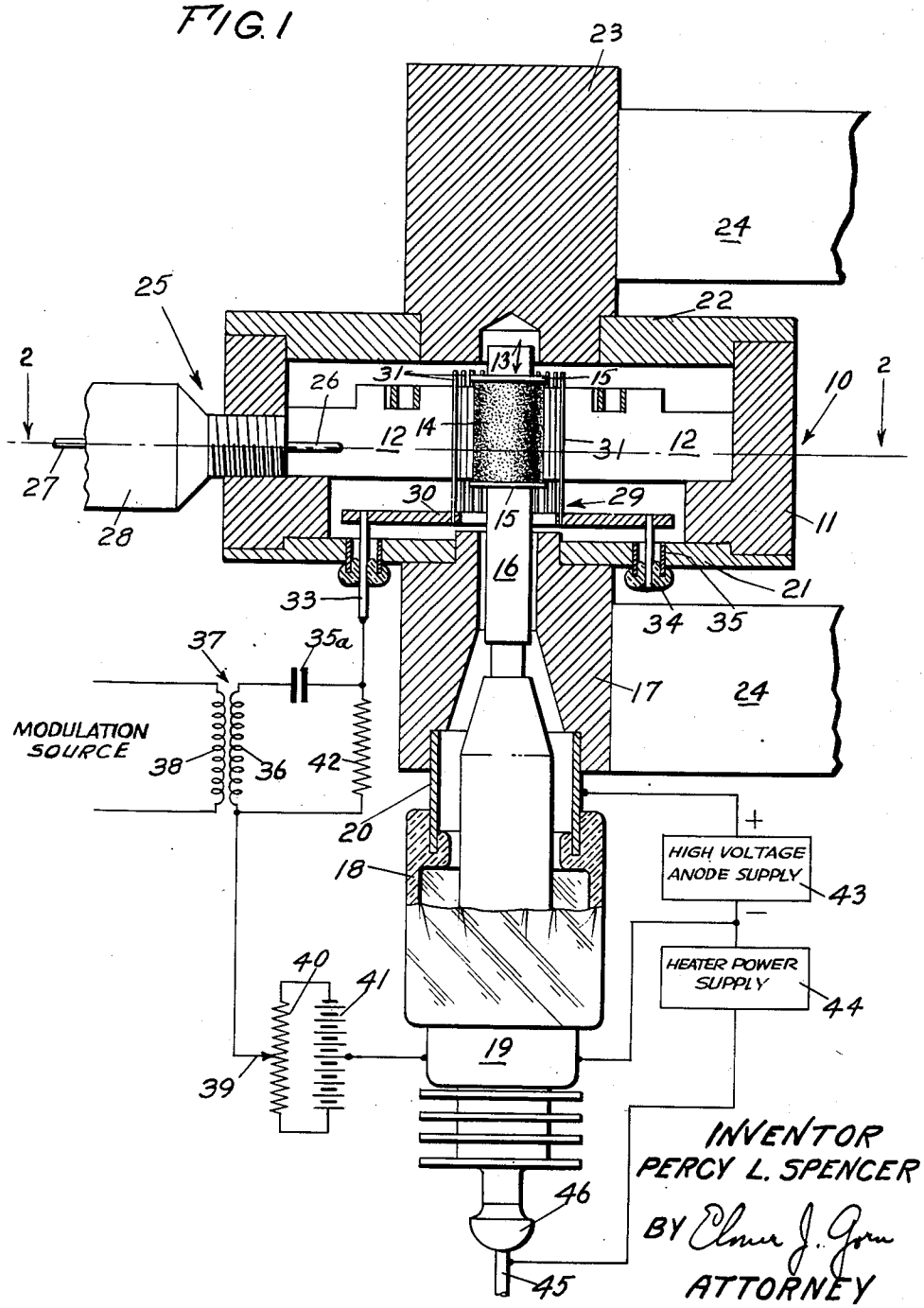
March 5, 1957 P. L. SPENCER 2,784,345

ELECTRON-DISCHARGE DEVICES

Filed June 26, 1951 4 Sheets-Sheet 1

FIG. 1



INVENTOR
PERCY L. SPENCER
BY Elmer J. Gorn
ATTORNEY

March 5, 1957 P. L. SPENCER 2,784,345

