Sept. 20, 1960 B. D. KUMPFER 2,953,715

LOW FREQUENCY MAGNETRON

Filed June 8, 1959 2 Sheets-Sheet 1

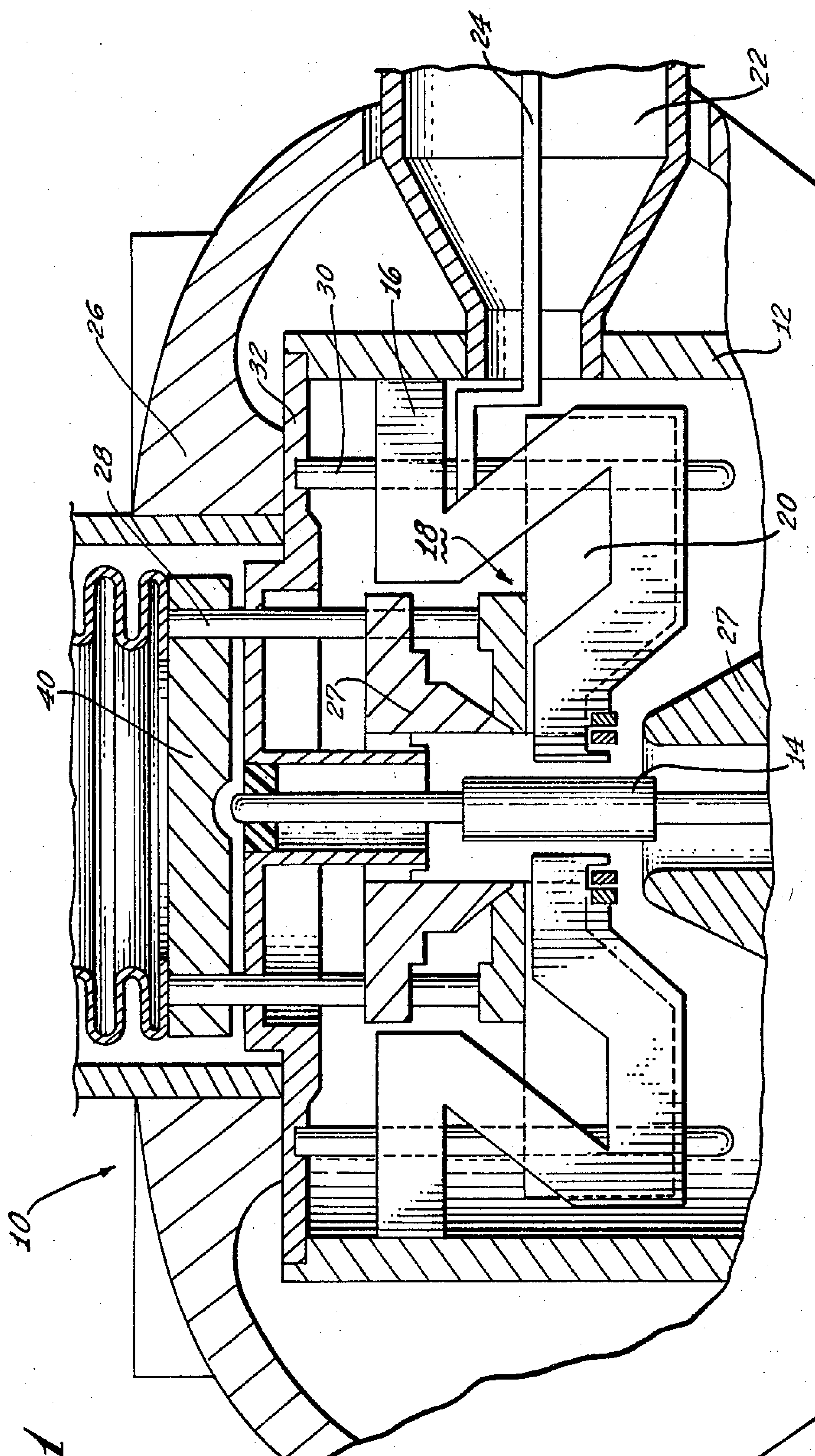


Fig. 1

