ABOUT FORMS OF ELECTRONIC AND IONIC DEVICES WITH THERMIONIC CATHODES

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ABSTRACT

The miniaturization of electronic and ionic devices with thermionic cathodes and the improvement of their vacuum properties are questions of very great interest to the electronic engineer. However there have been no proposals so far to analyse the problem of miniaturization of such devices in a fundamental way. The present work suggests a choice of the geometrical shape of the cathode, the anode and the envelope of the device, that may help towards such a fundamental approach.

It is shown that a design, in which the cathode and the envelope of the tube are made of thin prismatic shape and the anode coincides with the envelope, offers a striking advantage over the conventional cylindrical design, in respect of over-all size. The use of the prismatic shape will lead to considerable economy in materials and may facilitate simpler production techniques. In respect of the main criteria of vacuum, namely the grade of vacuum, the internal volume occupied by residual gases, the evolution of gases in the internal space and the diffusion of gases from outside into the device, it is shown that the prismatic form is at least as good as, if not somewhat superior to, the cylindrical form.

In the actual construction of thin prismatic tubes, many practical problems will arise, the most important being the mechanical strength and stablity of the structure. But the changeover from the conventional cylindrical to the new prismatic form, with its basic advantages, is a development that merits close attention.

1. INTRODUCTION

The problem of miniaturization of electronic and ionic devices is of great interest and importance. These devices will be unable to stand competition with semi-conductors, without considerable decrease in their size, because one of the major reasons for the preference shown to semi-conductors is their miniature size. It turns out further that the miniaturization of the device has an important bearing on its vacuum properties.[5] One may decrease the size of the cathode;[6] while this aspect presents a very important problem, there are others also which require attention, namely decrease of the electrode gap, decrease of the gap betwen the electrode and the envelope of the device, making the anode of the device serve as the envelope of the vacuum vessel, coating the glass wall of the vessel with metal so that it acts as the anode, substituting the tube socket by its thick glass bottom, reducing the dimensions of the electrodes and of the vessel, etc.

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The value of the anode current per unit volume of the vessel, namely

$$\frac{I_a}{V_{ves}} \cdot \frac{amp}{cm^3} \tag{1}$$

should be regarded as the most general criterion governing the efficient use of the volume of an electronic or ionic tube. This ratio may be designated as the coefficient of effective use of the tube-volume. If, however, one considers only the geometry or the design-shape of the tube, a parameter of less general character may be used to study the effective use of the tube volume. The construction-quality of the tube may be denoted by the ratio,[5]

$$\frac{V_{ves}}{S_{cathode}} = K_d, \tag{2}$$

if we accept the working surface of the cathode, $S_{cathode}$, as a basis for comparison. All possibilities must be explored to make this ratio as small as possible.

It is quite evident that if the size of the diode and its cathode-current density are constant, then the anode-current obtainable from the tube will be bigger if the design-parameter of the tube, K_d, is smaller, because then the working surface of the cathode will be bigger. One should however pay attention to the limitation imposed on the current by space-charge in an electronic diode. In this case, the value of the anode current of the diode is determined by the 3/2—power law,

$$I = P \cdot V_a^{3/2} \tag{3}$$

where P is one of the main parameters (perveance) of the diode, and its value depends on the size and design. There are the following formulas for this parameter:—

$$P_p = 2.33 \times 10^{-6}\, S r^{-2} \tag{4}$$

for a flat diode,

$$P_{c1} = 2.33 \times 10^{-6}\, S\, (r_a - r_c)^{-2} \tag{5}$$

for a cylindrical diode having cathode and anode radii large and close to each other, and

$$P_{c2} = 14.65 \times 10^{-6}\, h\, (r_a\, \beta^2)^{-1} \tag{6}$$

for a cylindrical diode having a small cathode radius and a large anode radius. In these formulas, S is the surface area of the anode, r is the distance between the cathode and the anode, r_c and r_a are the cathode and the anode radii, h is the working length of the cathode and of the anode, and β is a coefficient whose value depends on the ratio r_a/r_c. In practice, for the values of r_a and r_c most often used, $\beta = 1$. If we take into consideration that $(r_a - r_c) = r$, and, for the case of the cylindrical diode with a small cathode radius and a large anode radius, $r_a \cong r$, we see that

$$P_{c1} \cong 2.33 \times 10^{-6} S r^{-2} \tag{7}$$

and
$$P_{c2} \cong 2.33 \times 10^{-6} \cdot 2\pi h r \cdot r^{-2} \beta^{-2} = 2.33 \times 10^{-6} S \cdot r^{-2} \tag{8}$$

