ELECTROMAGNETICALLY OPERATED COUNTER

Filed Nov. 30, 1944 4 Sheets-Sheet 1

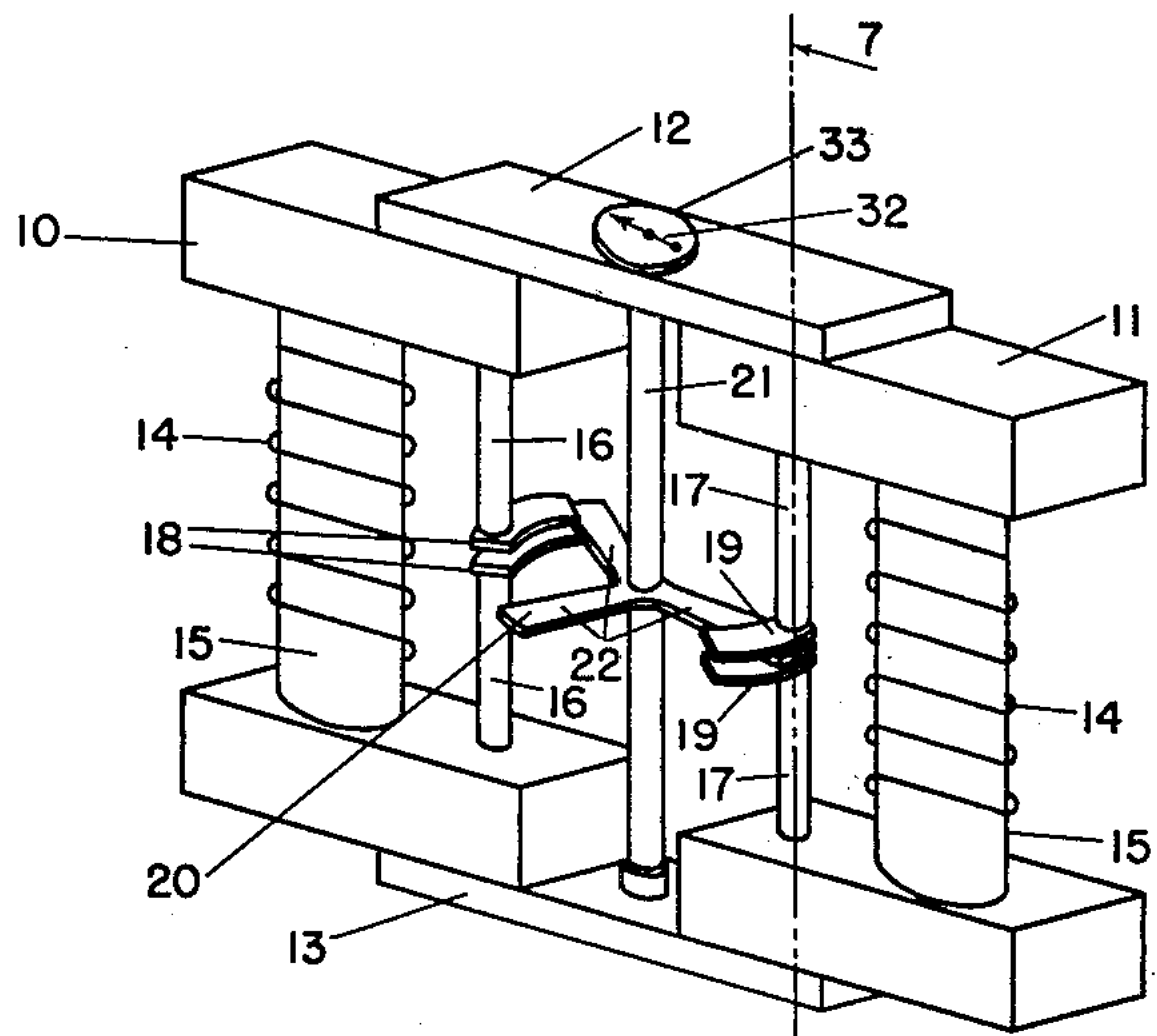


Fig. 1

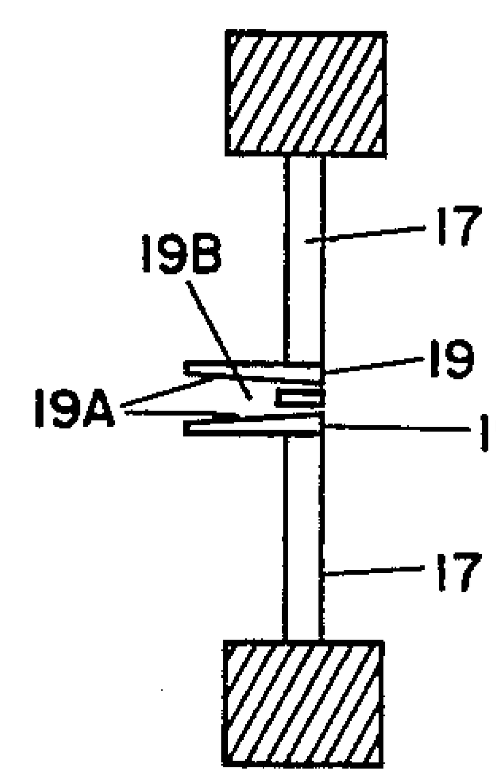


Fig. 7

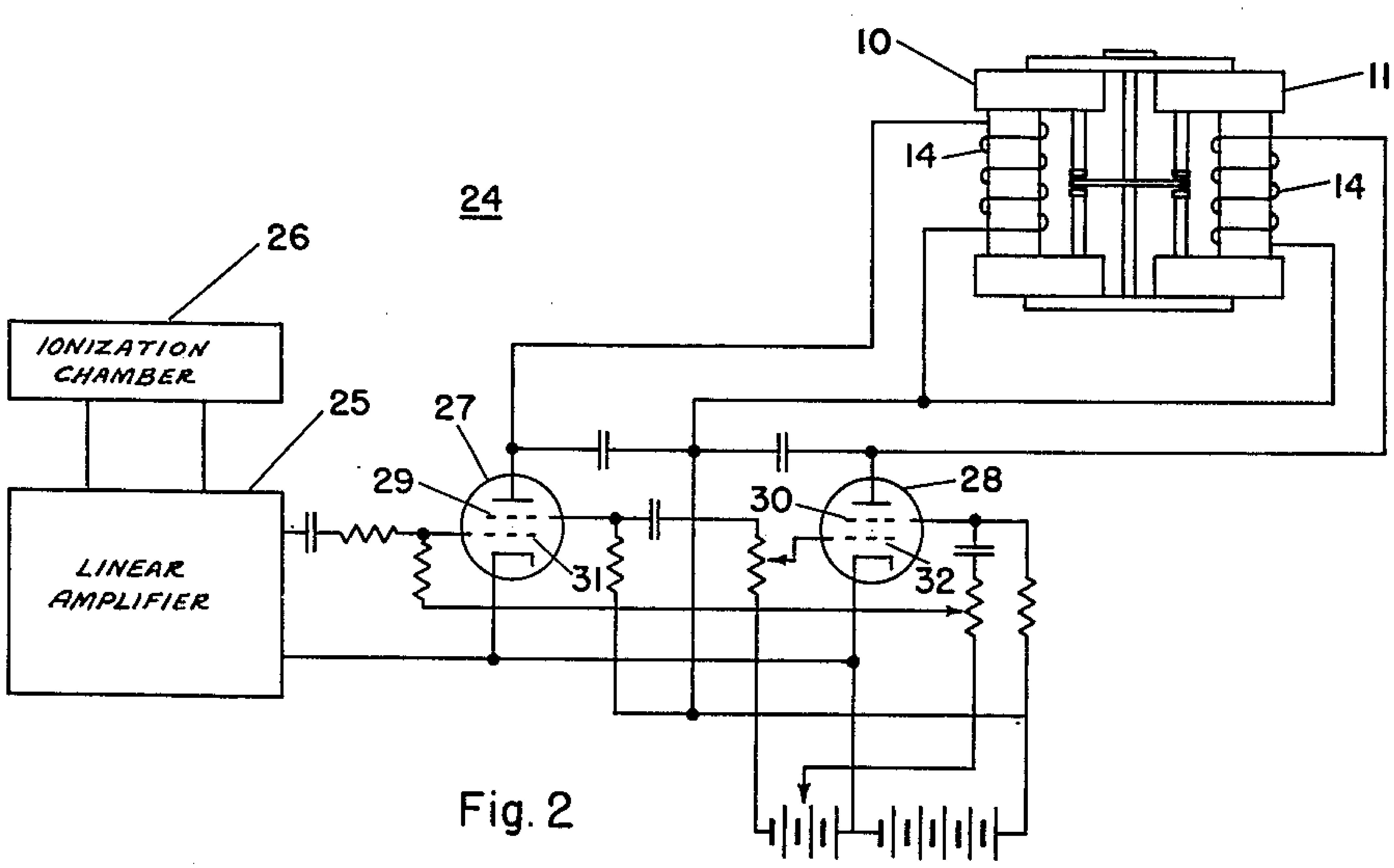


