

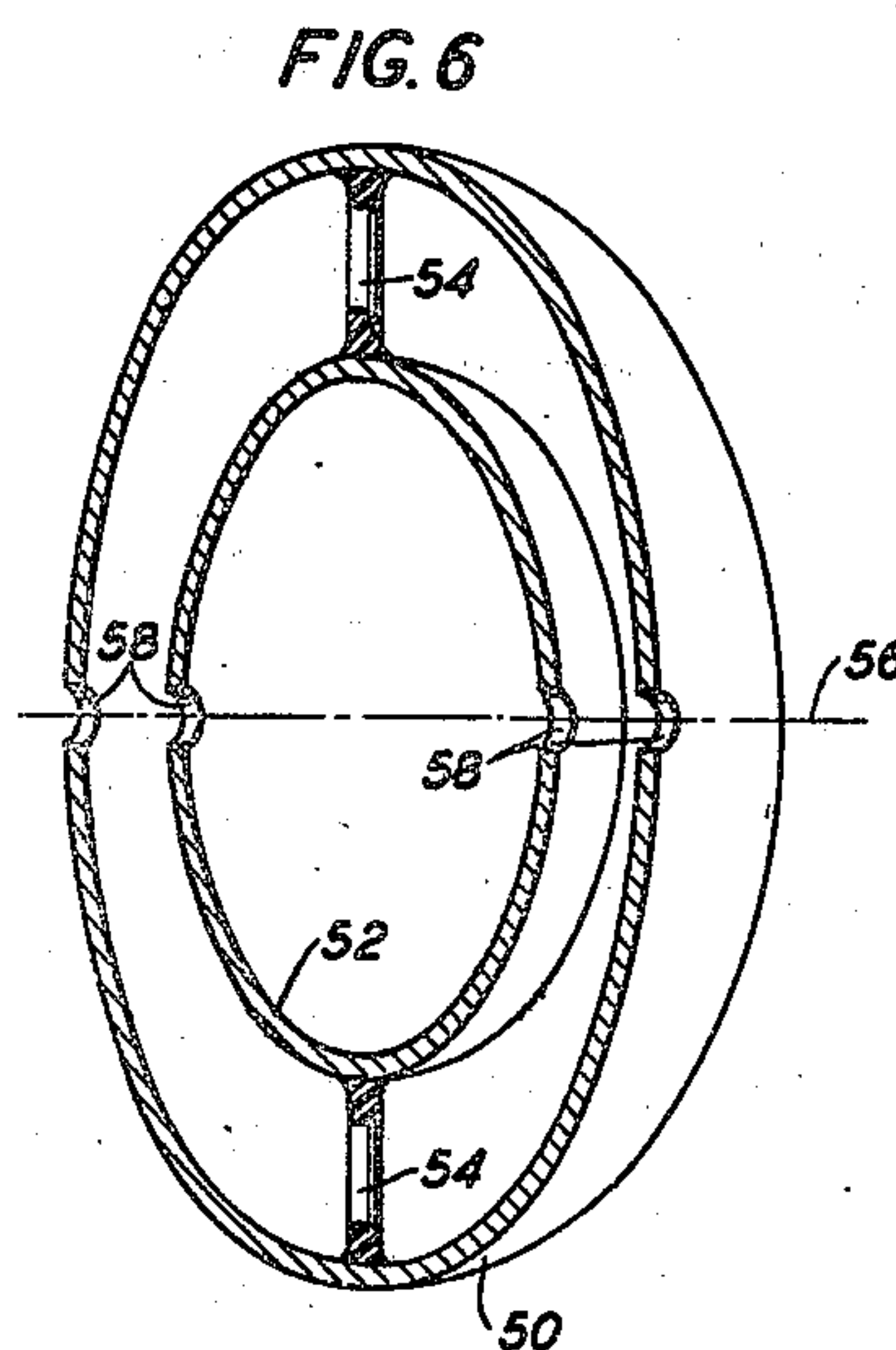
