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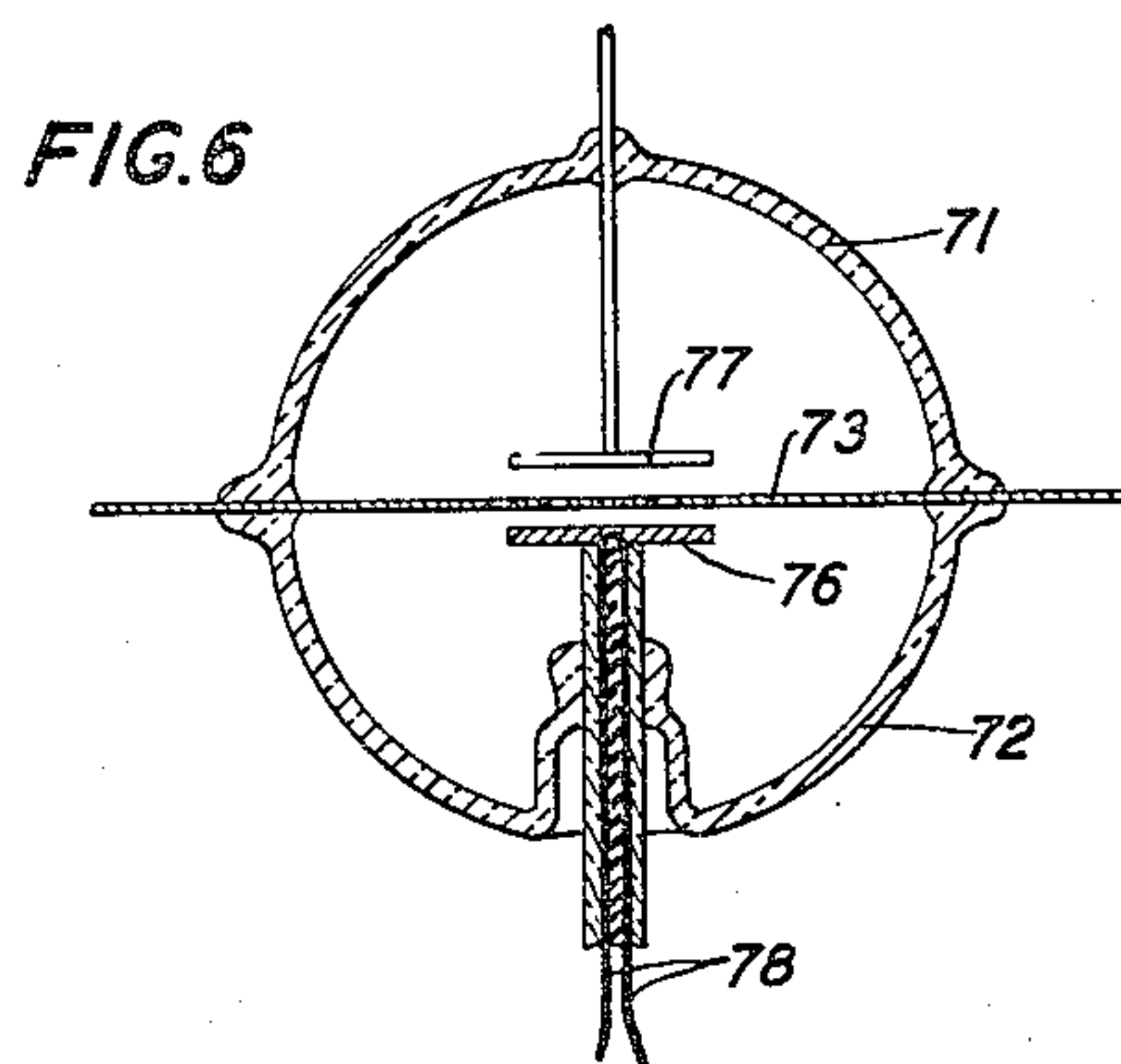
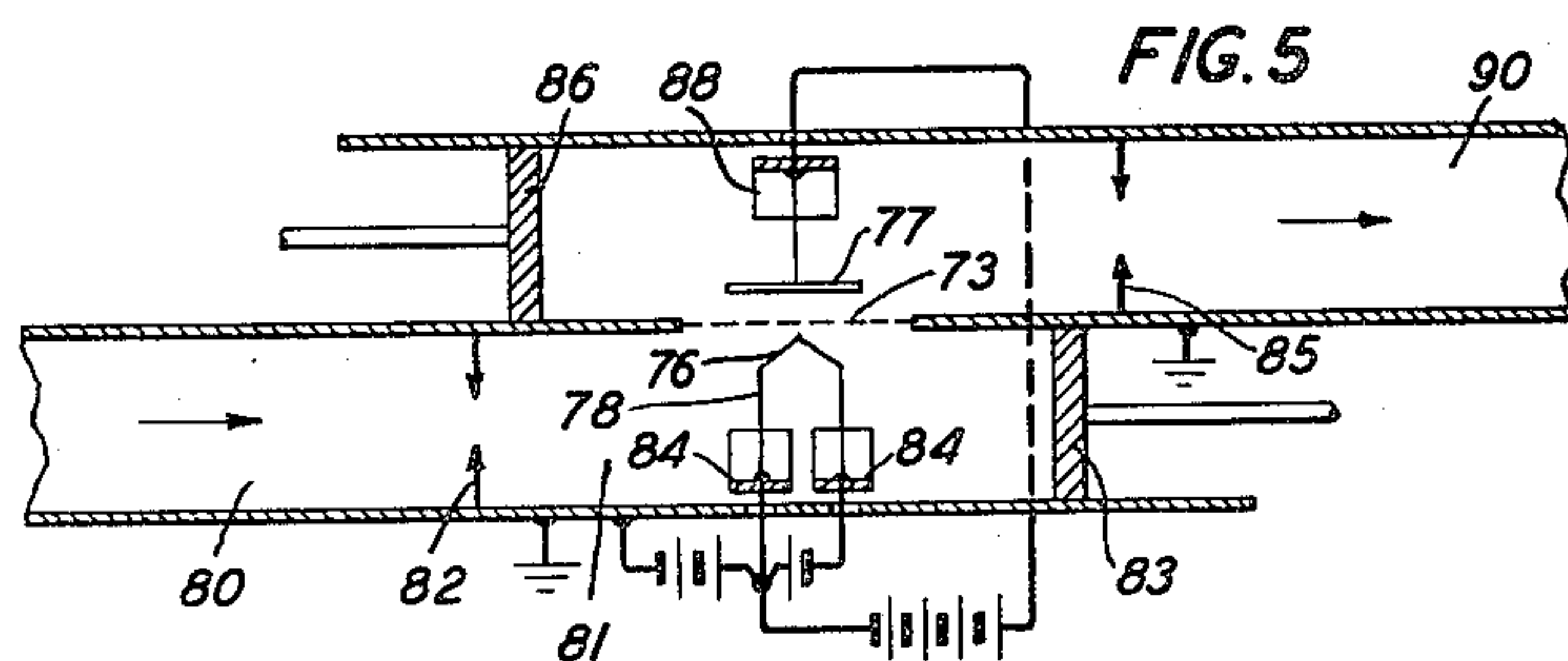
