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R. L. NORTON ET AL
ELECTRON TUBE APPARATUS

2,619,611

Filed May 29, 1951

4 Sheets-Sheet 1

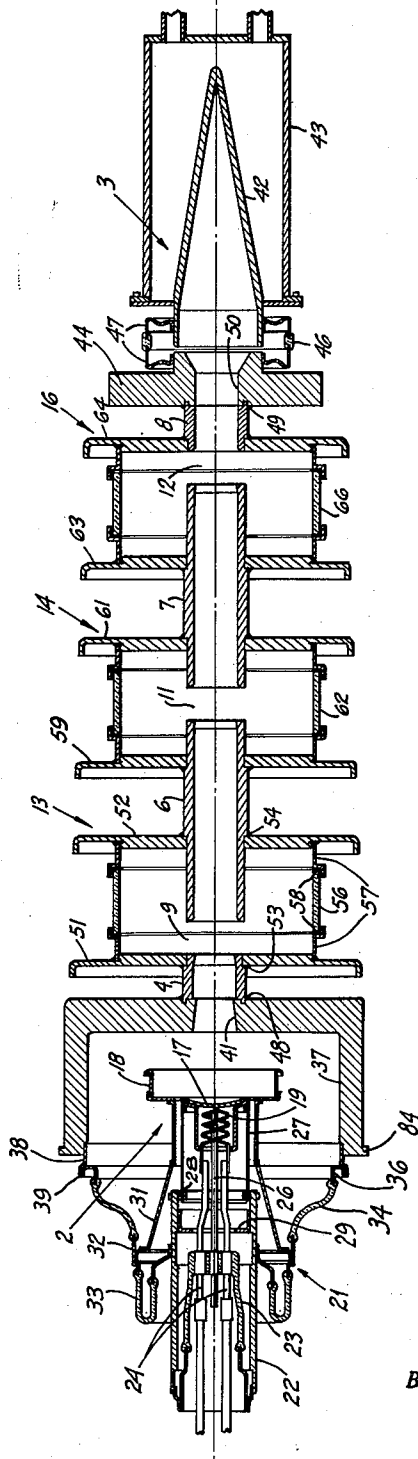


Fig. 1

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4 Sheets-Sheet 2

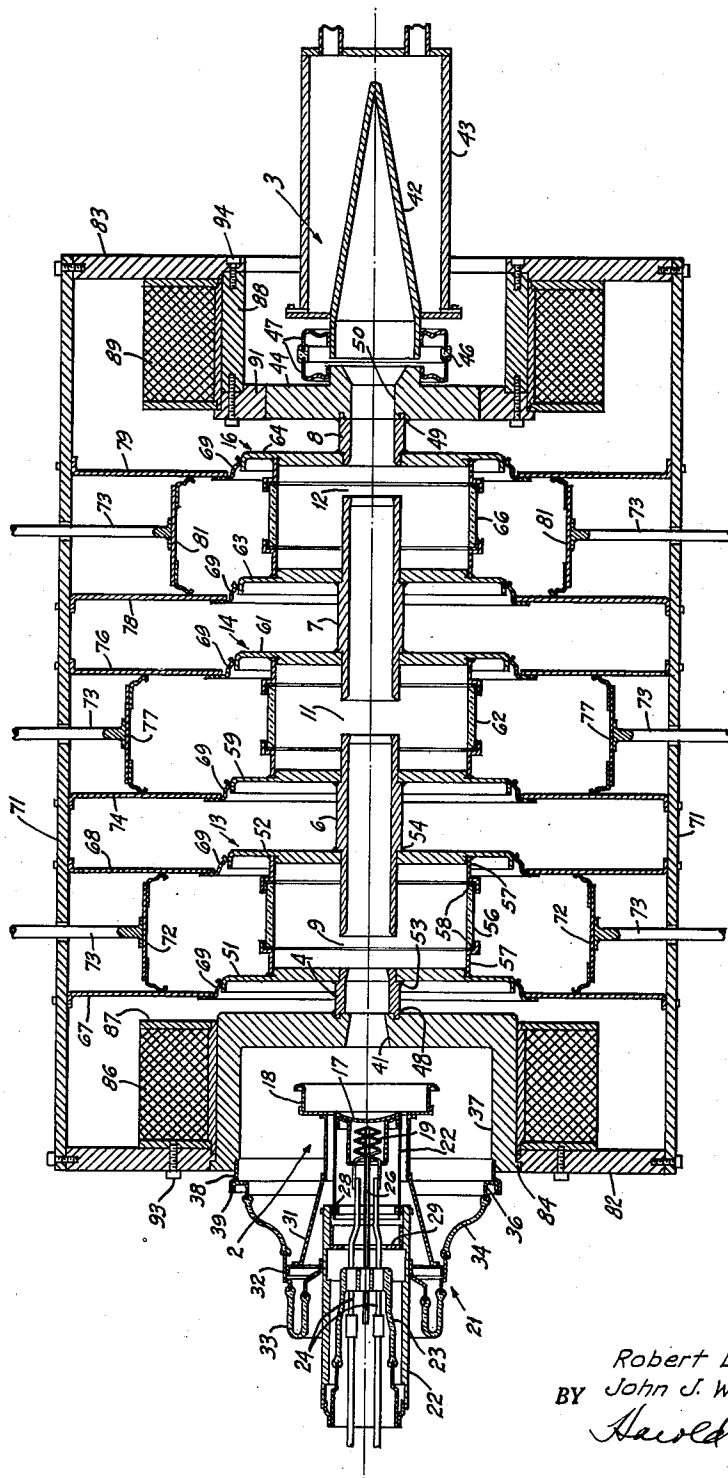


Fig. 2