ELECTRON-DISCHARGE DEVICES

Filed June 26, 1951 4 Sheets-Sheet 2

FIG. 2

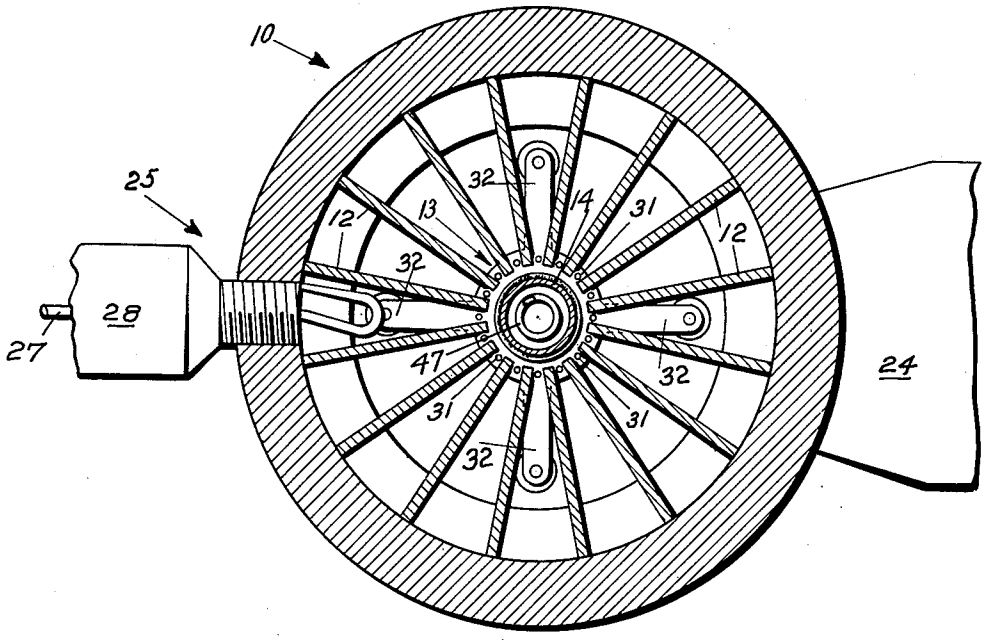
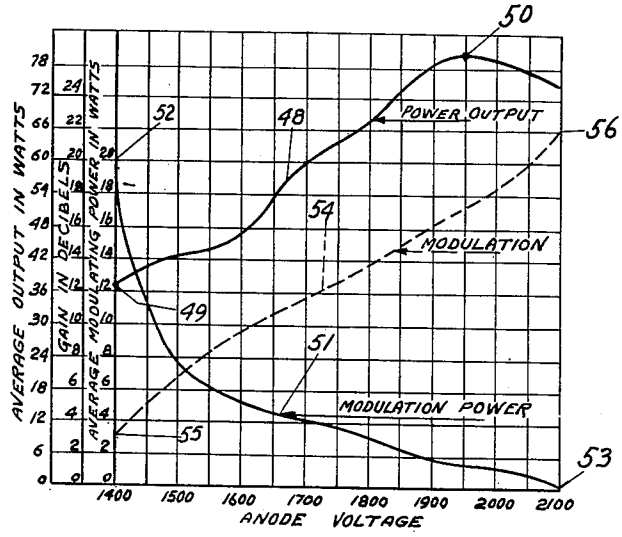


FIG. 3



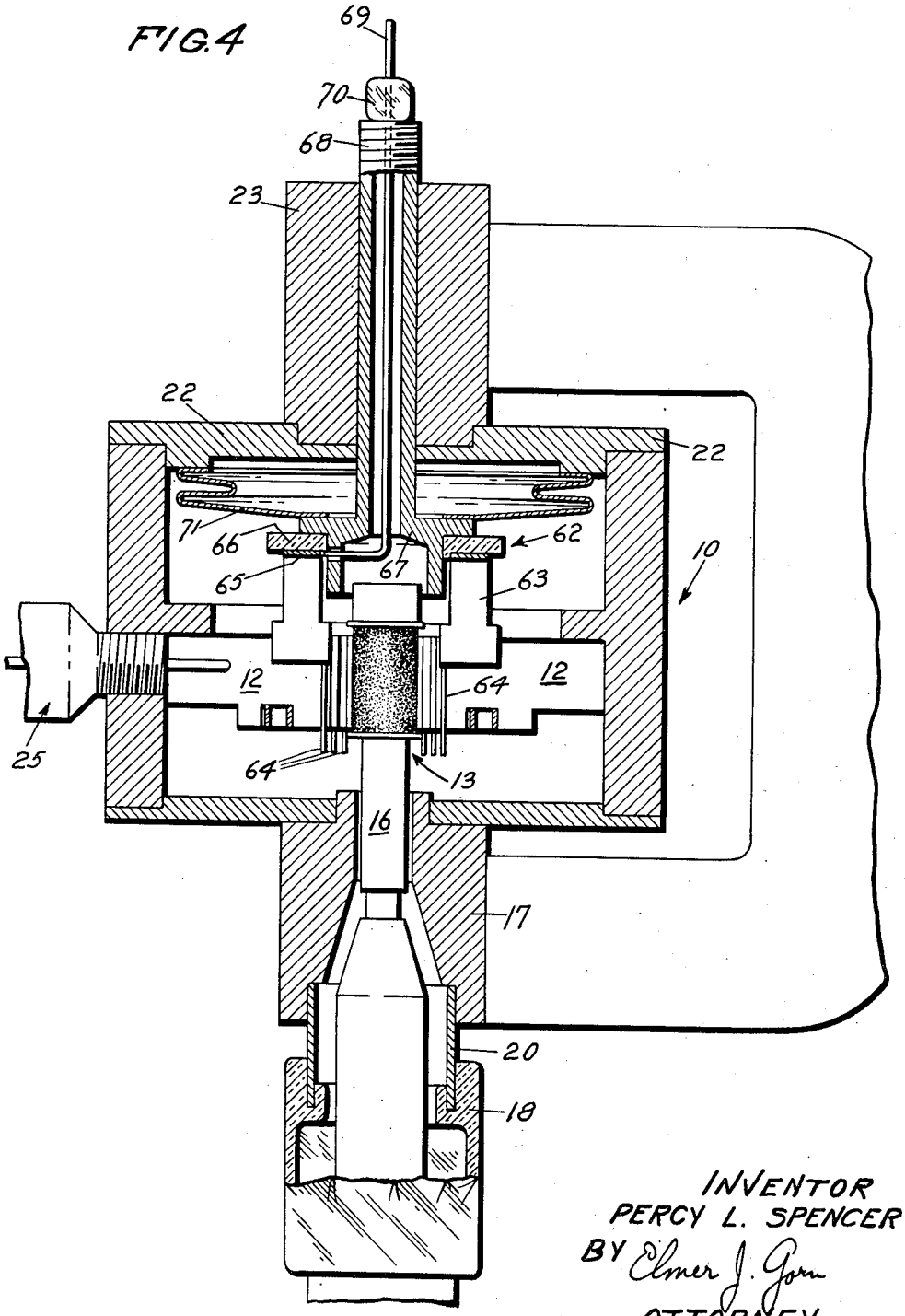
INVENTOR
PERCY L. SPENCER
BY Elmer J. Gorn
ATTORNEY