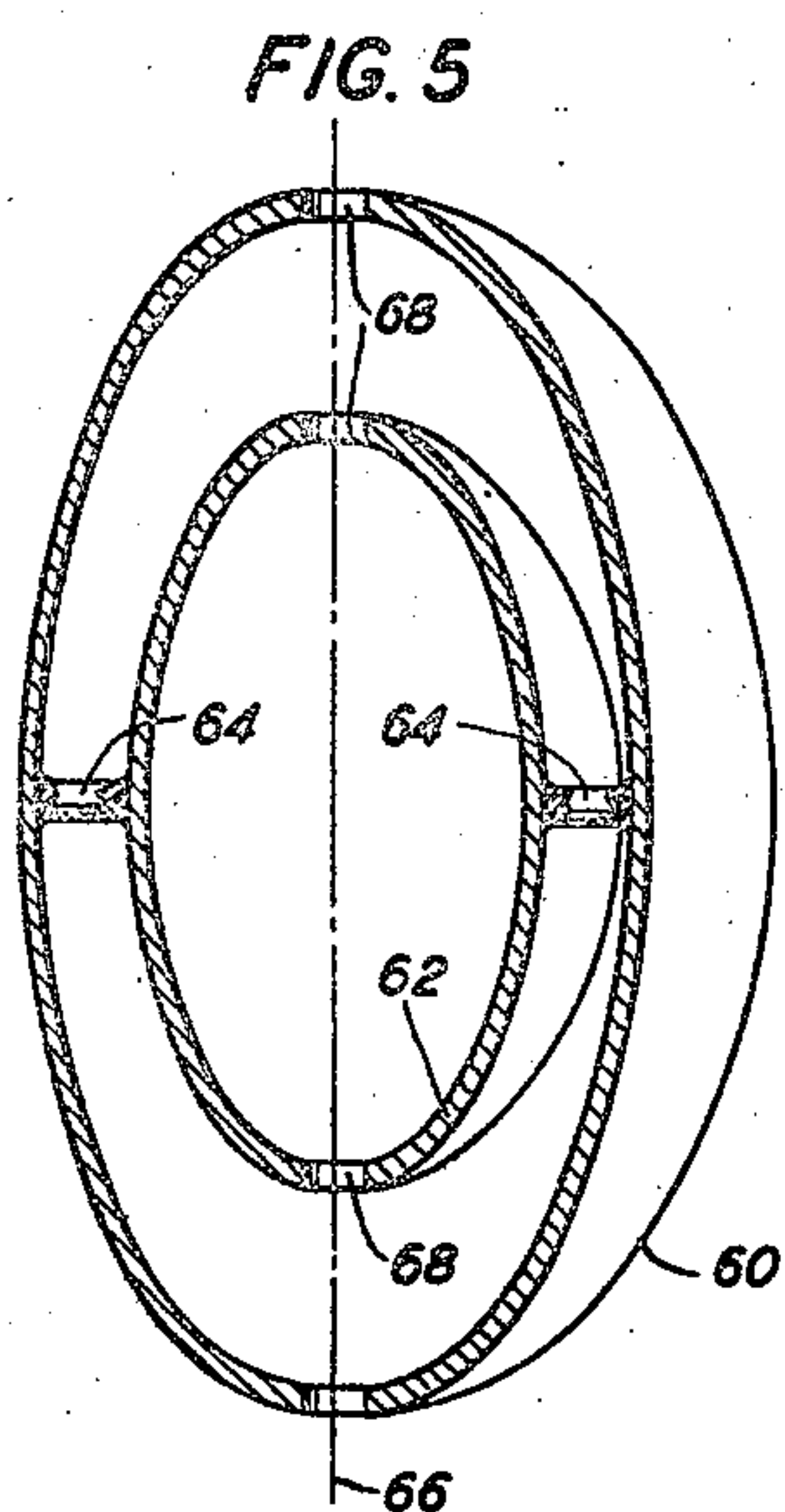
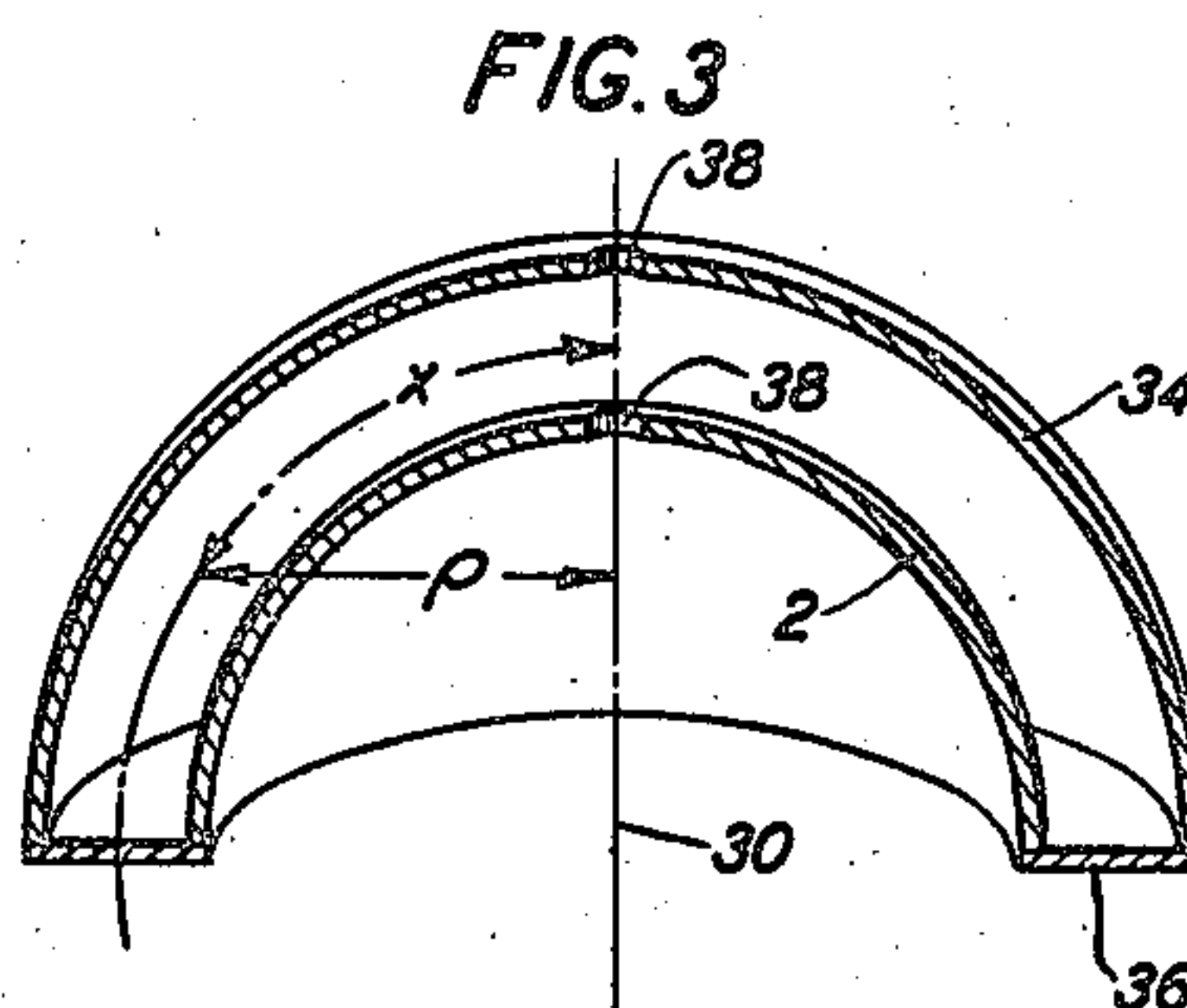