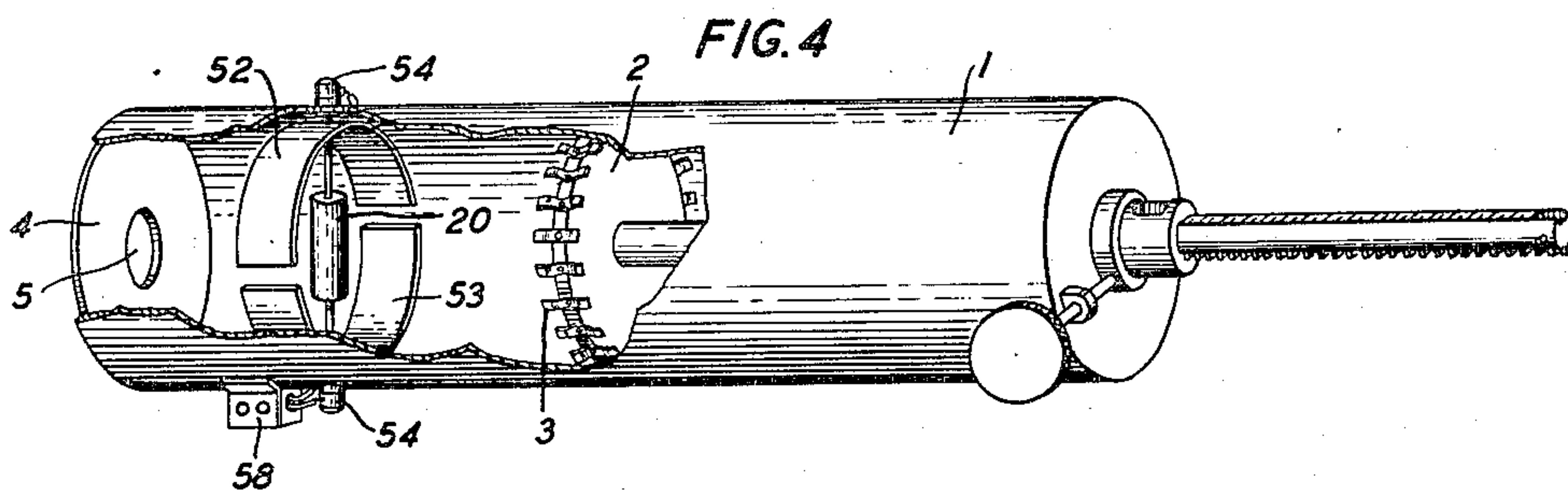
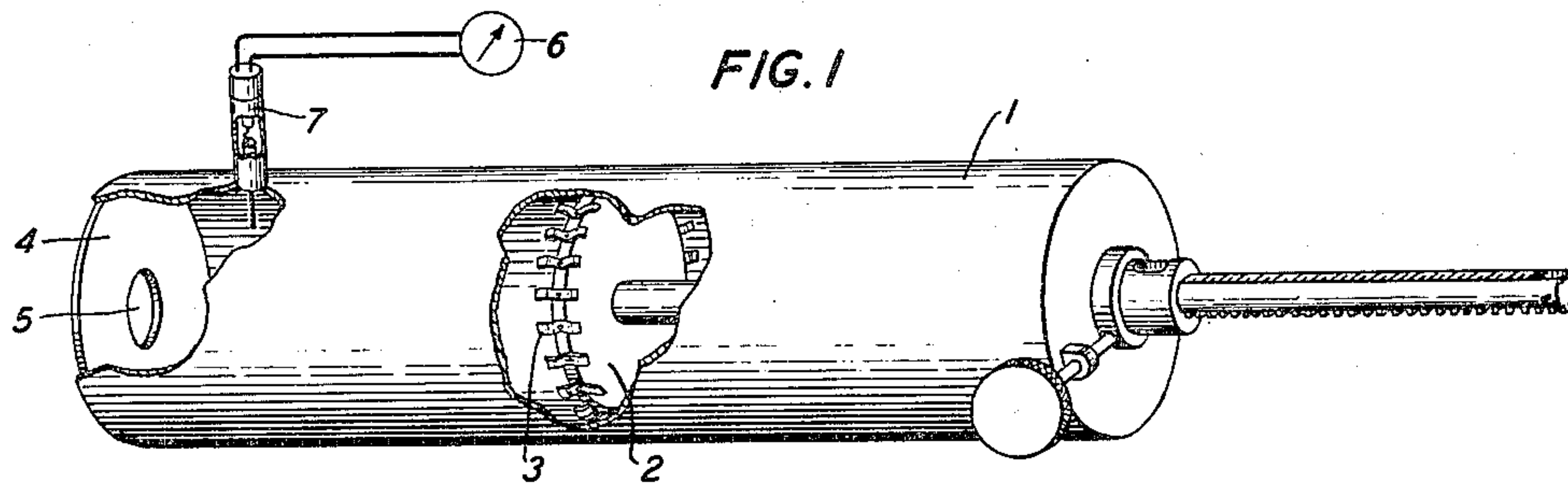
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2,106,771