INVENTOR:
Beverly D. Kumpfer

By Robert H. Lentz
Attorney

Sept. 20, 1960 B. D. KUMPFER 2,953,715

LOW FREQUENCY MAGNETRON

Filed June 8, 1959 2 Sheets-Sheet 2

Fig. 2

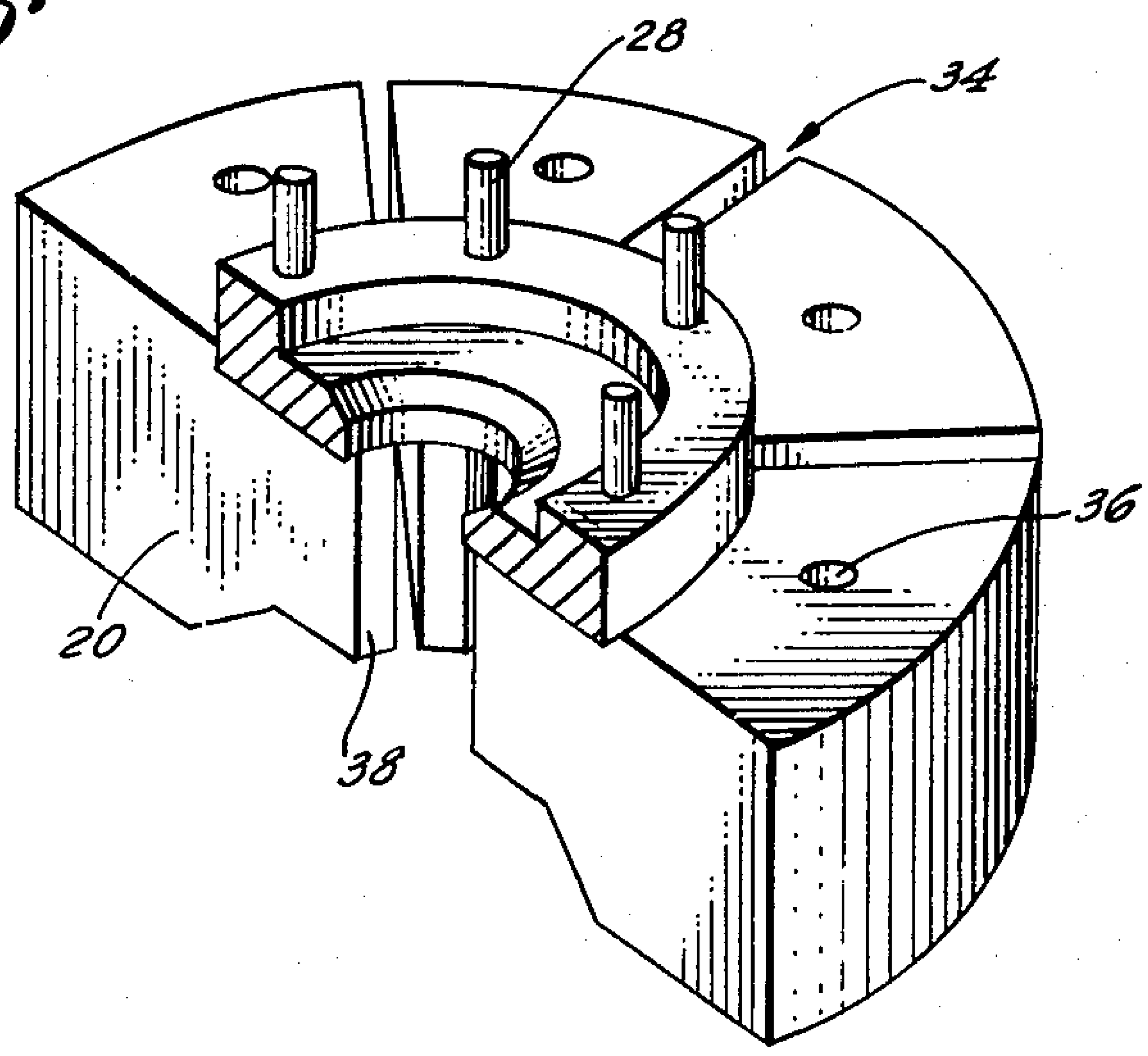


Fig. 3

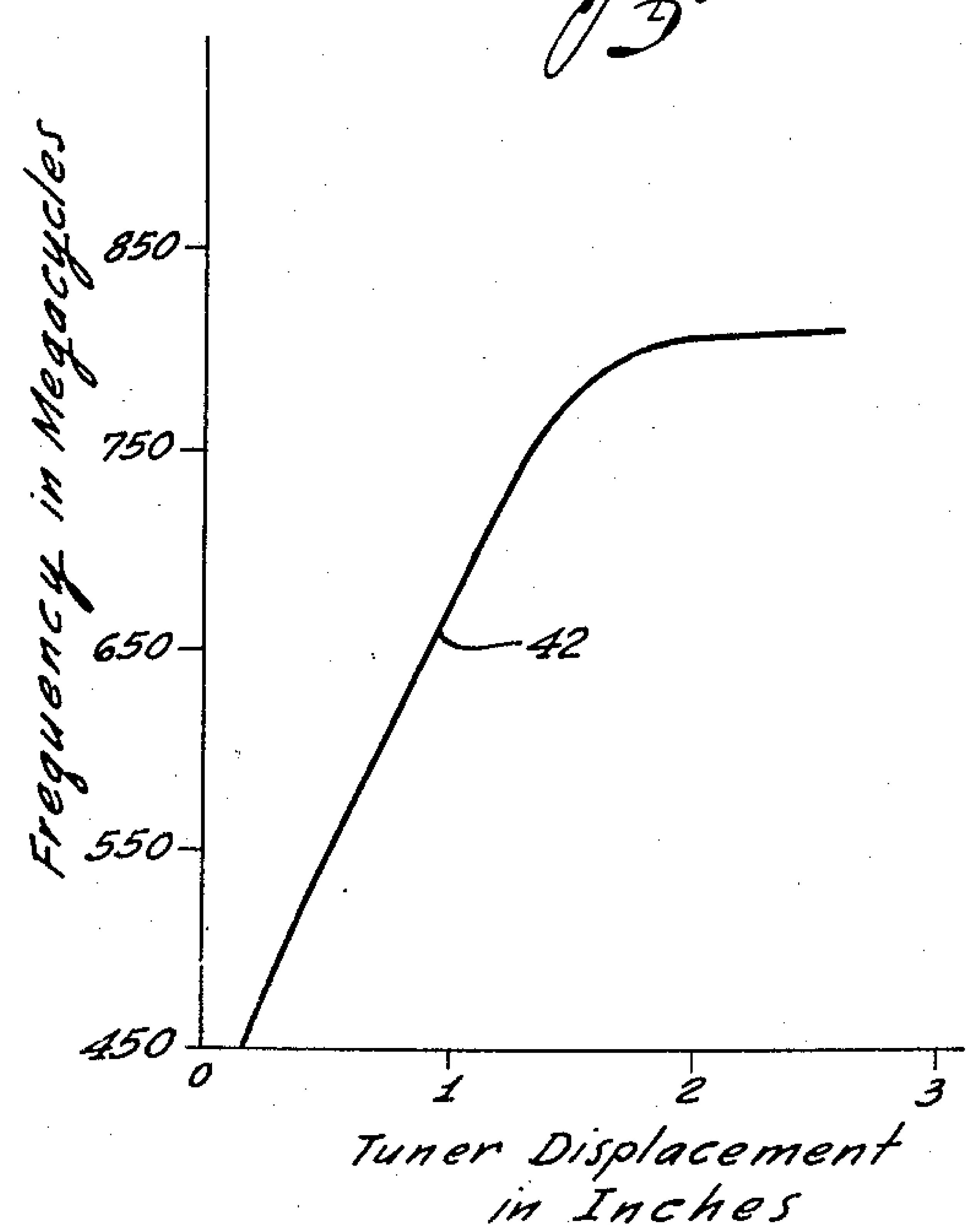
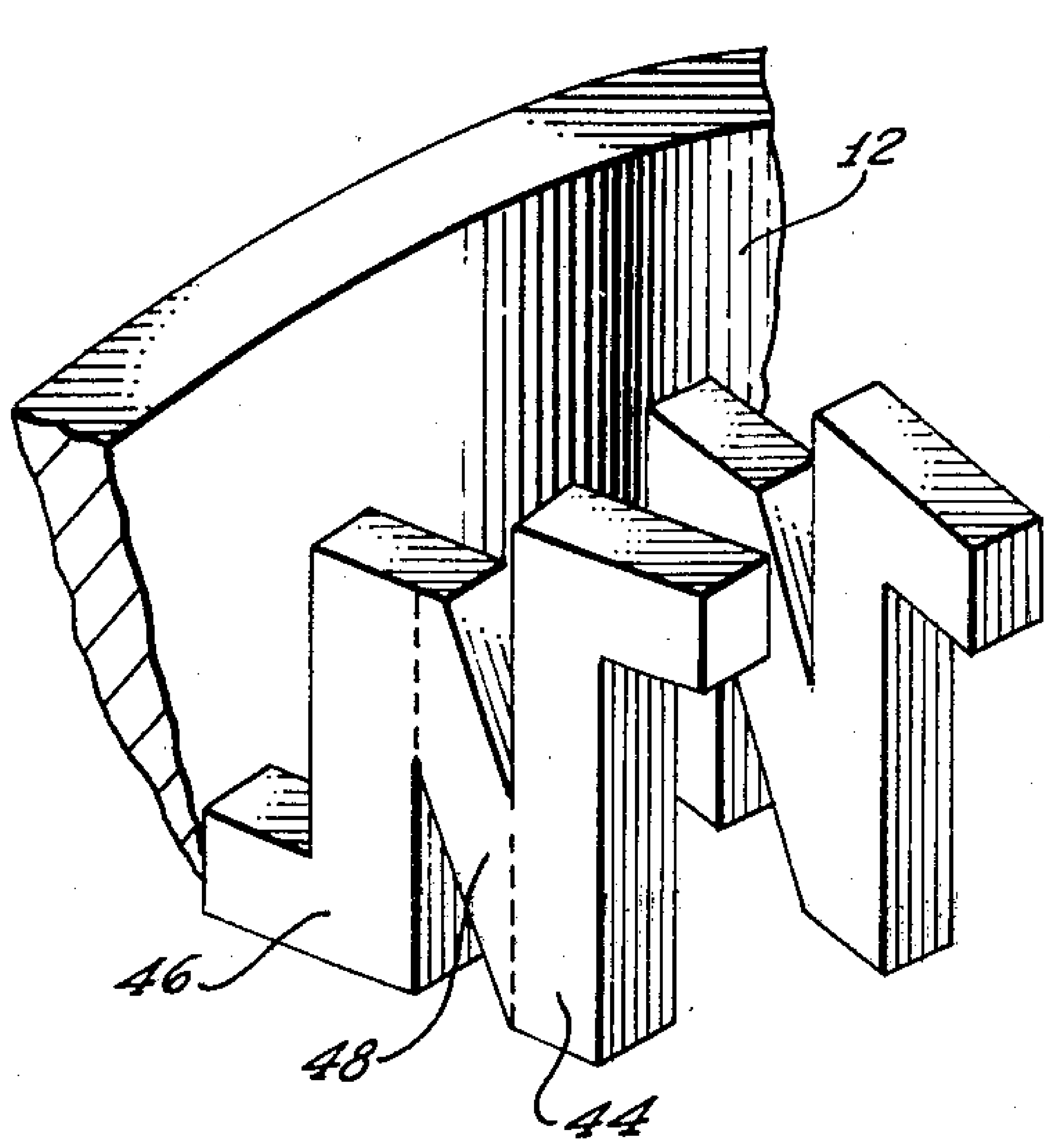