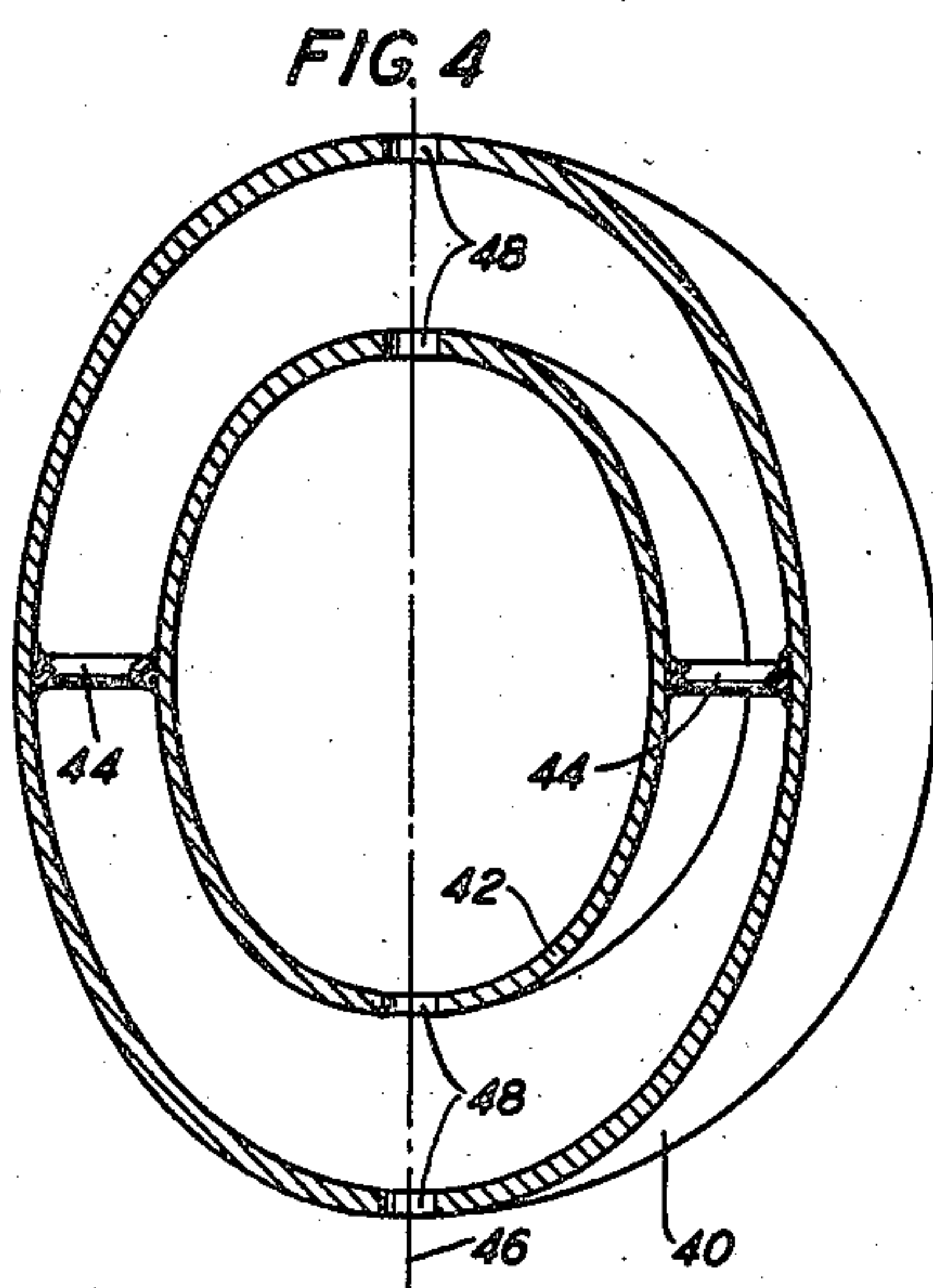
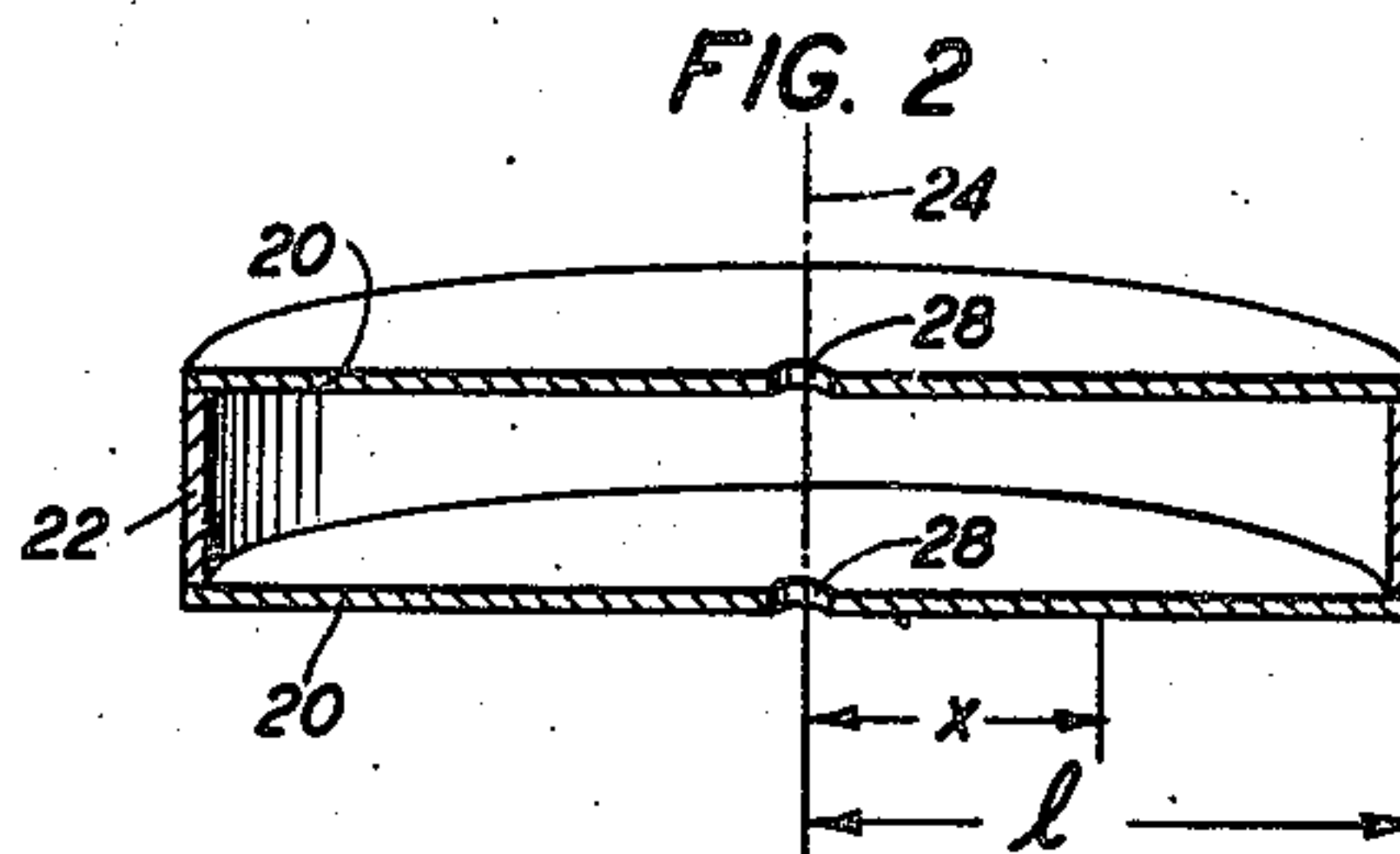