Fig. 2

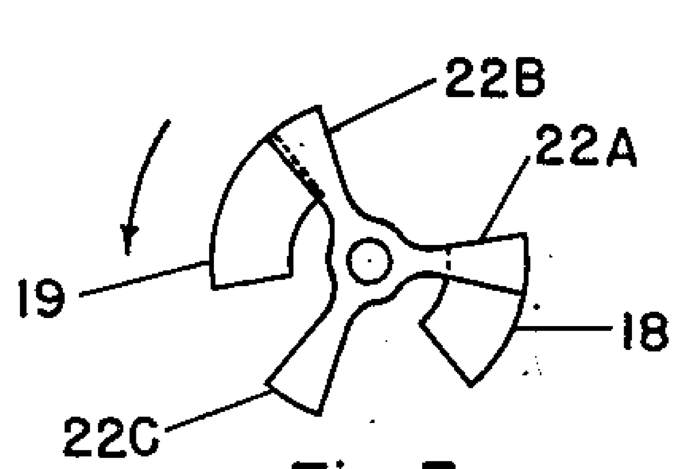


Fig. 3

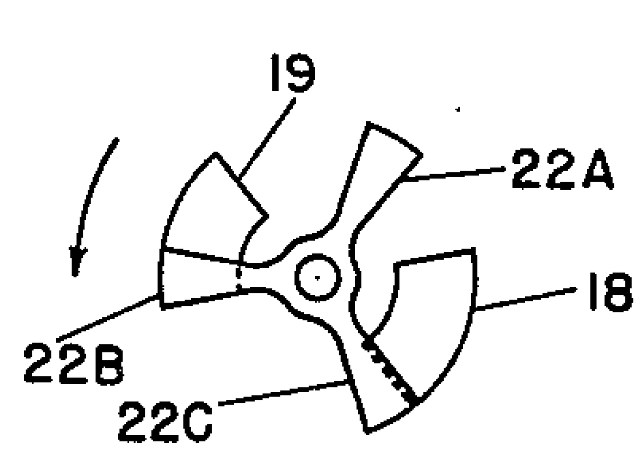


Fig. 4

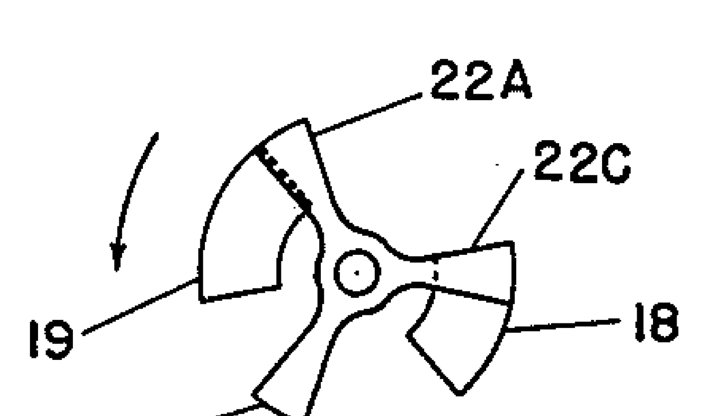


Fig. 5

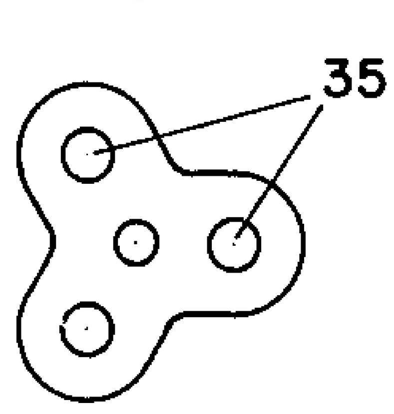