Fig. 4



INVENTOR:
Beverly D. Kumpfer

By Robert H. Leitz
Attorney

United States Patent Office

2,953,715

Patented Sept. 20, 1960

1

2,953,715

LOW FREQUENCY MAGNETRON

Beverly D. Kumpfer, Salt Lake City, Utah, assignor to Litton Industries of California, Beverly Hills, Calif.

Filed June 8, 1959, Ser. No. 818,775

12 Claims. (Cl. 315—39.75)

This invention relates to low frequency magnetrons and more particularly to low frequency magnetrons which utilize a modified form of vane structure in their resonant system.

In the prior art, anode structures of numerous configurations have been employed as part of the resonant circuit for multi-cavity magnetrons, the most successful of which has become known as the vane type anode. It is well known that one of the principal functions of the anode structure of the magnetron is to serve as a frequency determining element. It is further known that the frequency of operation of the anode is a function of the length of the vane elements, the length of the vanes being inversely related to the frequency of operation. Thus, a magnetron operable at 5,000 megacycles would in general be expected to employ vanes whose lengths are approximately one teenth the length of the vanes in a magnetron operable at 500 megacycles.

Although the conventional straight vane type structure have been found to perform reasonably well in magnetrons operating at frequencies as low as 300 megacycles, there are still several serious disadvantages attendant their use at this frequency owing to the excessive length of the vanes. Firstly, the inward thermal expansion of the vanes during operation is frequently excessive and causes distortion of the interaction space with attendant strap shorting, changes in the voltage gradient, and frequency instability. Secondly, the diameter of the anode becomes so large that unusually large external magnets are required to provide the requisite static magnetic field, thereby further increasing the size and weight of the assembled tube. Thirdly, the tuner structures required for the relatively large anode, low frequency magnetrons of the prior art are also of necessity relatively large and thus give rise to such problems as excessive tuner inertia in fast tuner applications, and the lack of positional stability of the tuner relative to the anode vanes when the vehicle carrying the tub is subjected to acceleration.