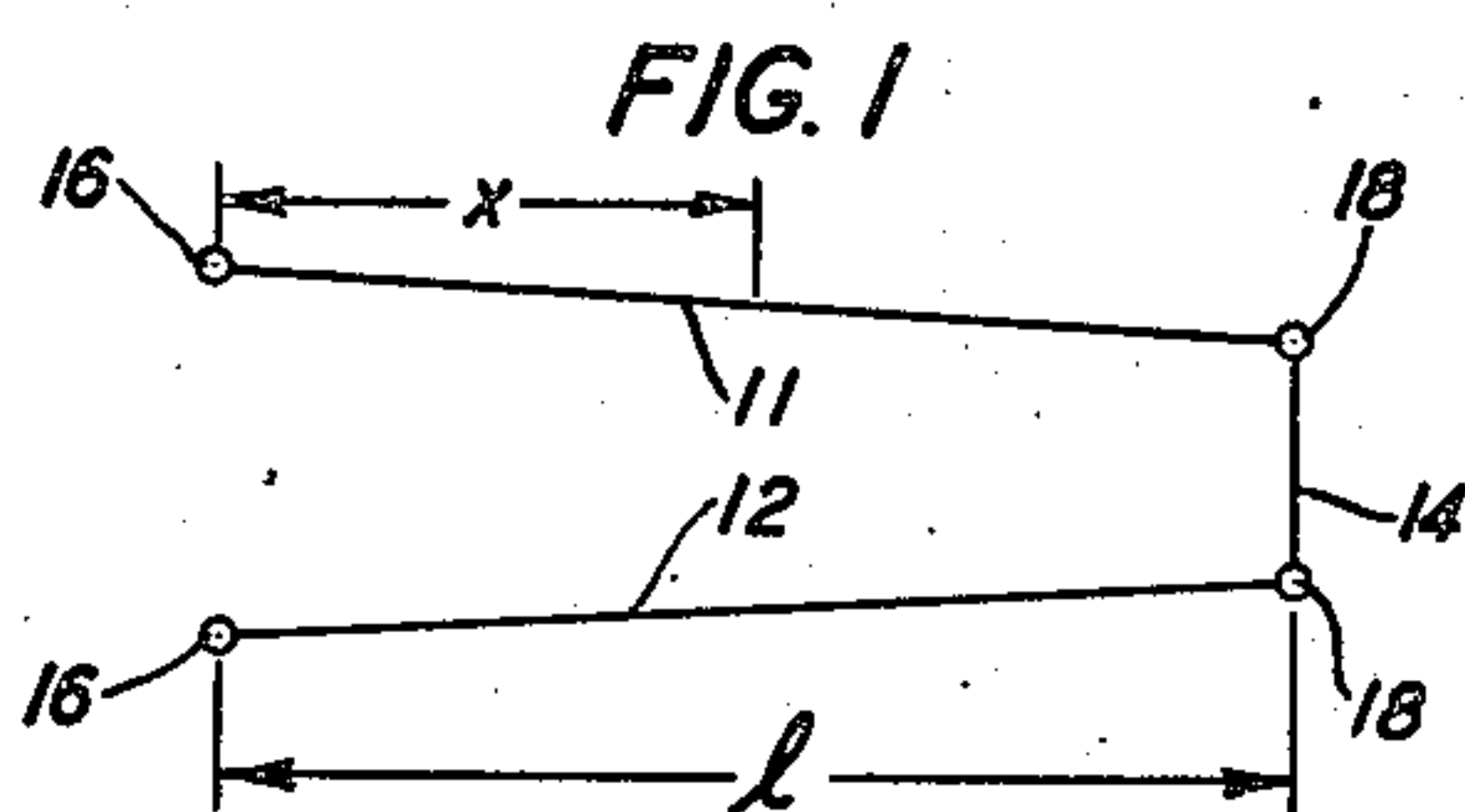
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2,405,612

