April 8, 1947. H. D. HAGSTRUM 2,418,469

TUNER FOR MULTI-RESONATOR

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FIG. 2

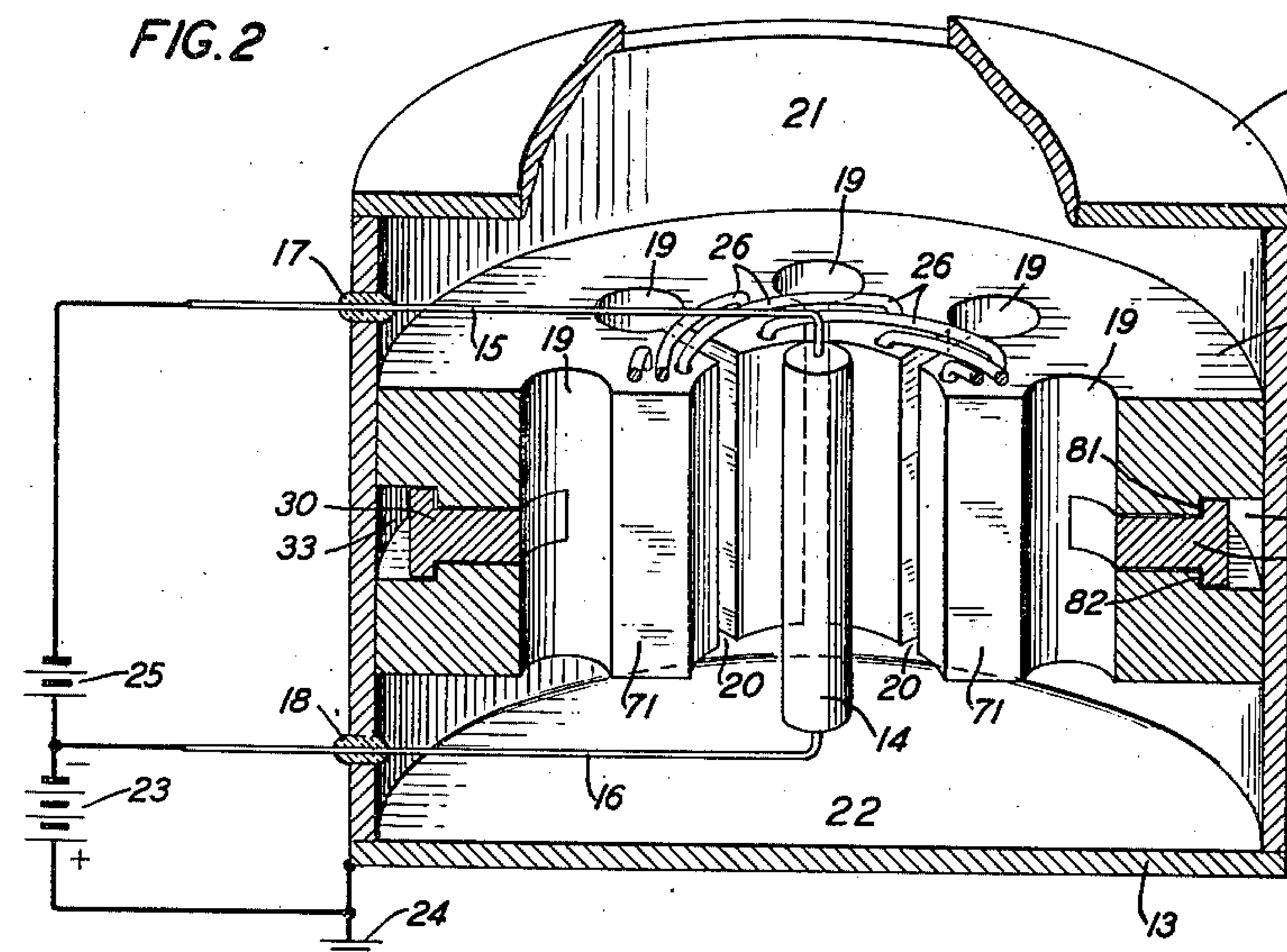

FIG. 3

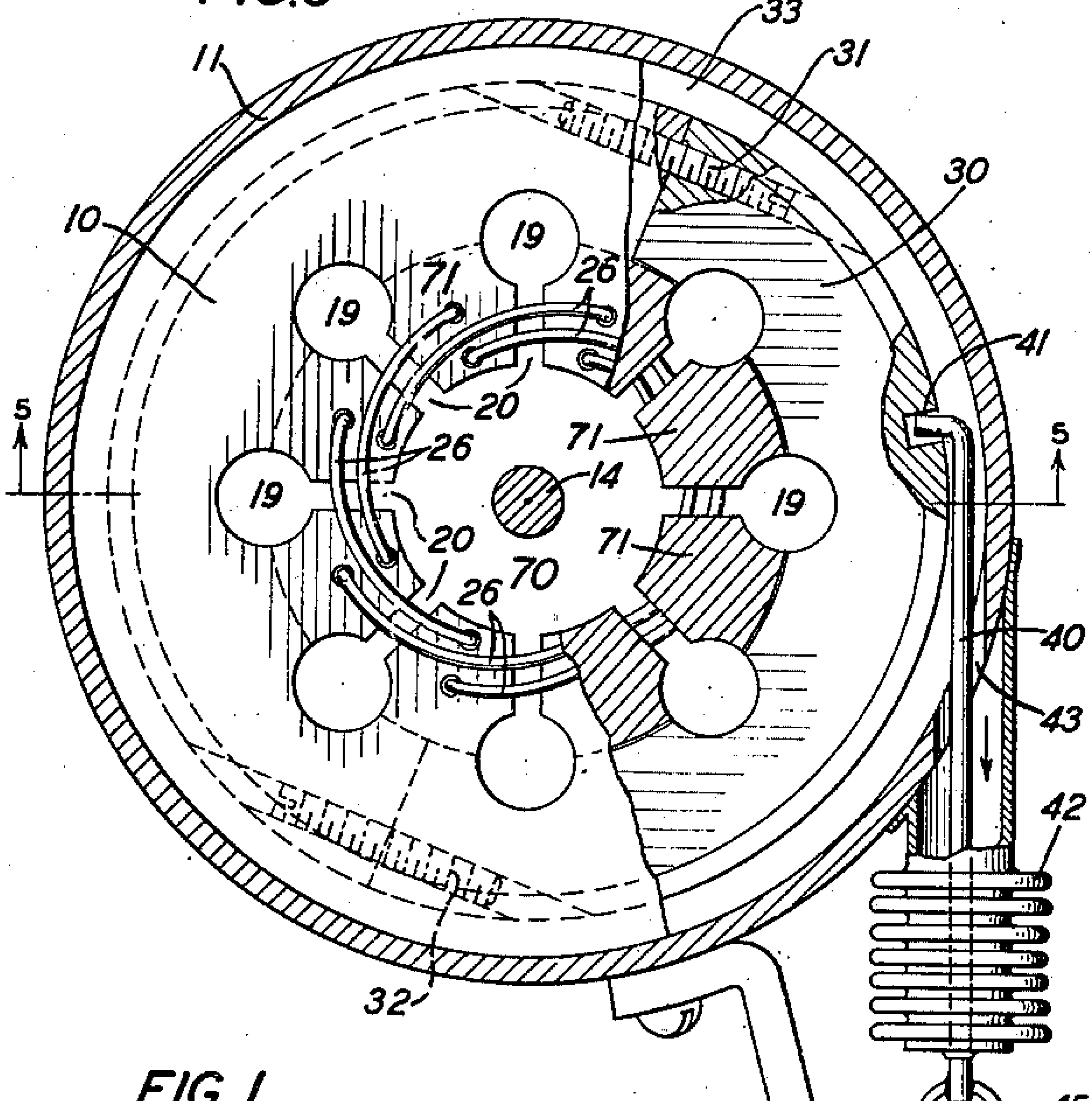