Fig. 6

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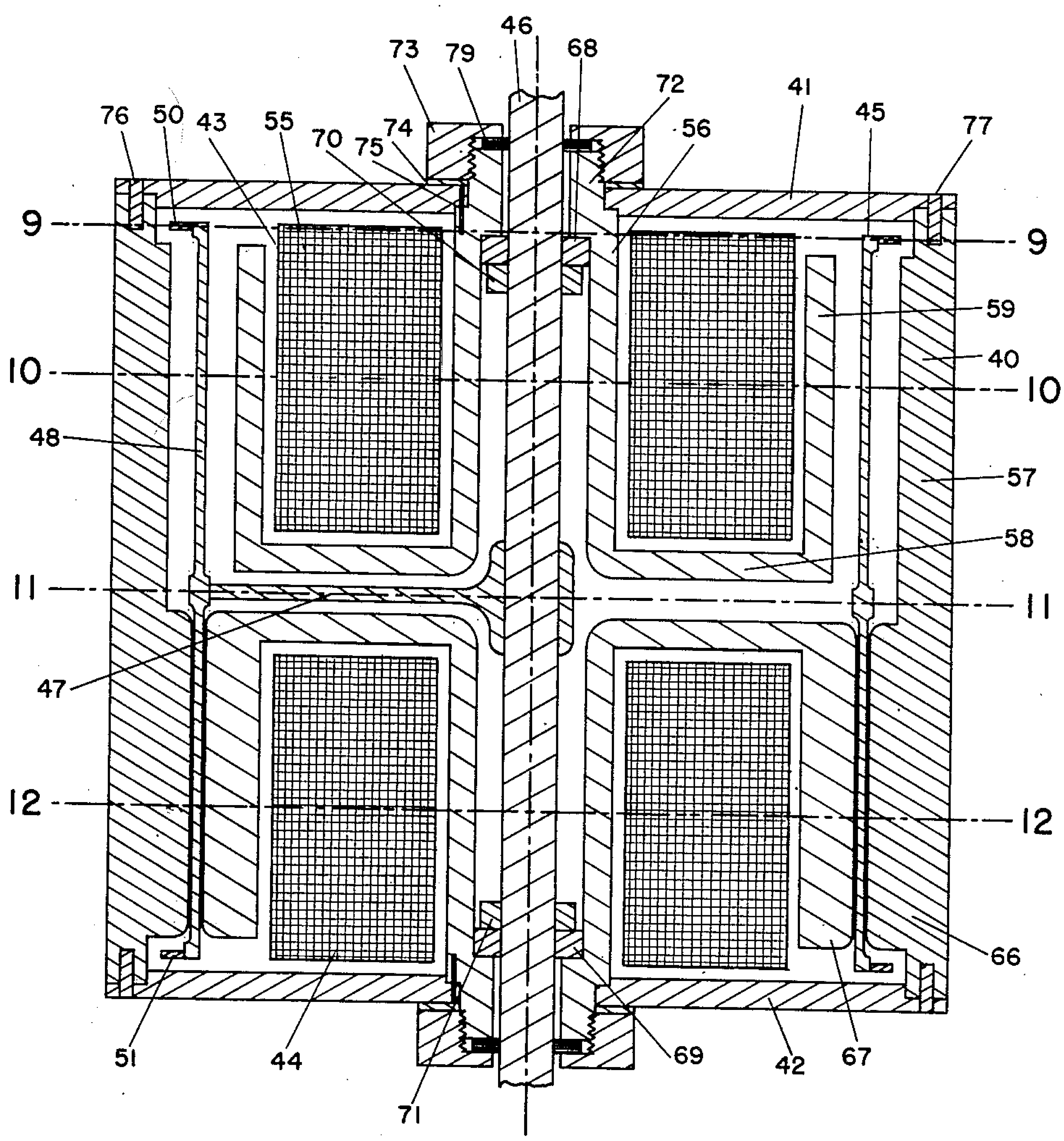


Fig. 8

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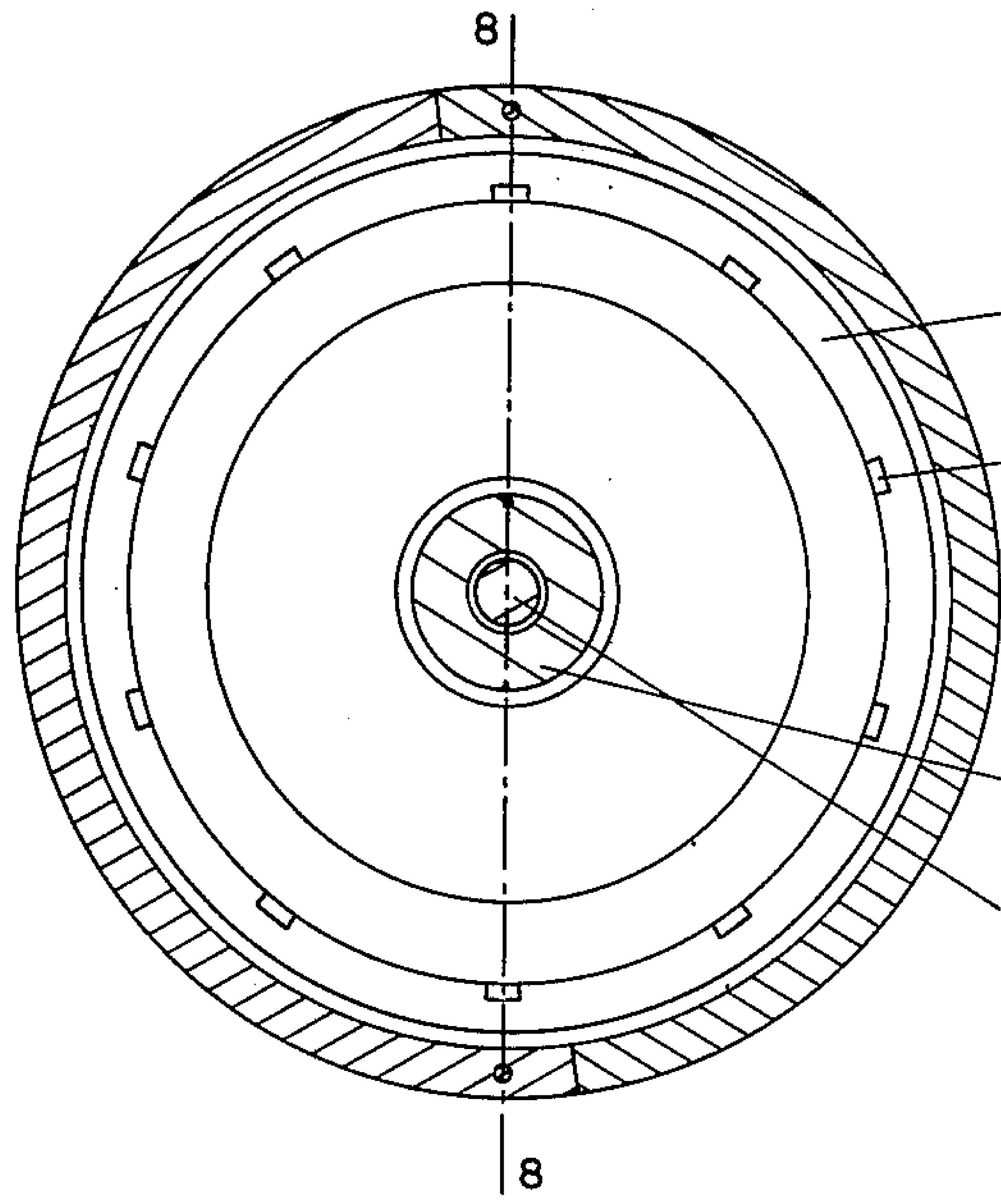