ULTRA-HIGH FREQUENCY RESONANT CAVITIES

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ULTRA HIGH FREQUENCY RESONANT CAVITIES

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5 Claims. (Cl. 178-44)

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This invention relates to novel and convenient forms of ultra-high frequency resonant cavities adapted for use in electron velocity variation systems and the like.

This application is a continuation in part of my copending application, Serial No. 308,376, filed December 9, 1939, relating to high frequency tanks and resonant cavities.

Rigorously exact mathematical methods for computing resonant frequencies of cavities are available for only a few simply shaped cavities such as cavities delimited by right circular cylindrical and by spherical surfaces. Even for cavities bounded by spheroids the computations would be extremely laborious since appropriate tables of functions are not available.

However, as will be demonstrated in the course of the following description, for structures of the general type exemplified by the continuously varying transmission line, the fundamental, or lowest, resonant frequency can be computed with a degree of accuracy entirely sufficient for the majority of practical applications. A number of forms of resonant devices of this type are extremely convenient in mechanical form.

It is an object of the invention therefore to provide a new class of resonant cavities and to teach the principles in accordance with which they may be proportioned.

It is a further object to provide convenient methods of determining the fundamental resonant frequencies of cavities bounded by spheroidal, and the like, surfaces.

Other objects will become apparent during the course of the following description of specific illustrative embodiments in connection with the accompanying drawing in which:

Fig. 1 is a diagrammatic representation of a continuously variable electrical transmission line employed to explain the nature of devices of the invention;

Fig. 2 shows in cross-sectional view a structure having a cavity defined by a cylinder and end discs which structure embodies certain characteristic features in common with structures of the invention;

Fig. 3 shows in cross-sectional view a resonant structure having a cavity defined by two concentric hemispheres and a plane ring joining their bases;

Fig. 4 shows in a cross-sectional view a structure having a cavity defined by two concentric spheres; and

Figs. 5 and 6 show in cross-sectional view struc-

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tures having cavities defined by two concentric spheroidal members.