FIG. 4

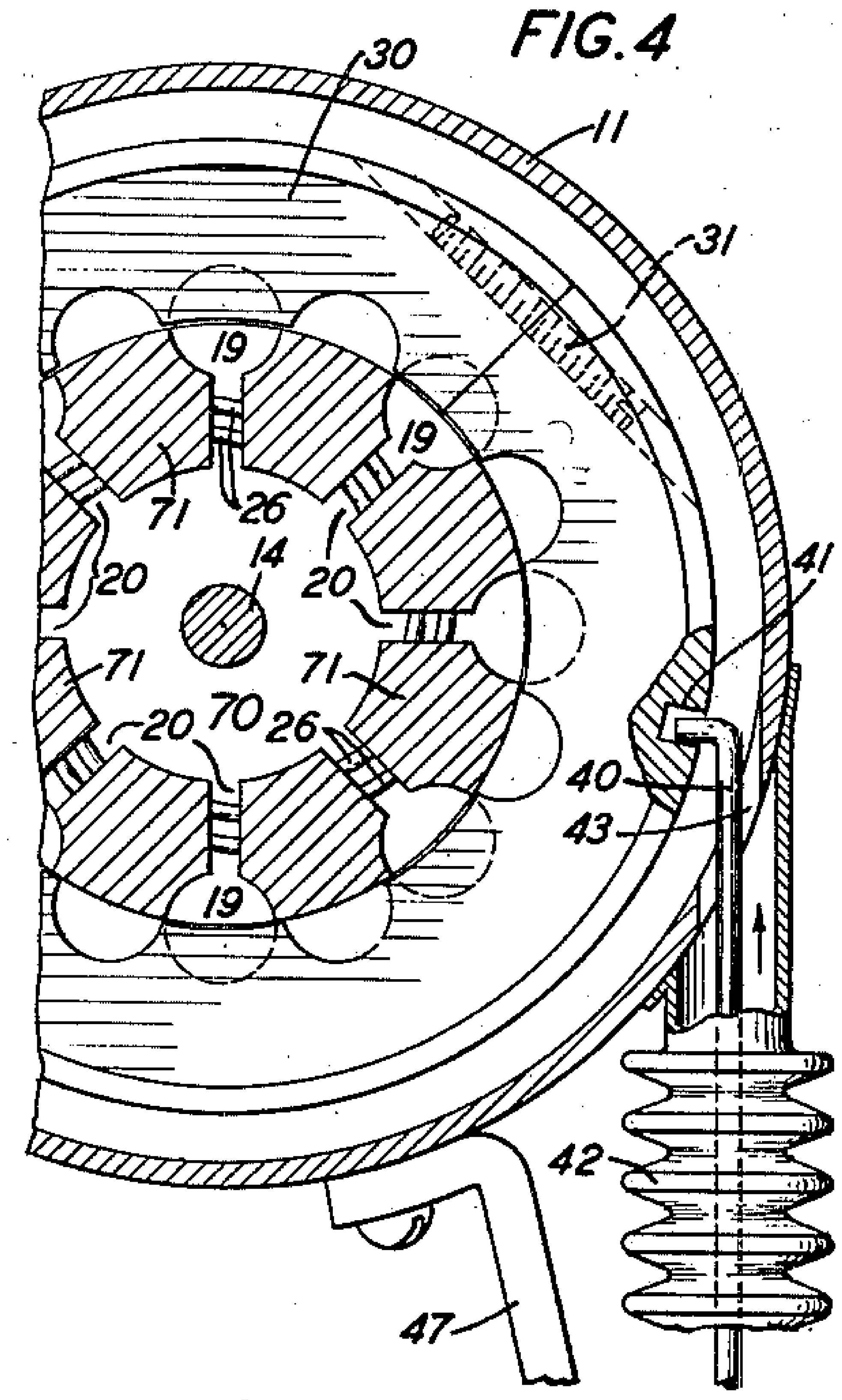

FIG. 1

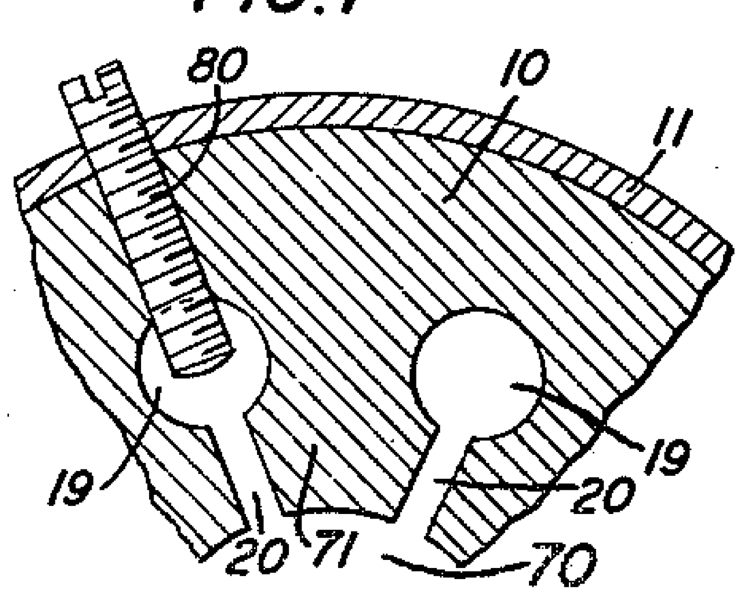