Fig. 9

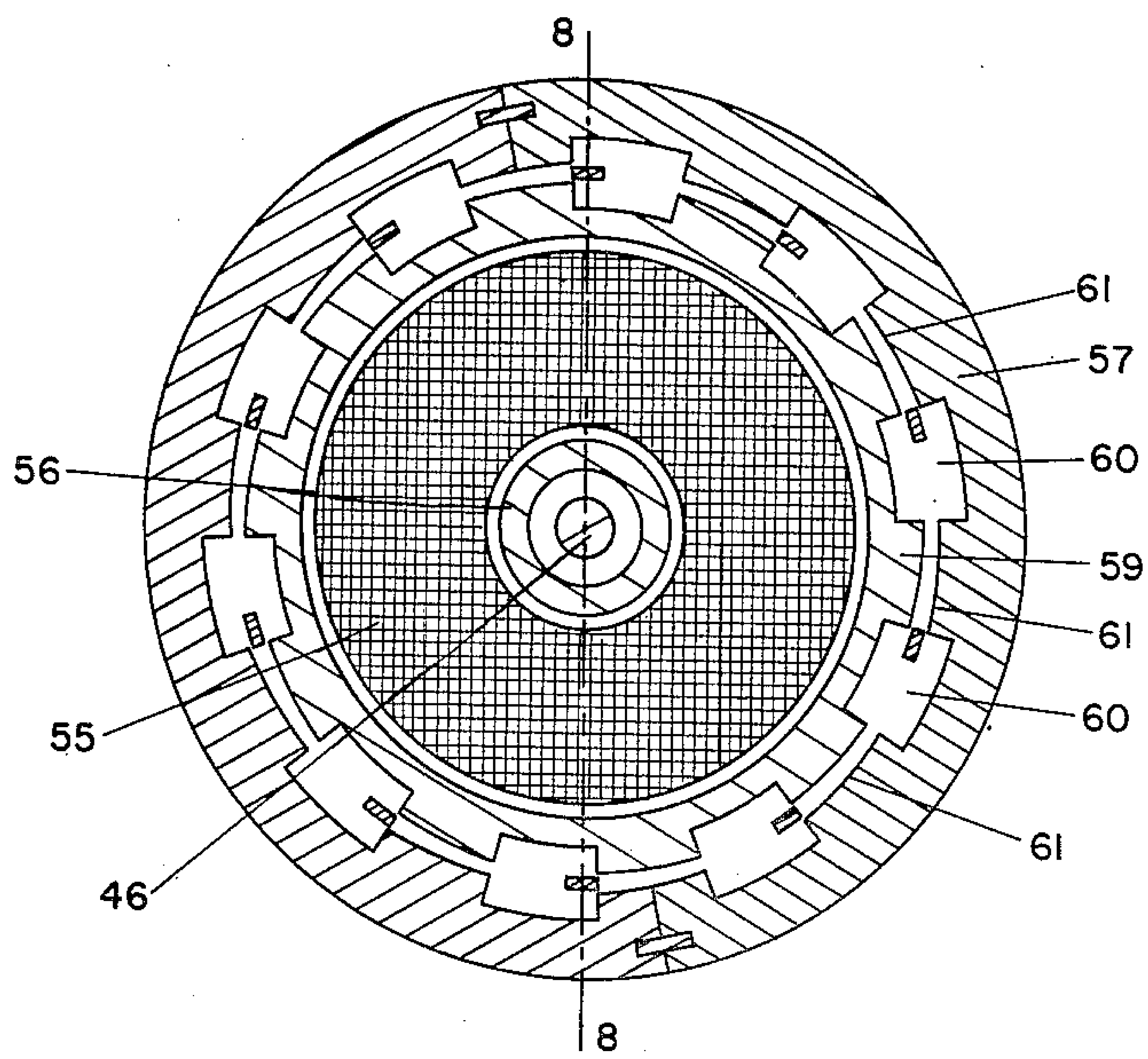


Fig. 10

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ELECTROMAGNETICALLY OPERATED COUNTER

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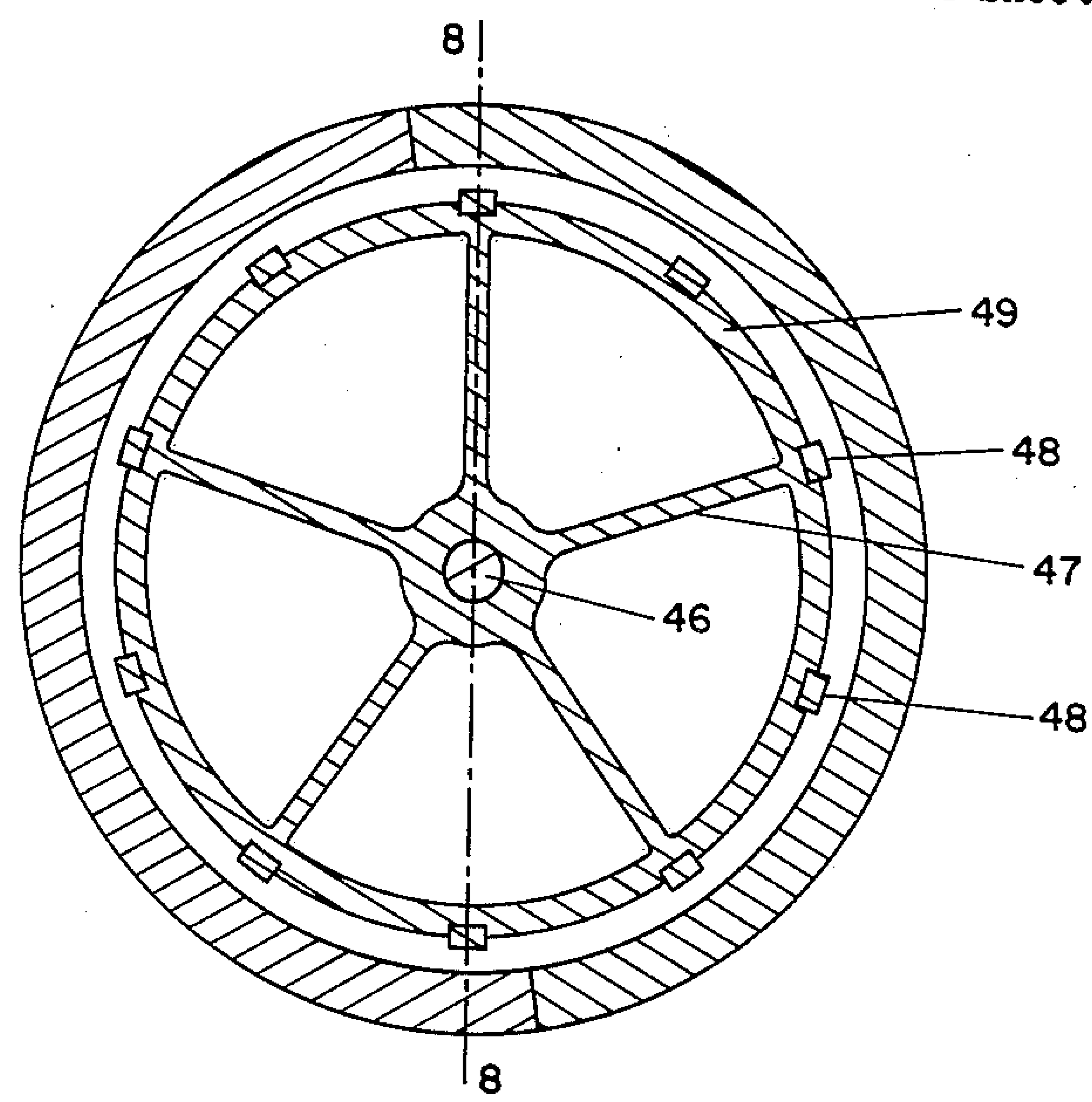


