Feb. 21, 1939. M. BOWMAN-MANIFOLD ET AL 2,148,398

COIL FOR PRODUCING A MAGNETIC FIELD OF APPROXIMATELY UNIFORM FLUX DENSITY FOR USE, FOR EXAMPLE, WITH CATHODE RAY TUBES

Filed Oct. 23, 1935 2 Sheets-Sheet 1

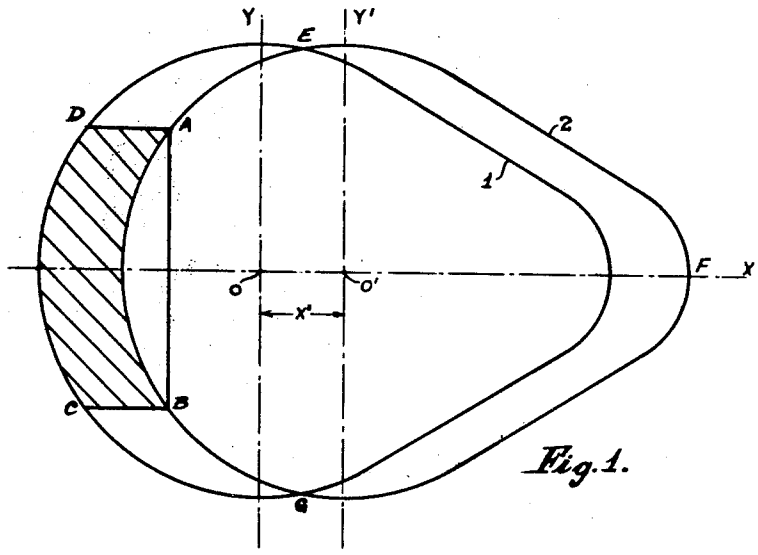


Fig. 1.

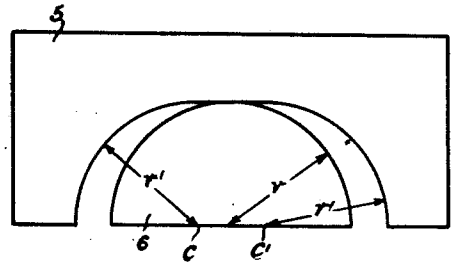


Fig. 2.

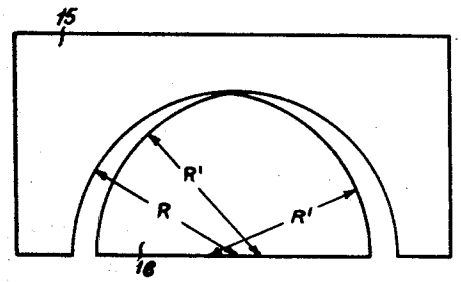


Fig. 3.

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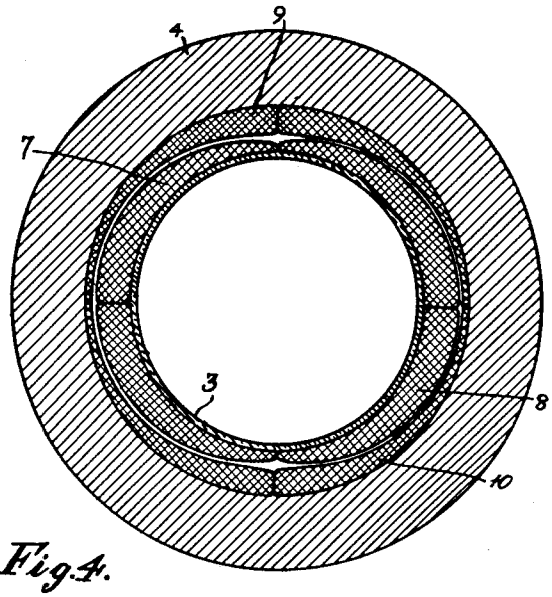


Fig. 4.