March 5, 1957 P. L. SPENCER 2,784,345

ELECTRON-DISCHARGE DEVICES

Filed June 26, 1951 4 Sheets-Sheet 3

FIG. 4



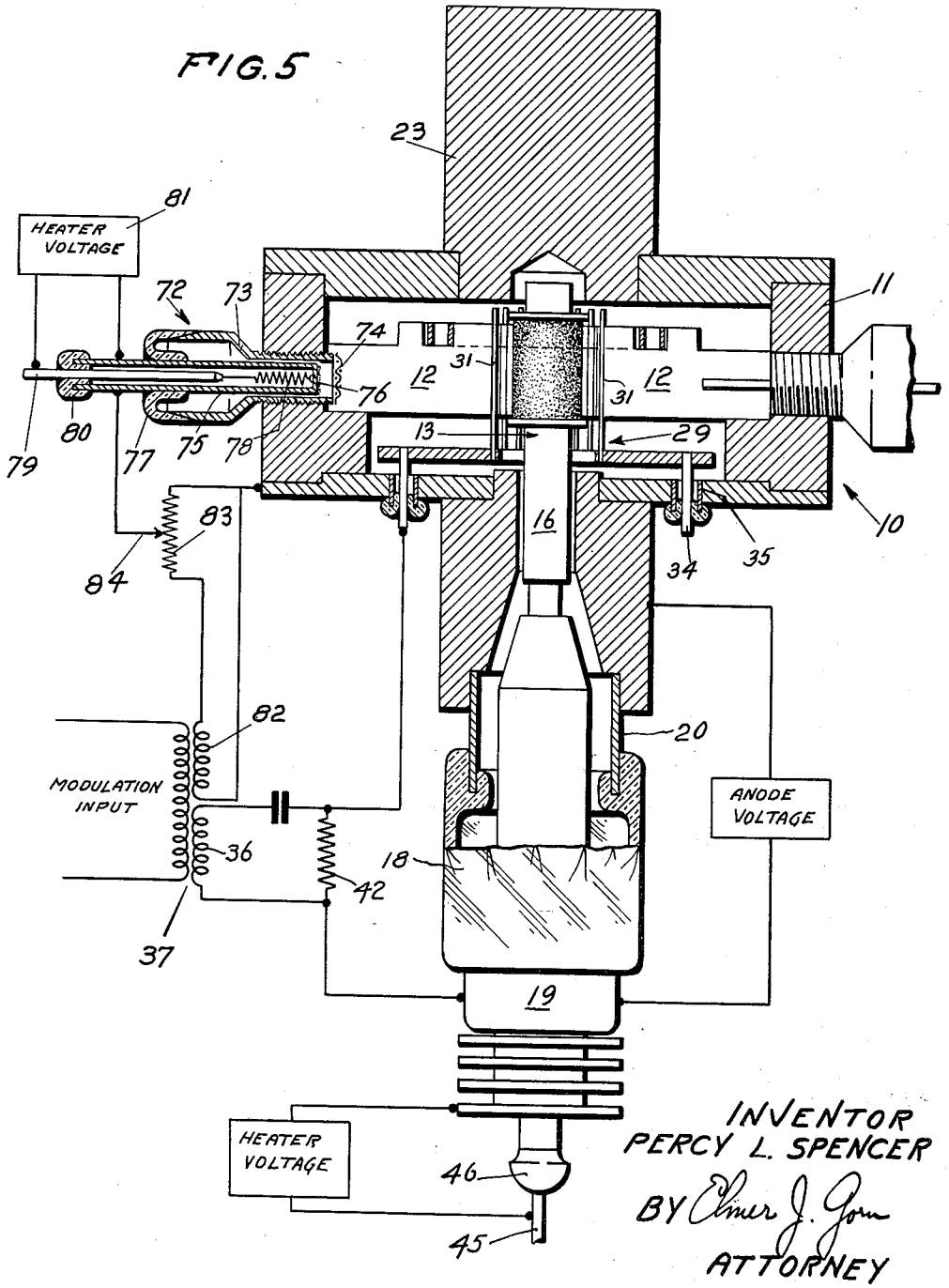
INVENTOR
PERCY L. SPENCER
BY Elmer J. Gorn
ATTORNEY

March 5, 1957 P. L. SPENCER 2,784,345

ELECTRON-DISCHARGE DEVICES

Filed June 26, 1951 4 Sheets-Sheet 4

FIG. 5



INVENTOR
PERCY L. SPENCER
BY Elmer J. Gorn
ATTORNEY

United States Patent Office 2,784,345 Patented Mar. 5, 1957

2,784,345

ELECTRON-DISCHARGE DEVICES

Percy L. Spencer, West Newton, Mass., assignor to Raytheon Manufacturing Company, Newton, Mass., a corporation of Delaware

Application June 26, 1951, Serial No. 233,634

27 Claims. (Cl. 315—39.63)

This invention relates to electron-discharge devices, and more particularly to electron-discharge devices of the magnetron type.

Magnetrons have become of outstanding importance as generators of electrical oscillations particularly at high frequencies such as frequencies lying within the microwave spectrum.

In the microwave range of frequencies, magnetrons have been developed to a point where they are more efficient than any of the other known types of oscillation generators as, for example, klystrons. Moreover, in high power applications, magnetrons may be made to produce considerably more microwave power for their weight and size than any of the other types of known microwave generators.

Heretofore, however, the uses to which magnetrons might be applied have been limited because of the difficulty in amplitude modulating the magnetron output over wide ranges of percentage modulation. It is well known that magnetrons may be pulse modulated going from cutoff to peak power by variation of the plate voltage. However, such modulation is not feasible for applications, such as modulating a microwave carrier signal with speech signals, since modulation of less than one hundred percent as would occur throughout a large percentage of the speech signals produces conditions in the magnetron wherein moding or shifting of the operating frequency may occur. When moding occurs, the power output and efficiency of the magnetron are sharply curtailed, and, furthermore, since it is normally desired that the frequency output of the magnetron remain constant, this type of modulation becomes impractical.