In accordance with the present invention, it has been found that the foregoing and other disadvantages of the prior art low frequency magnetrons may be overcome by utilizing magnetrons embodying an anode structure which employs van segments having an effective electrical length which is substantially longer than the radial distance from the vane tip to the associated back wall of the anode. More particularly, in accordance with the present invention, a reduction in the radial length of each of the vane segments is accomplished without raising frequency through the use of vanes having a folded configuration such that there is no longer a linear radial electrical path between the back of the vane to the front of the vane adjacent the interaction space. In addition, it is a further feature of the invention to provide an anode structure which may be tuned both capacitively and inductively by a single tuning ring of simplified tuning elements. Moreover, as will be disclosed in more detail hereinbelow, the advantage derived through the utilization of the modified form of vane segments of the invention are accompanied by increased tuning linearity over the frequency range of the magnetron.

2

It is, therefore, an object of the invention to provide an improved multi-cavity magnetron anode structure for low-frequency operation which employs vanes having a larger electrical length than radial length.

Another object of the invention is to provide a modified anode structure for low-frequency operation in which the thermal expansion of the vane segments in the radial direction is minimized.

A further object of the invention is to provide a multi-cavity resonant system which employs a single tuning ring mechanism to provide both capacitive and inductive tuning.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings in which several embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for purpose of illustration and description only, and are not intended as a definition of the limits of the invention.

Figugre 1 is a side elevation of a multi-cavity magnetron, partly in section, illustrating one form of improved anode vane element in accordance with the present invention;

Figure 2 is an isometric view partly in section of a portion of the tuning mechanism, in accordance with the invention, which is employed in the magnetron of Fig. 1;

Figure 3 illustrates a graph indicating the physical displacement of the tuner segments as a function of the magnetron operating frequency; and

Figure 4 is a fragmentary isometric view of an alternative form of vane element, according to the invention.

Referring now to the drawings, wherein the same reference characters designate like or corresponding parts throughout the several views, there is shown in Figure 1 a side view of a low frequency multi-cavity magnetron 10 embodying an anode structure and associated tuner device constructed in accordance with the teachings of the invention, for reducing the diameter of the magnetron while simultaneously facilitating the tuning thereof. As shown in Figure 1, the magnetron includes a conventional cylindrical anode block 12, a cathode 14, positioned concentrically with respect thereto, a plurality of regularly spaced vane segments 16 extending radially inward from the inside wall of the anode block and forming therewith a plurality of cavity resonators, and a tuner device generally designated 18 which has a plurality of tuner segments 20 extending into each of said cavity resonators. In addition, the magnetron also includes a coaxial horn type output structure 22 which functions in conjunction with an associated conductor 24 for extracting microwave energy generated within the magnetron's resonant system, and a permanent magnet 26 which cooperates with a pair of pole pieces 27 to provide a steady state magnetic bias within the interaction space formed between the cathode and the tips of the vanes.

Turning now to the details of the vane segments 16 as shown in Figure 1, it will be noted that each vane has a folded configuration in the plane of the vane to present an electrical length to the resonant system which is greater than the radial distance from the tip of the vanes to the back wall of the cavity resonators, the end of the vane farthest from the interaction space being affixed to the inner wall of the anode block as by brazing or the like. In accordance with the invention, the effective physical length of each vane as developed over its folded configuration may be several times as long as the radial distance from the tip of the vanes in the interaction space to the back wall of the cavity resonators, thereby permitting vanes of relatively large electrical length to be fitted into a space which would otherwise be far too small to accommodate a conventional straight vane operable at the same frequency.

In the particular embodiment of the invention shown in Fig. 1 each of the vanes includes a region having a substantially Z-shaped folded configuration, and an additional folded portion interconnecting the front end of the vane adjacent the interaction space with one end of the Z-shaped region. It will be noted, therefore, that in this embodiment of the invention a larger portion of each vane is located toward the rear or the inductive portion of the cavity resonators, this feature being used advantageously to enhance inductive tuning of the resonators as will be set forth in more detail hereinbelow.

Consider now the details of the tuning mechanism, a portion of which is shown in Fig. 2. As shown in this latter view the tuner comprises a short unitary cylindrical structure the lower end of which has been divided into a plurality of uniformly spaced segments **20** by a corresponding plurality of slots **34**, each slot having a width larger than the width of the associated anode vanes to permit the segments **20** to move axially into their associated cavity resonators. As further shown in both Figures 1 and 2, the tuner segments are movable with respect to the associated cavity resonators through the use of a plurality of support rods **28** to which the tuner is affixed at one end, the support rods being affixed at their other ends to a bellows seat **40** for axially moving the tuning mechanism. In addition, there is associated with the tuner a plurality of alignment rods **30**, shown in Fig. 1, which are affixed to a portion **32** of the tube envelope and extend through corresponding apertures **36** in the tuning segments **20**, as shown in Fig. 2.