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4 Sheets-Sheet 3

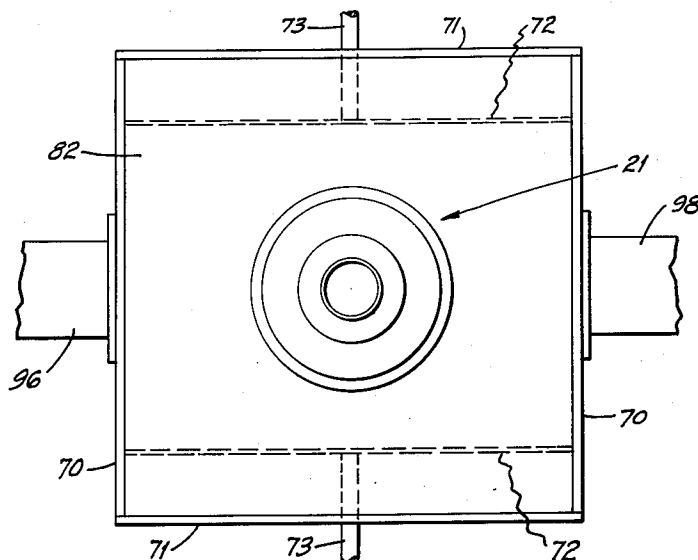


Fig. 3

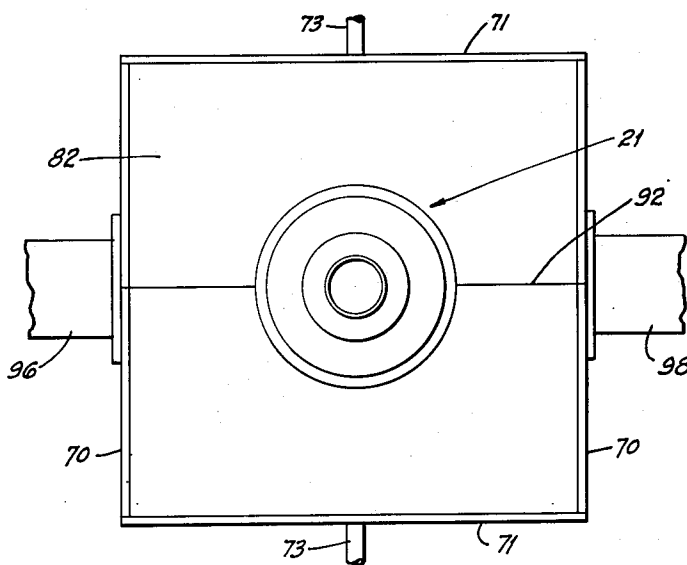


Fig. 5

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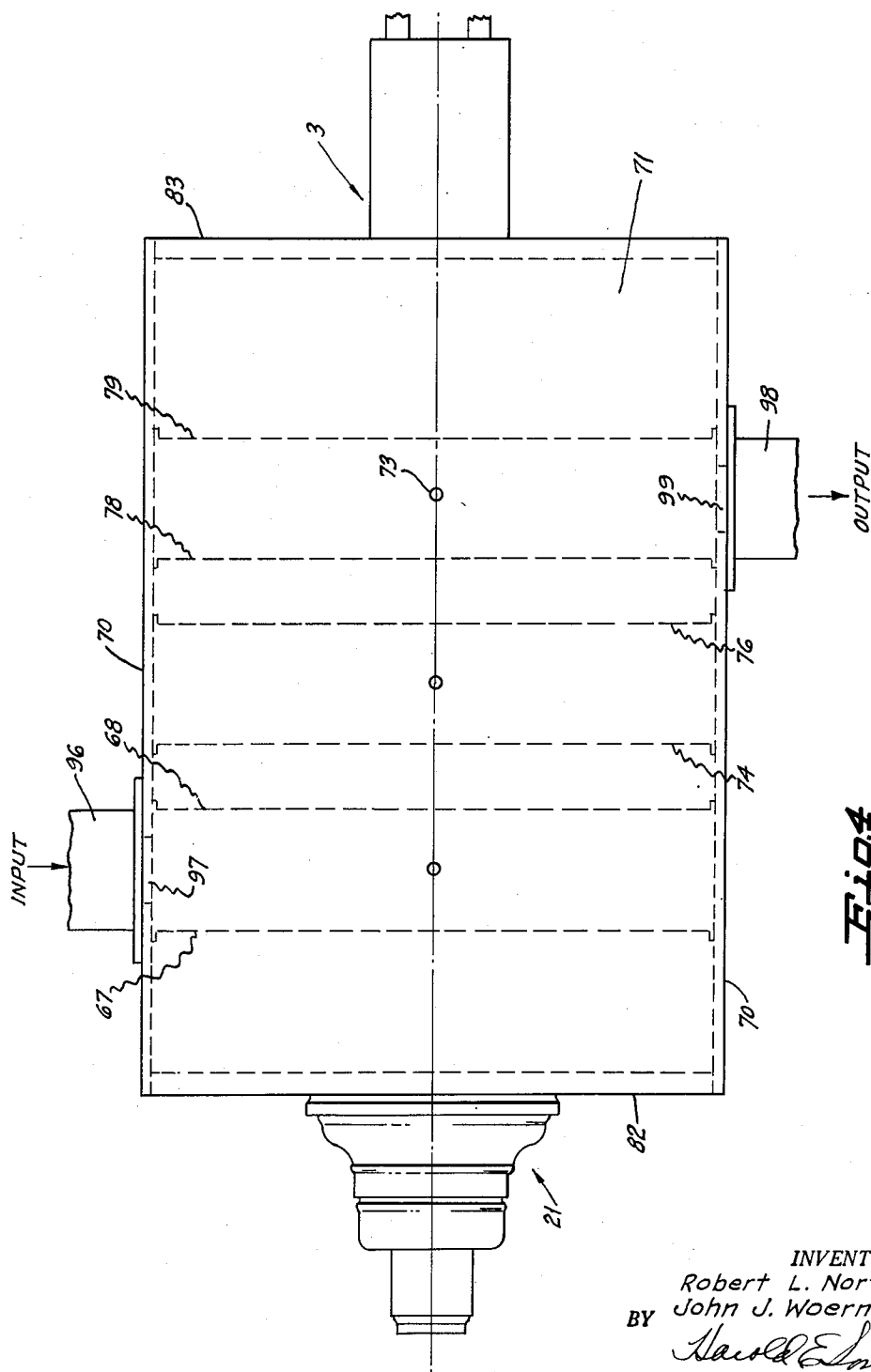


Fig. 4

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ELECTRON TUBE APPARATUS

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12 Claims. (Cl. 315-6)

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Our invention relates to electron tubes having cavity resonators, and more particularly to tubes of the velocity modulation type such as klystrons.