Moreover, modulation produced by varying the plate voltage requires the modulating signal applied to the magnetron to supply a large amount of power. As a result, a controllable modulating system for producing amplitude modulation of a magnetron output by variation of the magnetron anode voltage must be many times more bulky and expensive than the magnetron and power supply alone.

This invention discloses a grid arrangement which may be used in a magnetron to produce modulation of the output thereof. It is known that grids have been tried in magnetrons previously, but were considered unfeasible. This resulted from the fact that the grids, in order to produce control of the electron stream, were placed between the cathode and the anode in the electron stream. Such grids proved to be relatively ineffective in controlling the electron stream and became rapidly overheated, due to bombardment by the electrons.

This invention discloses that the elements of the grid structure will be effective to control the output amplitude when they are positioned adjacent the portions of the anode structure which are closest to the cathode. For example, the grid elements may be positioned between the anode members adjacent the ends thereof which are nearest the cathode. Grid elements so positioned have proved

to be particularly effective in controlling the amplitude of the output signal from the magnetron.

While the nature of the individual electron motion in the regions adjacent the tips of the anode members is extremely complex and not readily susceptible to analysis, an explanation of the grid control action which may be helpful in understanding this invention is as follows. The magnetron anode consists of a plurality of resonant circuits comprising cavity resonators, each cavity resonator, for example, being made up of a pair of adjacent anode members, together with the space therebetween. Electrons emitted from the cathode are attracted toward the anode in response to an electrostatic field applied between the anode and cathode by means of an external potential, and are caused to move circumferentially around the cathode by means of a magnetic field produced in the space between the anode and the cathode substantially perpendicular to the electrostatic field. Interaction between signal waves on the anode structure and the electron stream causes the electrons to form into groups which may be considered, for example, to resemble the spokes of a wheel extending radially outward and rotating past the anode members. These groups of electrons induce voltages on the anode members as they pass the tips thereof, thereby delivering oscillating energy to the cavities.

When grid wires are placed between the tips of the anode members and a potential is applied thereto, the groups of electrons are either pushed radially inward or pulled radially outward, depending upon the potential applied to the grid. If the groups of electrons are pushed inward away from the tips of the anode members, less alternating voltage is induced in the anode cavities, and, accordingly, less voltage is available to produce the grouping or bunching of electrons from the cathode into groups. Therefore, the amplitude of the output from the magnetron drops off. However, as the potential of the grid elements is moved in a positive direction, the electrons whirling about the cathode are permitted to approach closer to the anode members and are grouped more closely because they are more strongly affected by the alternating potentials between adjacent anode members, and, in turn, are able to couple more energy into the anode cavities both because they are grouped more closely and because they are closer to the tips of the anode members. Thus, it may be seen that, by positioning the grid elements adjacent the tips of the anode members, extremely effective control of the interaction mechanism which produces the oscillations in the magnetron may be achieved.

Moreover, since the grid elements are outside the main electron stream, the heating of the grid structure by electron bombardment is relatively small or nonexistent. In addition, the electron current to the grid structure is small or nonexistent, and hence the modulating power required to drive the grid sufficiently to produce a high degree of amplitude modulation of the magnetron output is relatively low.

This invention further discloses that the grid structure may be made integral with the tuning elements of a magnetron tuning structure, thereby producing a device wherein the electron stream may be modulated, and the magnetron may be mechanically tuned. Briefly, this is accomplished by insulating the tuning structure from both the anode and cathode of the magetron and attaching the grid elements to each of the tuning elements at points adjacent the tips of the anode members.

This invention further discloses apparatus whereby any variation of the mean frequency output of the magnetron produced by the modulating signal or by any other means may be compensated for by the use of electronic

tuning. Briefly, the electronic tuning may be a separate electron gun for shooting electrons into one of the cavities of the magnetron. This changes the dielectric constant of the cavity, thereby changing its resonant frequency in accordance with well-known principles.

Other and further objects and advantages of this invention will become apparent as the description thereof progresses, reference being had to the accompanying drawings, wherein:

Fig. 1 illustrates a partially broken away, longitudinal, cross-sectional view of a magnetron electron-discharge device having a grid structure embodying this invention, together with modulating and power supply circuits therefor;

Fig. 2 illustrates a transverse, cross-sectional view of the device shown in Fig. 1, taken along line 2—2 of Fig. 1;

Fig. 3 illustrates a graph showing the power output, modulating power input, and modulating gain of a magnetron device of the type shown in Figs. 1 and 2;

Fig. 4 illustrates a partially broken away, longitudinal, cross-sectional view of a tunable magnetron having grid elements attached to the tuning elements of the tuning structure; and

Fig. 5 illustrates a partially broken away longitudinal, cross-sectional view of a magnetron-discharge device having a control grid of the type illustrated in Figs. 1 and 2, and also an electronic tuning device, together with associated circuits for applying the modulating voltage thereto in synchronism with application of the modulating voltage to the grid to thereby compensate for any frequency deviation produced in the output of the device by application of a modulating voltage to the control grid.

Referring now to Figs. 1 and 2, there is shown a magnetron anode 10 comprising a cylindrical, conductive member 11 which may be made, for example, of copper. Extending radially inwardly from the inner surface of cylinder 11 is a plurality of anode members 12 which are shown here, for example, as planar, conductive members whose planar surfaces extend parallel to the axis of cylinder 11. Anode members 12 are alternately connected by conductive strapping at points on their upper edges adjacent their inner ends in a well-known manner in order to prevent spurious oscillations of the magnetron at undesired frequencies. Spaced from the inner ends of anode members 12 is a cathode structure 13 comprising a cathode cylinder 14 coated with electron-emissive material. Cylinder 14 is coaxial with cylinder 11 and extends to a point slightly beyond the upper and lower edges of the anode members 12. Conductive end shields 15 are attached to the ends of cathode cylinder 14, end shields 15 being annular members having a diameter somewhat greater than the diameter of cathode cylinder 14, and whose purpose is to substantially prevent movement of electrons axially out of the space between the cathode cylinder 14 and the anode members 12. Attached to the lower end of cathode cylinder 14 is a cylindrical support assembly 16 which extends downwardly through a hole in a magnetic pole piece 17. Support assembly 16 extends downwardly through a ceramic sleeve 18, and is attached to a metallic cup 19 which, in turn, is sealed to the lower end of sleeve 18. The upper end of sleeve 18 is attached to a metallic cylindrical member 20 which, in turn, is attached to magnetic pole piece 17. Pole piece 17 extends through an aperture in a lower cover plate 21 which is sealed to the lower end of anode cylinder 11. The upper end of anode cylinder 11 is closed by means of an upper cover plate 22 through which extends an upper magnetic pole piece 23. A magnetic field is produced between upper and lower pole pieces 23 and 17 in the space between the anode members 12 and the cathode 13 by means of a permanent magnet 24 whose pole portions are attached, respectively, to upper and lower pole pieces 23 and 17.

