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[54] **OUTPUT DEVICES FOR MICROWAVE TUBES SUCH AS KLYSTRONS, AND KLYSTRONS INCORPORATING SUCH OUTPUT DEVICES**

[75] Inventors: **Paul Aucouturier; Jean Hervier,** both of Paris 8e, France

[73] Assignee: **Thomson-CSF,** Paris, France

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[52] **U.S. Cl.** **315/5.39,** 315/3.5, 315/39.53, 333/26, 333/33

[51] **Int. Cl.** **H01j 25/10**

[58] **Field of Search** 315/5.39, 5.48, 3.5, 315/39.53; 333/26, 33

[56] **References Cited**

UNITED STATES PATENTS

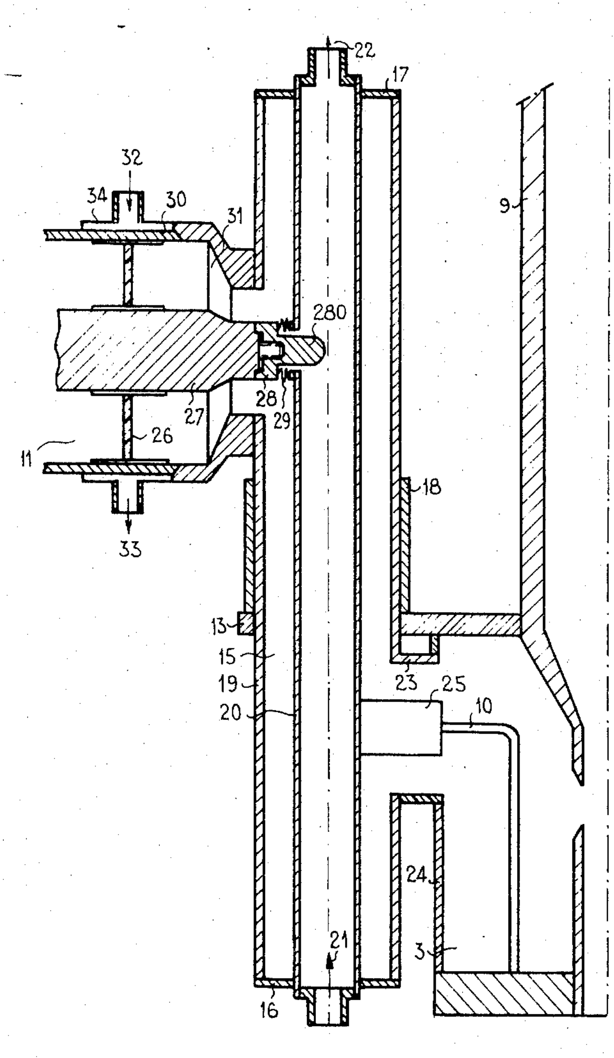
3,392,303	7/1968	Wolff et al.	315/5.39
3,310,704	3/1967	Symons et al.	315/5.39
3,644,771	2/1972	Kennedy	315/5.35
3,054,925	9/1962	Walter et al.	315/5.48

Primary Examiner—Rudolph V. Rolinec
Assistant Examiner—Saxfield Chatmon, Jr.
Attorney—John W. Malley, G. Lloyd Knight et al.

[57] **ABSTRACT**

Output devices for microwave tubes such as klystrons comprising an auxiliary coaxial line parallel to the direction of the electron beam in the tube, and connected between the output coupling loop which picks off the power from the tube, and a coaxial line section which constitutes the output line to which the load circuit is connected. The length of said auxiliary coaxial line determines the location of the output section. This device can in particular be used in klystrons and especially klystrons employing magnetic focussing.