Fig. 11

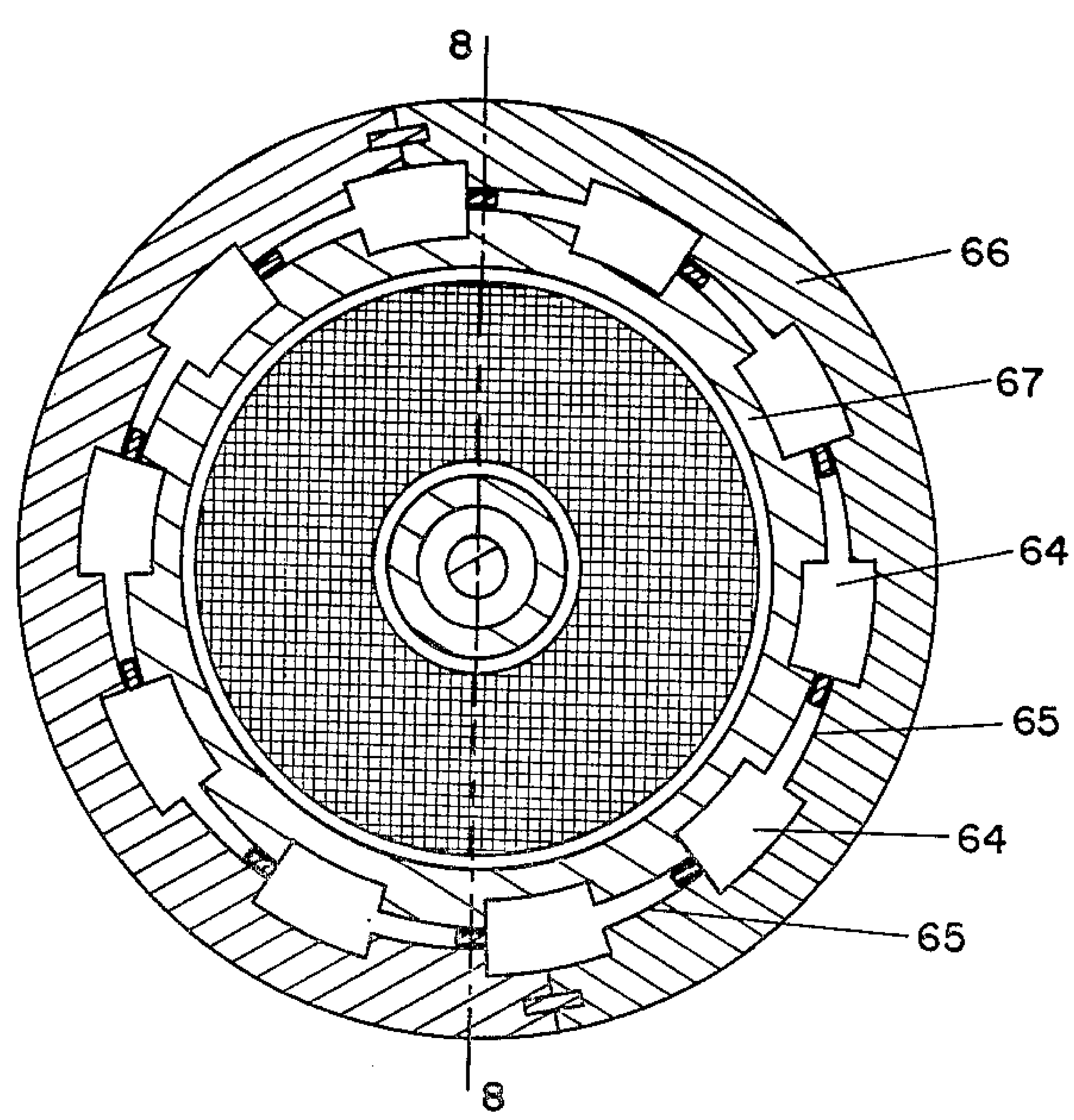


Fig. 12

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Patented Dec. 18, 1951

2,579,231

# UNITED STATES PATENT OFFICE

2,579,231

## ELECTROMAGNETICALLY OPERATED COUNTER

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Application November 30, 1944, Serial No. 565,993

8 Claims. (Cl. 318—503)

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This invention relates generally to a device for producing stepwise rotation of a rotatable element and, more particularly, to an electromagnetic device for producing stepwise rotation of an armature that may be connected to a counting mechanism for rapidly counting electrical impulses.

One of the applications for a device of this character is in the detection and counting of ionizing particles. A counter tube containing a pair of spaced electrodes upon which is impressed a suitable voltage is commonly used for this purpose. The counter tube is filled with gas at a pressure of a few centimeters of mercury so that entrance of a particle will produce a cumulative ionization between the electrodes and a comparatively large current flow in a circuit including the source of voltage and an external resistance. The cumulative ionization permits a flow of current, and the potential drop across the external resistance rises quickly, with the result that the net voltage across the tube electrodes falls to a point where the current again ceases to flow until the arrival of another ionizing particle. Since the number of voltage impulses produced across the external load resistance is directly proportional to he number of particles incident on the counter tube, an amplifier may be connected across the external resistance to operate a counting device.

It is therefore an object of the present invention to provide a device for producing stepwise rotation of a rotatable element.

It is another object of the invention to provide a simple, high speed counting device for use with counter circuits.

An additional object of the invention resides in the provision of a counting device wherein magnetic means are employed for rotating an armature stepwise in response to energization by an electrical impulse.

A still further object is to provide a counting device that is operated by the successive energization of a plurality of electro-magnets.

It is another object of this invention to provide an electromagnetically operated counting device having a very small moment of inertia and low friction loss.

It is also an object to provide an electromagnetically operated counting device constructed and arranged to produce unidirectional, stepwise rotation of a counting shaft.