An output coupling device 25 is provided comprising

a loop 26 extending into one of the cavities defined by anode members 12. One end of loop 26 is connected to the central conductor 27 of a coaxial line whose outer conductor 28 is inserted in an aperture in anode cylinder 11 and is sealed thereto. The other end of loop 26 is connected to the outer conductor 28. An insulating seal, not shown, which may be made, for example, of glass, is provided between central conductor 27 and outer conductor 28.

The magnetron structure described thus far is by way of example only, and any anode structure could be used. For example, at the lower frequencies, conventional inductors and capacitors could be used in place of the cavities defined by anode members 12. The output coupling device can be of any desired type such as, for example, a probe coupler or a coupler connected to the anode straps.

To modulate the output of the device, there is provided a grid structure 29 comprising an annular, disk-shaped grid support member 30 surrounding cathode support assembly 16 and spaced therefrom. Extending upwardly from member 30 between each pair of anode members 12 parallel thereto and adjacent the inner ends thereof is a grid wire 31 which may be positioned, for example, five to ten thousandths of an inch farther from the cathode than the tips of the anode members. It is to be clearly understood that the positioning and the type and shape of the grid structure is disclosed herein by way of example as one embodiment which produces good results. However, any desired shape and spacing of the grid structure may be used.

The grid support disk 30 to which the grid wires 31 are attached is supported by means of four arms 32 which are integral with disk 30 and which extend radially outwardly for a short distance, and are rigidly attached to support lead-in posts 33 comprising heavy wires which extend downwardly through apertures in lower cover plate 21. Posts 33 are rigidly supported with respect to plate 21 by means of insulating seals 34 which are attached to posts 33 and to cylinders 35 which are sealed into the apertures through lower cover plate 21 surrounding posts 33. Any desired bias and modulating signals may be applied to the grid structure 29 by application of the signals to one of the support posts 33.

There is shown by way of example a type of modulating circuit which can be used for application of modulation signals to the grid structure. This modulating circuit comprises a condenser 35*a*, one side of which is connected to one of the support posts 33, and the other side of which is connected to a secondary winding 36 of a modulation transformer 37 whose primary winding 38 is connected to a modulation source. The end of winding 36 which is not connected to condenser 35*a* is connected to the tap 39 of a potentiometer 40 which is connected across a bias battery 41. A tap on battery 41 is connected to the cathode 13 through the support structure thereof such that by adjusting potentiometer tap 39 a bias voltage may be produced at tap 39 which is either positive or negative with respect to the cathode 13.

This bias voltage is applied to the grid structure 29 by connecting tap 39 through a grid load resistor 42 to the grid support post 33. The condenser 35*a* is made large enough to pass the lowest desired modulation frequency signals, and the resistor 42 is made large enough to prevent substantial loading of the transformer 37. If desired, the modulation transformer 37 may have its secondary winding connected directly between the support posts 33 and the cathode. However, for some applications, it may be desirable to adjust the direct current bias applied to the grid, and the use of a coupling condenser and grid load resistor, as shown herein, may be used advantageously as a grid leak bias combination which, in the presence of large amplitude modulation signals, tends to move the direct current grid bias more

negative, thereby guarding against overheating of the grid structure by electron bombardment.

There is shown here by way of example a high voltage anode supply **43** connected between the cathode and anode of the magnetron, and a heater power supply **44** which is connected betwen the cathode and a heater lead-in wire **45**. Heater lead-in wire **45** extends through a glass seal **46** into the cathode support structure and passes up through cathode support structure **16** coaxial therewith and insulated therefrom, and is attached to one end of a heater coil **47** positioned inside cathode cylinder **14**. The other end of the heater coil **47** is attached to the cathode cylinder **14** such that by application of a voltage between the cathode through its support structure and the heater lead-in wire **45** current will flow through the heater coil **47** to heat the cathode cylinder **14** and its electron-emissive coating to electron emitting temperature.

Referring now to Fig. 3 there is shown the operating characteristics of a grid-controlled magnetron of the type shown in Figs. 1 and 2.

In Fig. 3, there is shown a graph wherein anode voltage is plotted along the horizontal axis, while the average power output in watts is plotted along the vertical axis. This curve is plotted for conditions approaching one hundred percent modulation with a circuit similar to that illustrated in Fig. 1 where a zero bias with respect to the cathode is applied at the potentiometer tap **39**, and the amplitude of a sinusoidal input to the modulating system is adjusted to a value where detection of the output modulation produces a wave form which is sinusoidal, but where an increase of the modulation amplitude would cause a squaring or clipping of the detected output wave form. The squaring or clipping is indicative of an approach to one hundred percent modulation. As may be seen from the graph, a curve **48** shows that, at fourteen hundred volts applied to the anode, approximately thirty-seven watts of power will be produced at the output of the device, as indicated by point **49**. As the anode voltage is increased, the power output for substantially one hundred percent modulation increases until at nineteen hundred and fifty volts a maximum output of approximately eighty-one volts is produced, as indicated by point **50**. Thereafter, as the anode voltage is increased, power output decreases.