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FIG. 5

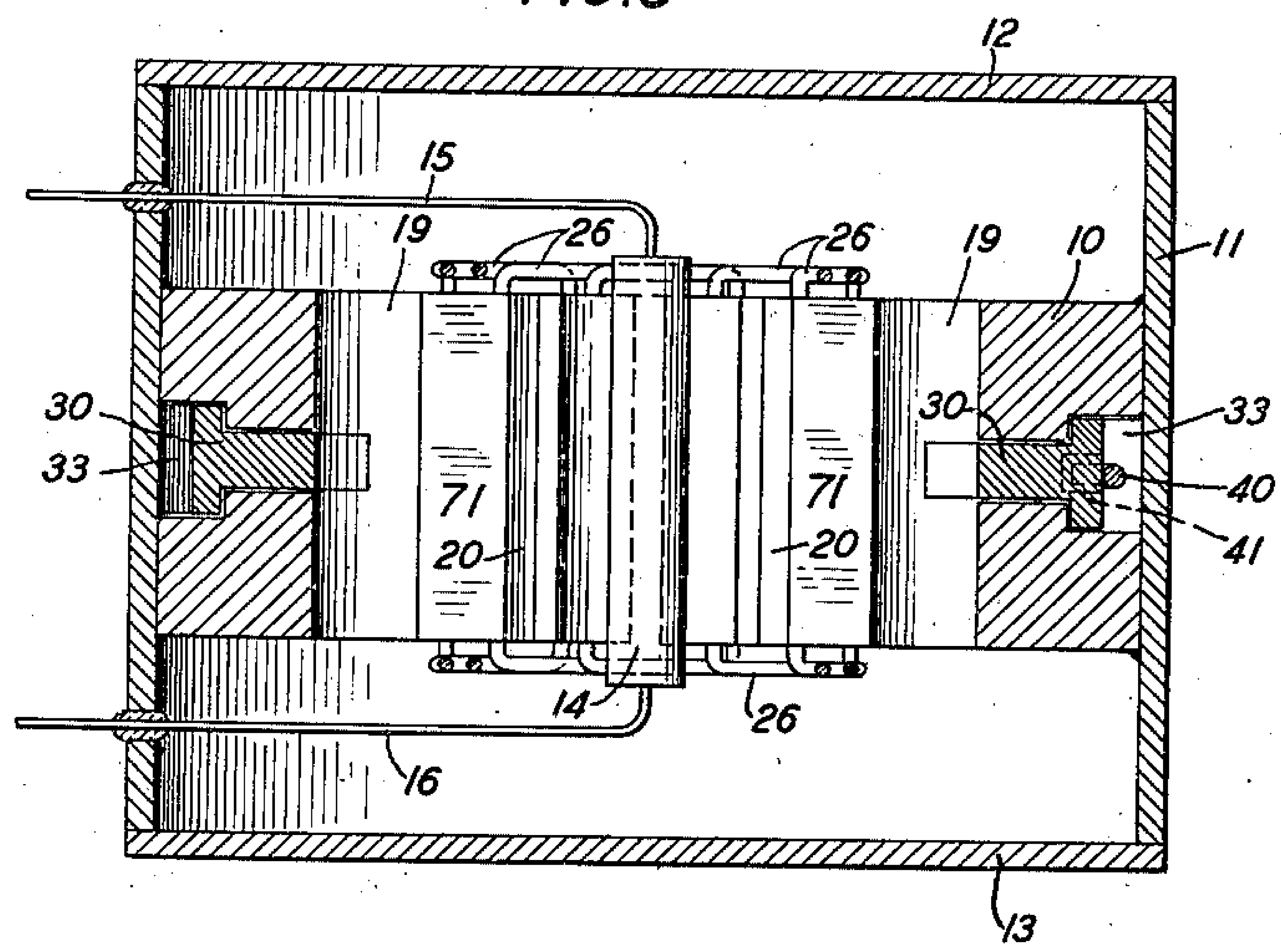