ULTRAHIGH FREQUENCY SIGNALING

Filed April 11, 1936

2 Sheets-Sheet 1



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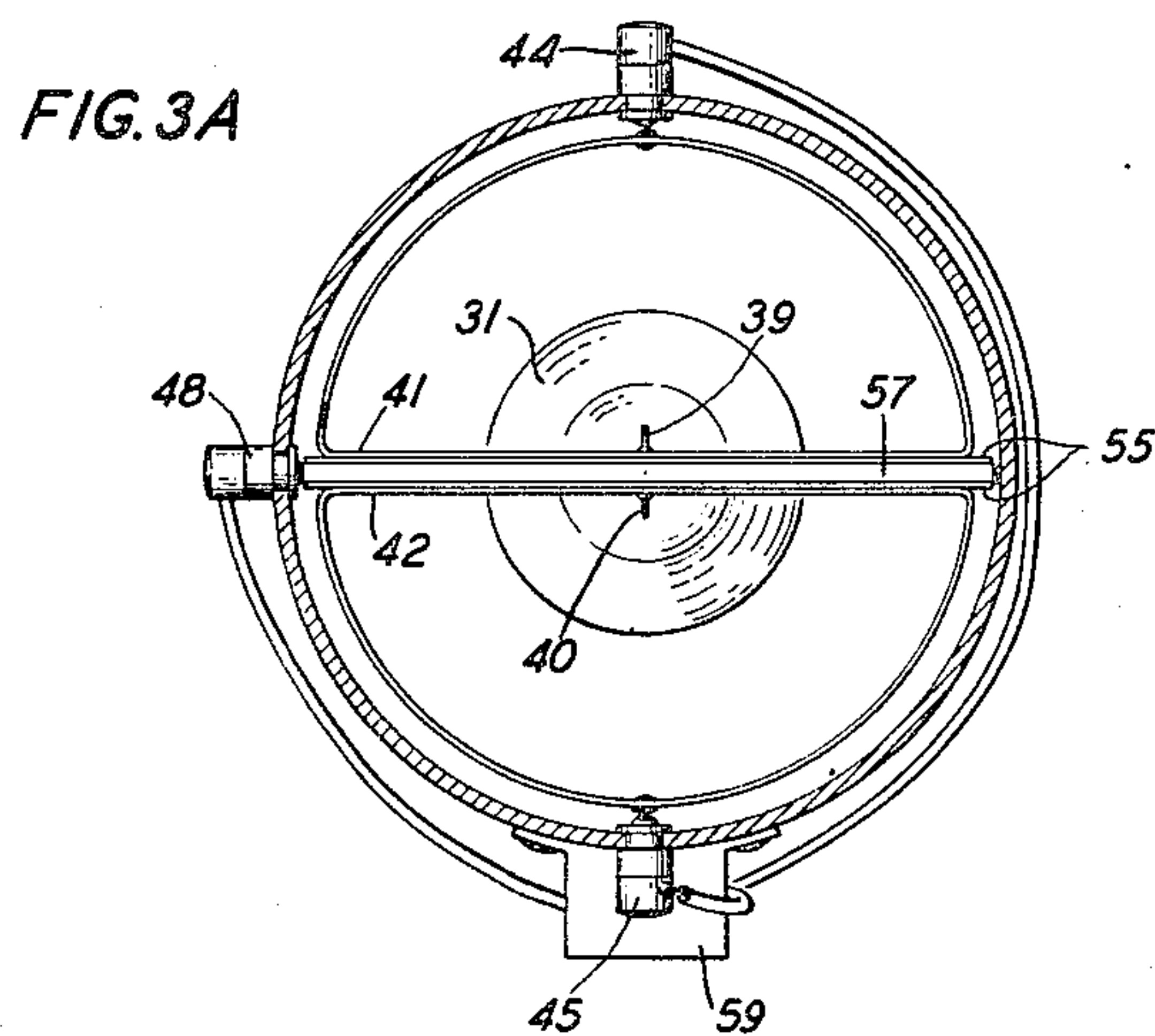