In more detail in Fig. 1 a transmission line comprising conductors 11 and 12, having a length l , input terminals 16, output terminals 18 and being uniformly variable in impedance along its length by virtue of a uniform variation of distance between the conductors, is shown. The variable distance X employed in the mathematical treatment of the structure hereinafter is measured from the open end of the line as shown in Fig. 1.

The line of Fig. 1 is shown short-circuited at its right end and open-circuited at its left end. The structure of Fig. 1 is the electrical analogue of resonant cavities which are characterized, for example, by a uniform variation of capacity between axial positions suitable for the application of electrical excitation and boundary surfaces thereof which correspond to the short-circuited end of the line of Fig. 1.

Forms illustrative of those which cavities of this type may take, are illustrated in Figs. 2 to 6, inclusive.

In Fig. 2 a structure is shown in which the cavity is defined by two discs 20 joined at their outer peripheries by a cylindrical member 22. The "input" terminals are the points at which the axial orifices 28 are located and the cylinder is the short circuit applied to the other end of the transmission line. The two parallel discs, of course, comprise a disc transmission line, the properties of which are explained in detail in my copending application, Serial No. 278,032, filed June 8, 1939, now Patent No. 2,235,506, dated March 18, 1941. The cavity is designed to be resonant at a particular predetermined frequency as will be presently explained when a velocity varied stream of electrons is directed along the path of axis 24.

In Fig. 3 a structure is shown in which the cavity is defined by two hemispheres 32 and 34 joined at their bases by plane ring member 36.

The cavity is designed to be resonant at a particular predetermined frequency, as will be presently explained, when a velocity varied stream of electrons is directed along the path of axis 30.

A plurality of the devices of either Fig. 2 or Fig. 3, or some of each, may, of course, be arranged with their orifices on a common axis so that all will respond to excitation by a single electron stream. In some systems it may be advantageous to proportion successive devices or groups of devices, so coaxially arranged, to be resonant at different frequencies so that response at a num-

ber of different frequencies will result on the part of some of the devices.

In Fig. 4 two spheres 40 and 42 are concentrically arranged with orifices 48 arranged along a common axis 46 to provide a rectilinear path along which an electron stream may be directed. Members 44 are made of insulating material and serve to hold the inner sphere 42 concentrically with respect to the outer sphere 40. The cavity between the two spheres is evidently the equivalent of two cavities as defined by the device of Fig. 3 placed base to base with member 36 of Fig. 3 omitted.

In some instances it will be desirable to proportion the device of Fig. 4 so that the fundamental resonance of the cavity within inner sphere 42 is substantially separated in frequency from the fundamental resonance of the cavity between spheres 40 and 42. In other instances the two fundamental resonances just mentioned may advantageously be identical or nearly so, to reinforce or supplement each other in their respective reactions upon the electron stream.

The devices of Figs. 5 and 6 are similar to that of Fig. 4 except that two ovoid or spheroidal members are substituted for the spheres of Fig. 4.

In Fig. 5 spheroidal members 60 and 62 have orifices aligned along the major axis 66. Members 64 are spacers of insulating material.

In Fig. 6 members 50 and 52 have orifices aligned along the minor axis 56. Members 54 are spacers of insulating material.

Figs. 5 and 6 illustrate that by merely changing the axis of excitation a given device of the invention may be made to respond to a different frequency as will become evident hereinafter.

In explanation of the theory underlying devices of the invention the transmission line of Fig. 1 will now be analyzed. At its left-hand terminals 16, this line is open-circuited while at its right-hand terminals 18 the line is short-circuited by the conductor 14. The voltage across the short-circuited end is, of course, substantially zero. The voltage across the open-circuited end of the line is maximum at the fundamental resonant frequency of the line.

If C be the capacity per unit length of the line and λ the wave-length of the fundamental resonant frequency then, with a degree of accuracy sufficient for the majority of practical applications, the following relation obtains

$$\lambda = 4l \sqrt{\frac{1+\psi}{1-\psi}} \quad (1)$$

where

$$\psi = \frac{\int_0^l C \cos \frac{\pi x}{l} dx}{\int_0^l C dx} \quad (2)$$

and l = length of line.