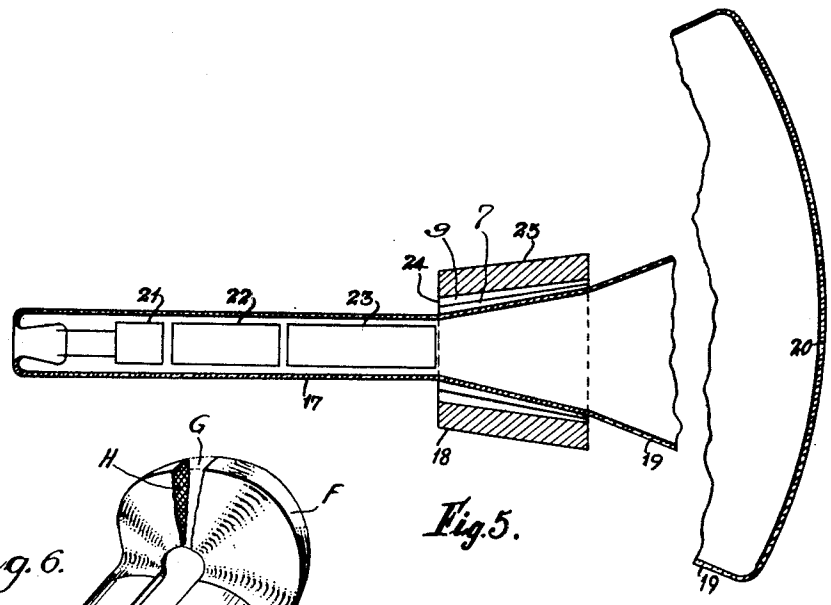


Fig. 5.

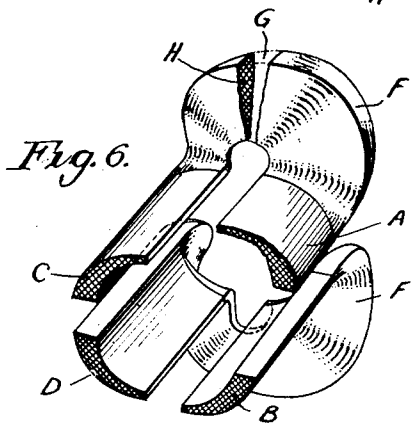


Fig. 6.

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Patented Feb. 21, 1939

2,148,398

UNITED STATES PATENT OFFICE

2,148,398

COIL FOR PRODUCING A MAGNETIC FIELD OF APPROXIMATELY UNIFORM FLUX DENSITY FOR USE, FOR EXAMPLE, WITH CATHODE RAY TUBES

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Application October 23, 1935, Serial No. 46,272
In Great Britain October 24, 1934

6 Claims. (Cl. 175—21)

The present invention relates to improvements in and relating to coils for producing a magnetic field of approximately uniform flux density, for use, for example, with cathode ray tubes.

Cathode ray tubes for current and potential analysis, and for use in television and like systems, are provided with means for deflecting the cathode ray and for causing it to trace out a desired path on a fluorescent or other screen associated with the tube. The deflecting means often comprise two deflecting coils, or two pairs of deflecting coils, arranged to produce deflection of the ray in two mutually perpendicular directions.

In television systems for example, it is generally required that the cathode ray should trace out on the screen a number of successive parallel lines, each slightly below the one preceding it, the arrangement being such that the area scanned is of rectangular shape. It is accordingly required that the deflecting coils should produce deflection of the ray in two co-ordinate directions, the deflection in one direction taking place at a higher frequency than the deflection in the other direction. Such a deflection of the ray is achieved in practice, in a manner well known per se, by feeding to the deflecting coils, or pairs of coils, deflecting currents of suitably chosen different frequencies. The deflecting currents are generally of saw-tooth wave form.

The method of scanning outlined above produces distortion if the area scanned is of other than the desired shape; consequently, the deflecting means must be so constructed and arranged that the area scanned is of the desired shape and dimensions. For example, if it is desired to scan a rectangular area on the screen, using deflecting currents of saw-tooth wave form, it must be arranged that for a given change of current in one deflecting coil or pair of coils, the distance moved through by the cathode ray on the screen is independent of the initial position of the scanning spot where the cathode ray strikes the screen.