Before discussing the electrical operation of the magnetron anode structure of the invention and the advantages provided thereby, consideration will be given first to the mechanical problems which the use of vanes of a reduced radial length overcome. Firstly, it will be recognized that the use of a vane segment whose configuration is folded provides a structure which when subjected to high temperatures will exhibit only limited thermal expansion in the radial direction as contrasted with the expansion of an electrically equivalent straight vane. One of the most important advantages which accrues from reduction of radial expansion is that distortion of the interaction space and shorting of the straps is substantially eliminated. Secondly, the use of such vanes eliminates the need for large and complicated tuner structures, which give rise to parastic resonances and further exhibit excessive tuner inertia in applications requiring rapid tuning. Finally, it will also be apparent to those skilled in the art that the use of the anode structures taught by the present invention reduces drastically the size and weight of the low frequency magnetrons in which they are employed, thereby facilitating the use of such tubes in airborne equipments.

In addition to solving the foregoing problems of the prior art, the present invention also permits the selection of an optimum configuration for the various tube types where either predominantly inductive or capacitive characteristics are required in the resonant system. This advantage will be appreciated when it is understood that in accordance with the invention the configuration of the vane may be formed such that certain portions thereof are disposed in either predominantly the inductive or capacitive portions of the resonant system.

Consider now the electrical effect of employing folded vanes in a typical low frequency magnetron operable at a frequency on the order of several hundred megacycles, for example. It will be recalled that one of the principal factors in determining the frequency of operation of a conventional straight vane type magnetron is the radial length of the vane, and that the frequency of operation in such a device is inversely related to the radial length of the vanes. While the length of the folded configuration vane required to produce oscillations at a preselected frequency and the length of the equivalent straight vane generally are not exactly equal because the folded configuration vane of the invention may have several regions which are so spaced with respect to one another that current flows therethrough in opposite directions, it may be shown that length of the folded configuration vane is also substantially inversely related to the frequency of operation of the magnetron. Accordingly, it is a relatively simple matter to determine the length of the folded vane which should be used to provide operation at any preselected fundamental frequency. The frequency of operation of the magnetron of the invention may then be varied by axially moving the tuner segments **20** within the cavity resonators defined by the vane segments.

In Figure 3 there is shown a graph illustrating the tuning characteristics of a magnetron of the form shown in Figure 1 which has been built in accordance with the invention. As shown by curve **42** representing a plot of tuner displacement versus resonant frequency, the novel anode structure of the invention and its associated tuning mechanism combine to provide relatively linear tuning over the operational range of the tube, in addition to the other advantages set forth previously. Moreover, it will be noted from Figure 2 that the construction of the tuner is extremely simple despite the fact that both inductive and capactive tuning are provided thereby.

In operation the tuner segment has a greater effect in varying the capacitance of the cavity resonators when it is disposed in a position adjacent portions of the vane nearest the cathode, whereas a greater change in the inductance of the cavity resonators is produced when the tuner is disposed in a position adjacent those portions of the vane which are remote from the cathode. Stated in another manner, when the tuner plunger is in the lower position shown in Figure 1, the magnetron is being more capacitively tuned whereas when the plunger is moved axially upwards, the magnetron becomes more inductively tuned.

It is to be expressly understood, of course, that the invention may be practiced by using vane configurations different from that shown in Figure 1. With reference to Figure 4, for example, there is shown an alternate form of anode structure, in accordance with the invention, the vane segments in this embodiment having an inverted L-shaped outer region **44** and reversed L-shaped inner region **46** interconnected by a diagonal middle region **48**, the three regions being separated by two dashed lines in the drawing to facilitate identification thereof. Accordingly, it should be understood that the basic concept of folded vanes, as taught by the present invention, encompasses the use of vanes wherein there is no direct or linear radial conductive path between the tip of the vanes and the back of the associated anode block, or stated differently, that the overall axial length of each vane with respect to the cathode axis is larger than the sum of the axial lengths of the front end of the vane adjacent the interaction space and the back end of the vane adjacent the anode block.

It has been found that the utilization of the basic concepts herein set forth may be employed to provide an anode structure whose radius is less than one-half the developed length of the folded vanes or stated alternatively, the effective electrical length of the vanes. In addition, there is provided a reduction of thermal expansion of the vanes substantially eliminating distortion of the interaction space and the attendant strap shorting and frequency instability heretofore experienced by prior art low frequency magnetrons.