The graph of Fig. 3 also shows a curve **51** which is a plot of modulation input power versus anode voltage with the modulation input power being plotted in watts along the vertical axis, and the anode voltage being plotted along the horizontal axis. At fourteen hundred volts anode voltage, as indicated at point **52**, twenty watts of modulating power is required to produce the desired substantially one hundred percent modulation. However, as anode voltage is increased, the modulating power decreases rapidly until at twenty-one hundred volts, as indicated by point **53**, less than one-half watt of modulating power is required to produce substantially one hundred percent modulation.

There is also shown on the graph of Fig. 3 a curve **54** which is a plot of the modulation power gain in decibels versus anode voltage with the modulation gain being plotted along the vertical axis, and the anode voltage being plotted along the horizontal axis. At fourteen hundred volts anode voltage, as indicated by point **55** on the curve **54**, the modulation gain is approximately three decibels. The gain increases rapidly with anode voltage, however, until at twenty-one hundred volts a gain in excess of twenty-two decibels is produced, as indicated by point **56** on curve **54**.

Thus, it may be seen that a grid-controlled magnetron of the type disclosed herein may be operated over a wide range of anode voltages. Furthermore, the sinusoidal shape of the detected output wave form conforms closely with the wave form of the modulating signal input, thereby indicating that this type of grid-controlled magnetron has substantially linear modulating characteristics. In addition, with the particular type and positioning of the grid structure disclosed in connection with Figs. 1 and 2, frequency modulation of the output signal produced by application of a modulating signal to the grid is very low. As a result, no frequency compensation will be required for many applications of this magnetron.

Referring now to Fig. 4, there is shown a further modification of this invention wherein a mechanical tuning structure is provided in conjunction with the grid structure.

In this embodiment, the anode structure **10**, cathode structure **13**, magnetic pole pieces **17** and **23**, and output coupling device **25** are substantially similar to those shown in Figs. 1 and 2. However, a tuning structure **62** is provided for varying the frequency of the magnetron, said tuning structure comprising a plurality of tuning elements **63**, one of said elements extending into each of the cavities made up of anode members **12** adjacent the tips of said anode members. The tuning elements **63** are conductive and insertion of the elements into the cavities adjacent the tips of the anode members increases the capacitance of the cavities, thereby lowering the resonant frequency. Each of the tuning elements **63** has a conductive wire **64** extending downwardly from the lower edge thereof at a point adjacent the inner ends of the anode members, conductive wires **64** being adapted to act as grid elements.

In order to allow the tuning elements **63** and grid elements **64** to have a modulation voltage applied thereto, the tuning elements **63** are insulatedly supported with respect to the anode and the cathode in the following manner. Tuning elements **63**, which extend to a point above anode members **12**, are attached at their upper ends to a metallic ring **65** which, in turn, is bonded to a ceramic support disk **66**. Ceramic disk **66** is, in turn, attached to a movable magnetic pole piece **67** which extends upwardly through a hole in upper magnetic pole piece **23** and is adapted to be slidable therein. The upper end of magnetic pole piece **67** which extends out of upper pole piece **23** is threaded, as at **68**, to engage a mechanical tuning head, not shown, for controlling the movement of pole piece **67**. Thus, the tuning elements **63** are insulated from the movable pole piece **67**. To provide an electrical contact between the tuning elements **63** and an external connection, a lead-in wire **69** is arranged to pass downwardly through pole piece **67**, which is hollow, coaxial with pole piece **67** and spaced therefrom, lead-in wire **69** being attached at its lower end to support ring **65**. Lead-in wire **69** is insulatedly sealed by means of a glass bead **70** to the upper end of magnetic pole piece **67**. A bellows **71** is provided to create a movable vacuum seal between pole piece **67** and the anode structure **10**. Specifically, bellows **71** has one edge thereof connected to pole piece **67**, and the other edge thereof connected to the upper cover plate **22** of anode **10**.

Thus, it may be seen that by application of a modulating voltage to lead-in member **69**, the desired voltage will be applied to the tuning elements **63** and conductive wires **64** to produce the desired modulation control of the output power. At the same time, the average frequency of the output power may be controlled by adjustment of the position of the tuning elements **63** axially of the anode cavities by movement of the magnetic pole piece **67**.

Referring now to Fig. 5, there is shown a still further modification of this invention wherein means are provided for electronically tuning the magnetron synchronously with the modulating signal to automatically compensate for any frequency variation produced by application of the modulation voltage to the control grid. The magnetron-discharge device and associated circuits shown in Fig. 5 are substantially similar to those illustrated in Fig. 1. However, an electron gun **72** is pro-

vided for injecting electrons into one of the cavities defined by anode members 12. Electron gun 72 comprises a cylindrical, conductive member 73 which is inserted through an aperture in anode cylinder 11 into one of the cavities. The end of cylindrical member 73 which extends into the cavity is covered by a wire mesh 74 which acts as a grid for electron gun 72.

Positioned inside cylinder 73 is a cathode cylinder 75 which is coaxial with cylinder 73. One end of cylinder 75 terminates adjacent grid 74 in a flat plate 76, the surface of which is parallel to grid 74 and is coated with electron-emissive material. Cylinder 75 is insulatedly supported with respect to cylinder 73 by means of a glass seal 77. A heater coil 78 is provided inside cathode cylinder 75 adjacent end plate 76. One end of heater coil 78 is connected to end plate 76, and the other end of heater coil 78 is connected to a lead-in member 79 which extends out beyond the exterior end of cathode cylinder 75, and is insulatedly supported with respect thereto, and sealed therein by a glass seal 80. A heater voltage supply 81 is connected between lead-in member 79 and cathode cylinder 75, thereby supplying heater current to coil 78 and heating end plate 76 such that the electron-emissive coating thereon becomes active to copiously emit electrons.