It would appear, therefore, that in all the cases treated above, the perveance is determined by the two main dimensions: the surface area of the anode and the spacing between the cathode and the anode. This shows that, even in the case of the electronic diode working under space - charge saturation, a smaller value of K_a will result in enhanced anode current, corresponding to the increase in the cathode surface area. However, in the case of cylindrical diodes, wherein S_{anode} is not equal to $S_{cathode}$ and β has a value other than unity, the relation between the design - parameter and the anode current becomes somewhat more complicated. For the flat diode, $S_{anode} = S_{cathode}$, and therefore the perveance, P, is inversely proportional to K_a.

We shall confine ourselves for the present to the comparison of the design-parameters of diodes of different geometrical shapes, for the temperature saturation condition. The electrostatic capacitances of these various diodes will differ, and the relation between the design-parameter and the diode-capacity is also a matter of interest. But this question will be treated separately. It may also be noted that the value of the perveance P is inversely proportional to the square of the inter-electrode spacing. Hence the minimum value of this distance is desirable if we wish to have large anode current in a tube working under the space-charge saturation condition.

2. GENERAL CONSIDERATIONS RELATING TO THE GEOMETRICAL FORM OF TUBES

At present electronic and ionic tubes with thermionic cathodes are made mostly with flat or cylindrical electrode structures and with cylindrical or spherical (pear-shaped) envelopes. The last-mentioned is comparatively rare, the most commonly used being the cylindrical shape for the envelope. All alternative forms must be compared with this form. The flat electrode system used in modern electronic and ionic devices with thermionic cathodes comprises a flat anode and a cathode of any shape other than the prismatic one.

The prismatic shape of the thermionic cathode, especially the thin prismatic shape, has considerable advantages over other forms.[6]

It will be of interest to compare the prismatic shape of anode and envelope with the cylindrical shape. Making the tube envelope serve as the anode will facilitate the reduction of the size of the tube. This can be done for the cylindrical form as well as the prismatic. The anode coincides with part of the cylindrical envelope in some high frequency power tubes, ignitrons and a few others. But no serious attention has been paid to this evidently advantageous design feature. Electronic and ionic devices with thermionic cathodes have not so far been made of thin prismatic shape. This shape is quite new. Making the envelope serve as the anode in tubes of this shape is a development that remains to be carried out.

In the first place, it is essential to compare tubes with cylindrical envelopes and electrodes with tubes of prismatic structure. For both types of tubes, there will be two practical cases: the envelope being separate from and encompassing the anode, and the envelope serving as the anode. The significant point of the comparison will be the size of the tube. It turns out that tubes based on the new prismatic form are smaller in size than the most widely used cylindrical shaped tubes.

Let h denote the height of the electrode system, identical for the cylindrical and the prismatic form. The volume enclosed in the tube corresponding to this height will be called the useful or main volume. There will be additional volumes inside the tube. These will be approximately equal in both forms of tubes, will be kept down to a minimum, and may be assumed to be of secondary importance. These auxiliary volumes are omitted from the comparison. Let d_p

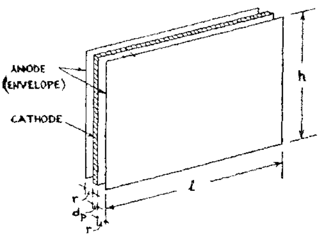

FIG. I
Prismatic form of tube (flat parallel electrodes).