While the magnetron anode construction of the invention has been described with reference to only two particular forms of vane configurations it will be understood that various modifications could be made in the construction thereof without departing from the spirit and scope of the invention. Accordingly, it is to be expressly understood that the foregoing description shall be interpreted only as illustrative of the invention, and that the appended claims be accorded as broad an interpretation as is consistent with the basic concept herein taught.

What is claimed as new is:

1. In a multi-cavity magnetron for generating microwave energy, the combination comprising: a cathode having an axis; an anode including an anode block positioned concentrically with respect to said cathode, and a plurality of regularly spaced vanes extending inwardly therefrom toward said cathode and forming with said anode block a plurality of cavity resonators, each of said resonators having a back wall remote from said cathode, said vanes having an inner end adjacent said cathode and an electrical length in the plane of the vane substantially larger than the radial distance from the inner end of said vane to the back wall of said cavity resonators; and coupling means for extracting microwave energy from said anode.

2. In a multi-cavity magnetron for generating microwave energy, the combination comprising: a cathode having an axis; and including an anode block surrounding said cathode, and a plurality of regularly spaced vanes extending inwardly therefrom toward said cathode and forming with said anode block a plurality of cavity resonators, and an interaction space adjacent and concentric with said cathode, each of said cavity resonators having a back wall remote from said cathode, each of said vanes having a front region adjacent said interaction space, a back region adjacent said back wall, and a central region interconnecting said front and back regions, at least one of said regions extending non-perpendicularly with respect to said cathode axis; and a coupling means for extracting microwave energy from said anode.

3. In a tunable multi-cavity magnetron for generating microwave energy, the combination comprising: a cathode having an axis; an anode surrounding said cathode and including a plurality of regularly spaced vanes extending inwardly toward said cathode said vanes forming a plurality of cavity resonators and an interaction space adjacent to and concentric with said cathode, each of said cavity resonators having a back wall remote from said cathode, said vanes having a folded configuration in the plane of the vane which includes a front region adjacent said interaction space, a back region adjacent said back wall, and a central region interconnecting said front and back regions, at least one of said regions extending non-perpendicular with respect to said cathode axis; a tuning mechanism for varying the frequency of operation of the magnetron, said tuning mechanism including a plurality of tuner segments respectively associated with said cavity resonators; tuner support means movably disposed parallel to the axis of the cathode for supporting each of said segments in movable spaced relationship with respect to said cavity resonators; and a coupling means for extracting microwave energy from said anode.

4. In a multi-cavity magnetron for generating microwave energy, the combination comprising: a cathode having an axis; an anode surrounding said cathode including a plurality of regularly spaced vanes extending toward said cathode forming a plurality of cavity resonators and an interaction space adjacent and concentric with said cathode, each of said cavity resonators having a back wall remote from said cathode at a predetermined radial distance therefrom, each of said vanes having a folded configuration of a predetermined developed physical length in the plane of the vane at least half again larger than the radial distance from the region adjacent the interaction space to the back wall of said cavity resonators.

5. In a tunable multi-cavity magnetron, the combination comprising: a cathode having an axis; an anode including an anode block surrounding said cathode, and a plurality of regularly spaced vanes extending inwardly toward said cathode from said block forming a plurality of cavity resonators and an interaction space adjacent and concentric with said cathode, said vanes having a tip adjacent said interaction space and a folded configuration whereby the physical length thereof is larger than the radial distance from the tip of said vane to the back wall of said cavity resonators; a tuner device for varying the frequency of operation of the magnetron, said tuner device includes a plurality of tuner segments corresponding respectively to said resonators forming a disc-like member, and a plurality of support rods movably disposed parallel to the axis of the cathode and associated with said tuner segments for supporting each of said segments in movable space relationship with the corresponding cavity resonator of said anode; and coupling means for extracting microwave energy from said anode.

6. In a low frequency multi-cavity magnetron, the combination comprising: a cathode having an axis; an anode surrounding said cathode having a plurality of regularly spaced vanes extending inwardly toward said cathode forming a plurality of cavity resonators and an interaction space adjacent and concentric with said cathode, said anode further including means forming a back wall for each of said cavity resonators remote from said cathode, said vanes having a folded configuration which includes a front region adjacent said interaction space, a back region adjacent said back wall, and a central region interconnecting said front and back regions to provide a physical length in the plane of the vane at least half again as large as the radial distance from the front region of said vane to the back wall of said cavity resonators; and coupling means for extracting microwave energy from said anode.

