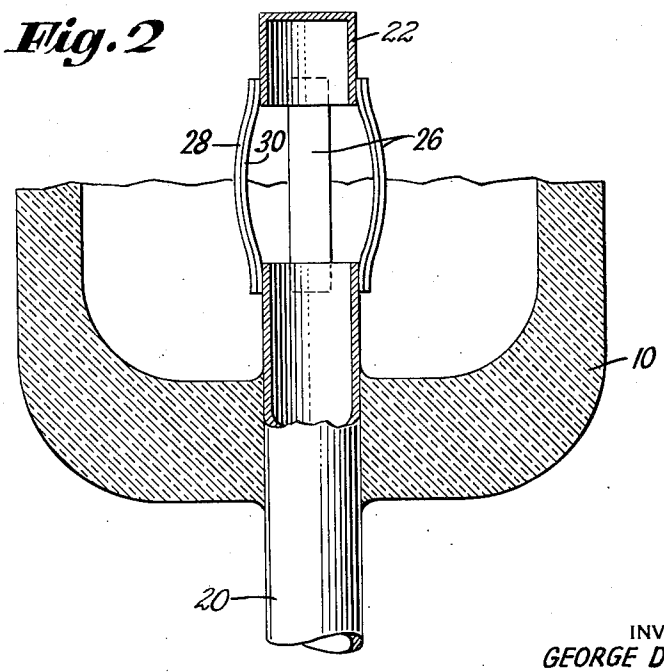


Fig. 2



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ELECTRON TUBE

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My invention is directed toward electron tubes.

Conventionally, the transconductance of an electron tube having closely spaced electrodes (for example, cathode-grid and anode-grid spacings of a few thousandths of an inch) remains constant only when these spacings and the cathode heater power of the tube do not vary. However, when the heater power varies, the dissipation varies and, therefore, the electrode spacings may vary. In addition, the variations in heater power produce variations in cathode temperature, and this would result in variations in transconductance even if the interelectrode spacing were, by some means, held constant. In general, the change in transconductance produced by changes in spacing is in the same direction as that produced solely by a change in cathode temperature. Therefore the change in transconductance is the sum of the changes due to the separate effects.

In many applications, it is highly desirable to employ tubes having closely spaced electrodes wherein the cathode heater power can vary over a relatively wide range, while the tube transconductance remains essentially constant. Many attempts have been made to produce such tubes but, in so far as I am aware, such attempts have been unsuccessful. In contradistinction, I have succeeded in producing such a tube.

In accordance with the principles of my invention, my tube comprises essentially, in an evacuated envelope, an anode electrode, a control grid spaced apart from said anode, and a cathode electrode spaced apart from said grid. One or both electrodes are mounted on members formed from materials which either contract or do not expand appreciably as the ambient temperature increases; i.e. materials that possess either a negative coefficient of thermal expansion or an essentially zero expansion coefficient.

As explained in more detail hereinafter, when electrode support members having an essentially zero thermal coefficient are employed in my invention, the transconductance variations with changes in heater power can be substantially reduced. Further, when one or more members having negative coefficients of thermal expansion are utilized, these transconductance variations can be substantially eliminated.

Illustrative embodiments of my invention will now be described with reference to the accompanying drawings wherein:

FIG. 1 shows one embodiment of my invention utilizing electrode support members having an essentially zero coefficient of thermal expansion; and

FIG. 2 shows another embodiment of my invention in which one of the electrode support members has a negative coefficient of thermal expansion.

FIG. 1 shows a triode having small electrode spacings and useful as an oscillator or amplifier at very high frequencies. This triode has an evacuated glass envelope **10**. An indirectly heated cathode is positioned within the envelope and, for example, is constituted by a nickel cap **22** which is coated with a conventional electron emissive material and which is fastened to a first tubular support member **20** (normally of copper). A cathode heater in the form of a tungsten wire coil **24** coated with aluminum oxide is positioned within member **20**. A grid **14**, welded to disc **15** (usually of copper) which separates the upper and lower parts of envelope **10**, is positioned parallel to and closely spaced from the cathode. An

anode **18** is positioned above grid **14** and is welded to a second tubular support member **16**.

In operation, input and output resonant cavities are placed around the two halves of the tube; the input cavity is coupled between the grid disc **15** and tubular member **20**, while the output cavity is coupled between the grid disc and tubular member **16**.

It is well known to the art that when a tube such as that shown in FIG. 1 is operated, a change in heater power produces a change in transconductance. This change in transconductance can be intolerably large when the tube is operated from a power supply that may permit considerable change in heater power. For example, it is not uncommon for a 10 percent change in heater voltage to produce a 20 percent change in transconductance in tubes of this class when constructed as heretofore. The transconductance increases or decreases as the heater power increases or decreases.