It is among the objects of our invention to provide a cavity type klystron having one or more cavity resonators disposed along the drift tube, and wherein a portion of the resonator lies within the evacuated envelope and another portion of the resonator is arranged external to the envelope.

Another object is to provide an electron tube apparatus of the character described having tuning means in the external portion of the resonator structure to achieve a wide tuning range for the tube.

Another object includes the provision of such tube apparatus in which the evacuated tube is fabricated as a unit separate from the external cavity structure, and in which the external structure provides a socket for receiving the tube.

Still another object is to provide such apparatus wherein the central portion of the resonator lying within the evacuated envelope is circular in shape to conform with cylindrical envelope construction, and wherein the external structure containing the tuning means is of rectangular configuration.

A further object is to provide apparatus of the character described in which the evacuated envelope is readily insertable into the external structure.

Still further objects relate to improvements in the focusing magnet and other external portions of the construction, and also to improvements in the electron tube structure per se.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of our invention. It is to be understood that we do not limit ourselves to this disclosure of species of our invention, as we may adopt variant embodiments thereof within the scope of the claims.

Referring to the drawings:

Figure 1 is an axial sectional view of the evacuated tube portion of our apparatus; and

Figure 2 is a similar view of the complete apparatus showing the tube inserted in the external socket structure.

Figure 3 is an end elevation view of the apparatus; and

Figure 4 is a plan view of the same.

Figure 5 is an end view similar to Figure 3 illustrating a modified construction.

In terms of broad inclusion our improved elec-

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tron tube apparatus comprises an elongated evacuated envelope, a cavity resonator disposed transversely of the envelope axis and having a central portion within the evacuated envelope and an outer portion external to the envelope, and tuning means in the external portion of the resonator. The external portion of the resonator structure is preferably rectangular in shape and the tuning means preferably comprises a slidable plunger in such rectangular portion. In our improved apparatus the external resonator structure serves as a socket for receiving the evacuated envelope, whereby replacement of the tube in the equipment is simplified.

Other improved features of our apparatus have to do with the envelope construction and also with the external structure carrying the focusing magnet and external portions of the resonator. Our apparatus embodying a klystron type of tube preferably includes a plurality of resonators, say three, spaced along the drift tube of the electron discharge device.

In greater detail, and referring to the drawings, Figure 1 shows the evacuated tube only and Figure 2 illustrates the tube in conjunction with the external socket structure. Referring first to Figure 1, the tube per se comprises an elongated generally cylindrical envelope having an electron gun 2 at one end and a collector electrode 3 at the other end. The electron beam from the gun to the collector passes through a drift tube made up of metal sections 4, 6, 7 and 8 extending axially of the envelope and having gaps 9, 11 and 12 therebetween. Such gaps are bridged by cavity resonator structures generally designated at 13, 14 and 16.

Electron gun 2 includes a disk-shaped cathode 17 and a surrounding focusing electrode 18, the cathode being heated by a coil 19, all of which is supported by a stem 21 forming an end of the evacuated envelope. The stem illustrated comprises a tubular metal cathode terminal 22 carrying an inside glass press 23 through which the heater coil leads 24 and center rod 26 are sealed. Cathode disk 17 is carried by a cylindrical support 27 fastened to the inner end of terminal 22 by a retaining ring 28, a heat shield 29 being preferably arranged in the terminal member to protect glass press 23. Focusing electrode 18 is carried by a conical support 31 fastened to a terminal ring 32, the latter being sealed to the cathode terminal member by a glass envelope section 33. A second glass section 34 sealed between terminal ring 32 and a metal supporting ring 36 completes the stem structure. Cathode

17 may be of the oxide coated type heated by radiation from the heater coil 19, as illustrated, or it may be of a material such as tantalum heated by electron bombardment from a filament, all in accordance with conventional practices.

The electron gun is housed in a cup-shaped metal section 37 of the envelope, which section is of iron and functions both as an anode for the gun and as a pole piece of a focusing magnet structure hereinafter described. Stem 21 is supported on pole piece 37 by an end ring 38 into which the ring 36 is brazed at 39. An aperture 41 in anode piece 37 is aligned with the cathode and is coaxial with the drift tube.