6 Claims, 5 Drawing Figures



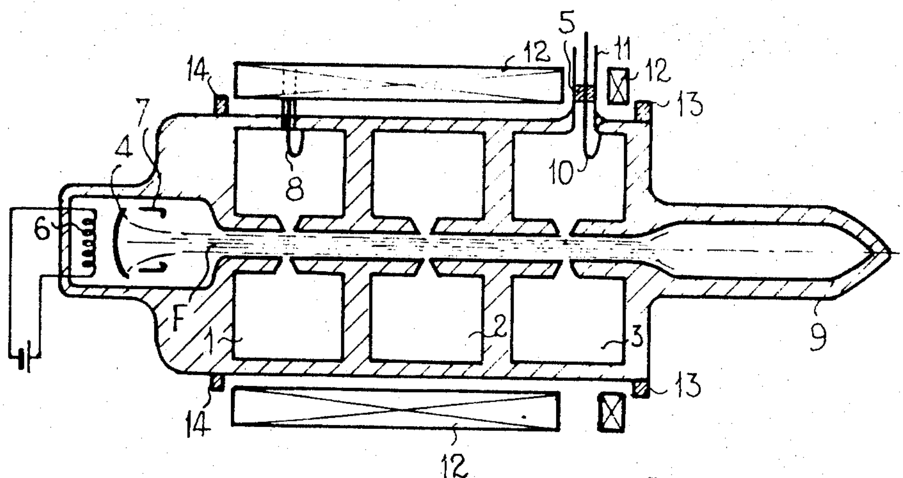
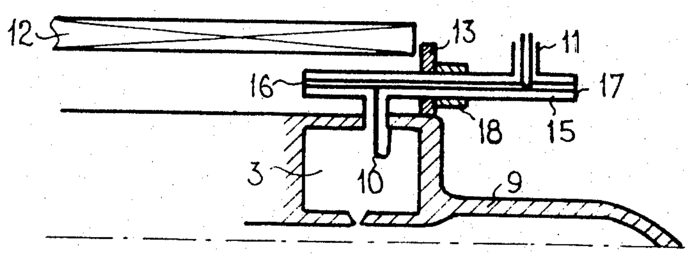