FIG. 6

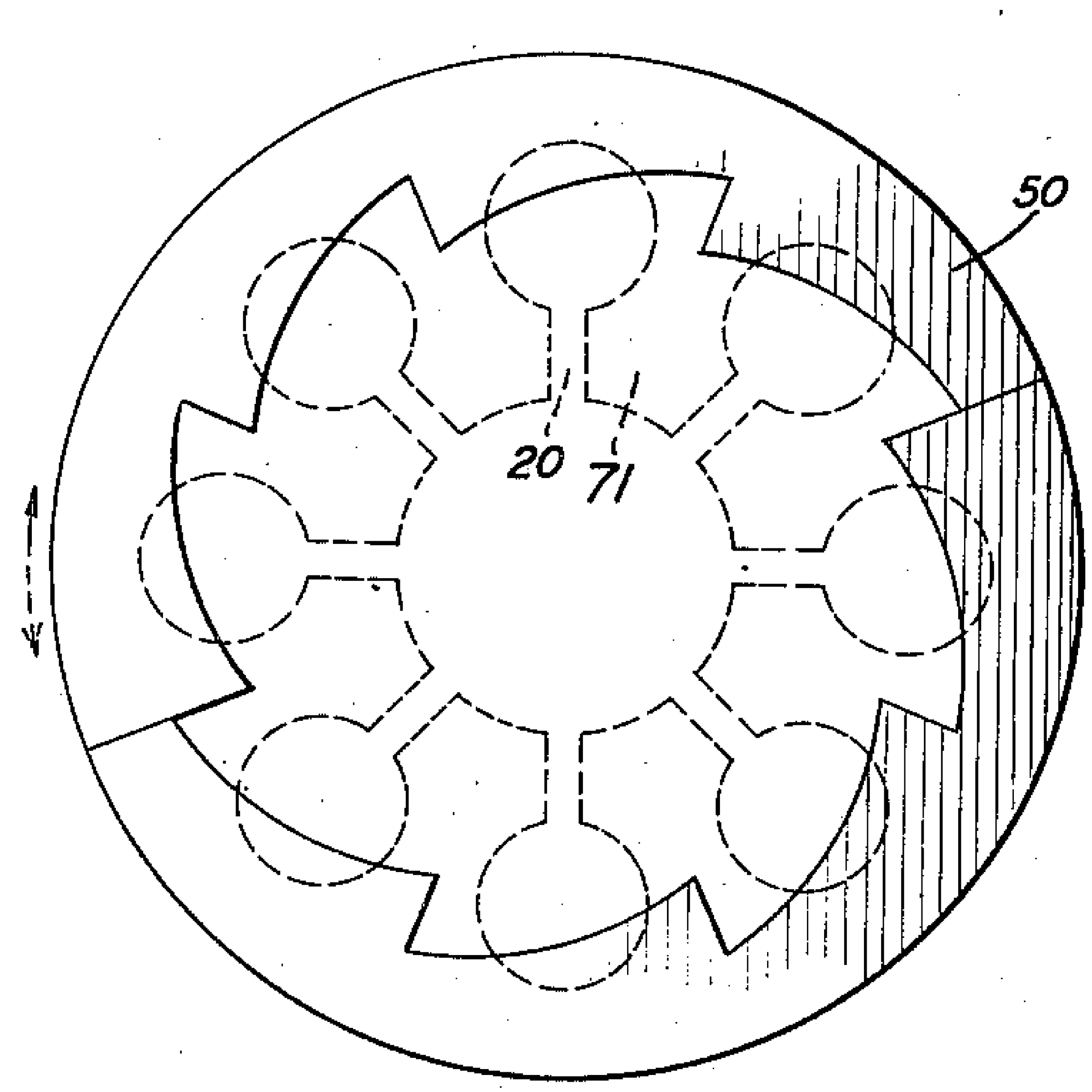
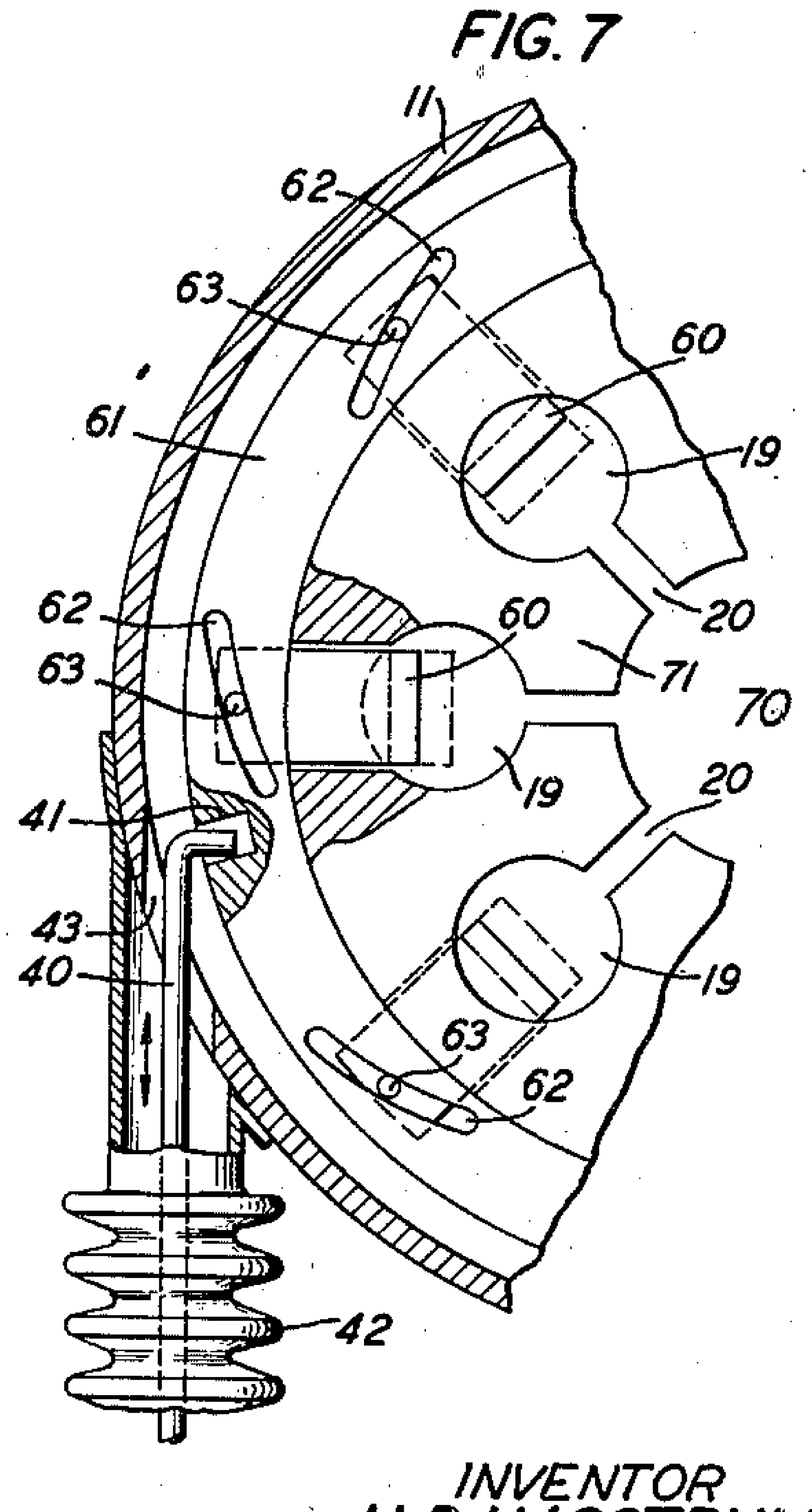