7. In a tunable multi-cavity magnetron for generating microwave energy the combination comprising: a cathode having an axis; an anode surrounding said cathode and including an anode block remote from said cathode and a plurality of regularly-spaced vanes extending from said block toward said cathode forming a plurality of cavity resonators and an interaction space adjacent and concentric with said cathode, each of said cavity resonators having a predetermined inductance and capacitance and a back wall formed by said block, each of said vanes having a folded configuration in the plane of the vane which includes a front portion adjacent said interaction space, a back portion adjacent said back wall, and a central portion interconnecting said front and back portions, at least one of said regions extending non-perpendicular with said cathode axis; a tuner for varying the frequency of operation of the magnetron, said tuner comprising a unitary structure forming a plurality of uniformly spaced segments corresponding respectively to said plurality of cavity resonators, said segments being axially movable over a predetermined range in spaced relationship with respect to said cavity resonators, said segments being disposed adjacent said front portions of the vanes nearest the cathode to provide a predominantly capacitive tuning of said cavity resonators when the tuner is at one end of its axial range, and being disposed adjacent said back portions of the vanes to provide predominantly inductive tuning of said resonators when said tuner is at the other end of its axial range.

8. In a low frequency multi-cavity magnetron for generating microwave energy the combination comprising: a cathode having an axis; a resonant system surrounding said cathode, said resonant system including a cylindrical anode block and a plurality of regularly spaced vanes extending therefrom toward said cathode forming a plurality of cavity resonators and an interaction space adja-

cent and concentric with said cathode, each of said vanes including a region having a substantially Z-shaped folded configuration to present an electrical length to the resonant system which is substantially longer than the radial distance from said interaction space to said anode block.

9. In a multi-cavity magnetron for generating microwave energy the combination comprising: a cathode having an axis; a resonant system surrounding said cathode having a cylindrical block and a plurality of cavity resonators and an interaction space adjacent and concentric with said cathode, each of said cavity resonators having a back wall remote from said cathode having a predetermined radial distance therefrom, each of said vanes having a tip end adjacent said interaction space with a folded configuration in the plane of the vane to present an electrical length to the resonant system which is greater than the radial distance from the tip of the vanes to the back wall of the cavity resonators.

10. In a tunable multi-cavity magnetron for generating microwave energy the combination comprising: a cathode having an axis; an anode surrounding said cathode including a cylindrical block remote from said cathode and a plurality of regularly-spaced vanes extending from said block toward said cathode forming a plurality of cavity resonators and an interaction space adjacent and concentric with said cathode, each of said cavity resonators having a predetermined inductance and capacitance and a back wall formed by said block, said vanes having a folded configuration in the plane of the vane which includes a front portion adjacent said interaction space, a back portions adjacent said back wall, and a central portion interconnecting said front and back portions, at least one of said regions extending non-perpendicular with said cathode axis; a tuner for varying the frequency of operation of the magnetron, said tuner comprises a short unitary cylindrical structure the lower end of which has been divided into a plurality of uniformly spaced segments by a corresponding plurality of slots, said segments having a movable spaced relationship with said cavity resonators, said segments being disposed toward said back portions of said vanes remote from the cathode to provide a predominantly inductive tuning of said cavity resonators.

11. In a multi-cavity magnetron for generating microwave energy the combination comprising: a cathode having an axis; and an anode surrounding said cathode, said anode including a cylindrical block remote from said cathode and a plurality of regularly spaced vanes extending from said block toward said cathode forming a plurality of cavity resonators and an interaction space adjacent and concentric with said cathode, each of said vanes having an axial length with respect to the cathode axis which is larger than the sum of the axial lengths of the front end of the vane adjacent tò the interaction space and the back end of the vane adjacent said block.

12. The magnetron defined in claim 11 which further includes a tuner device for varying the frequency of operation of the magnetron, said tuner comprising a substantially cylindrical structure forming a plurality of uniformly spaced segments corresponding respectively to said resonators, and a plurality of support rods connected to said segments and movably disposed parallel to the axis of the cathode for supporting each of said segments in movable spaced relationship with the corresponding cavity resonators of said anode; and coupling means for extracting microwave energy therefrom.

No references cited.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,953,715 September 20, 1960

Beverly D. Kumpfer

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 31, for "teenth" read -- tenth --; line 58, for "van" read -- vane --; column 2, line 26, for "Figugre" read -- Figure --.

Signed and sealed this 11th day of April 1961.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

ARTHUR W. CROCKER

Acting Commissioner of Patents