FIG. 1

FIG. 2



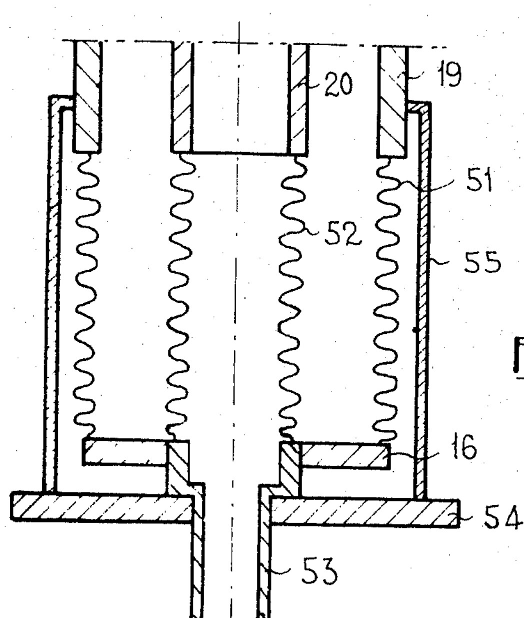


FIG. 5

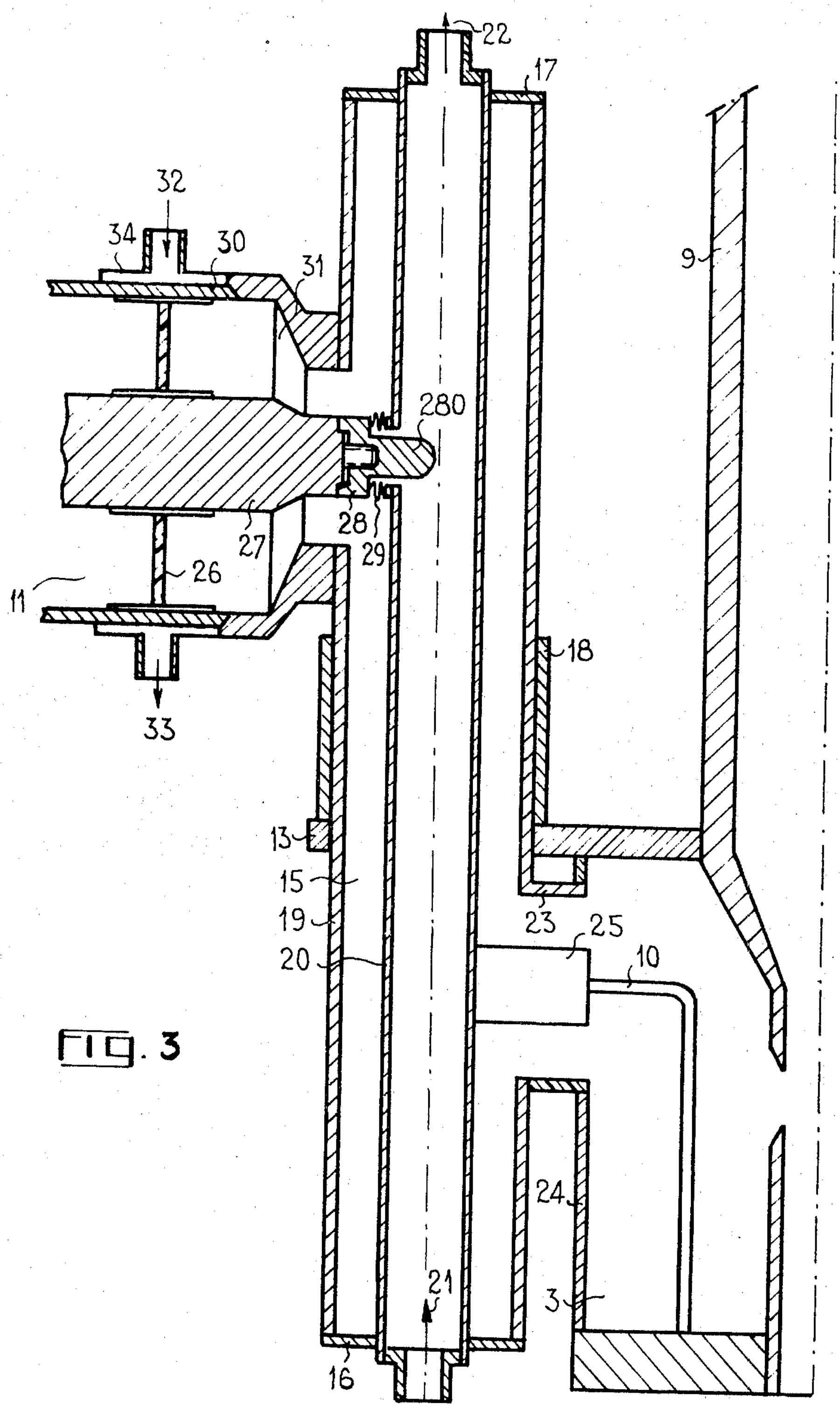

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FIG. 3

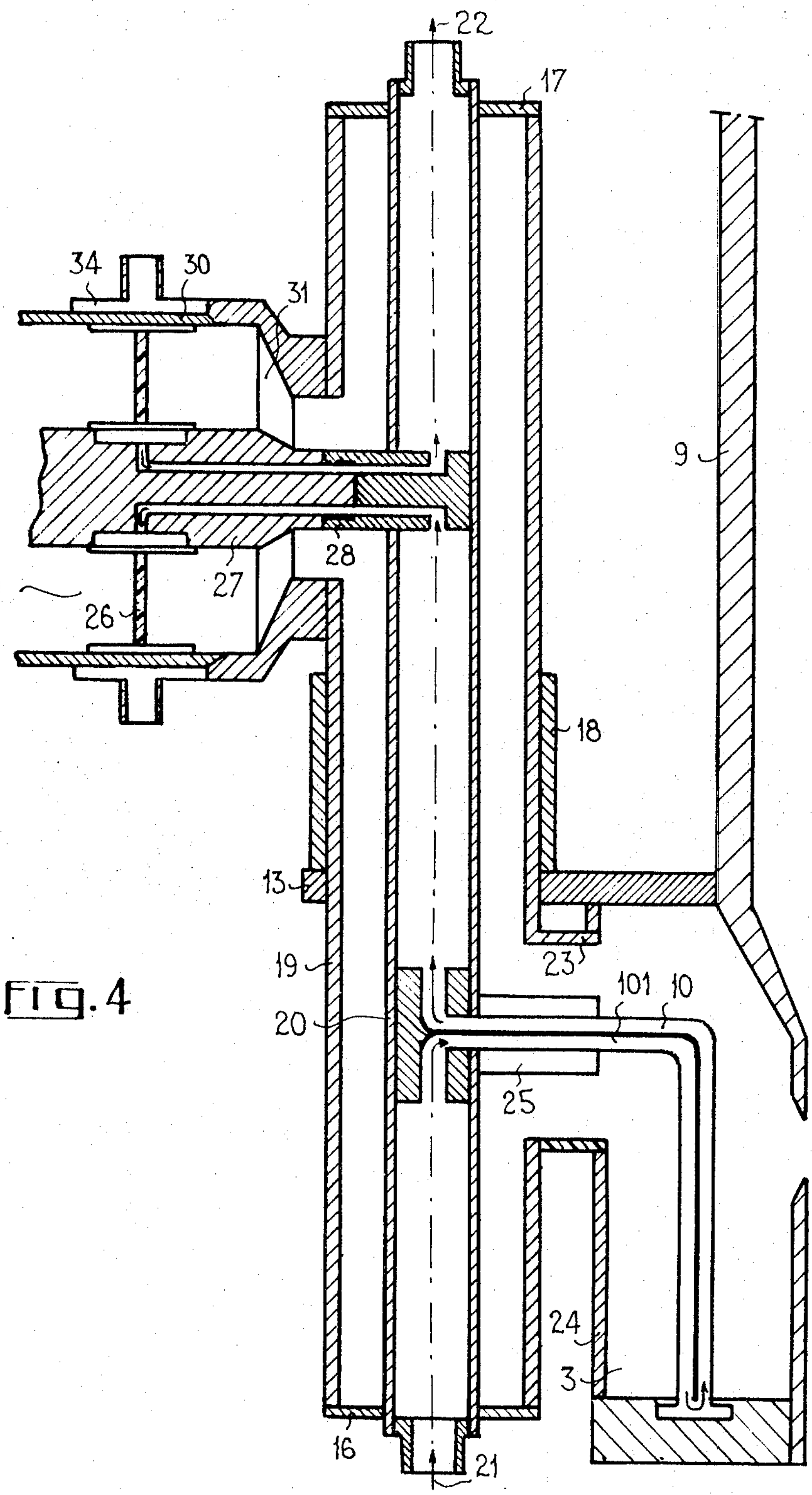

FIG. 4

OUTPUT DEVICES FOR MICROWAVE TUBES SUCH AS KLYSTRONS, AND KLYSTRONS INCORPORATING SUCH OUTPUT DEVICES

The present invention relates to improvements in the output devices of microwave tubes such as klystrons. It relates more particularly to devices which enable the substantial high-frequency power delivered by klystron amplifiers, to be picked off, these powers moreover possibly covering sufficiently wide frequency bands for there to be problems of matching. The invention likewise relates to improved klystrons of this type.

In this kind of tubes, the high-frequency power is generally picked off by a coupling loop provided in the final cavity for the collector, the output device comprising, in addition to said coupling loop, a section of transmission line, coaxial line for example, terminated in a flange to which the load network is connected.

The design of these output devices poses a number of problems which are the more difficult to resolve the higher the output power and the wider the frequency band covered.

In the klystrons which have thus far been used, the coupling loop and line section constituting the output device are fixed directly to the body of the klystron at the level of the last cavity, on a vacuum-tight window which provides separation between the body of the evacuated klystron and the load circuits which are at atmospheric pressure or may even be pressurized to beyond that level. This arrangement has severe drawbacks.

In other words, the line section or flange used for the connection of the tube to the load circuit, is arranged at a location where the electron beam of the klystron still has to be focussed, this indeed particularly accurately ; it is in this region that the defocussion of the beam, due to deceleration in the last cavity, is the most crucial.