FIG. 7



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TUNER FOR MULTIRESONATORS

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Application May 4, 1944, Serial No. 534,019

5 Claims. (Cl. 315—5)

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This invention relates to arrangements for tuning an electromagnetic resonator of the cavity type and especially to devices adapted for simultaneously and uniformly tuning the several cavities of a multicavity resonator. The invention is particularly applicable to microwave apparatus.

The need for tuning a cavity resonator may arise in many situations involving the handling of microwaves, as in the generation and transmission of such waves. It is customary where power outputs of several kilowatts are required, to generate microwaves in a magnetron oscillator which employs a multicavity resonator. While the oscillating system of the magnetron may be predesigned to operate approximately at a desired frequency, it is desirable to be able to adjust the operating frequency after the oscillator has been connected to a transmission system. One reason for this is that the operating frequency of a system made up of an oscillator and a load, which system may also include an intermediate transmission medium therebetween depends not alone upon the dimensions of the oscillator but also upon the impedance presented to the oscillator by the load and any such transmission medium. Oscillators have in certain cases been produced in quantity, inspected and tested in a standardized transmission circuit and those oscillators operating outside a prescribed frequency band have been rejected as unsatisfactory. Of the oscillators passing such a test, some operate in the test circuit at a frequency close to one edge of the band. These marginal oscillators, when placed in the system for which they ultimately are intended, which system may differ somewhat from the test circuit in its impedance characteristics, may operate at a frequency outside the band limits, and be unsatisfactory for that reason. An oscillator which is off frequency can usually be brought to operate within the band by a small change in the resonating properties of the oscillator. Other reasons for tuning the oscillator are to permit a selection of the final operating frequency and to permit the frequency to be changed from time to time as desired. A further reason is to enable manufacturing tolerances to be relaxed while insuring a commercial product which readily can be made to operate within its prescribed frequency band.

In accordance with the invention, means are provided for altering the shape of a single cavity or of one or more of the cavities of a multicavity resonator. For tuning over a wide frequency

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band, the simultaneous tuning of a plurality of the cavities of a multicavity resonator is desirable as the range which may be covered is many times that which may be covered by tuning one cavity alone.

It is often important, in operating a multicavity magnetron, to maintain as nearly as possible a symmetrical pattern of electric and magnetic fields. In this way, operating conditions in the respective individual cavities may be kept similar. For this purpose, means are provided in accordance with the invention whereby a plurality, preferably all, of the cavities of a multicavity resonator are tuned in a manner that is uniform for all the cavities affected. Mechanical arrangements are shown for simultaneously tuning the several cavities.

In the drawings,

Fig. 1 is a fragmentary view of a multicavity resonator with means for tuning one of the cavities;

Fig. 2 is a sectional view, in perspective, of a multicavity magnetron having a tuning element for simultaneously tuning the individual cavities;

Fig. 3 is a plan view, partly broken away, showing a magnetron like that of Fig. 2 together with means for adjusting the tuning element from outside the vacuum chamber of the magnetron;

Fig. 4 is a fragmentary view similar to that shown in Fig. 3 except that the tuning element is shown moved with respect to its position in Fig. 3;

Fig. 5 is a cross-sectional view of the magnetron shown in Figs. 2, 3 and 4;

Fig. 6 is a plan view of a tuning element of a different shape from that shown in Figs. 3 and 4; and

Fig. 7 is a fragmentary view, showing a modified form of tuning system in accordance with the invention.