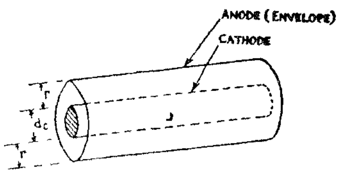

FIG. II
Cylindrical form of tube (anode and envelope the same.).

represent the thickness of the rectangular prismatic cathode (Fig. I) and let d_c be the cathode-diameter in the cylindrical tube (Fig. II). The cathode-to-anode spacing is taken as r, the same for both tube structures. In order to make these tubes of different geometrical forms equivalent in their electrical parameters, it will be necessary to use the same cathode material, same operating temperature and identical surface areas of emission. If S_p and S_c are the working surface areas of the prismatic and cylindrical cathodes, and these are equal, we have

$$S_c = S_p \tag{9}$$

That is

$$\pi\, d_c h = 2\, lh, \tag{9a}$$

and hence

$$d_c = 2/\pi \cdot l \tag{10}$$

We shall now determine the main volumes for the two cases, assuming that the anode coincides with the envelope. For the prismatic design, the volume is

$$V_p = (l + 2\,r)\,(d_p + 2\,r)\,h \tag{11}$$

For the cylindrical tube, the corresponding volume is

$$V_c = \pi/4 \cdot (d_c + 2\,r)^2\,h \tag{12}$$

$$= 1/\pi \cdot (l + \pi\, r)^2\,h \tag{12a}$$

Combining equation 11 and equation 12a, we obtain

$$\frac{V_c}{V_p} = \frac{(l + \pi\, r)^2}{\pi\,(l + 2\,r)\,(d_p + 2\,r)} \tag{13}$$

Denoting the ratio l/d_p as x and the ratio r/d_p as y, the above equation may be re-written as

$$\frac{V_c}{V_p} = \frac{(x + \pi\, y)^2}{\pi\,(x + 2\,y)\,(1 + 2\,y)} \tag{14}$$

Likewise the ratio of volumes may be arrived at for tubes in which the anode and the envelope are separate, the distance of separation being denoted by

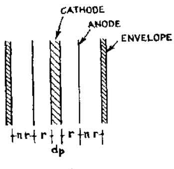

FIG. III

Prismatic tube structure in which anode and envelope are separate.

$n.r.$ For this case, the volume of the prismatic tube (Fig. III) will be

$$V_p = (l + 2\,nr)\,(d_p + 2\,r + 2\,nr)\,h \tag{15}$$

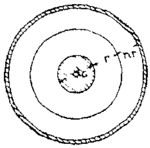

FIG. IV
Cylindrical tube structure in which anode and envelope are separate.

The volume of the cylindrical tube (Fig. IV) will be

$$V_c = \pi/4 \cdot (d_c + 2r + 2nr)^2 h \tag{16}$$

Then, for the ratio V_c/V_p, we have

$$\frac{V_c}{V_p} = \frac{\pi [d_c + 2r(n+1)]^2}{4(l + 2nr)[d_p + 2r(n+1)]} = \frac{[x + \pi y(1+n)]^2}{\pi(x + 2yn)[1 + 2y(n+1)]} \quad (17), (18)$$

In both cases, the numerical value of V_c/V_p is an index of the superiority of one design over the other. It is evident that if we have a short prismatic tube (small value of l and hence of x), such a design will be no better than, and may be inferior to, the cylindrical form. A fairly large numerical value of the factor x is needed to establish, in a decisive way, the superiority of the thin prismatic structure over the conventional cylindrical form. A tube with the prismatic-shaped envelope will be less strong mechanically against atmospheric pressure than the cylindrical tube. Special attention will have to be paid to the question of the mechanical strength of the prismatic tube. Therefore the advantage of this form of tube will be substantial only when a large numerical value of the ratio V_c/V_p is achieved, which in turn corresponds to a large factor x for the prismatic tube.

We now turn to a study of the design-parameter of the two tube-forms.

3. CALCULATION OF THE DESIGN PARAMETER (K_d).

The parameter K_d is calculated below for the main forms and designs of electrodes and vessels. The cylindrical and the prismatic structures are the main forms considered, whereas the main designs are tubes in which the anode and the envelope are one and the same, and tubes in which the two are separate. As stated already, only the main volumes are considered, namely the volumes of the parts of the vessels where the electrodes are situated.