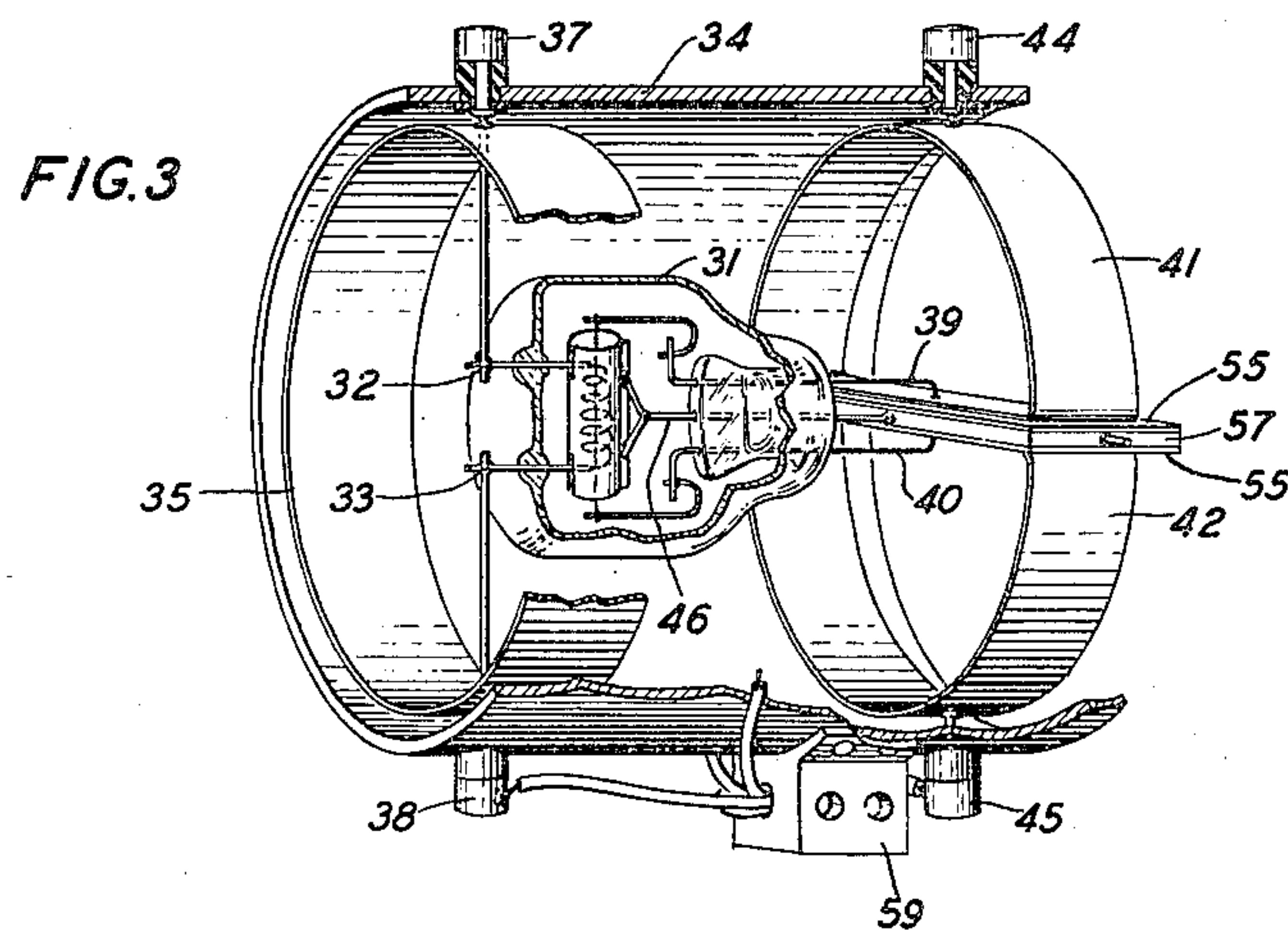
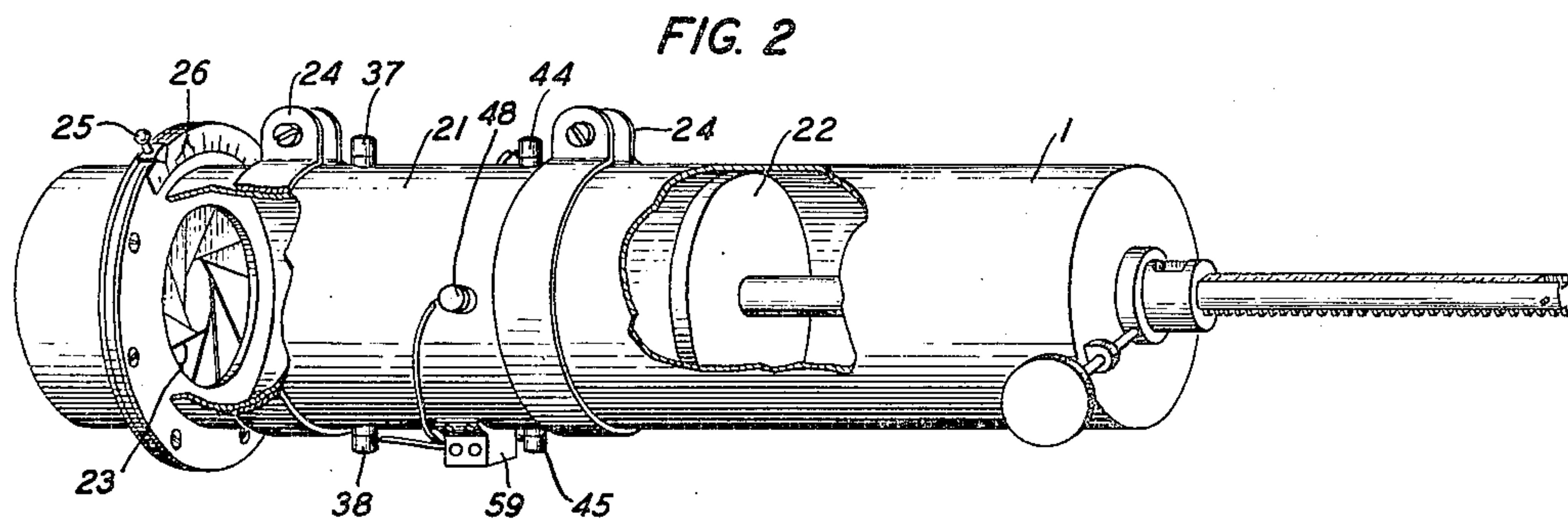
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ULTRAHIGH FREQUENCY SIGNALING

