Sept. 6, 1938. C. A. HEDDEN 2,129,058

TRANSFORMER FOR A METAL LOCATOR

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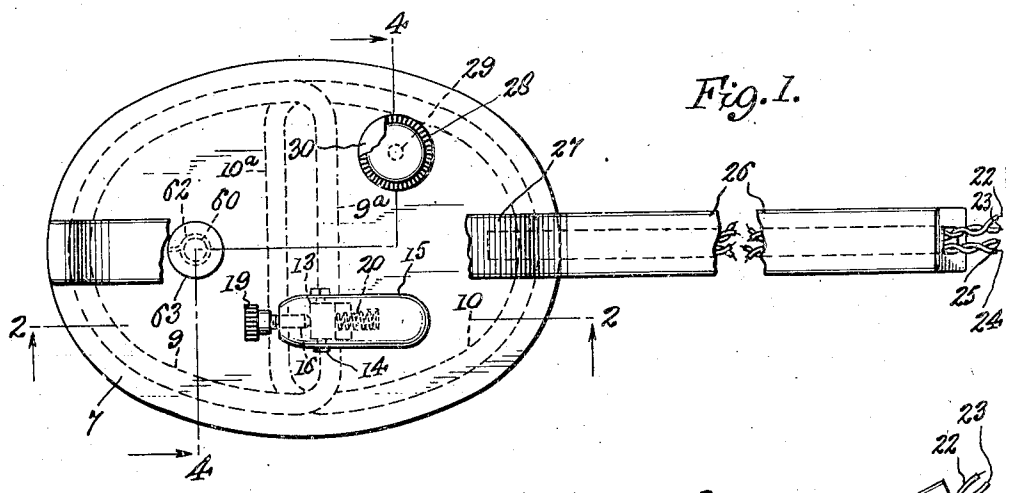

Fig. 1.

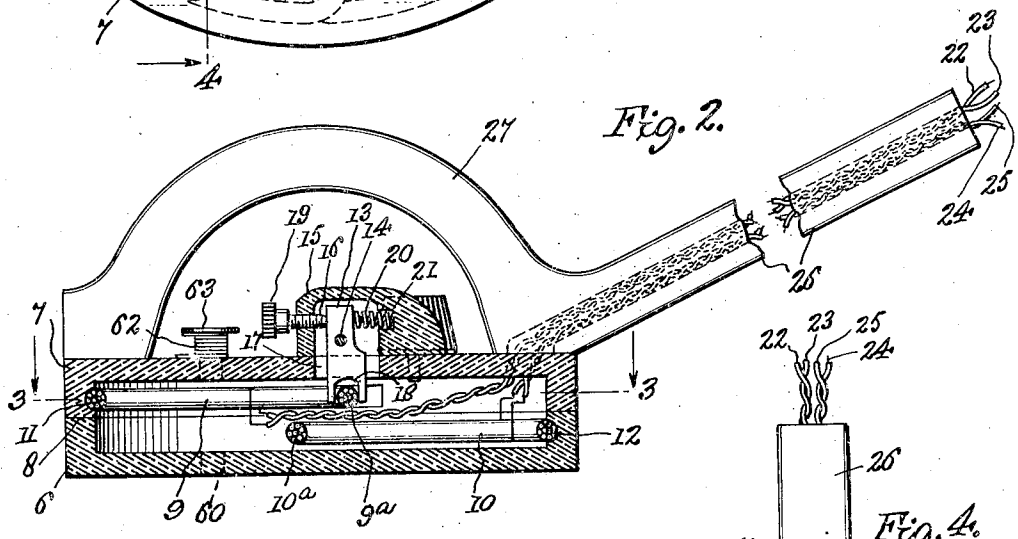

Fig. 2.

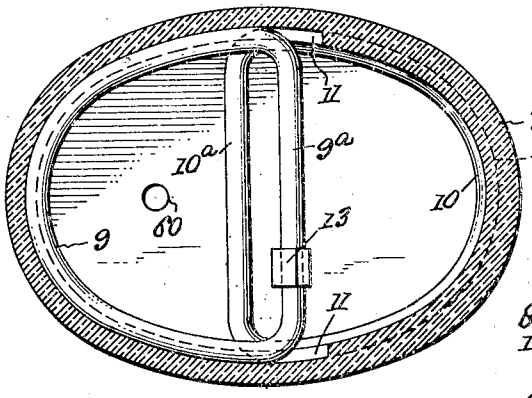

Fig. 3.

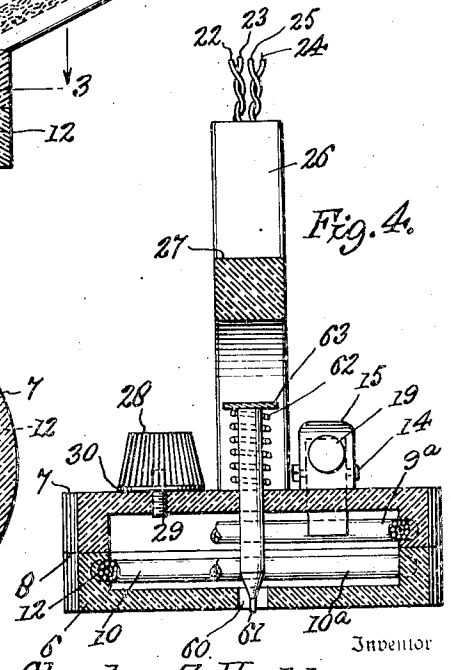

Fig. 4.