If the deflection of the beam in either co-ordinate is not a linear function of the deflecting current, that is, if it is not independent of the initial position of the scanning spot, the following undesirable result will occur; if the beam is converging while it passes through the deflecting field, different portions of the beam will be differently deflected, and sharp focus will be lost, while even if the beam be assumed to be infinitely thin, distortion of the picture will arise, as already explained.

It has proved in practice very difficult to provide deflecting coils capable of operating without introducing distortion of the kind discussed above.

A further difficulty which has been encountered in designing deflecting coils for cathode ray tubes will now be considered. Such tubes usually comprise an envelope having a frusto-conical portion joined to a cylindrical portion, and the coils have usually been mounted on the cylindrical part of the envelope of the tube; for convenience, this part of the envelope will be referred to as the neck of the tube.

When a set of coils is required to reflect the cathode ray through large angles, it is necessary to make the diameter of the neck of the tube relatively large, in order that the deflected beam shall not hit the neck but shall pass unobstructed into the frusto-conical portion of the tube. For large angles of deflection, therefore it is necessary to make the diameter of the coils relatively large; inefficient coils are thus obtained, not only on account of the large diameter, but also since it may be necessary to make the length to diameter ratio of the coils relatively small; with a coil of which the length to diameter ratio is small, the uniformity of the field obtained is found to be poor.

It is one of the objects of the present invention to provide coils suitable for use, for example, as deflecting coils for a cathode ray tube which are so constructed and arranged that the deflection of the ray in each co-ordinate-direction depends only on the deflecting current fed to the coils, so that distortion of the area scanned due to the deflecting coils is avoided. This will be realized if the set of coils for deflecting the ray in each direction produces a magnetic field which, in every plane at right angles to the axis of the cathode ray tube, is of uniform strength and direction over the area which the cathode ray beam traverses.

Another object of the invention is to provide a coil adapted to produce a magnetic field substantially only where it is required, without the expenditure of magnetising energy in producing a field elsewhere, thereby reducing the magnetising energy which is necessary to produce a field of the required flux density.

It is a further object of the invention to provide coils which are suitable for use, for example, as deflecting coils in association with a cathode ray tube in which it is desired to deflect the ray through large angles.

It should be borne in mind that coils according to this invention, while they are well suited for use with cathode ray tubes, are not so limited in

their application, but can be employed for many other purposes in which a field of very uniform flux density is required.

The present invention accordingly provides a coil wound about a space of cylindrical or frusto-conical shape, and adapted to produce within said space a magnetic field substantially at right angles to the axis of said space, said coil lying wholly outside the cylinder or cone of which said space fills a part, wherein said coil comprises a plurality of turns having active portions which lie close to said space and approximately parallel to the axis thereof, and wherein said active portions are so arranged that when current is passed through said coil, the magnetic field set up within said space, in a plane at right angles to the axis thereof, is substantially uniform.

According to a feature of the present invention, a coil is wound to fill the whole or a part of the space defined by the surfaces of two imaginary solid figures both in the form of cylinders or conical frusta of substantially the same size and shape, of which one has been displaced bodily from a position of substantially complete coincidence with the other in a direction at right angles to the direction of the axes of the said figures through a distance short compared to the dimensions of each figure in a plane at right angles to the axis thereof, the winding being carried out in such a manner that when, in operation, current is caused to flow in said coil, the direction of current flow in that part of said coil which is on one side of a plane of intersection lying substantially at right angles to the direction of said displacement and containing two lines of intersection of the surfaces of said figures is opposite to the direction of current flow in the part of said coil lying in the other part of said space; the coil may be located within and close to a sheath of magnetic material which serves as a return path for the magnetic flux.

In the preceding paragraph, the term cylinder is to be understood to mean the solid figure generated by a straight line which moves so that it is always parallel to a fixed straight line, and so that the ends trace out a closed curve. The term is not intended to include those solid figures having a cross-section approaching the rectangle in shape, and the displacement referred to is effected along either of the two axes of symmetry of the cross-section. When the surfaces of the figures intersect one another along more than two lines, the plane of intersection referred to in the preceding paragraph is the median plane; it will be found that whatever the shape of the figures in cross-section, no difficulty will be found in determining this median plane.