Collector 3 at the opposite end of the envelope comprises a hollow conical electrode 42, say of copper, cooled by a water jacket 43. This electrode is supported from a disk-shaped metal section 44 of the envelope, which section is of iron and functions as the second pole piece of the focusing magnet described later herein. A glass envelope section 45 sealed between flanges 47 provides a supporting connection between the collector electrode and pole piece 44. An aperture 50 in pole piece 44 is aligned with the collector electrode and is coaxial with the drift tube.

The above described elements of the electron tube function in a manner well known for klystron tubes of this type, namely, an electron beam from gun 2 is accelerated by a positive potential on anode 37 and passes through the drift tube, past the interaction spaces provided by gaps 9, 11 and 12, and finally terminates on collector electrode 3. The three cavity resonators 13, 14 and 16 coacting with the interaction spaces at gaps 9, 11 and 12 serve as the frequency determining elements of the device. In the tube illustrated, which functions as an amplifier, the input signal for modulating the electron stream is fed into the first resonator 13 and the radio-frequency output is taken from the third resonator 16, in accordance with the usual manner for three-cavity type klystrons.

An important feature of our tube apparatus resides in the construction of the cavity resonators. In our device the resonators are made in two parts, viz., an inner portion structurally integral with the evacuated envelope, and an outer portion external to the envelope. Figure 1 shows only those inner portions of the resonators which form part of the tube envelope.

Continuing with the description of Figure 1, drift tube end section 4 is connected to anode piece 37 at braze 48 and the other end section 8 is connected to piece 44 at braze 49. The intermediate sections 6 and 7 of the drift tube are axially aligned with the end sections 4 and 8, these several sections forming parts of the side walls of the evacuated envelope. The drift tube sections are of metal, preferably copper. Cavity resonators 13, 14 and 16, which are disposed transversely of the envelope axis, are mounted on the drift tube sections and form additional side wall portions of the evacuated envelope. In other words, the resonator structures provide vacuum-tight walls bridging the gaps between the drift tube sections.

Input resonator 13 comprises parallel disk-shaped metal end walls 51 and 52 metallurgically bonded to drift tube sections 4 and 6 at brazes 53 and 54, these end walls being also preferably of copper. A cylinder 56 of insulating material is sealed between the end walls, preferably by sealing to inwardly extending metal flanges 57

which are brazed to the inner surfaces of the end walls. The cylindrical wall 56 may be of glass fused to the sealing flanges 57, but we prefer to make the wall of ceramic and metallurgically bond it to copper flanges 57 at the brazes 53. A dense ceramic, such as the alumina or zircon type ceramic bodies, is satisfactory for the wall section 56. Known ceramic-to-metal bonding techniques, such as first metalizing the ends of the ceramic by the molybdenum powder sintering process and then brazing the metallized ends to the metal parts with silver solder, may be employed. A ceramic cylinder between the end walls of the cavity resonator is particularly desirable in a tube structure of this type, not only because of improved electrical properties but also on account of the superior mechanical strength of the ceramic body and brazed joint construction. Such mechanical considerations are especially important in a tube of our description where one is dealing with considerable length and massive parts.

The intermediate resonator 14 is of similar construction having end walls 59 and 61 brazed to drift tube sections 6 and 7 and with an insulating cylinder 62 sealed between such walls. Likewise, the output resonator 16 is made up of end walls 63 and 64 brazed to drift tube sections 7 and 8 with an insulating cylinder 66 sealed therebetween.

For convenience of plugging the tube into an external structure, the end walls of the cavity resonators are preferably made of different diameters decreasing in size from one end of the tube to the other, preferably from the cathode end to the collector end as illustrated. For the same purpose, the pole piece 37 at the cathode end is of largest diameter and the pole piece 44 at the collector end is of smallest diameter relative to the other parts. To further assist in such plug-in operation, the end walls of the resonators are preferably provided with back-turned lips along the peripheral edges.