Referring now to Fig. 1, a fragment of a multicavity resonator 10 is shown, in section, including two individual resonating cavities 19. Extending radially into one of the cavities 19 is a tuning rod or screw 80, which may be adjusted to any desired position. The tuning of the cavity containing the screw 80 is affected by the position of the screw therein and, due to the presence of coupling between the adjacent cavities 19, the position of the screw 80 is found to affect materially the tuning of the multicavity resonator as a whole. The coupling arrangement is more fully described hereinafter in connection with Figs. 2, 3, 4 and 5. Provision may be made in well-known manner for retaining vacuum within the cavities of the resonator while making the element 80 adjustable from outside the evacuated space. An example is shown employing a metallic bellows for such a purpose, in Figs. 3, 4 and 7.

In Figs. 2, 3, 4 and 5, the principal working parts of a magnetron oscillator are shown so as to more fully explain how the invention is to be embodied in an oscillator and to show how a plurality of tuners may be operated simultaneously. The oscillator has an anode 10 which may be a perforated metal block fitted snugly within a vacuum-tight container, the latter comprising a side wall portion 11, and end plates 12 and 13. In a central perforation 70 in the anode block there may be mounted a cathode 14 which may contain a heating element and be supported by wires or conductive rods 15 and 16 entering the vacuum chamber through suitable dielectric seals 17 and 18, respectively.

The anode 10 comprises a multicavity resonator having a plurality of individual resonating cavities 19 each connected through a slot 20 with the central perforation 70, the portions 71 of the anode block between adjacent slots 20 forming anode segments in well-known manner. End spaces 21 and 22 are provided between the ends of the anode 10 and the plates 12 and 13, respectively. The spaces 21 and 22, together with the slots 20 and the anode-cathode space comprising the perforation 70, serve to provide electromagnetic coupling between the individual cavities 19. An initial steady potential difference between the anode 10 and the cathode 14 may be provided in any suitable manner as by means of a pulsing generator or other source and represented here for simplicity as a battery 23, the positive terminal of which may be connected to the casing of the magnetron and grounded as at 24. Heating current may be supplied to the cathode through the conductors 15 and 16 from a suitable source such as a battery 25, the cathode being heated either directly or indirectly, as desired. An initial steady magnetomotive force in a direction substantially parallel to the cathode may be supplied in any suitable manner.

A set of connectors or straps 26 may be used to interconnect the anode segments according to any desired scheme for the purpose of favoring one particular mode of oscillation among several possible modes of a multiresonant system, as has become customary in this art.

The magnetron oscillator shown is of the general type disclosed in U. S. Patent 2,063,342 issued December 8, 1936, to A. L. Samuel. Various arrangements are known in the art for leading off electromagnetic waves generated within an oscillator of this type and supplying them to a transmission system or utilization circuit. Any suitable output device may be employed with the oscillator disclosed and will be readily supplied by one skilled in this art.

In the arrangement of Figs. 2, 3 4 and 5, a rotatable tuning element 30 is provided which passes through or projects into several, and preferably all, of the individual cavities 19. The element 30 may be in the form of a ring composed of two parts joined together by screws 31 and 32 as shown in Fig. 3. The ring 30 is preferably assembled in a peripheral or circumferential groove 33 which may be cut into the anode block 10 as by turning in a lathe. Bearing surfaces may be provided as by means of shoulders at 81 and 82. The position of the element 30 in the groove 33 may be seen in Fig. 2. The groove intersects the individual tuning cavities, making a plurality of tuning openings preferably arranged in a circular array about the central axis of the opening 70. A portion or segment of the element 30 projects into the individual cavity 19. The inner edge or surface of the element 30 preferably has a non-circular outline or contour of a pattern which repeats itself the same number of times as their individual cavities 19 so that when the element 30 is rotated about the central axis of the magnetron, the amount and disposition of the material projecting into the cavity 19 is the same for each cavity but varies according to the angular position of the element 30. Figs. 3 and 4 show a plurality of circular scallops arranged in radial symmetry on the inner edge of the element 30, one extreme angular position being indicated in Fig. 3 in which the scallops are centered upon the individual cavities. Fig. 4 shows the element 30 rotated approximately 22½ degrees which is the correct displacement in the case of a resonator with eight symmetrically spaced cavities as shown, to withdraw the scalloped portion of the element 30 entirely within the anode block 10. By rotating the element 30, any intermediate position between those shown in Figs. 3 and 4, respectively, may be obtained, the effect of rotating the element 30 being to vary the tuning properties of all the cavities 19 simultaneously and in the same degree.