The term conical frustum is intended to cover a frustum of the solid figure generated by a line—which is usually straight—and which moves so that one point in it remains fixed, while any other point therein traces out a closed curve such, for example, as a circle.

The axis of a solid figure, for the purpose of this specification is intended to mean a line running longitudinally through the figure, but not intersecting the surface thereof, the axis lying substantially in a median position; for example, the axis in the case of a right circular cylinder or frustum is the axis of symmetry of the figure.

The coils necessarily should be arranged in a fashion wherein the figures forming the boundaries thereof either have two actual points of intersection or are arranged so closely together that the coil sections substantially touch each other.

A coil according to a further feature of this invention comprises a plurality of turns each having two active portions arranged substantially parallel to one another and to the active portions of the other turns, and is so constructed that when, in operation, current flows in said coil, the current per unit angle in the active parts of the turns of said coil in the neighbourhood of a plane which contains the longitudinal axis of the coil and cuts the lines of force inside the coil substantially at right angles, is greater than the current per unit angle in the neighbourhood of a plane which also contains said axis but is at right angles to said first-mentioned plane. By the expression "current per unit angle" is meant the current which flows through the part of the cross-section of the coil bounded by two straight lines which intersect at the axis of the coil and make a unit angle with one another.

The longitudinal axis of the coil, referred to in the above paragraph, is a line lying within the coil in a substantially median position, which does not intersect the active parts of said turns but is substantially parallel to said active parts.

My invention will best be understood by reference to the following figures in which

Fig. 1 is an explanatory diagram,

Figs. 2 and 3 are coil forms,

Fig. 4 is a cross-sectional view of the coils used as electron beam deflecting means, and

Fig. 5 is an embodiment used in conjunction with the cathode ray tube.

Fig. 6 is a perspective view of a coil wound in accordance with my invention with one end cut away for purposes of clarity.

Before particular embodiments of the invention are described, reference will be made for purposes of explanation to Fig. 1 of the accompanying drawings; the disposition of the closed curve 1 in this figure with respect to axes X and Y, is exactly the same as that of the curve 2 with respect to axes X and Y', and the distance X' between the Y and Y' axes is small compared to the distance from the origin O to any point on the curve 1.

Now the distance between the curves along any line parallel to the X axis is constant and equal to X', and hence the area of the parallelogram enclosed by the curves 1 and 2 and any pair of lines, parallel to the X axis and separated by an infinitely small distance, is constant. Thus it will be clear that if a line such as AB is drawn parallel to the Y and Y' axes, the area of the cross-hatched portion ABCD between the two curves is proportional to the length AB.

Let it now be assumed that the line CDEFG represents the boundary of a tunnel, of constant cross section, cut in a block of magnetic material such as iron, the tunnel extending downwards into the paper. The curves 1 and 2 then represent cross sections of two identical cylinders having as axes lines drawn perpendicularly downwards into the paper through points O and O', and a coil of wire of uniform cross section is according to this invention wound in the space enclosed by the surfaces of these cylinders; the winding is carried out in such a manner that the parts of the turns lying in the space between the surfaces of the cylinders run parallel to the axes of the cylinders, the arrangement being such that when a current is passed through the coil, the direction of current flow in the part of the space to the left of the plane extending vertically downwards and

containing the lines of intersection of the surfaces through E and G is opposite to the direction of current flow in the part of the space to the right of that plane. There is thus a uniform distribution of current over the whole of the space between the cylinders.