Figures 2, 3 and 4 show the tube above described in conjunction with the structure lying outside the evacuated envelope, which external structure completes the cavity resonators and the focusing magnetic circuit. The end walls of input resonator 13 are extended by outer rectangular wall sections 67 and 68 having apertures for receiving the central disk-shaped wall sections 51 and 52 on the envelope. These outer wall sections, also preferably of copper, are detachably connected to the center wall sections by spring contact fingers 69 on the outer sections frictionally engaging the peripheral edges of the center sections. By this construction it is seen that the resonator 13 is made up of two parts, namely, a circular central portion within the evacuated envelope and an outer rectangular portion external to the envelope, the insulating cylinder 56 providing a vacuum-tight partition wall between the internal and external portions of the resonator. As shown in Figures 3 and 4 the other two outer walls of the resonator are formed by the metal side plates 70 of the external structure. Support for the transverse walls 67 and 68 is provided by upper and lower plates 71 of the external structure, as shown in Figure 2.

Tuning means are provided in the external portion of the resonator. Such means preferably comprise a pair of oppositely disposed rectangular plungers 72 slidably engaging the walls of the outer rectangular portion of the resonator. These plungers are actuated by suitable plunger rods 73

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whereby the size of the resonator may be adjusted to vary its resonant frequency. An important advantage of this resonator construction is that the operating frequency of the device may be varied over a relatively wide band of frequencies. This feature is very important in certain applications and contributes materially to the utility of an electron tube apparatus of the subject type.

The intermediate resonator 14 is of similar external construction having outer rectangular end wall sections 74 and 76 forming extensions of the central wall sections 59 and 61, and having tuning plungers 77. The output resonator likewise has outer rectangular end wall sections 78 and 79 forming extensions of the central wall sections 63 and 64, and is provided with tuning plungers 81.

The outer end sections of the several resonators have their apertures graded in size to match the stepped diameters of the wall sections on the tube envelope. This is clearly shown in Figure 2 and enables the tube containing the internal portions of the resonators to be plugged endwise into the external structure, namely, to be plugged in from left to right as illustrated in the last mentioned view. In other words, the external structure provides a socket for the tube, which socket structure contains the outer portions of the cavity resonators. This is an important feature in the practical application of large tubes in this kind of apparatus, as will be readily appreciated.

The housing or casing provided by the external structure is completed by metal end plates 82 and 83 bolted to the lateral wall plates 70 and 71 as shown in Figures 2, 3 and 4. These end plates are apertured to receive the ends of the tube and are fitted to the pole piece sections 37 and 44 carried by the envelope. Front end plate 82 has an aperture sized to slidably engage pole piece 37, the latter having a lip 84 to provide a stop when the tube is fully inserted. End plate 82 also carries one section 86 of the focusing coil magnet, which coil surrounds the tube and is held by a metal retaining ring 87 fastened to the external structure. The back end plate 83 has an inwardly projecting iron sleeve 88 carrying the other section 89 of the focusing coil magnet. An inner ring 91 on sleeve 88 is sized to slidably fit on the periphery of the disk-shaped pole piece 44 on the tube envelope.

In our construction end plates 82-83 and upper and lower plates 71 of the external structure are made of iron and function as elements of the magnetic circuit. In other words, these parts provide an iron yoke for the magnet to confine the external magnetic field, which yoke connects the pole pieces of the envelope. This magnet and pole piece construction, wherein the external magnet structure coacts with pole pieces on the evacuated envelope, provides a highly efficient magnetic field concentrated along the axis of the tube. Such a field is desirable in a device of this kind to insure an electron stream of optimum density through the drift tube.

Another desirable result achieved by our construction is that the external portions of the resonators as well as the heaviest parts of the magnetic device are carried by and form a structurally integral part of the external socket structure, it being understood that the upper and lower plates 71 serve the dual function of magnet circuit elements and supports for the external resonators. Side plates 70, which form lateral walls of the resonators, are preferably of copper. These side plates may be continuous, as illustrated, or

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may be made in sections to extend only across the sides of the resonators.