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2 Sheets-Sheet 2



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ULTRAHIGH FREQUENCY SIGNALING

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Application April 11, 1936, Serial No. 73,940
In France September 11, 1935

16 Claims. (Cl. 250—36)

This invention relates to the transmission of ultra-high frequency electromagnetic waves and more especially, but not exclusively, to methods and apparatus for the generation and utilization of high frequency electromagnetic waves in dielectric guides.

A principal object of this invention is to provide new and improved apparatus and corresponding methods for improving efficiency and matching impedances in the operation of dielectric guides. Another object of this invention is to provide for the generation of short electromagnetic waves for purposes of radio transmission or for transmission through dielectric guides.

Another object of this invention is to provide for the reception and utilization of power transmitted by short electromagnetic waves through space or through a dielectric guide. All of these objects and other objects and advantages of this invention will become apparent upon consideration of a limited number of examples of practice in accordance with the invention which I have chosen for presentation in the following specification. It will be understood that this specification relates to these particular embodiments of the invention and that the scope of the invention will be indicated by the appended claims.

Referring to the accompanying drawings,

Fig. 1 is a view of an electrically resonant cavity having properties fundamental to impedance matching;

Fig. 2 shows one form of the apparatus as used to match a source of waves to a dielectric guide;

Figs. 3 and 3A show in detail a suitable generator or source of dielectrically-guidable waves;

Fig. 4 is a further modification adapted for the reception of electromagnetic waves; and

Figs. 5 and 6 show still other modifications applicable to the amplification or repeating of short electromagnetic waves.

A "dielectric guide", as the term is employed in this specification, is a guide for electromagnetic wave comprising a dielectric medium bounded by a discontinuity. The medium may be any good insulator, preferably of low loss. If it has a relatively high dielectric constant the discontinuity may be the interface between the material and the surrounding air. The discontinuity may also be at the boundary of the medium and a surrounding metal shell. As will be obvious from the disclosures hereinafter, fluid dielectrics are particularly adaptable to these purposes, and when this fluid is air the construction becomes extremely simple. The guide may conveniently take a cylindrical form though other shapes might be preferable for particular cases.

It has been shown in my application for Letters Patent, Serial No. 745,457, filed September 25, 1934, on a Filter system for high frequency elec-

tric waves that under certain preferred conditions waves may be propagated along a dielectric guide and be reflected by discontinuities placed in the path. Typical discontinuities are tightly fitting pistons and iris diaphragms placed perpendicularly to the axis of the guide. The very act of reflecting a wave gives rise to reactive components not unlike those introduced by inductances or capacities in ordinary alternating current practice.

A short piece of guide may be terminated at its two ends in an iris and a piston respectively. This provides a highly resonant chamber analogous in nature to the resonant air columns or organ pipes familiar in acoustics. Fig. 1 shows one form of such an electrically resonant chamber. As illustrated the chamber comprises a hollow brass cylinder 1, perhaps 5 inches in diameter and 2 feet long, near one end of which is a tightly fitting piston 2 which is adjustable in position by means of a handwheel, pinion and rack. Good electrical contact may be had between the piston 2 and the wall of cylinder 1 by means of several phosphor bronze fingers 3 arranged around the periphery of the piston 2 or by balls retained in a V-shaped groove. At the other end of the cylinder is fitted an end plate 4 in which is cut a circular opening 5 having a diameter of say one-half that of the chamber itself.

Applicant has found by both mathematical analysis and experiment that when such a chamber is excited by an alternating electromotive intensity having a frequency of say 2000 mc. and the chamber is varied in length by moving the piston 2 conditions of resonance can be set up within the chamber. Resonance occurs at regular half-wave intervals in accordance with the more usual standing wave phenomena. Even in this simple form the device functions as a wave meter, and the rod attached to piston 2 may be appropriately scaled for this purpose. This resonant condition is indicated by the maximum reading of a meter 6 when activated by a crystal detector 7 loosely coupled to the resonant cavity.