Now, since the cross-hatched area ABCD is proportional to the length AB, and since it can be assumed that the current per unit area is constant, the total current flowing through the area ABCD is proportional to the length AB. The magneto-motive force in the loop ABCD encircling the area ABCD is proportional to the current flowing through the area ABCD, and hence is proportional to the length AB. The return path of lines of force passing from A to B comprises the path AD and BC and a path through the surrounding iron, which will be assumed to be of zero reluctance. The lengths AD and BC are both equal to the small displacement X' and are thus small compared with AB for most values which AB may have. The whole return path may thus be assumed to be of zero reluctance. The reluctance of the air path from A to B is proportional to the length AB, and since this is substantially the only reluctance in the loop ABCD, the reluctance of that loop is also proportional to the length AB. Since the flux density is proportional to the magneto-motive force, and inversely proportional to the reluctance, it follows that the flux density along AB is independent of the length of that line.

The construction and method of mounting of a pair of coils according to the present invention, for use as the deflecting coils of a cathode ray tube, will now be described by way of example.

Referring to Fig. 4, there is shown a cross-sectional view of two sets of coils wound in accordance with my invention and applied to the use of deflecting the cathode ray beam in a cathode ray tube in two co-ordinates. Accordingly, the complete coils are illustrated as being 90° apart from each other in position. The coils embrace the tube **3**, and the inner set of coils **7**, **8** are intimately held against the outer periphery of the cathode ray tube, and the outer set of coils **9**, **10** are illustrated as slightly apart from the inner set of coils. Surrounding both sets of coils is a magnetic shield **4** illustrated in cross-section.

The coils may be connected together in series or in parallel depending upon the inductance value desired, the arrangement being made such that current flows in one direction in the left-hand section of the coils **7** and **8**, for example, and flows in the opposite direction in the right-hand portions thereof.

The inner coil may be wound on the form shown in Fig. 2 which comprises a wooden block **5** having a channel or groove cut in it, and a portion **6** in the shape of a half of a right-circular cylinder, the form in actual practice usually being made of wood. As illustrated in Fig. 2, the coil sides would be slightly apart due to the positioning of the section **6** against section **5** of the form. After the coils are wound on the form, the sides may be pushed together, and it is in this fashion that the coils of Fig. 4 are made.

The same situation prevails as regards the outer coil which may be wound on the form shown in Fig. 3. The coil sides will be apart somewhat due to the coincident section, or touching the section or sections **15** and **16** of the form. The coils are wound so as to fill substantially all of the space excluding the coincident space between the two substantially right-circular cylinders which have been moved from a coaxial position along a line at right angles to the axis of the cylinder. In this case, the coil sides may be forced together after winding, and it is in this fashion that the outer coils illustrated in Fig. 4 are made.

It will be obvious that the parameters of any coil depends upon the particular purpose for which the coil is to be used. For instance, in the deflection of a cathode ray beam a certain number of ampere turns may be required to adequately deflect the beam by a desired amount, and the inner circumference of the coil must be large enough to allow the tube neck or other section to which the coil is applied to pass through the coil in a position where the tube is embraced by the coil. Accordingly, r and r', illustrated in Fig. 2, must be sufficiently great to allow the coincident portions of the cylinders of which they are the radii to substantially equal the outer periphery of the section of the cathode ray tube to which the coil is to be applied. Also, the distance through which the cylinders are moved relatively to each other must be great enough to provide a space between the two cylinders which is large enough to accommodate the required number of turns which are to furnish sufficient ampere turns to provide the desired result. It will be seen therefore that the calculation r, r', c, and c' may be determined by the particular parameters of the coil concerned and will depend upon the size of the element which is to be accommodated inside the coil, the number of ampere turns required, and the size of the wire of which the coil is to be wound.

In the case of the coil identified as **9**, **10**, which was wound on the form shown in Fig. 3, the radius R, which determines the outer radius of the coil, is substantially the same as the inner radius of the sheath **4**, subject of course to allowing for pushing the sides of the coil together after they have been wound on the form.

The coils **9** and **10** are mounted upon the coils **7** and **8**, if desired with the interposition of suitable insulating material, or of suitably shaped separating members, and the whole coil assembly is surrounded by a magnetic sheath **4** which may be built up from semi-circular or circular laminations. The coils **9** and **10** are connected in series or parallel, and it is arranged that when current flows in one direction in the upper halves of these coils, it flows in the opposite direction in the lower parts thereof. The resultant field due to coils **7** and **8** is at right angles to that produced by coils **9** and **10**. The overall length of the outer coils may be made rather less than that of the inner coils, if desired.