In high-power klystrons, the kind more particularly at issue here, the focussing is generally produced by magnetic lenses in the form of coils whose magnetic circuits are closed by soft iron polepieces in accordance with a well known technique.

Using the output devices thus far known, it is necessary, in order to be able to connect the load network to the output of the tube, for the focussing coil to terminate before the region where the output device is fixed, and this disturbs the focussing function which is no longer properly ensured right up to the collector. In certain kinds of equipment, in order to reduce the severity of this disturbance, an auxiliary focussing coil is added at the other side of the output device considered in relation to the first coil, that is to say between said device and that polepiece of the tube which is arranged at the level of the collector. This kind of design increases the bulk, weight and cost of the focussing system. In all cases, there is a hiatus in focussing which is the greater the thicker the section of output line, being therefore especially marked in the case of high power tubes.

Moreover, the operations of connection of the tube to the load circuit are extremely difficult, this connection taking place in a particularly restricted zone between the focussing coils ; the problems of cooling these output devices, which are the more severe the higher the power they are transmitting, are quite delicate and for example require water circuits of quite

complex design ; finally, impedance matching is not readily possible and this is more of a nuisance the wider the frequency band within which the klystron operates.

The object of the invention is to design output devices which enable the high-frequency power produced by klystrons to be picked off, in particular the power produced by klystron amplifiers operating in wide frequency bands, which devices are improved in terms of their design and arrangement so that they do not disturb the focussing of the klystron electron beam, so that they enable connection to the load network to be effected and so that they are easy to cool even where very large output powers are being handled.

According to the invention there is provided an output device for microwave tubes such as klystrons, for picking off the high-frequency power delivered by the tube within a wavelength range extending around a mean wavelength *l*, which device comprises an output coupling loop arranged on said tube, a section of coaxial output line outside said tube and connected to a circuit called load circuit in which said power is utilised, and a vacuum-tight isolating window which provides a seal between the body of the evacuated tube and the load circuit, and an auxiliary coaxial line connecting said coaxial output line and said output coupling loop, said auxiliary coaxial line being parallel to the direction of the electron beam propagating within the tube and having a length substantially equal to $(2n + 3)$ ¼, where n is a whole number, said auxiliary coaxial line being short-circuited at its two ends, said output coupling loop and said coaxial output line respectively being connected to said auxiliary coaxial line at distance substantially equal to one-fourth from its two ends.

Other objectives, features and results of the invention will become apparent from the ensuing description given by way of a non-limitative example and illustrated by the attached figures in which :

FIG. 1 is a highly schematic sectional view of a klystron amplifier with magnetic focussing, equipped with a prior art output device ;

FIG. 2 is a highly schematic sectional view illustrating the principle of an output device in accordance with the invention fitted to a klystron only part of which has been shown ;

FIG. 3 is a sectional view schematically illustrating one embodiment of the device shown in FIG. 2 ;

FIG. 4 illustrates a variant embodiment of the device shown in FIG. 2

FIG. 5 is a schematic view of a short-circuited variable end of the coaxial line fitted to the klystron output devices in accordance with the invention.

FIG. 1 illustrates, highly schematically, a high-power klystron amplifier provided, in this example, with three cavities **1**, **2** and **3**. The electron source producing the electron beam F which propagates along the klystron axis, is constituted for example by a cathode **4** emitting electrons and heated by a filament **6**. A system of electrodes appropriately arranged and biassed and schematically illustrated at **7**, concentrates the beam F emitted by the cathode **4** along the klystron axis.

The beam F, accelerated by the electric field developed by the bias voltages which are applied in the conventional manner by supply means which have not been shown here, is modulated by the input high-frequency voltage to be amplified, applied to the first cavity **1** by a coupling loop schematically indicated by

8, and finally picked up by the collector 9. The amplified high-frequency power is picked off by a device which, as already stated, comprises a coupling loop 10 and a coaxial output line 11. A vacuum-tight isolating window 5 provides a sealed transition between the tube and the coaxial output line.

Because of the high output power, the diameter of this line is relatively large, and, as already mentioned, necessitates the termination of or a substantial interruption in the focussing coils 12 which surround the klystron and focuss the beam F. The elements 13 and 14 schematically indicate the polepieces associated with these coils.