(a) *Tubes in which the wall serves as the anode, or the anode is formed by a metallic coating on the internal walls of the vessel*

(i) *Tube with flat parallel electrodes* (Fig I)

The electrodes can be made of any flat form, and the parameter K_d will be the same for devices with the same cathode surface area S_{cathode}, thickness of of cathode d_p, and electrode gap r. In practice, the rectangular form of electrodes corresponding to the prismatic shape is convenient. Rectangular, directly heated

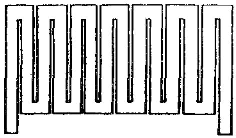

FIG. V

Form of cathode (directly heated) for the prismatic tube.

cathodes may, for example, have the form shown in Fig. V. The anode must be placed on both sides of the cathode. Let us consider as the working area only the two large opposite surfaces of the cathode structure. Indirectly heated oxide-coated cathodes may also be of the same form.

The capacity of the vessel is

$$V_{\text{ves}} = \tfrac{1}{2}\, S\,(d_p + 2\,r)\ \text{cm}^3 \tag{19}$$

The design-parameter of the prismatic tube will then be

$$K_{d_p} = \frac{V_{\text{ves}}}{S_{\text{cathode}}} = \frac{d_p + 2\,r}{2} \cdot \frac{\text{cm}^3 \text{ of vessel}}{\text{cm}^2 \text{ of cathode}} \tag{20}$$

(ii) *Tube with cylindrical cathode and anode* (Fig. II)

The working cathode surface-area is

$$S_{\text{cathode}} = \pi\, d_c\, h\ \text{cm}^2 \tag{21}$$

The internal volume of the vessel is

$$V_{\text{vessel}} = \tfrac{1}{4}\,\pi\,(d_c + 2r)^2\, h\ \text{cm}^3 \tag{22}$$

The design-parameter of cylindrical tube is

$$K_{d_c} = \frac{V_{\text{ves}}}{S_{\text{cathode}}} = \frac{(d_c + 2r)^2}{4d_c} \cdot \frac{\text{cm}^3}{\text{cm}^2} \tag{23}$$

(*b*) *Tubes in which the anode and the envelope are separate.*

(i) *Tube with flat parallel electrodes.*

The prismatic form of the vessel is again a reasonable choice. The cathode and the anode are of the same shape as previously considered, and the vessel is a prism embracing the anode. (Fig. III).

The internal volume of the vessel is

$$V_{\text{ves}} = S_{\text{cathode}}\ \tfrac{1}{2}(d_p + 2r + 2nr)$$

$$= S_{\text{cathode}}\ \tfrac{1}{2}\left[d_p + 2r(1+n)\right] \text{cm}^3 \qquad (24)$$

Then

$$K_{a_p} = \frac{V_{\text{ves}}}{S_{\text{cathode}}} = \frac{d_p + 2\,r(1+n)}{2}\cdot\frac{\text{cm}^3}{\text{cm}^2} \qquad (25)$$

(ii) *Tube with cylindrical electrodes* (Fig. IV).

The working surface of the cathode is

$$S_{\text{cathode}} = \pi\, d_c\, h\ \text{cm}^2 \qquad (26)$$

The internal volume of the vessel is

$$V_{\text{ves}} = \tfrac{1}{4}\,\pi\,(d_c + 2\,r + 2\,nr)^2\,h\ \ \text{cm}^3 \qquad (27$$

The design-parameter of the tube is

$$K_{a_c} = \frac{V_{\text{ves}}}{S_{\text{cathode}}} = \frac{d_c + 2\,r\,(1+n)}{4\,d_c}\cdot\frac{\text{cm}}{\text{cm}^2} \qquad (28)$$

4. Comparison of the Design Parameters of Thin Prismatic and of Cylindrical Tubes

Previously we compared the volumes of cylindrical and any rectangular prismatic form of tube structure. The present comparison will deal with thin prismatic forms of electronic and ionic tubes having thin prismatic thermionic cathodes. We shall, consider as working surface of the cathode only the two broad faces and neglect the narrow sides. We shall maintain the condition of equivalence of the thin prismatic and the cylindrical tubes.