This change in transconductance with heater power will be explained briefly below. (A more detailed and somewhat mathematical treatment of the factors causing the shift in transconductance with cathode temperature can be found in my paper, "The Influence of the Internal Correction Voltage on the Proper Ratings of Receiving-Type Tubes," published in The Sylvania Technologist, vol. 10, No. 3, July 1957, pp. 71–77, and in the IRE Transaction on Electron Devices, vol. ED–5, No. 2, April 1958, pp. 69–75.)

When the heater power is increased, tubular member **20** is increased in length because of increased temperature, and as a result the spacing s_1 between cathode **22** and grid **14** is decreased. From Child's law, it is known that the space current i is thereby increased considerably; with no other change, the current is proportional to $1/s_1^2$, and the transconductance g_m is also proportional to $1/s_1^2$.

If the heater power is abnormally high, the temperature of tubular member **16** also rises, and this produces a decrease in the distance s_2 between grid **14** and anode **18**. This also causes an increase in i and g_m because the amplification factor of the tube is reduced. (More particularly, μ varies directly with spacing s_2.) Further, the space-charge current i depends upon the amplification factor μ in approximate accordance with the equation

$$i=G(e_c+c_p/\mu)^{3/2}$$

in which G is the perveance, e_c is the grid bias, and e_p is the anode voltage. Hence, as shown in this equation, when μ is decreased, i is increased. Furthermore, if i is increased, then g_m is increased, since g_m is the partial derivative of the current i with respect to the grid voltage e_c.

To circumvent the increase in g_m with decrease in the spacing s_2 due to an increase in heater power, I use a material for that part of tubular member **20** within the envelope which has substantially zero coefficient expansion. As a result of this construction, the change in g_m with change in heater power is reduced to a relatively small value, but is not completely eliminated.

I shall now describe (*a*) why there is still a small change in g_m with heater power, and (*b*) how a further extension of my invention allows me to produce tubes in which the change in g_m with heater power is zero or—if I should desire to do so—a tube could be made in which an increase in heater power produces a decrease in g_m.

It is known that when the current in a tube is limited by the space charge, a virtual cathode is formed at a plane somewhere between the cathode and grid. The virtual cathode is separated from the actual cathode by a distance x_m and the potential of the virtual cathode is V_m volts below that of the actual cathode. As described in my above-mentioned paper, an increase in cathode tem-

perature increases V_m; this is equivalent to both a decrease in negative grid bias and an increase in anode voltage. As a result, the current i and transconductance g_m increase. Furthermore, an increase in heater power increases x_m, and this is equivalent to decreasing the cathode-grid spacing s_1; as previously noted, decreasing s_1 increases i and g_m.

To nullify the change in g_m by change in heater power produced by both decreasing s_1 and increasing V_m and x_m, I replace that part of tubular member **20** situated above the glass by a barrel-shaped member of bi-metal (for example, copper and Invar) construction. Such a member, as shown in FIG. 2, can be formed by welding strips **26** of bi-metal (for example copper and Invar) to collars as shown in FIG. 2, or it can be one-piece construction. The inside element **30** of the bi-metal (Invar) has a lower coefficient of expansion than the outside element **28** (copper). In operation, an increase in cathode heating power raises the temperature of the bi-metal member and the strips bow outward. Consequently, the cathode moves downward and s_1 is increased. By proper choice of materials and dimensions, the effect of the decrease in s_1 can be made to balance the effects of the increase in V_m and x_m.

It will be understood by those skilled in the art that high-frequency currents on the strips **26** can induce small currents to flow in the heater coil **24**, and that the effect of these currents can be neutralized by inserting a quarter-wave stop below the vacuum seal **25**.

What is claimed is:

1. An electron discharge tube having, within an evacuated envelope, separate cathode and anode electrodes having electrode supporting members and a control grid interposed between the electrodes, at least one of said supporting members having a negative coefficient of thermal expansion, said supporting member including a hollow tube and a plurality of bimetal strips securing said supporting member to the electrode supported thereby.

2. An electron discharge tube having, within an evacuated envelope, separate cathode and anode electrodes having electrode supporting members and a control grid interposed between the electrodes, at least one of said supporting members having a negative coefficient of thermal expansion, said supporting member including a hollow tube and a plurality of bimetal strips securing said supporting member to the electrode supported thereby, each strip having an outside element and an inside element, the inside element having a lower coefficient of thermal expansion than the outside element, and the other supporting members having a negligibly small coefficient of thermal expansion.

3. An electric discharge tube comprising an evacuated envelope, an anode, a hollow anode supporting member fastened to said anode and projecting from one end of said evacuated envelope, said anode supporting member having a negative coefficient of thermal expansion, a cathode, a cathode supporting member projecting from the other end of said evacuated envelope, a plurality of bimetal strips coupling said cathode to said cathode supporting member, each strip having an outer element and an inner element, the outer element having a different coefficient of expansion than the inner element, and a control grid attached to said evacuated element, said control grid being interposed between said cathode and anode.

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