FIG. 2 provides a highly schematic illustration of the principle of the output device in accordance with the invention. The high-frequency power is again picked off in the last cavity 3 using the coupling loop 10. But this coupling loop 10 is no longer directly connected to the coaxial output line section 11 which is used to connect the klystron to the load circuit. The connection is effected through the medium of a coaxial line 15 parallel to the direction of propagation of the electron beam within the tube. This line 15 is short-circuited at the two ends 16 and 17. The coupling loop 10 supplies to it power which it has picked off from the tube, being in fact connected to its central conductor at a distance substantially equal to a quarter of the mean wavelength 1 of the power produced by the klystron, namely ¼, from the end 16. The output line section 11 receives this output power, being itself connected to the line 15 at a distance of around ¼ from the second end 17 of said line.

The distance between the points of connection of the loop 10 and the section 11 to the line 15, is in the order of an odd whole number multiple of the quarter wavelength, namely $(2n + 1)$¼. The total length of the line 15 is thus around $(2n + 3)$¼.

Because of this arrangement, power transmission is suitably effected from the loop 10 to the line section 11, the two short-circuits, located at ¼ from these two elements, not affecting this transmission and the line section 11, whose position along the axis of the tube is defined by the choice of n, being located beyond the zone in which the focussing coils 12 are located, so that these latter can extend uninterruptedly to the level of the collector 9. It is merely necessary to arrange for these coils to have a slightly larger internal diameter so that they can be located around that part of the line 15 which is terminated by the end 16. As far as the polepiece 13 is concerned, this need merely have an opening formed in it to pass the line 15.

To prevent any possible magnetic losses due to the passage of the line 15 through the polepice 13, a soft steel sleeve 18 can be arranged around the line 15 as the figure shows

In the figure, the vacuum-tight window has been omitted.

It should be noted that the device in accordance with the invention is particularly relevant to magnetically focussed klystrons because of the problem of the coils. However, it can be used in electrostatically focussed klystrons for reasons of bulk and case of manufacture or connection to the load circuit.

Thus, an improved kylstron of the kind hereinbefore described, retains good focussing over the whole length of the electron beam trajectory. Moreover, the connection of the load circuit to the output line section 11 is readily effected and indeed at a point which is easily accessible. Finally, the cooling of the output device is very much facilitated as FIGS. 3, 4 and 5 will show, as also is its matching within a wide frequency band.

FIG. 3 illustrates in section and in a more detailed manner than FIG. 2, an embodiment of an output device in accordance with the invention.

(In all these figures, similar references indicate similar elements).

As already indicated, the external conductor 19 and the internal conductor of the coaxial line 15, are short-circuited at their two ends by short-circuiting caps 16 and 17. The central conductor 20 of said line can thus very easily by used to cool the output device. All that is necessary is to pass through it a cooling fluid such as water as indicated by the two arrows 21 and 22.

In the example illustrated here, n is made equal to 0 and the total length of the line 15 is equal to ¾ l.

The coupling loop 10 is connected to the line 15 through the medium of a coaxial line section whose outer conductor 23 is brazed to the walls 24 of the output cavity 3 and whose inner conductor 25, carrying the loop 10, is connected to the inner conductor of the line 15.

In this embodiment, the vacuum-tight window 26 is arranged in the output line section 11 hose inner conductor 27 is connected to that 20 of the line 15. This connection is made for example through the medium of a component 28 screwed to the conductor 27 and fixed to the centre conductor 20 of the line 15 by a flexible diaphragm 29 which, because of its elasticity, enables the inherent mechanical tolerances to be compensated and correct electrical contact to be established between these various elements. The ceramic ring 26 constituting the vacuum-tight window is brazed for example to the centre conductor 27 of the section 11 and to its outer conductor 30 which latter, through a conventional taper junction 31, is fixed to the outer conductor 19 of the line 15.