The general principles of impedance matching as here disclosed are much the same for all of the forms of dielectrically guided waves. However, for purposes of illustration, we shall assume below that the so-called H_1 type of wave is involved. The nature of this particular type of wave is disclosed in my application, Serial No. 701,711, filed December 9, 1933, and of dielectrically guided waves in general in my application, Serial No. 745,457, supra. Resonance is associated with a condition of standing waves. The latter results when two oppositely directed trains of similar waves of the same length and roughly the same amplitude meet. In the case at hand the two trains correspond respectively to

a train being propagated to the right in Fig. 1 and another due to the forerunners of the first train being reflected by the piston 2. When the chamber is properly tuned so that the amplitude is maximum, reflection takes place at both the piston 2 and the end wall 4 surrounding the iris opening 5. When stable conditions have been reached, only enough power will flow into the chamber through the iris 5 to make up the relatively low dissipation incurred by reason of the resistivity of the walls of the chamber and perhaps other losses involved in functioning of apparatus placed within the chamber. The chamber as a whole presents to waves approaching the iris 5 from the left an impedance that may vary over a wide range depending on the proximity to resonance to which the cavity is tuned and also on the size of the iris opening.

Nodes and loops of electric force prevail within the chamber. These correspond respectively to regions along the axis of the chamber where the electric force is minimum and maximum. The space near a loop of electric force will appear as a high external impedance to a small sink or a small source located in that space. Similarly a node of electric force will appear as a low external impedance. Intermediate points provide intermediate impedances. It is a general principle well known in electric science that a device functions most efficiently when it looks into its own characteristic impedance. A resonant cavity such as shown in Fig. 1 may therefore be used as a suitable external impedance into which either a source or a sink of waves may efficiently operate. For present purposes we may regard as typical sources, as the term is used above, generators of electric waves, outputs of amplifiers or the ends of wave guides delivering power to the system. Similarly, a typical sink might be a detector or other form of receiver of electric waves, the input to an amplifier or the end of a wave guide into which electric waves are being delivered.

According to this view the chamber may be regarded as an impedance matching device or transformer somewhat analogous in nature to the simple tuned circuit common in radio. As is well known the latter is frequently used to approximate a match between say a radio antenna and the grid input to the first stage of a radio frequency amplifier, the impedance match being effected by tapping the respective units across the proper number of turns of the inductance.

Fig. 2 discloses a generator of electric waves which utilizes these fundamental principles. It consists of an oscillator unit 21 together with a piston assembly 22 and an adjustable iris 23 arranged in the order shown. These may conveniently be fastened together by external clamps 24. For frequencies of 2000 mc. it is appropriate to make the external shells of these units of 5 inch brass pipe and to use air as the internal dielectric.

The adjustable iris 23, which may be of the type employed in cameras, is provided with a handle 25 for regulating the diameter of the iris opening and a cooperating index and scale 26. Alternatively, interchangeable plates in which holes of appropriate size have been cut may be employed.

The oscillator unit 21, shown in detail in Figs. 3 and 3A, comprises a spiral grid Barkhausen tube 31. The two terminals of the positively charged spiral grid are connected by radial leads 32 and 33 to diametrically opposite points on the guide 34, through a by-pass condenser made in

the form of a slightly smaller inner ring 35 insulated from the main walls of the guide 34 by means of thin mica. External connections to this ring are had through either of the binding posts 37 and 38. The latter are insulated from the main guide by means of bakelite bushings. The purpose of the by-pass condenser is to prevent any appreciable part of the wave power resident inside the chamber from being communicated to the exterior. The filament leads 39 and 40 of the Barkhausen tube lead respectively to insulated tin-foil strips 41 and 42, each comprising another by-pass condenser, and ultimately to the exterior through two binding posts 44 and 45. The anode lead 46 connects to a rigid diametral plate 57 which in turn is connected electrically to the walls of the main guide. The two tinfoil strips 41 and 42 are insulated from the more rigid diametral conductor 57 by means of mica 55. They continue around the inside walls of their respective halves of the guide to their binding posts 44 and 45. These three plates together constitute a relatively thin by-pass condenser which lies along an equipotential path of the H_1 type of wave generated. This condenser does not, therefore, greatly influence the propagation of the H_1 type of wave. The separation between the three by-pass structures and the wall of the guide has been exaggerated in the drawings. A fifth binding post 48 grounded on the main guide provides a connection to the anode. It is possible and in fact often desirable to interchange connection 57 with either 41 or 42. This avoids placing the pipe at the relatively high constant potential prevailing on the anode of the Barkhausen tube. Separate wires lead from the binding posts, over the outside of the guide to a plug connector 59 and thence to a direct current power supply not shown. The Barkhausen tube used in the particular generator just disclosed has been described more fully by Messrs. Kelly and Samuel in *Electrical Engineering*, vol. 53, page 1504, November 1934.

The use of a Barkhausen oscillator in this connection is only illustrative. Magnetron oscillators, spark oscillators or other sources of waves might by slight modification also be used.

The best position for the oscillator relative to the two ends of the chamber as well as the settings of the piston and the iris opening of Fig. 2 are functions of the respective impedances of oscillator and the external load and can best be arrived at by experiment. In general they will not be the same as might be predicted from the more ideal case disclosed in Fig. 1. If a single frequency is desired it is of course possible to construct an extremely simple generator with all dimensions fixed.