Modulation transformer 37 has an additional winding 82 thereon across which is connected a potentiometer 83. A variable tap 84 of potentiometer 83 is connected to the cathode cylinder 75. One end of potentiometer 83 is connected to the magnetron anode 10, and hence to the cylinder 73 to which is attached grid 74. Thus, a component of the modulation voltage is applied between the grid 74 and the cathode cylinder 75, thereby varying the number of electrons injected into the cavity from the electron gun 72. This, in turn, varies the resonant frequency of the cavity, thereby tuning the magnetron.

The polarity of winding 82 is chosen such that the signal applied to the electron gun 72 will produce tuning of the magnetron which is in opposition to any tuning produced by the modulation signal applied to the grid structure 29. The potentiometer tap 84 is adjusted such that the proportion of the modulation signal applied to the electron gun 72 is just sufficient to compensate for any frequency deviation produced by application of the modulation signal to the grid structure 29.

If desired, an additional direct current bias may be applied to the electron gun 72, adjustment of which will adjust the average output frequency of the magnetron.

In the grid modulation circuit illustrated in Fig. 5, the adjustable bias supply comprising battery 41 and potentiometer 40 have been omitted, and the junction between the grid load resistor 42 and secondary winding 36 has been connected directly to the cathode 13 through the cathode support structure.

If desired, however, the biasing arrangement shown in Fig. 1 or any other desired biasing arrangement may be used.

This completes the description of the particular embodiments of the invention illustrated herein. However, many modifications thereof will be apparent to persons skilled in the art without departing from the spirit and scope of this invention. For example, the invention is not necessarily limited to magnetrons having a circular anode and cathode structure, but may be applied to linear magnetron devices, as well as to magnetron traveling wave amplifiers. Accordingly, it is desired that this invention be not limited by the particular details of the embodiments described herein, except as defined by the appended claims.

What is claimed is:

1. An electron-discharge device comprising a source of electrons, a cavity anode structure capable of simultaneously producing a plurality of high frequency fields in the space between said source and said cavity anode structure, means adjacent said anode structure for producing a magnetic field in the space between said electron source and said anode structure, and a grid structure comprising a plurality of grid elements, said grid elements being positioned adjacent and between portions of said anode structure which are nearest to said electron source.

2. An electron-discharge device comprising a source of electrons, a periodic electrode spaced from said electron source and capable of simultaneously producing a plurality of high frequency fields in the space between said source and said periodic electrode, means adjacent said periodic electrode for producing a magnetic field in the space between said electron source and said periodic electrode, and a grid structure comprising a plurality of grid elements, said grid elements being positioned adjacent and between portions of said periodic electrode which are nearest to said electron source.

3. An electron-discharge device comprising a substantially evacuated envelope containing a source of electrons, an anode structure spaced from said electron source and capable of simultaneously producing a plurality of high frequency fields in the space between said source and said anode structure, means adjacent said anode structure for producing a magnetic field in the space between said electron source and said anode structure, and a grid structure comprising a plurality of grid elements, said grid elements being positioned adjacent and between portions of said anode structure which are nearest to said electron source.

4. An electron-discharge device comprising a source of electrons, an anode structure comprising a plurality of cavity resonators spaced from said electron source, means adjacent said anode structure for producing a magnetic field in the space between said electron source and said anode structure, and a grid structure comprising a plurality of grid elements, said elements extending into different cavities of said anode structure in regions having relatively high dielectric currents during operation of said device.

5. An electron-discharge device comprising a source of electrons, a periodic electrode spaced from said electron source and capable of simultaneously producing a plurality of high freqency fields in the space between said source and said periodic electrode, means for producing an electrostatic field between said source and said periodic electrode, means adjacent said periodic electrode for producing a magnetic field in the space between said electron source and said periodic electrode substantially perpendicular to said electrostatic field, and a grid structure comprising a plurality of grid elements, said grid elements being positioned adjacent and between portions of said periodic electrode which are nearest to said electron source.

6. An electron-discharge device comprising a source of electrons, an anode structure spaced from said electron source and capable of simultaneously producing a plurality of high frequency fields in the space between said source and said anode structure, means for producing an electrostatic field between said source and said anode structure, means adjacent said anode structure for producing a magnetic field in the space between said electron source and said anode structure substantially perpendicular to said electrostatic field, and a grid structure comprising a plurality of grid elements, said grid elements being positioned adjacent and between portions of said anode structure which are nearest to said electron source.

7. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode, magnet means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, and a grid structure comprising a plurality of grid elements, said grid elements being positioned adjacent portions of said anode structure which are nearest to said

cathode and further from said cathode than said portions are spaced from said cathode.

8. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode and capable of simultaneously producing a plurality of time-varying electrostatic fields in the space between said cathode and said anode structure, said anode structure comprising a plurality of anode members, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, and a grid structure comprising a plurality of grid elements, said grid elements being positioned adjacent and between said anode members.

9. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode, said anode structure comprising a plurality of anode members, adjacent ones of said anode members, together with the space therebetween, defining cavity resonators, magnet means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, and a grid structure comprising a plurality of grid elements, said grid elements being positioned adjacent and between the inner ends of said anode members.

10. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode, said anode structure comprising a plurality of anode members, adjacent ones of said anode members, together with the space therebetween, defining cavity resonators, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, and a grid structure comprising a plurality of grid elements, said grid elements being positioned between said anode members and at substantially the same distance from said cathode as the edges of said anode members which are nearest said cathode.

11. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode and capable of simultaneously producing a plurality of time-varying electrostatic fields in the space between said cathode and said anode structure, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, an electrode structure comprising a plurality of conductive elements, said elements being positioned adjacent portions of said anode structure which are nearest to said cathode and at substantially the same distance from said cathode as said portions, and said electrode structure being insulatedly supported with respect to said anode structure and said cathode.

12. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode and capable of simultaneously producing a plurality of time-varying electrostatic fields in the space between said cathode and said anode structure, magnet means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, an electrode structure comprising a plurality of conductive elements, said elements being positioned adjacent and between portions of said anode structure which are nearest to said cathode, and said electrode structure being insulatedly supported with respect to said anode structure.

13. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode, signal output means coupled to said anode structure, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, an electrode structure comprising a plurality of elements, said elements being positioned adjacent portions of said anode structure which are nearest to said cathode and further from said cathode than said anode structure is from said cathode, and signal input means coupled to said electrode structure.

14. An electron-discharge device comprising a cathode, an anode structure surrounding said cathode and spaced therefrom, said anode structure comprising a plurality of anode members extending radially toward said cathode, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, and an electrode structure comprising a plurality of elements, said elements being positioned adjacent and between portions of said anode structure which are nearest to said cathode.

15. An electron-discharge device comprising a cathode, an anode structure surrounding said cathode and spaced therefrom, said anode structure comprising a plurality of anode members extending radially toward said cathode, adjacent ones of said anode members, together with the space therebetween, defining cavity resonators, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, and an electrode structure comprising a plurality of elements, said elements being positioned adjacent and between portions of said anode structure which are nearest to said cathode.

16. An electron-discharge device comprising a cathode, an anode structure surrounding said cathode and spaced therefrom, said anode structure comprising a plurality of anode members extending radially toward said cathode, alternate anode members being connected by conductive strapping, magnet means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, and an electrode structure comprising a plurality of elements, said elements being positioned adjacent and between portions of said anode structure which are nearest to said cathode.

17. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode, said anode structure comprising a plurality of anode members, adjacent ones of said anode members, together with the space therebetween, defining cavity resonators, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, a tuning structure movably and insulatedly supported with respect to said anode structure, said tuning structure comprising a plurality of tuning elements extending into said cavity resonators, and means for applying a control potential to said tuning structure.

18. An electron-discharge device comprising a cathode, an anode structure surrounding said cathode and spaced therefrom, said anode structure comprising a plurality of anode members, adjacent ones of said anode members, together with the space therebetween, defining cavity resonators, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, a tuning structure movably and insulatedly supported with respect to said anode structure, said tuning structure comprising a plurality of tuning elements extending into said cavity resonators, and means for applying a control potential to said tuning structure.

19. An electron-discharge device comprising a cathode, an anode structure surrounding said cathode and spaced therefrom, said anode structure comprising a plurality of anode members extending radially toward said cathode, adjacent ones of said anode members, together with the space therebetween, defining cavity resonators, magnet means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, a tuning structure movably and insulatedly supported with respect to said anode structure, and a plurality of grid elements attached to said tuning structure, said grid elements being positioned adjacent portions of said anode structure which are nearest to said cathode.

20. An electron-discharge device comprising a cathode, an anode structure comprising a plurality of cavities spaced from said cathode, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, a tuning structure movably and insulatedly supported with respect to said anode structure, a plurality of grid elements attached to said tuning structure, said grid elements being posi-

tioned adjacent portions of said anode structure which are nearest to said cathode, and a lead-in conductor for applying a signal to said grid elements.

21. An electron-discharge device comprising a cathode, an anode structure surrounding said cathode and spaced therefrom, said anode structure comprising a plurality of anode members extending radially toward said cathode, alternate anode members being connected by conductive strapping, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, a tuning structure movably and insulatedly supported with respect to said anode structure, and a plurality of grid elements attached to said tuning structure, said grid elements being positioned between portions of said anode structure which are nearest to said cathode.

22. An electron-discharge device comprising a cathode, an anode structure comprising a plurality of cavities spaced from said cathode, magnet means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, a tuning structure movably and insulatedly supported with respect to said anode structure, a plurality of grid elements attached to said tuning structure, said grid elements being positioned adjacent portions of said anode structure which are nearest to said cathode, and means for applying a bias potential and a signal to said grid elements.

23. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, an electrode structure comprising a plurality of conductive elements, said elements being positioned between portions of said anode structure which are nearest to said cathode, a lead-in conductor for applying a signal to said elements, and an electronic tuner coupled to said anode structure.

24. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, an electrode structure comprising a plurality of elements, signal input means coupled to said electrode structure, and an electronic tuner coupled to said anode structure.

25. An electron-discharge device comprising a cathode,

an anode structure surrounding said cathode and spaced therefrom, said anode structure comprising a plurality of anode members extending radially toward said cathode, magnet means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, an electrode structure comprising a plurality of elements, signal input means coupled to said electrode structure, and an electronic tuner coupled to said anode structure.

26. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, an electrode structure comprising a plurality of elements, signal input means coupled to said electrode structure, an electronic tuner coupled to said anode structure, and a modulating system coupled to both said signal input means and said electronic tuner.

27. An electron-discharge device comprising a cathode, an anode structure surrounding said cathode and spaced therefrom, said anode structure comprising a plurality of anode members extending radially toward said cathode, means adjacent said anode structure for directing electrons emitted from said cathode along paths adjacent said anode structure, an electrode structure comprising a plurality of elements, signal input means coupled to said electrode structure, an electronic tuner coupled to said anode structure, and a modulating system coupled to both said signal input means and said electronic tuner.

References Cited in the file of this patent

UNITED STATES PATENTS

1,387,985	Hull	Aug. 16, 1921
1,957,327	Elser	May 1, 1934
2,013,093	Frantz	Sept. 3, 1935
2,217,745	Hansell	Oct. 15, 1940
2,295,816	Wilson	Sept. 15, 1942
2,408,903	Biggs et al.	Oct. 8, 1946
2,409,038	Hansell	Oct. 8, 1946
2,432,608	Desch et al.	Dec. 16, 1947
2,444,419	Bondley	July 6, 1948
2,449,794	Steele	Sept. 21, 1948
2,468,127	Smith	Apr. 26, 1949
2,508,280	Ludi	May 16, 1950
2,538,087	Derby	Jan. 16, 1951