The cooling of the vacuum-tight window 26 is effected by water circulation 32, 33 through a jacket 34. Moreover, the component 28 is extended, at 280, into a tube constituted by the centre conductor 20 of the line 15, in order to short-circuit the thermal impedance which is presented in particular by the flexible diaphragm 29.

In the case of very high-power tubes, it may be necessary to provide still more efficient cooling of the coupling loop and the vacuum-tight window. FIG. 4 provides an example of the design of this kind of device. The coupling loop is then constituted by two parallel tubes 10 and 101 through which cooling water circulates in the direction of the arrow 21. Similarly, for the cooling of the vacuum-tight window, a double circuit provides delivery and return of water from the central conductor 20 of the line 15, to the vacuum-tight window 26.

In another variant embodiment which has not been shown, the vacuum-tight window can be arranged at any point between the output line section 11 and the body of the tube, and in particular in the coaxial line 15.

In yet another variant embodiment, the short-circuiting caps 16 and 17 terminating the coaxial line 15 can be adjustable in order to provide the best possible matching of the output device.

FIG. 5 illustrates an embodiment of adjustable caps of this kind. The ends of the internal **20** and external **19** conductors of the line **15**, are extended as FIG. **5** indicates in the case of the short-circuiting cap **16** for example, in the form of two flexible diaphragms **51** and **52** having diameters corresponding to the conductors **19** and **20**. The short-circuiting cap **16** is attached to the end of these diaphragms.

The position of this cap can be adjusted by means of a mechanism comprising, for example, a screwed rod **53** which is hollow in order to pass water and is attached to the cap **16**, carrying screwed on to it a knurled nut **54** which abuts against a ring **55** the latter being fixed to the conductor **19**. The adjusting arm of the short-circuiting cap makes it possible to vary the impedance presented by the output device and in particular by the vacuum-tight window, and consequently to vary the load impedance of the tube. This kind of improvement facilitates the operation of klystrons within a wide frequency range.

What we claim, is :

1. An output device for microwave tubes such as klystrons, for picking off the high-frequency power delivered by the tube functioning within a wavelength range extending around a mean wavelength L, which device comprises an output coupling loop arranged on said tube, a section of coaxial output line outside said tube and connected to a load circuit in which said power is utilized, and a vacuum-tight isolating window which provides a seal between the body of the evacuated tube and the load circuit and, an auxiliary coaxial line connecting said coaxial output line and said output coupling loop, said auxiliary coaxial line being parallel to the direction of the electron beam propagating within the tube and having a length substantially equal to $(2n + 3)$ L/4, where n is a whole number, said auxiliary coaxial line being short-circuited at its two ends, said output coupling loop and said coaxial output line respectively being connected to said auxiliary coaxial line at distances substantially equal to L/4 from its two ends and said coaxial output line being oriented in a direction perpendicular to said auxiliary coaxial line.

2. An output device for a microwave tube according to claim **1**, further comprising an intermediate coaxial line section whose center conductor is connected to said output coupling loop and to the center conductor of said auxiliary coaxial line, the center conductor of said coaxial output line being itself connected to said central conductor of said auxiliary coaxial line.

3. An output device for a microwave tube according to claim **1**, wherein a cooling fluid circuit is established through the center conductor of said auxiliary coaxial line.

4. An output device for a microwave tube according to claim **3**, wherein said cooling fluid arriving in the center conductor of said auxiliary coaxial line circulates through said output coupling loop constituted by two series-arranged hollow tubes and through the center conductor of said coaxial output line before leaving said center conductor of said auxiliary coaxial line.

5. An output device for a microwave tube according to claim **1**, wherein the ends of said auxiliary coaxial line are short-circuited by adjustable short-circuiting pistons.

6. An output device for a microwave tube according to claim **1**, wherein the focussing of the electron beam propagating within said tube is effected by magnetic coils the ends of which are terminated by polepieces, said coils surrounding the assembly of the tube body and that end of said auxiliary coaxial line connected to said output coupling loop, the polepiece adjacent said output device having a hole at the location of said auxiliary coaxial line, and a soft iron sleeve surrounding said auxiliary coaxial line from and beyond said polepiece at the side opposite to said coils.

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