The output of the generator issues from the iris opening either into the surrounding space or into a connected wave guide or other apparatus coupled thereto. If the wave power is permitted to radiate, its characteristics may be explored by means of a suitable probe. By this means it can readily be verified that the field is polarized in the plane of the connectors 32 and 33 of Fig. 3 and that it possesses considerable directivity as it is launched into space.

Fig. 4 shows a modification of the resonant chamber that is well adapted for the efficient reception of electric waves. The construction is for the most part similar to that described above. A detector unit 20 in cartridge form replaces the spiral grid Barkhausen tube 31 shown in Fig. 3. Crystals of silicon, galena or carborundum in suit-

able mountings may be used for this purpose. For the H_1 type of wave this detector is capacitively connected to diametrically opposite points on the walls of the guide through by-pass condensers 52 and 53. Connections to the exterior of the guide are made through insulated binding posts 54 and thence to the plug connector 58 to which may be connected a signal indicating device. A piston 2 and an iris diaphragm 4 are arranged exactly as shown in Fig. 1.

For some purposes it may be desirable to mount the detector in a short section of pipe as a separate unit and when needed connect to it the piston assembly and iris mounting by external clamps as disclosed in Fig. 2. It is possible to use in place of the crystal detector a thermionic diode or triode. In this case it is necessary to provide for direct current power to the various electrodes. This can be done by means of by-pass condensers of the type described hereinbefore.

The function of the tuned chamber in this case is to impress a maximum of wave power received through the iris 5 onto the crystal detector 20. In this connection it is convenient to regard the chamber as a transformer which matches the medium outside the iris to the crystal detector within. If waves arriving over guides are to be received, the chamber is simply clamped directly to the guide and appropriate adjustments are made for an optimum signal. If radio waves are to be received it may be desirable to place a horn-like structure outside the iris in order to increase pick-up and further enhance the strength of the received signal.

Fig. 5 shows an application of the resonant chamber principle to the amplification or repeating of hyper-frequency waves. This subject-matter is more fully disclosed and claimed in my pending application for Letters Patent, Serial No. 104,524, filed October 7, 1936. For best results a vacuum tube of special design should be used; a suitable structure is illustrated in Fig. 6. The tube may be a triode, as illustrated, in which the grid is a perforated metal septum that divides the tube into two separate chambers. The metal septum comprising the grid extends through the walls of the glass envelope and is sufficiently large that if necessary it may be soldered or otherwise connected into a metal sheet of considerable expanse. By this means the two halves of the vacuum tube may be placed in separate compartments or chambers with no coupling except the electron flow through the grid and the very small amount of electric induction (capacity effect) through the meshes of the grid or screen.

One of the limitations on the use of ordinary vacuum tubes as amplifiers of extremely high frequencies is an uncontrollable coupling between grid and plate circuits that results from the proximity of the grid and plate leads in the glass seal and other parts of the tube. The type of tube here disclosed makes possible arrangements whereby the grid and plate circuits or compartments are almost completely shielded from one another.

Referring again to Fig. 6, 71 and 72 are the two halves of a glass envelope which is or may be roughly spherical in shape. These halves are separated by a metal septum 73 extending through the walls of the glass envelope sufficiently far to be electrically connected into a still larger metallic sheet when necessary. As already mentioned this septum is perforated so as to function as a grid through which electrons can readily pass. Lines of electric force on the other hand

do not readily extend through these meshes except perhaps those associated or attached to space electrons. A source of electrons 76, which in this case is a heated cathode, and a plate 77 are located on opposite sides of the grid 73. The relative dimensions and spacings of the filament, grid and plate as well as the size of the perforations themselves conform in general to the prevailing practice of good vacuum tube design. The wires leading to the filament and plate, respectively, should preferably approach from diametrically opposite directions and preferably be perpendicular to the plane of the grid 73.

The grid 73 may be perforated by a series of circular holes as illustrated in Fig. 6 or it may consist of square or other shaped openings such as might result from a basket weave of metallic wires. In Fig. 5 the lead wires to the plate and filament pass through insulating bushings set in the walls of the guide. These prevent short-circuiting the direct current or low frequency components flowing in the wires. By-pass condensers 84 and 88, which may be of the type illustrated in Fig. 4, may be used to prevent the high frequency waves residing in the guide from escaping through the bushings to the exterior. The electric force of the wave may be assumed to be in the plane of the paper and perpendicular to the plane of the grid.

In Fig. 5 waves advance from left to right in dielectric guide 80, through the iris diaphragm 82 and into the cylindrical metal chamber 81 which is bounded at its other end by the movable piston 83. The chamber may be filled with a low loss dielectric such as air. The waves which represent a voltage difference between the top and bottom of this chamber impinge on the filament leads 78. By this means the total voltage difference is communicated to the small space between filament 76 and grid 73. (The latter is maintained at the potential of the guide, viz., earth potential.) This voltage difference will tend either to increase or to decrease the electron flow between filament and plate depending on the polarity of the instantaneous voltage. This change of electron flow passes not only across the space between filament and grid but also across the space between grid 73 and plate 77. The latter is in the other chamber, which is similar in all respects to chamber 81, and induces in this chamber a new electromotive force and consequently a new set of waves, in general of higher amplitude than those prevailing in chamber 81, for transmission over dielectric guide 90. Consideration of the time of transit of electrons in the discharge device may make it desirable in certain embodiments of the latter that the frequencies employed be relatively low, such for specific example as those lying near the cut-off frequency of a metallic tubular guide two feet in diameter.