The above relations are remarkably accurate for structures in which C varies continuously along the structure. For example, if C is proportional to the distance X from the open end of the line then by the above formula 1, $\lambda = 2.62l$. The rigorously exact value of λ is known to satisfy the equation

$$J_0\left(\frac{2\pi l}{\lambda}\right) = 0 \quad (3)$$

Since the first root of this equation is 2.40, from Equation 3, $\lambda = 2.62$ checking the value obtained from Formula 1. One structure having the capacity C vary in proportion to the distance

from the open end of the line is that shown in Fig. 2 where the radius of the discs is l . Along the axis 24 the voltage E is maximum at the fundamental resonant frequency of the device and at the peripheries of the discs 20 (short-circuited by cylindrical member 22) the voltage is substantially zero, so that the electrical conditions are as described above for the structure of Fig. 1.

In the case of the structure of Fig. 3 the capacity C is proportional to

$$\rho = a \sin \frac{x}{a}$$

where x is the distance from the driving point along the arc of the median sphere between the spherical surfaces. From the above formulae, for the case of Fig. 3

$$\psi = \frac{\int_0^l \sin \frac{x}{a} \cos \frac{\pi x}{l} dx}{\int_0^l \sin \frac{x}{a} dx} \quad (4)$$

where

$$l = \frac{\pi a}{2}$$

and a is the radius of the median sphere. From the above

$$\psi = \frac{1}{3}, \frac{16l^2}{\lambda^2} = 2, \lambda = 2\sqrt{2}l = \pi\sqrt{2}a$$

This checks with results obtained by J. J. Thompson at page 375 in the book entitled "Recent Researches in Electricity and Magnetism," published by Oxford University in 1893.

As the cavity of the structure of Fig. 4 is simply two cavities of the structure of Fig. 3 combined, the former will have the same resonant wave-length where the radii of the inner and outer spheres are the same for the two devices. Because of the larger conducting surfaces and the elimination of the ring 36 (of Fig. 3) the structure of Fig. 4 will be of higher electrical efficiency.

When the integrals required in Equation 2 cannot be calculated in closed forms, they can be evaluated graphically or numerically. Thus it is obvious that the above method permits the computation of resonant wave-lengths of cavities of general shapes such as those exemplified by Figs. 5 and 6. The latter structures facilitate control of the distance between the two paths across the inter-spheroidal cavity and therefore lend themselves particularly well for use in electron stream coupling systems.

The above-described arrangements are illustrative of the principles of the invention. Numerous other arrangements and structures within the spirit and scope of the invention will occur to those skilled in the art and no attempt has been made to exhaustively cover all possible structures. The scope of the invention is defined in the following claims.

What is claimed is:

1. In an ultra-high frequency system, a resonant device comprising solely two parallel spheroidal conducting members, and electroconductively insulating members, having high electrical impedance to the frequencies of the system, said last-stated members serving to space said conducting members with respect to each other, said two conducting members having a common point about which they are concentric, said conducting members being of different dimensions, the larger

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enclosing the smaller, said conducting members being provided with orifices, said orifices being on a common axis whereby the cavity between said members and the cavity within the inner member may both be excited to resonance by the projection of an electron beam along the said axis by means external to the outer member.

2. The device of claim 1 the cavity enclosed within the inner member being proportioned to be resonant at a different frequency from that at which the cavity between the two members is resonant whereby said device may be employed to emphasize the oscillation of the ultra-high frequency system at either of two frequencies.

3. The device of claim 1, the cavity enclosed within the inner member being proportioned to be resonant at the same frequency as that at which the cavity between the two members is resonant whereby said device may provide extremely effective frequency stabilization at the common resonant frequency of the two cavities.

4. In an ultra-high frequency system, a resonant device comprising solely two parallel ovoid conducting members and electroconductively insulating members having high impedance to the

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frequencies of the system, said last-stated members serving to space said conducting members with respect to each other, said two conducting members being concentric with respect to a common point, one conducting member enclosing the other, the conducting members being proportioned so that the cavity enclosed between them will be resonant at any one of a plurality of frequencies depending upon which of a like plurality of axes, excitation to resonance is impressed and orifices in both conducting members along a particular axis whereby the interovoid cavity will be resonant at a particular predetermined frequency upon the projection of an electron beam along said axis and the device may stabilize the frequency of the system at the said particular predetermined frequency.

5. The device of claim 4, the dimensions of the ovoid members being proportioned to provide a second resonance within the inner ovoid at a second particular predetermined frequency whereby the device can respond by resonance at either of the two particular predetermined frequencies.

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