These and other features of the invention contributing to its simplicity of construction and dependability in operation will be apparent from the following detailed description of a preferred and alternative embodiment taken with the accompanying drawings, in which:

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Fig. 1 is a front elevational view in perspective of a counting device;

Fig. 2 is a schematic diagram of the counting device of Fig. 1 in combination with a switching circuit, an amplifier, and a counting chamber;

Fig. 3 is a top plan view of the rotor and lower pole pieces of the counting device;

Fig. 4 is a view similar to Fig. 3 showing the parts of the counting device in different relative positions;

Fig. 5 is another view similar to Fig. 3 showing the relative positions of the parts of the counting device in a still further phase of its operation;

Fig. 6 is a view similar to Fig. 3 showing an alternative construction of the armature;

Fig. 7 is a vertical section taken on the line 7—7 of Fig. 1 and showing the tapered construction of the pole pieces;

Fig. 8 is an axial section of a second embodiment of the invention having an armature of cage-like construction and for reasons of clarity not showing the parts normally seen in elevation.

Fig. 9 is a horizontal transverse section of reduced dimensions of the embodiment of Fig. 8 taken on the line 9—9 of Fig. 8.

Fig. 10 is a horizontal transverse section of reduced dimensions taken on the line 10—10 of Fig. 8 showing the position of the armature bars with respect to one of the electro-magnets;

Fig. 11 is a horizontal transverse section of reduced dimensions taken on the line 11—11 of Fig. 8 and showing the spider that supports the armature bars; and

Fig. 12 is a horizontal transverse section of reduced dimensions taken on the line 12—12 of Fig. 8 and showing the position of the armature bars with respect to the second electro-magnet.

In general, the counting device of this invention comprises a rotatable armature made either wholly or in part of a magnetic material and a plurality of spaced electromagnets which may be successively energized to produce intermittent rotation of the armature.

With reference to the embodiment of Fig. 1, a diametrically opposed pair of G-shaped electromagnets 10 and 11 are maintained in spaced relation and fastened together by strips 12 and 13 of non-magnetic material. Each of the electromagnets 10 and 11 includes a coil 14 wound around the intermediate portion of a core 15.

The electromagnet 10 has poles 16, 16 and the electromagnet 11 is similarly provided with poles 17, 17, the pole faces of each pair being adjacent one another. Pole shoes 18, 18 and 19, 19 specially shaped and arranged are secured to the pole faces of electromagnets 10 and 11 respectively.

An armature 20 mounted on a free-running, vertical shaft 21, having its ends journaled in the fastening strips 12 and 13, rotates freely between the pole shoes 18, 18 and 19, 19 of the two electromagnets. The armature 20 is preferably formed either in whole or in part of a magnetic material having a high magnetic permeability such as soft iron, and it is desirable that for high speed operation the armature be made as small and light as possible. In the embodiment shown the armature 20 is formed with three equally spaced lobes or coplanar arms 22 of magnetic material. The arrangement is such that the readily magnetized lobes 22 traverse the magnetic fields between the pairs of pole shoes 18, 18 and 19, 19 when the electromagnets 10 and 11 are alternately energized.

The pairs of parallel pole shoes 18, 18 and 19, 19 are in this instance of elongated arcuate shape, the degrees of curvature being the same as that of a circle with its center at the axis of the armature. Referring to Fig. 7 of the drawings, it may be seen that the pole shoes 19, 19 are provided with the tapered surfaces 19A that define an air gap 19B of a width that decreases in the direction of motion of the armature. The field intensity is greatest at the narrowest part of the air gap 19B. Thus the taper of the pole shoes insures rotation of the armature each time to the desired position, namely, successive registration and retention of the lobes at the point between the pole shoes where the magnetic field is strongest. The length and arrangement of the pole shoes with respect to the armature lobes is such as to insure unidirectional rotation of the armature. Pole shoes 18, 18 are provided with tapered surfaces similar to the tapered surfaces 19A.

In the embodiment of Fig. 1 the pole shoes extend in a leading or clockwise direction with respect to the poles 16, 16 and 17, 17 and the armature lobes come to rest at a point between the poles. Thus the field intensity at the rest position of the armature lobes is increased not only by the decrease in width of air gap but also by the mass of the poles. However, the effect of decrease in width of air gap on the field intensity is far greater than the effect of the poles on the field intensity and therefore it is not essential that the pole shoes extend in a leading dirction. If, for example, the pole shoes were so mounted on the poles that the shoes extended in a lagging or counterclockwise direction the armature lobes would still come to rest at the narrowest point of the air gap.

Fig. 2 shows a switching circuit 24 for the counting device of Fig. 1 and a conventional linear amplifier 25 together with an ionization chamber or counter tube 26 for controlling the energization of the electromagnets 10 and 11. The electrical impulse resulting from the ionization in the tube or chamber 26 by a charged particle is amplified by the linear amplifier 25 and impressed upon the input side of the switching circuit 24.

The illustrative switching means for the electromagnets comprises the circuit 24 including a pair of negatively biased electron tubes 27 and 28, which may be type 6L6 beam power amplifying tetrodes, or any other desirable type. Fig. 2 indicates the manner of connecting the tubes 27 and 28 to suitable "C" and "B" battery terminals.



One terminal of coil 14 of the electromagnet 10 is connected to the anode of tube 27 and the other terminal of this coil is connected to the positive terminal of the anode current supply; likewise, one terminal of coil 14 of electromagnet 11 is connected to the anode of tube 28 and the other terminal of this coil is connected to the positive terminal of the anode current supply. The main purpose of connecting these coils between the anodes of the respective tubes 27 and 28 and the positive terminal of the anode current supply is to minimize the disturbing effect of any substantial counterelectromotive forces that may be set up in the coils 14, 14' upon the normal operation of the switching circuit. If these coils were connected between the screen grids of the respective tubes and the positive terminal of the anode current supply, the counterelectromotive forces produced in these coils might cause the current in the amplified tubes to build up slowly and continue for a period longer than desired and in so doing interfere with the proper operation of the switching circuit.

When no impulse is supplied by the amplifier 25 to the switching circuit 24, the negative bias on grid 31 of tube 27 is of such magnitude as to permit that tube to conduct and thereby energize electromagnet 10 connected in series with its plate. At the same time, tube 28 is cut off by a high negative bias on grid 32, with the result that it is not conducting and the coil 14 of the electromagnet 11, with which it is in series is not energized. When an impulse from the amplifier 25 is impressed on the grid 31 of tube 27, it increases the negative bias until tube 27 cuts off and thus causes a de-energization of the coil 14 of electromagnet 10. A rise in the screen grid potential of tube 27 occurs when this tube cuts off and this reduces the negative bias on grid 32 of tube 28 to the point where tube 28 becomes conducting and the coil 14 of electromagnet 11 is energized. A drop in the screen potential of tube 28 occurs when this tube becomes conducting and this keeps the grid of tube 27 negative for a time determined by the time constants of the coupling condensers and resistors involved. This keeps current flowing in electromagnet 11 long enough to permit the armature 20 to rotate its required sixth of a rotation, even though the impulse supplied by the amplifier may be of extremely short duration. After a suitable time interval as determined by the time constants of the coupling condensers and resistors the voltages of the elements of the vacuum tubes return to their normal conditions with the bias on the grid of tube 27 of such magnitude as to permit that tube to conduct and thereby energize electromagnet 10 in series with its plate. Thus the armature has been rotated an additional sixth of a rotation and the entire apparatus is ready for the next impulse. Consequently, the operation of the electromagnets 10 and 11 in producing rotation by the armature 20 supporting shaft 21 will be best understood by referring to Figures 3, 4, and 5 wherein the three similar lobes or arms have been designated as 22A, 22B, and 22C. In the position of Fig. 3, the armature 20 is being held in the relative position shown by the energization of electromagnet 10 producing a magnetic field across the pole shoes 18, 18. The initial effect of an electrical impulse is to de-energize electromagnet 10 and energize electromagnet 11, in the manner that has been described, and rotate the armature one-sixth of a turn in a counter-clockwise direction, represented by the new position of the lobes 22A, 22B, and 22C in Figure 4. Movement of the lobe 22B is being inhibited at this time by the magnetic field across the pole shoes 19, 19 of the energized electromagnet 11. Completion of the impulse cycle causes de-energization of electromagnet 11, releasing lobe 22B, and at the same time drawing lobe 22C between the pole shoes 18, 18 of the then re-energized electromagnet 10. The position of the armature after completion of the above described cycle is shown in Fig. 5.