In order to increase substantially the voltage impressed between filament and grid the chamber between the piston 83 and the iris diaphragm 82 is tuned in accordance with principles set forth above. In a similar way the output chamber may be tuned by changing the distance between the piston 86 and the iris diaphragm 85. Neither of these dimensions can be specified precisely. In practice, therefore, it will be necessary to adjust them to the prevailing conditions of frequency and load.

This application discloses and claims certain subject-matter that is disclosed in my allowed application for Letters Patent, Serial No. 745,457, 75

filed September 25, 1934. Reference is made also to my pending application Serial No. 104,524, filed October 7, 1936, which discloses and claims the general subject-matter of Figs. 5 and 6 of the instant application.

What is claimed is:

1. In combination, a wave guide carrying dielectrically guided waves and a hollow metallic chamber coaxial with said guide and in energy transfer relation therewith, said guide being separated from said chamber by an iris diaphragm, and the proportions of said chamber and the size of the iris being such that said chamber is resonant.
2. A receiver of electromagnetic waves of ultra-high frequency transmitted through free space comprising a chamber having an orifice for the admission of high frequency waves and a reflecting boundary opposite said orifice, said orifice and reflecting boundary being so spaced apart that said chamber is resonant at or about the frequency of said waves, and means within said chamber for converting said waves into conduction currents.
3. A generator of electromagnetic waves of ultra-high frequency comprising a chamber having an orifice for the emission of high frequency waves into free space and a reflecting boundary opposite said orifice, and means within said chamber for converting alternating conduction currents into displacement current waves, said orifice and reflecting boundary being so spaced apart that said chamber is resonant to said displacement current waves.
4. A wave meter comprising a resonant chamber having an opening therein for the admission of wave energy, indicating means responsive to the waves in said chamber, and means for varying the proportions of said chamber whereby the frequency at which said chamber is resonant is varied.
5. In combination with a dielectric guide, a generator of dielectrically guided waves located within the guide and a connection to said generator comprising a strip-like conductor disposed with its wider surface perpendicular to the lines of electric force.
6. In combination, a hollow prismatic metallic chamber having an orifice in one end thereof for the passage of high frequency electromagnetic waves, a conduction current circuit, and means for coupling said circuit in energy transfer relation with waves in said chamber, the proportions of said chamber and the size of said orifice being such that said chamber is resonant at or about the frequency of said waves.
7. In combination, a dielectric guide comprising a metallic pipe, an electromagnetic wave energy translating device located within said guide adapted for the generation or reception of dielectrically guided waves, and a conduction current circuit connected to said device comprising a strip-like conductor disposed with its wider surface perpendicular to the electric field associated with said waves.
8. A combination in accordance with claim 7 in which said conduction current circuit extends through the wall of said pipe and carries relatively low frequency currents.
9. A signal transmission system comprising a wave guide consisting essentially of a metallic pipe and an enclosed dielectric medium, said guide carrying signal-modulated dielectrically guided waves, and within the end portion of said guide a

resonant chamber comprising as its respective end boundaries an iris diaphragm and a substantially perfect reflector, both disposed across said pipe, and within said chamber a translating device for generating or receiving said dielectrically guided waves, the impedance and longitudinal position of said device and the position and size of the aperture in said iris diaphragm being so correlated as to substantially match the impedances of said guide and said device.

10. In combination, a wave guide for high frequency electromagnetic waves consisting of a metallic pipe containing a gaseous dielectric medium, and a termination for said guide comprising a metallic reflector aligned with said pipe and means producing an impedance discontinuity in said pipe, said reflector and said means being spaced apart along the path of the waves carried within said pipe so as to establish standing waves between them, and a translating device disposed in said standing waves at such point that the impedance of said translating device is matched to the impedance of said guide.

11. In combination with a wave guide carrying dielectrically guided waves, means for receiving said waves comprising a reflector closing the end of said guide, a receiving circuit disposed in the path of both the direct and the reflected waves, and means associated with said receiving circuit for substantially confining standing waves to the vicinity of the said receiving means.

12. A dielectric guide consisting essentially of a metallic pipe and a dielectric medium enclosed thereby, and means for receiving hyper-frequency electromagnetic waves transmitted through said pipe comprising a terminal circuit structure aligned with said pipe and in the path of said waves, means for causing the waves that pass beyond said structure to be reflected back towards it, and means within said pipe having such compensating reactive impedance as to substantially match the impedance of the receiving means to the impedance of the guide.

13. A combination in accordance with claim 12 in which said reactive impedance means is an apertured metallic barrier disposed within said pipe and transverse to the axis thereof.

14. A hyper-frequency electrical transmission system comprising a metallic pipe containing a dielectric medium and carrying dielectrically guided waves, and a metallic-walled chamber coaxial with said pipe comprising as part of its boundary an apertured metallic barrier upon which said waves are incident and through which they are admitted to said chamber, said chamber being substantially resonant at the frequency of said waves.

15. A combination in accordance with claim 14 comprising in addition a wave launching or receiving structure disposed within said chamber and matched to the impedance of said pipe.

16. In combination, a wave guide comprising a metallic pipe containing a dielectric medium through which dielectrically guided waves are carried, a metallically bounded cavity opening into said pipe, a thin, metallic barrier partially closing the opening between said cavity and said pipe to give said cavity a definite length such that the said cavity is resonant at the frequency of said waves, and electromagnetic wave translating means disposed in the standing waves created in said cavity.

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