The parts of the turns outside the sheath **4** pass over the wall of the tube **3**, and are so arranged that they lie in planes substantially at right angles to the longitudinal axis of the tube; the magnetic field due to them thus produces little or no effect on the action of the deflecting field in the tube. The sheath may be formed by winding over the active portions of the turns of the deflecting coils a thick coil of iron wire; the shape of the sheath is of little importance, provided it provides flux-return paths of a reluctance which is negligible compared with the reluctance across the tube.

It is found that a coil of the form last described above, that is to say a coil wound to fill the space between the surfaces of two substantially right circular cylinders displaced from one another, is capable of producing a uniform field in the absence of an iron sheath. It is also found that in

the absence of the iron sheath, the inductance of such a coil is approximately halved.

Referring to Fig. 5, a cathode ray tube has a glass envelope comprising a cylindrical portion 17 of about one inch diameter closed at the left hand end, and having the other end joined to a right circular conical frustum 18 2½ inches in length; the frustum 18 has a diameter at its larger end of 2 inches, and this larger end is joined to the smaller end of a second right circular frustum 19 which flares at a greater rate than the first frustum and is closed at its larger end by an end wall 20. A fluorescent screen is mounted on this end wall.

Within the cylindrical portion 17 is mounted an electron gun which may be of any suitable kind, and comprises essentially a cathode and modulator assembly 21, a first anode 22 and a second anode 23. It is arranged that the second anode 23 lies near to the smaller end of the first frustum.

Mounted upon the outer wall of the first frustum 18 are two pairs of deflecting coils indicated by reference 24; these coils are of a form very similar to that of the coils described with reference to Fig. 4, but instead of being wound to fit a cylindrical portion of the tube, they are wound to fit a frusto-conical portion. The coils are conveniently wound on formers such as are described in Figs. 2 and 3, but differing in that the winding boundaries are not cylindrical, but frusto-conical. The formers are so constructed that the depth of the winding space decreases towards the wider end, and the nature of the resulting coil is therefore such that its thickness decreases as its diameter increases, as shown in Fig. 5. This is necessary in order that the same number of turns shall be accommodated at the narrower end as at the wider end.

A laminated iron yoke 25 having a conical hole therein may, if desired, be mounted as a snug fit over the scanning coils 24, and a cross section through the coils in a plane at right angles to the longitudinal axis of the tube appears much as is shown in Fig. 4. The end portions of the turns of the coils are arranged to lie in planes substantially at right angles to the longitudinal axis of the tube, and thus the magnetic field due to these portions produces little effect on the deflecting field.

The part of the envelope on which the coils are mounted may be of other than right-circular frusto-conical shapes; for example, the tube may have a part in the shape of a frustum of a pyramid and the coils may be wound on this part. The coils may also be wound on a portion of the tube which is in part of one shape, for example cylindrical, and in part of another, for example conical. Thus the envelope of the tube may comprise a cylindrical portion flaring out into a single frusto-conical portion having a fluorescent screen at its larger end, the coils being arranged partly on each of the two portions. The coils may then be wound on formers so arranged that the winding space is of constant depth along the cylindrical parts, and tapers along the conical parts in the manner already described.

In an arrangement such as that last described, the inner pair of coils only may lie on both the cylindrical and the conical parts of the tube, the outer coils being arranged to lie over the cylindrical portions only of the inner coils. The end turns of the inner coils may be spread along the surface of the frusto-conical part of the tube, thus giving the maximum length for the outer coils and the maximum length for the magnetic yoke if one is employed.