We will first consider the case where thc envelope acts as the anode.

From the previous section, we have

$$\frac{K_{a_c}}{K_{a_p}} = \frac{(d_c + 2\,r)^2}{2\,d_c\,(d_p + 2\,r)} \qquad (29)$$

If the cathode working surfaces are to be equal.

$$S_{\text{prismatic}} = 2hl = S_{\text{cylindrical}} = \pi\, d_c\, h$$

whence

$$d_c = 2\,l/\pi \qquad (30)$$

Substituting this value of d_c, and taking once again $l = x\,d_p$ and $r = y\,d_p$, we may write

$$\frac{K_{a_c}}{K_{a_p}} = \frac{(x + \pi\,y)^2}{\pi x(1 + 2y)} \qquad (31)$$

The ratio of the design parameters is a function of x and y. Fig. VI is a graphical representation of the behaviour of this ratio, as x is varied, keeping y constant. The ratio K_{dc}/K_{dp} grows, with either increasing x or decreasing x,

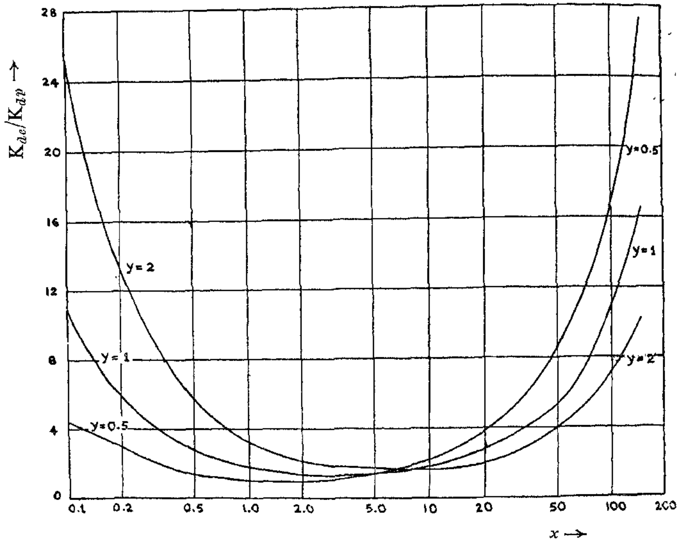

FIG. VI

Graph showing the influence of the factors x and y on the design parameters of tubes in which the anode and the envelope coincide ($n=0$).

from its minimum value to infinity. From this circumstance, one is apt to conclude that there may be two designs of prismatic tubes offering very great advantage in volume over the cylindrical tube, namely, one, the thin prismatic form with the cathode placed along the length of the envelope, resulting in a large value of $x=l/d_p$ (Fig. I), and, two, the thin prismatic form with the cathode placed across the envelope as shown in Fig VII, resulting in a small value of x. But it is to be borne in mind that, for small values of x, the expression derived above for K_{dc}/K_{dp} is incorrect as we have ignored the side gaps between the anode and the cathode. If we take these gaps into account, for small values of x, the ratio K_{dc}/K_{dp} is close to or less than unity. In respect of volume, the type of thin prismatic form evidently offers no advantage over the cylindrical form. In respect of mechanical strength, it will be inferior. On the other hand, in the case of the first type, the volume of the tube may be made many times less than the volume of the equivalent cylindrical tube.

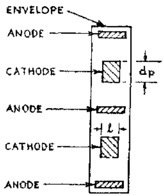

FIG. VII
Cross section of an alternative form of prismatic tube.