It will thus be seen that a single impulse produces an advance of one-third of a revolution in the armature 20 and that this movement of the armature occurs in two steps due to the alternate de-energization and energization of the two magnets. In other words, three impulses are required to turn armature 20 through a complete revolution.

A greater number of counts per armature revolution can be achieved by suitably increasing the number of electromagnets and armature lobes and providing switching means to give the required sequential energization.

Means are also provided for indicating the rotations of the armature 20. The indicating means may take a variety of well-known forms, but in the illustrative embodiment a pointer 32 is connected through appropriate mechanism to the upper end of the vertical armature shaft 21 and disposed in cooperative relation to a counter dial 33 to provide means proportionately responsive to rotation of armature 20. A revolution counter suitable for the purpose is disclosed in Patent 2,038,946 issued April 28, 1936, in the name of W. D. Marsh. If desired, the mechanical counter may be calibrated to read directly in terms of the electrical impulses impressed upon the switching circuit.

By way of indicating its possibilities, the counting device described herein has been operated successfully at a counting speed of 2000 pulses per minute.

Referring now to Fig. 6, there is shown an alternative construction of the armature wherein the armature is formed of a highly conductive material such as copper or aluminum with magnetic inserts or cores 35 in each lobe or arm of the armature. The operation of the armature shown in Fig. 6 is the same as that of the armature previously described in connection with Figs. 1 through 5. The purpose of making the body of the armature of highly conductive material is to reduce oscillation which may occur as the armature comes to rest. Where a highly conductive material is used, large eddy currents are set up and tend to resist motion of the armature and thus damp out any tendency toward oscillation that may be present.

It has been found that in most cases the construction shown in Fig. 6 need not be used because the friction of the indicating mechanism is sufficient to prevent oscillation of the armature and this is particularly true where the indicating mechanism embodies a gear train. In cases where the friction of the indicating mechanism is insufficient, the armature construction shown in Fig. 6 may advantageously be used.

Referring now to Figs. 8 through 12 which show a second embodiment of the device of the present invention, the structure there shown comprises generally a cylindrical casing 40 and end plates 41 and 42 which form part of and also partially enclose a pair of electromagnets 43 and 44. The casing 40 is longitudinally divided into two parts to permit assembly of the device. Rotatable within the casing 40 there is a cage-like armature 45 mounted on a central shaft 46 by means of a spider 47 which is fixed to the shaft. Referring particularly to Figs. 8 and 11, the armature comprises a plurality of bars 48 (in this case ten) of magnetic material mounted parallel to the axis of shaft 46 but spaced therefrom. The bars 48 are supported at the middle by being mounted in the supporting ring 49 of the spider 47. At their ends the bars 48 are further supported by the stiffening rings 50 and 51. The armature 45 is rotatable with shaft 46 to cause the bars 48 to pass between the pole pieces of the electromagnets 43 and 44.

Referring now to Figs. 8 and 10, the electromagnet 43 comprises an annular coil 55 having a hollow central core 56 of a megnetically permeable material such as silicon steel. One pole of the electromagnet 43 is formed by the end plate 41 and the upper portion (as seen in Fig. 8) of the casing 40. The portion of casing 40 that forms part of the pole may be considered as a pole piece 57. The other pole of electromagnet 43 is formed by an annular connecting member or yoke 58 and a cylindrical pole piece 59 which confronts the pole piece 57 but is spaced therefrom to a sufficient extent to permit free passage of the armature bars 48 between the pole pieces.

The construction of the pole pieces 57 and 59 is best shown in Fig. 10 of the drawings. Referring to that figure, the inner surface of pole piece 57 and outer surface of pole piece 59 are recessed at corresponding, uniformly spaced points around their periphery to form areas 60 in which the pole pieces are relatively widely spaced. Since the pole pieces are widely spaced in areas 60, the intensity of the magnetic field is relatively low in these areas. Between the areas 60 the pole pieces 57 and 59 are spaced relatively close together to form arcuate passages 61 interconnecting the areas 60 and having a radial width only slightly greater than the radial width of the armature bars 48. The passages 61 and areas 60 are so located that the armature bars 48 may pass therethrough as the armature is rotated.

The passages 61 are provided with tapered walls as best shown in Fig. 10 to ensure desired position of the armature bars. When the electromagnet 43 is energized, the armature rotates in a counter-clockwise direction and the bars 48 are drawn through the passages 61 to the counter-clockwise ends of these passages. Upon de-energization of electromagnet 43, the bars 48 are moved through the areas 60 by electromagnet 44 in the manner described below.

The electromagnet 44 is similar in construction to the electromagnet 43 in that it is provided (see Fig. 12) with pole pieces 66 and 67 that cooperate to define areas 64 of relatively low field intensity and tapered passages 65 wherein the field intensity is relatively high. However, the areas 64 and passages 65 are circumferentially offset with respect to the areas 60 and passages 61 in such a way that each area 64 is opposite a passage 61 and each passage 65 is opposite an area 60.

The electromagnets 43*a* and 44*a* are energized alternately as in the case of electromagnets 10 and 11 of Fig. 1. When electromagnet 43 is energized, the armature bars 48 are drawn through passages 61 to the counter-clockwise ends of the passages and when electromagnet 44 is energized, the armature bars 48 are drawn through the passages 65 to the counter-clockwise ends of the passages. Thus, the armature rotates in a stepwise manner and moves through an angle of approximately 36° for each complete cycle of energization and de-energization of one of the electromagnets. It is thus evident that ten pulses are required to produce one revolution of the armature. Since the passages 61 and 65 are tapered, the armature bars 48 are accurately positioned with respect to the pole pieces and precise synchronization of armature movement and magnet energizataion is ensured.