Referring to Fig. 6, there is shown a perspective view of the coil with one end thereof cut away for purposes of clarity, and with the other end illustrated to show how, for some applications of the coil at least, the ends of the coil must be bent upwardly and away from the active sections. Four sections A, B, C and D have been illustrated here in a manner which shows them forced apart slightly in order to bring out the distinct sections. The sections A, B, C and D are similar to the sections shown as coils 7 and 8 in Fig. 4. Where the coil is used as a deflecting means for the electron stream of a cathode ray tube, for instance, then the ends of the coil where the windings pass from the section C to the section A, for instance, are bent upwardly and forced apart so as to allow passage of the neck of the tube therebetween. In this figure, one end section F is illustrated and, in order to show the cross-sectional appearance of this end section, the end has been cut away and illustrated in skeleton form at G. The cross-sectional appearance on a cutting plane passing on an angle to the end is illustrated at H. Naturally, the bottom or lower bent section should be substantially identical with the upper, and this has not been broken away. The lower section also is referred to as F.

As has already been stated, the application of the invention is not limited to coils for use in association with cathode ray tubes; furthermore, the invention is not limited to the embodiments described. Many other uses for coils according to the invention, and many modifications thereof within the scope of the appended claims will occur to those versed in the art.

We claim:

1. A coil wound to substantially fill the whole of the space, excluding the coincident space, defined by the surfaces of two imaginary conical frusta of substantially the same size and shape, of which one has been displaced bodily from a position of substantially complete co-incidence with the other in a direction at right angles to the direction of the axes of the said conical frusta through a distance short compared to the dimensions of each conical frustum in a plane at right angles to the axis thereof, said coil comprising a plurality of turns so disposed that when, in operation, current flows in said coil, the direction of current flow in that part of said coil which is on one side of a plane of intersection lying substantially at right angles to the direction of said displacement and containing two lines of intersection of the surfaces of said conical frusta, is opposite to the direction of current flow in the part of said coil lying in the other part of said space.

2. A coil wound to substantially fill the whole of the space, excluding the coincident space, defined by the surfaces of two imaginary cylinders having a substantially circular cross-section and of substantially the same size and shape, of which one has been displaced bodily from a position of substantially complete co-incidence with the other in a direction at right angles to the direction of the axes of the said cylinders through a distance short compared to the dimensions of each cylinder in a plane at right angles to the axis thereof, said coil comprising a plurality of turns so disposed that when, in operation, current flows in said coil, the direction of current flow in that part of said coil which is on one side of a plane of intersection lying substantially at

right angles to the direction of said displacement and containing two lines of intersection of the surfaces of said cylinders, is opposite to the direction of current flow in the part of said coil lying in the other part of said space, and a sheath of magnetic material embracing at least a part of said coil.

3. A coil wound to substantially fill the whole of the space, excluding the coincident space, defined by the surfaces of two imaginary conical frusta of substantially the same size and shape, of which one has been displaced bodily from a position of substantially complete co-incidence with the other in a direction at right angles to the direction of the axes of the said conical frusta through a distance short compared to the dimensions of each conical frustum in a plane at right angles to the axis thereof, said coil comprising a plurality of turns so disposed that when, in operation, current flows in said coil, the direction of current flow in that part of said coil which is on one side of a plane of intersection lying substantially at right angles to the direction of said displacement and containing two lines of intersection of the surfaces of said conical frusta, is opposite to the direction of current flow in the part of said coil lying in the other part of said space, and a sheath of magnetic material embracing at least a part of said coil.

4. A coil according to claim 1, the thickness of which is less at the wider end of the frustum than at the narrower end thereof.

5. A coil wound to fill substantially the whole of the space, excluding the coincident space, between two surfaces of tubular form, said tubes having a cross section approaching the circular in form and of substantially the same shape and size, one of which has been displaced bodily from a position of substantially complete coincidence with the other in a direction at right angles to that direction which is axial to said surfaces through a distance short compared to the dimensions of each surface in a plane at right angles to the axis thereof, said coil comprising a plurality of turns disposed in said space so that when current flows in said coil the direction of current flow in that part of the coil which is on one side of a plane of intersection lying substantially at right angles to the direction of said displacement and containing two lines of intersection of said surfaces is opposite the direction of current flow in the part of said coil lying in the other part of said space.

6. A coil wound in accordance with claim 5 in which said surfaces both comprise two parts, one of said parts being in the form of a cylinder and the other of said parts in the form of a frustum of a cone.

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