Any suitable mechanical means may be supplied for rotating the element 30 from outside the vacuum chamber. In Figs. 3 and 4 there is shown by way of example, a tangential rod 40 with a bent end engaging a notch 41 in the outer edge of the element 30. To maintain the vacuum, the rod may be manipulated through any suitable flexible closure such as a bellows 42, preferably of metal and sealed over an opening 43 by which the rod 40 passes through the wall 11. Suitable means such as a thumbscrew 44 coupled to the rod 40 through a ring 45 rotatably secured in a groove 46 may be provided for controlling the motion of the rod 40 and the thumbscrew 44 may be supported as by a bracket 47 secured to the wall 11.

It will be evident that rotation of the thumbscrew 44 will cause axial motion of the rod 40 tangentially with respect to the element 30, which will in turn produce rotation of the element 30 and variation of the tuning in all the chambers 19 simultaneously.

Fig. 6 illustrates the use of a tuning element 50, similar to the element 30 except that the element 50 has a serrated inner edge. It will be evident that rotation of the element 50 will produce simultaneous tuning of all the chambers 19 exactly as in the case of the element 30, except that the variation in the tuning with respect to the angular displacement of the rotatable element will follow a somewhat different law in the two cases.

Fig. 7 shows another modification of the tuning system in which an individual tuning rod or plunger 60 is provided projecting into each resonating cavity 19. In this case all the rods 60 are operated simultaneously by means of a rotatable element 61 containing a series of inclined slots 62 each of which engages and controls the motion of a pin 63 attached to one of the rods 60. It will be evident that the element 61 mechanically intercouples the rods and that rotation of the element 61 will cause the rods to move radially with respect to the cavities 19, thereby tuning all the cavities simultaneously. In Fig. 7, the extreme inner and outer positions of the rods are indicated by broken lines.

It will be evident to those skilled in this art that other suitable means are known for rotating a part, such as the tuning element herein, from outside a vacuum chamber, for example, a lever arrangement supported by a flexible diaphragm may be employed. It will also be evident that the rotatable tuning element might be placed at the top or bottom of the anode plate 10 instead of being arranged in a slot 33. The tuning element would then control the size and shape of the opening between the individual cavity 19 and the adjacent end space. The element could be rotatably supported in the end space in any suitable manner. This latter arrangement would be appropriate in case it was desired to have the output coupling inserted centrally into one of the cavities 19 in a radial direction, as is commonly done.

The material of the tuning element 30, 50 or 60 may be conductive such as solid metal, or it may be any suitable material metalized or covered with a conductive coating of suitable depth to confine within the cavity electromagnetic waves of the desired operating wavelength. On the other hand, the tuning element may be partly or wholly composed of a dielectric material so as to vary the electric properties of the space within the cavities.

What is claimed is:

1. A resonator comprising a member containing a plurality of individual resonating cavities arranged in radial symmetry about a central axis, and a tuning element rotatable about said axis, said tuning element having a plurality of non-circular portions each extending into one of said resonating cavities by a variable amount depending upon the angular position of the tuning element.

2. A resonator containing a plurality of resonating cavities each having a tuning opening, said openings being positioned in a circular array about a central axis, and a tuning element rotatably mounted with respect to said central axis, said tuning element having a non-circular contour defining a plurality of segments each extending into one of said resonating cavities through the respective tuning opening by a variable amount depending upon the angular position of the tuning element.

3. A resonator comprising a member containing a plurality of individual resonating cavities arranged to have radial symmetry about a central axis, and a tuning element rotatable about said axis, said tuning element having a serrated edge the respective teeth of which project each into one of the said individual cavities, whereby the tuning of the resonator depends upon the angular position of the tuning element.

4. A resonator comprising a perforated block containing a plurality of individual resonating cavities arranged in a circular array about a central axis, and a tuning element rotatable about said axis, said tuning element having a plurality of segments each extending into one of said resonating cavities by a variable amount depending upon the angular position of the tuning element.

5. A resonator comprising a perforated cylindrical block containing a plurality of individual resonating cavities arranged in radial symmetry with their axes parallel to the cylindrical axis of said block, the block having a circumferential groove in its outer surface, said groove intersecting each of said individual cavities, and an annular tuning element rotatably mounted in said groove, said tuning element having a non-circular inner surface the contour of which has a plurality of projections as numerous as the individual cavities in the resonator, whereby rotation of said tuning element simultaneously varies the tuning properties of the several individual cavities.

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