We will now compare the design parameters of cylindrical and prismatic tubes having separate anodes and envelopes. In this case,

$$\frac{K_{d_c}}{K_{d_p}} = \frac{[d_c + 2r(1+n)]^2}{2d_c[d_p + 2r(1+n)]} \tag{32}$$

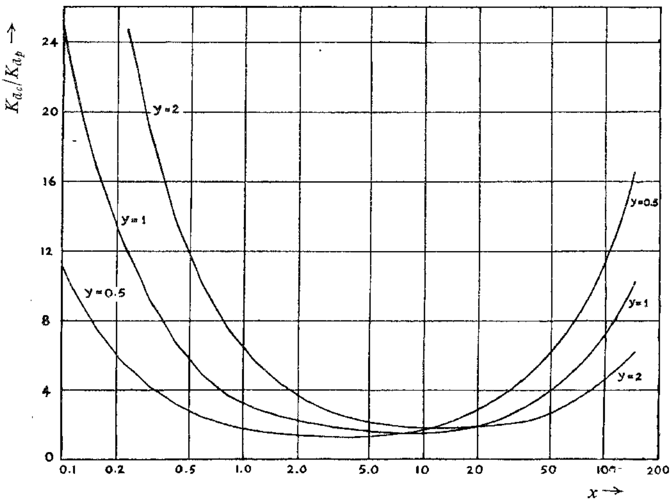

FIG. VIII
Graph showing the influence of the factors x and y on the design parameters of tubes in which the anode and the envelope are separate ($n=1$).

Making the substitutions, $d_o \cong 2l/\pi$, $l = x\,d_p$, $r = y\,d_p$, we have

$$\frac{K_{d_c}}{K_{d_p}} = \frac{[x + y\,\pi(1+n)]^2}{\pi x[1 + 2y(1+n)]} \tag{33}$$

If we take $n = 1$, the ratio of the design parameters is

$$\left(\frac{K_{d_c}}{K_{d_p}}\right)_{n=1} = \frac{(x + 2\pi y)^2}{\pi x(1 + 4y)} \tag{34}$$

The curves of $(K_{d_c}/K_{d_p})_{n=1}$, for three values of y are plotted in Fig. VIII These show, that, with the thin longitudinal prismatic design, a large increase in K_{d_c}/K_{d_p} may be realised through a large increase in x. Also a decrease in the value of y, which signifies a decrease in the inter electrode gap, makes for a better design.

The formulas for K_{d_c}/K_{d_p} set forth above give somewhat exaggerated values of this ratio. Formulas which allow for the side-gap between the cathode and the anode, in the case of tubes in which the anode and the envelope coincide, and for the space between the narrow end sides of the cathode and the envelope, in the case of tubes in which the anode and the envelope are apart, will be more accurate. The ratios of volumes derived in Section 2, include these side-gaps. If the cathode working surfaces are equal in area $(S_c = S_p)$, then

$$\frac{V_c}{V_p} = \frac{K_{d_c}}{K_{d_p}} \tag{35}$$

In assessing the relative merits of the tube-forms, the ratios of volumes previously set forth may be taken into account.

In equation (18) giving the ratio of volumes V_c/V_p, taking $n = 1$ and $y = 1$, as x assumes values from 100 to 1000, the ratio of volumes ranges from 7 to 64. Numerical values of x ranging to 1000 are quite practical. For instance, one may have cathode-thickness, $d_p = 0.1$ mm. and cathode length, $l = 100$ mm. making $x = l/d_p = 1000$.

Even if no approximations are made with regard to the volumes, the advantage with regard to over-all size, of the prismatic form is unmistakable. It should be regarded as quite feasible to have a prismatic tube occupying only one-tenth of the volume of an equivalent cylindrical tube. In the actual designing of the tube, the problem of overheating may arise, but it is probable that this can be solved without any undue lowering in (V_c/V_p).

5. COMPARISON OF THE VACUUM PROPERTIER OF THE CYLINDRICAL AND THIN PRISMATIC TUBE FORMS

In this section the two tube forms are compared, in respect of their vacuum moduli, the internal volume occupied by residual gases, the evolution of gases in the internal space and the diffusion of gases into the tube from the outside atmosphere.

(a) Vacuum Moduli

It has been previously emphasized[5] that the vacuum modulus (K_v) and the relative grade of vacuum (λ/r) have an inverse dependence on the interelectrode gap (r), and that it is desirable to keep r as small as possible. The minimum value of r may be selected almost independently of the actual geometrical form of the tube. In other words, the same small value of r is possible equally for the cylindrical and the thin prismatic tube forms. The relative grade of vacuum and the vacuum modulus attainable are about the same in both cases.