Referring to Fig. 8, the shaft rotates in and is supported by a pair of bushings 68 and 69 and axial displacement of the shaft is prevented by a pair of rings 70 and 71 that are fixed to the shaft 46 and fit snugly against the bushings 68 and 69. The bushing 68 is mounted within the hollow core 56 of electromagnet 43 and the core is provided with an extension 72 that passes through the plate 41. Core 56 is held in place with respect to end plate 41 by a nut 73 which is threaded to the end of extension 72, a washer 74 being inserted between the unt and end plate. Between the nut 73 and extension 72 there is a felt washer 79 that bears lightly against shaft 46.

In assembling the counting device it is important that the pole pieces of the electromagnets 43 and 44 be properly aligned with respect to one another and a number of alignment pins are provided for this purpose. Near the shaft 46 there is a pin 75 that extends through end plate 41 and into a hole in core 56 to ensure proper relative positioning of the end plate, core, and pole piece 59. Near the periphery of end plate 41 there are a pair of pins 76 and 77 that extend through the end plate and into the pole piece 57. Proper alignment of pole pieces 57 and 66 is achieved automatically by virtue of the fact that both pole pieces form part of the casing 40.

The bushing 69 is mounted similarly to the bushing 70 and end plate 42 is provided with alignment pins similar to those provided in end plate 41. The shaft 46 may be connected to any suitable indicating or recording device for counting the speed of rotation of the shaft and consequently the number of electrical impulses transmitted from an ionization chamber such as the chamber 26.

From the above description it is apparent that the present invention provides an unusually compact and effective device for counting electrical impulses. Since the armature may be made relatively light as compared with the magnetic force available for moving the armature, the device is capable of counting a relatively large number of impulses in a unit time. The embodiment of Figs. 1 to 7 is unusually simple in construction. The embodiment of Figs. 8 to 12 while somewhat more complicated in construction possess the advantage that a relatively large tractive force is available for rotating the armature because of the fact that a large proportion of the metal of the armature is concentrated in the the magnetically permeable armature bars near the periphery of the armature. The armature is light in weight and has a small moment of inertia. The large tractive force coupled with the small moment of inertia of the armature permits accurate operation of this construction at unusually high speeds.

It will be apparent to those skilled in the art that various modifications can be made without departing from the principles of the invention as disclosed herein, and for that reason it is not intended that it should be limited other than by the scope of the appended claims.

We claim:

1. In a device for counting electrical impulses, a rotatable armature having three spaced cores of magnetic material, two separate electromagnets for producing stepwise rotation of the armature, and a switching circuit for alternately energizing the electromagnets, said switching circuit including a normally conducting negatively biased electron tube controlling energization of the coil of one electromagnet and a normally non-conducting and more negatively biased electron tube controlling energization of the coil of the other electromagnet, means responsive to a signal impressed upon the circuit for increasing the negative bias of the normally conducting tube until it cuts off, said tube thereby emitting a positive pulse and means for applying said positive pulse to the control electrode of the normally non-conducting tube to reduce the negative bias of the normally non-conducting tube until it becomes conductive.

2. In a device for counting electrical impulses, a rotatable armature having three spaced cores of magnetic material, two separate electromagnets for producing stepwise rotation of the armature, and a switching circuit for controlling the energization of the electromagnets, said circuit including a negatively biased normally conducting tetrode having the coil of one electromagnet connected across its output circuit, a more negatively biased normally non-conducting tetrode having the coil of the other electromagnet connected across its output circuit, means responsive to a signal impressed upon the circuit for increasing the negative bias of the normally conducting tetrode until it cuts off, said tetrode thereby emitting a positive pulse and means for applying said positive pulse to the control electrode of the normally non-conducting tetrode to reduce the negative bias of this tetrode until it becomes conductive.

3. In a device for counting electrical impulses, a rotatable armature having three spaced cores of magnetic material, two separate electromagnets for producing stepwise rotation of the armature, and a switching circuit for alternately energizing the electromagnets, said switching circuit including a normally conducting negatively biased electron tube controlling energization of the coil of one electromagnet and a normally non-conducting and more negatively biased electron tube controlling energization of the coil of the other electromagnet, means responsive to an impulse signal impressed upon the circuit for increasing the negative bias of the normally conducting tube until it cuts off, said tube thereby emitting a positive pulse and means for applying said positive pulse to the control electrode of the normally non-conducting tube to reduce the negative bias of this tube until it becomes conductive, the bias potentials of said circuit being of such magnitude as to cause the circuit to be self-restoring to its normal condition upon the disappearance of the impulse signal.

4. In a device for counting electrical impulses, a rotatable armature having three spaced cores of magnetic material, two separate electromagnets for producing stepwise rotation of the armature, and a switching circuit for alternately energizing the electromagnets, said switching circuit including a normally conducting negatively biased electron tube controlling energization of the coil of one electromagnet and a normally

non-conducting and more negatively biased electron tube controlling energization of the coil of the other electromagnet, means responsive to an impulse signal impressed upon the circuit for increasing the negative bias of the normally conducting tube until it cuts off, said tube thereby emitting a positive pulse, means for applying said positive pulse to the control electrode of the normally non-conducting tube to reduce the negative bias of this tube until it becomes conductive, the bias potentials of said circuit being of such magnitude as to cause the circuit to be self-restoring to its normal condition upon the disappearance of the impulse signal, and means controlling the bias potentials to effect a time delay in the self-restoring operation of the circuit.

5. An apparatus for counting electrical impulses comprising in combination a rotatable shaft for use in a counting mechanism, an armature mounted upon said shaft, said armature including a plurality of equally spaced cores of high permeability, a plurality of diametrically spaced electromagnets surrounding the armature, said electromagnets each including two pole shoes constructed and arranged to receive the cores of the armature freely therebetween, electronic amplifying means responsive to each electrical impulse to be counted, a switching circuit connecting said amplifying means to said electromagnets and adapted to energize said electromagnets alternately whereby each energized electromagnet attracts one of said permeable cores between its pole shoes and inhibits further armature movement until the same electromagnet is deenergized.

6. The apparatus of claim 5 wherein the plurality of cores of high permeability equals three and the plurality of electromagnets equals two.

7. In a device for counting electrical impulses, the combination comprising a rotatable armature for use in a counting mechanism, said armature including a plurality of separate cores of magnetic material equally spaced about the axis of rotation of the armature, a plurality of diametrically spaced electromagnets surrounding the armature, said electromagnets each including a pair of spaced poles arranged to receive the cores of the armature freely therebetween, each pair of poles having pole shoes constructed and



arranged to form a magnetic field therebetween having an intensity that increases in the direction of rotation of said armature, said pole shoes further extending more than half the angular spacing between adjacent armature cores, electronic amplifying means responsive to each electrical impulse to be counted, a switching circuit connecting said amplifying means to said electromagnets and adapted to energize said electromagnets alternately whereby each energized electromagnet attracts one of said permeable cores between its pole shoes and inhibits further armature movement until the same electromagnet is deenergized.

8. The apparatus of claim 7 wherein said plurality of equally spaced cores equals three and said plurality of electromagnets equals two.

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