Figure 5 shows a modification in which the external structure including the transverse external wall sections of the resonators, is split lengthwise along a plane 92 axially of the tube. This permits the upper half of the structure to be removed or hinged for insertion of the tube downwardly into the lower half as a cradle. This has certain advantages over endwise insertion because there is less wear and tear on the contact fingers. In order to replace a tube with the split structure shown in Figure 5, the bolts 93 and 94 (Figure 2) are first removed to release the magnets, after which the upper half of the structure is opened or lifted off. The tube and encircling magnet coils may then be lifted out. In the case of the split external structure shown in Figure 5, the resonator wall sections on the envelope need not be of different diameters, as will be readily understood.

Figures 3 and 4 also show the input and output transmission lines, which are illustrated as wave guides although coaxial lines may be employed. The input line 96 is coupled with the input resonator through an iris opening 97 in a side wall plate 70 and the output line 98 is coupled with the output resonator through an iris opening 99 in the other side wall plate.

We claim:

1. An electron tube apparatus comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope and forming side walls of the evacuated envelope, said drift tube comprising spaced sections with a gap therebetween, a cavity resonator disposed transversely of the envelope axis adjacent said gap and having a central portion within the evacuated envelope and an outer portion external to said envelope, and tuning means in the external portion of the resonator; said resonator comprising metal end walls mounted on adjacent drift tube sections and extending outwardly from said sections, and a cylinder of insulating material having a diameter larger than that of the drift tube sealed between said walls and providing a vacuum-tight partition wall between the internal and external portions of the resonator.

2. An electron tube apparatus comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope and forming side walls of the evacuated envelope, said drift tube comprising spaced sections with gaps therebetween, a plurality of cavity resonators disposed transversely of the envelope axis adjacent said gaps and forming walls of the envelope across said gaps, each of the resonators having a central portion within the evacuated envelope and an outer portion external to said envelope, tuning means in the external portions of the resonators, a focusing magnet concentric with the drift tube and having pole pieces adjacent opposite ends of the envelope, and an outer metallic shell member connecting the pole pieces, said shell member providing support for the external portions of the resonators.

3. A cavity resonator type electron tube comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope and forming

side walls of the evacuated envelope, said drift tube comprising spaced sections with a gap therebetween, a cavity resonator disposed transversely of the envelope axis adjacent the gap, said resonator comprising metal end walls mounted on adjacent drift tube sections, and extending outwardly from said sections axially extending flanges on said end walls, and a cylinder of insulating material having a diameter larger than that of the drift tube sealed to said flanges and providing a vacuum-tight wall across said gap.

4. A cavity resonator type electron tube comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope and forming side walls of the evacuated envelope, said drift tube comprising spaced sections with a gap therebetween, a cavity resonator disposed transversely of the envelope axis adjacent the gap, said resonator comprising metal end walls mounted on adjacent drift tube sections, and extending outwardly from said sections axially extending flanges on said end walls, and a cylinder of ceramic having a diameter larger than that of the drift tube metallicity bonded to said flanges and providing a vacuum-tight wall across said gap.

5. A cavity resonator type electron tube, comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope and forming side walls of the evacuated envelope, said drift tube comprising spaced sections with gaps therebetween, a plurality of circular cavity resonator portions disposed transversely of the envelope axis at the gaps, said resonator portions comprising disk-shaped metal end walls mounted on adjacent drift tube sections and extending outwardly from said sections, and cylinders of insulating material having diameters larger than that of the drift tube sealed between said walls and providing vacuum-tight walls across the gaps, the outer edges of said disk-shaped end walls providing terminals for the resonators.

6. A cavity resonator type electron tube, comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope and forming side walls of the evacuated envelope, said drift tube comprising spaced sections with gaps therebetween, a plurality of circular cavity resonator portions disposed transversely of the envelope axis at the gaps, said resonator portions comprising disk-shaped metal end walls mounted on adjacent drift tube sections and extending outwardly from said sections, and cylinders of insulating material having diameters larger than that of the drift tube sealed between said walls and providing vacuum-tight walls across the gaps, the outer edges of said disk-shaped end walls providing terminals for the resonators, said resonator end walls decreasing in diameter from one end of the tube to the other.