(b) Volume occupied by residual gases

For tubes equivalent in their electrical parameters - those with the smaller internal free volume will possess better vacuum properties, as the harmful effect of residual gases is reduced. In the comparison made below, only the volumes required to house the electrode systems inside the tube envelopes are considered, the additional volumes inside being ignored on the assumption that such volumes will be small and approximately equal for equivalent tubes of the two different geometrical forms.

For the prismatic tube (Fig. III) the free part of the main volume is

$$\begin{aligned} V_{pf} &= h\,(d_p + 2r + 2nr)\,(l + 2r) - h\,l\,d_p \\ &= 2hr\,(nl + l + 2nr + 2r + d_p) \end{aligned} \tag{36}$$

Far the cylindrical tube (Fig. IV), the corresponding volume is

$$\begin{aligned} V_{cf} &= h\,\tfrac{1}{4}\,\pi\,(d_c + 2\,r + 2\,nr)^2 - h\,\tfrac{1}{4}\,\pi\,d_c^2 \\ &= h\,\pi\,r\,(1+n)\,[d_c + r\,(1+n)] \end{aligned} \tag{37}$$

The ratio of the free volumes is

$$\frac{V_{cf}}{V_{pf}} = \frac{\pi\,(1+n)\,[d_c + r\,(1+n)]}{2\,(nl + l + 2\,nr + 2\,r + d_p)} \tag{38}$$

From the equality of cathode working surfaces $(d_c = 2l/\pi)$, and assuming $l = x\,d_p$ and $r = y\,d_p$, the ratio becomes

$$\frac{V_{cf}}{V_{pf}} = \frac{2x + \pi y\,(1+n)}{2\,[x + 2y + 1/(1+n)]} \tag{39}$$

For numerical values of x in the region of tens and hundreds, the ratio of free volumes V_{cf}/V_{pf} attains values closely to unity, whether $n = 0$ or $n \neq 0$. The conclusion is that the two tube forms are approximately the same, so far as the main volumes occupied by residual gases are concerned.

(c) Internal evolution of gases

It is assumed that the materials of the anode, the envelope and other parts of the tube are the same, as also the working temperature of the two tubes. It is further assumed that the volume of the evolved gas is proportional to the area of the evolving surface and that the rates of evolution are the same. [7, 8, 9]

For the cylindrical form with separate anode and envelope, the gas-evolving surfaces of interest are:

$$F_c(\text{cathode}) = 4 \cdot \tfrac{1}{4}\,\pi\, d_c^2 + 2\,\pi\, d_c \cdot h$$
$$= 4 \cdot (x\, d_p/\pi)\,(x\, d_p + \pi\, h)\,, \tag{40}$$

$$F_c(\text{anode}) = 2\,\pi\, h\,(d_c + 2\,r)$$
$$= 4\,h\, d_p\,(x + \pi\, y)\,, \tag{41}$$

and $$F_c(\text{envelope}) = \pi h(d_c + 2nr + 2r) + \tfrac{1}{4}\, 2\pi(d_c + 2r + 2nr)^2$$
$$= 2\,h\,d_p[x + \pi\, y(1 + n)] + 2(d_p^2/\pi)[x + \pi\, y(1 + n)]^2 \tag{42}$$

The corresponding gas-evolving surfaces for the prismatic form are

$$F_p(\text{cathode}) = 2\,hl = 2\,h\,x\,d_p, \tag{43}$$

$$F_p(\text{anode}) = 4\,hl = 4\,h\,x\,d_p, \tag{44}$$

and $$F_p(\text{envelope}) = 2h(l + 2r) + 2h(d_p + 2r + 2nr) + 2(l + 2r)\,(d_p + 2r + 2nr)$$
$$= 2d_p\,\{h[x + 1 + 2y(2 + n)] + d_p(x + 2y)[1 + 2y(1 + n)]\} \tag{45}$$

If a comparison is made of the gas evolving surfaces of the cathodes, we have

$$\frac{F_c(\text{cathode})}{F_p(\text{cathode})} = 2\left(\frac{x\,d_p}{\pi h} + 1\right) \tag{46}$$

$$\cong 2\left(\frac{1}{\pi} + 1\right) = 2.63, \tag{47}$$

if $h = g\,d_p$ and $g \simeq x$. Accordingly the prismatic cathode has a gas-evolving surface area approximately 2.5 times smaller than the cylindrical cathode.

The ratio of the gas-evolving surface areas of the anodes is

$$\frac{F_c(\text{anode})}{F_p(\text{anode})} = \frac{4\,h\,d_p(x + \pi\, y)}{4\,h\,x\,d_p} = \frac{x + \pi y}{x}\,, \tag{48}$$

which approximates to unity, for large values of x.

The ratio of the gas-evolving surface-areas of the envelopes, assuming $h = g\,d_p = l = x\,d_p$, becomes

$$\frac{F_c(\text{envelope})}{F_d(\text{envelope})} = \frac{[x + \pi\, y\,(1 + n)\,]\,[\pi\, x + x + \pi\, y\,(1 + n)\,]}{\pi\,\{x\,[x + 1 + 2y\,(2 + n)] + (x + 2y)[1 + 2y\,(1 + n)]\}} \tag{49}$$

Fig. IX shows how this ratio varies with x and y. It is higher than unity by $10 - 30\,\%$ for values of x in the order of tens and higher.

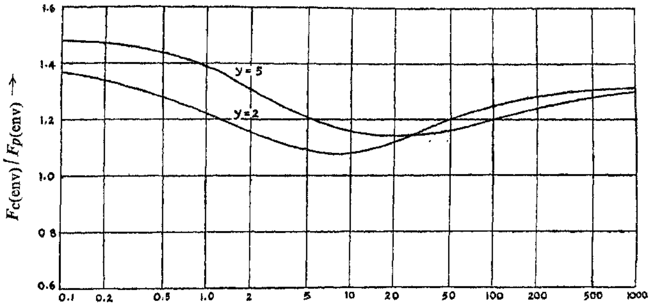

FIG. IX

Graph showing the influence of the factors x and y on the ratio $F_{c(envelope)}/F_{p(envelope)}$, $(n=1)$

From the standpoint of the internal gas evolving surfaces, the prismatic form possesses some advantage over the cylindrical form.

(d) Diffusion of gases into the tubes

The diffusion of geses will be dependent on the surface area of the envelope of the tube. The ratio of the envelope surface-areas of the equivalent prismatic and cylindrical tubes has been obtained already. For large values of x, in the range 100 and upwards, the surface area of the cylindrical envelope will be $20 - 30\,\%$ larger than that of the prismatic envelope. Accordingly the diffusion of gases into the cylindrical tube will be more.

The conclusion is that, from a consideration of the main vacuum properties, the thin prismatic tube is approximately equal, if not somewhat superior, to the equivalent cylindrical tube.

6. CONCLUSION

In the light of the foregoing considerations, it follows that the thin flat prismatic structure should get precedence over the cylindrical form. The smaller the thickness of such a tube, the smaller will be the magnitude of the design parameter K_d. The flat prismatic form brings about a considerable reduction in the volume of the tube. The decrease in size will reduce the evolution of residual gases. There will also be considerable saving in materials. The technology of production, will, in all probability, be simplified and automatized. There is no doubt that the flat prismatic tube will be cheaper to produce. This form, with its compactness, will be more convenient to use in many applications. There are thus many reasons why there should be a transition from the production of cylindrical tubes with thermionic cathodes to that of prismatic tubes. But there is a lot of conservatism that hampers this process, because the cylindrical form is more conventional and has been in use for many years. There may be unexpected difficulties, even major ones, in the realisation of this process. One hurdle to be crossed is the problem of the mechanical strength, against atmospheric pressure, of the flat prismatic vessel. So far as this point is concerned, the cylindrical form is evidently advantageous. In the case of prismatic structure, it will be necessary to reinforce the vessel with internal or external fins or some other means, in order to secure some rigidity. But these difficulties must be overcome, as the perspective of transition, from the cylindrical to the prismatic form of various electronic and ionic tubes with thermionic cathodes, is a very attractive one.

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