7. A cavity resonator type electron tube, comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope and forming side walls of the evacuated envelope, said drift tube comprising spaced sections with gaps therebetween, a plurality of circular cavity resonator portions disposed transversely of the envelope

axis at the gaps, said resonator portions comprising disk-shaped metal end walls mounted on adjacent drift tube sections and extending outwardly from said sections, cylinders of insulating material having diameters larger than that of the drift tube sealed between said walls and providing vacuum-tight walls across the gaps, the outer edges of said disk-shaped end walls providing terminals for the resonators, and pole pieces adjacent opposite ends of and forming portions of the envelope.

8. A cavity resonator type electron tube, comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope and forming side walls of the evacuated envelope, said drift tube comprising spaced sections with gaps therebetween, a plurality of circular cavity resonator portions disposed transversely of the envelope axis at the gaps, said resonator portions comprising disk-shaped metal end walls mounted on adjacent drift tube sections and extending outwardly from said sections, cylinders of insulating material having diameters larger than that of the drift tube sealed between said walls and providing vacuum-tight walls across the gaps, the outer edges of said disk-shaped end walls providing terminals for the resonators, a cup-shaped pole piece adjacent the cathode end of the envelope and forming portions of the envelope about said cathode, and a disk-shaped pole piece forming portions of the envelope adjacent said collector electrode.

9. A cavity resonator type electron tube apparatus, comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope and forming side walls of the evacuated envelope, said drift tube comprising spaced sections with gaps therebetween, a plurality of circular cavity resonator portions disposed transversely of the envelope axis at the gaps, said resonator portions comprising disk-shaped metal end walls mounted on adjacent drift tube sections and extending outwardly from said sections, cylinders of insulating material having diameters larger than that of the drift tube sealed between said walls and providing vacuum-tight walls across the gaps, the outer edges of said disk-shaped end walls providing terminals for the resonators, and pole pieces adjacent opposite ends of and forming portions of the envelope, said pole pieces and resonator end walls decreasing in diameter from one end of the tube to the other.

10. A cavity resonator type electron tube apparatus, comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope and forming side walls of the evacuated envelope, said drift tube comprising spaced sections with gaps therebetween, a plurality of circular cavity resonator portions disposed transversely of the envelope axis at the gaps, said resonator portions comprising disk-shaped metal end walls mounted on adjacent drift tube sections and extending outwardly from said sections, cylinders of insulating material having diameters larger than that of the drift tube sealed between said walls and providing vacuum-tight walls across the gaps, the outer edges of said disk-shaped end walls providing terminals for the resonators; an external structure providing a socket for the en-

velope, and outer cavity resonator portions on the external structure registrable with the circular resonator portions of the envelope and having contacts engageable with said terminals.

11. A cavity resonator type electron tube apparatus, comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope and forming side walls of the evacuated envelope, said drift tube comprising spaced sections with gaps therebetween, a plurality of circular cavity resonator portions disposed transversely of the envelope axis at the gaps, said resonator portions comprising disk-shaped metal end walls mounted on adjacent drift tube sections and extending outwardly from said sections, cylinders of insulating material having diameters larger than that of the drift tube sealed between said walls and providing vacuum-tight walls across the gaps, the outer edges of said disk-shaped end walls providing terminals for the resonators, pole pieces adjacent opposite ends of and forming portions of the envelope; an external structure providing a socket for the envelope, outer cavity resonator portions on the external structure registrable with the circular resonator portions of the envelope and having contacts engageable with said terminals, and a focusing magnet on the external structure and having parts registrable with said pole pieces.

12. A cavity resonator type electron tube apparatus, comprising an elongated evacuated envelope, an electron gun at one end of the envelope and a collector electrode at the other end, a drift tube extending axially of the envelope

and forming side walls of the evacuated envelope, said drift tube comprising spaced sections with gaps therebetween, a plurality of circular cavity resonator portions disposed transversely of the envelope axis at the gaps, said resonator portions comprising disk-shaped metal end walls mounted on adjacent drift tube sections and extending outwardly from said sections, cylinders of insulating material having diameters larger than that of the drift tube sealed between said walls and providing vacuum-tight walls across the gaps, the outer edges of said disk-shaped end walls providing terminals for the resonators; an external structure providing a socket for the envelope, and outer cavity resonator portions on the external structure registrable with the circular resonator portions of the envelope and having contacts engageable with said terminals, said external structure being separable along a longitudinal plane for receiving the envelope.

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