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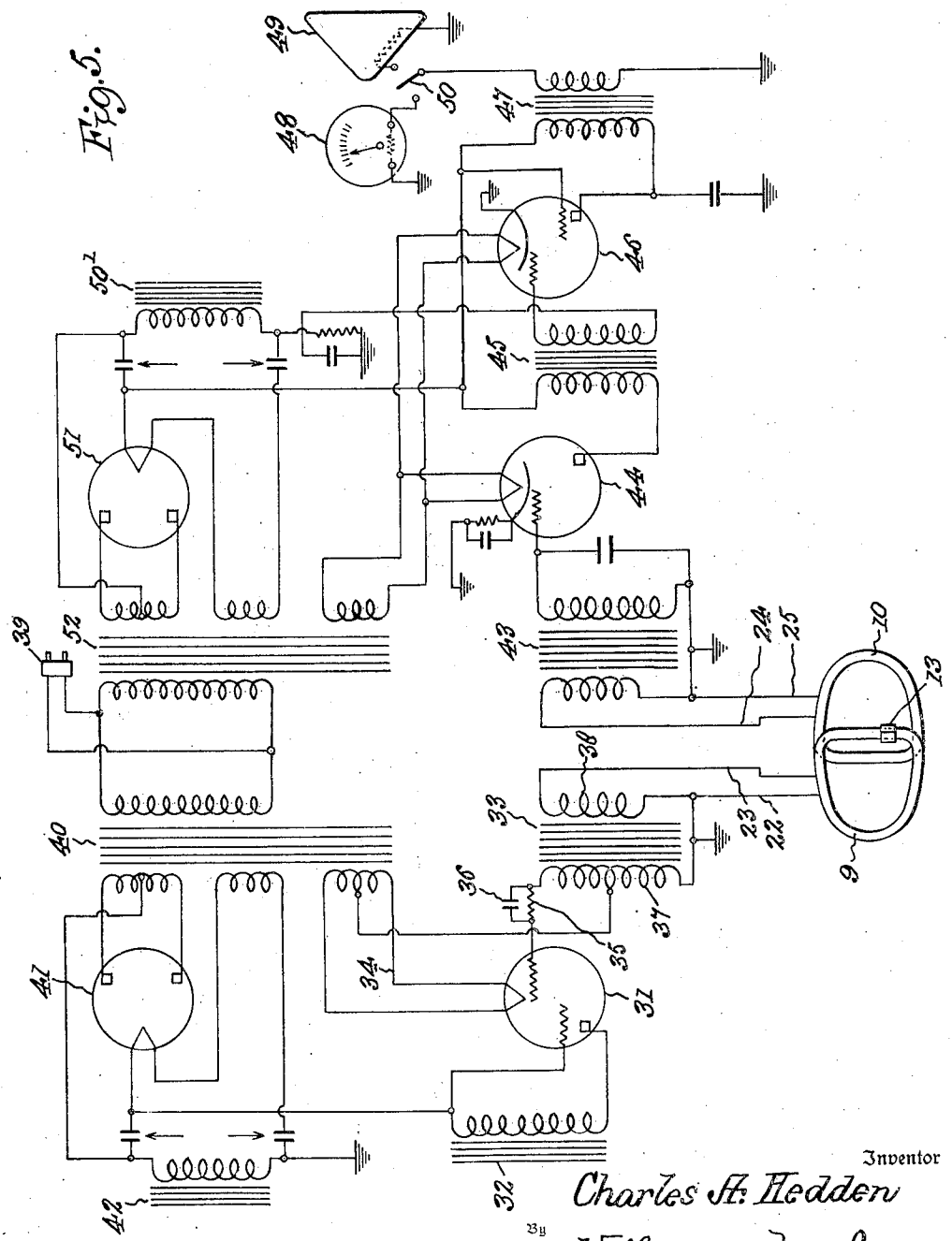
Fig. 5.



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TRANSFORMER FOR A METAL LOCATOR

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Application July 11, 1936, Serial No. 90,223

3 Claims. (Cl. 171—242)

The present invention relates to improvements in metal locators and has for an object to produce a device which will not only detect generally the presence of metal through non-metallic bodies or substances but will definitely locate the position of the metal with reference to localized portions of the body or substances.

The device will have application to the locating of metallic particles in the human body, to revealing the presence of hack-saws or other jail-breaking tools being smuggled to prisoners in magazines and the like, and wherever it is necessary to determine the exact location of metal for any purpose.

A further object of the invention resides in providing an improved metal locator of an electrical nature in which the act of detection and location is controlled with great sensitivity by the use of balanced induction coils, the balance being extremely delicate and subject to be destroyed when the smallest particle of metal enters the magnetic field.

A still further object of the invention resides in providing an easily manipulated and controlled hand instrument of such construction as to permit of its movement through a wide range of movement from the amplifier whereby the instrument may be easily and quickly applied to localized surfaces for the purpose of detecting and locating the presence of metal.

The invention also contemplates, in connection with such hand instrument, adjustments that may be made in the relative overlapping positions of the coils and in the magnetic field thereof.

It is also to be noted that the improved device will determine and distinguish between magnetic and non-magnetic metals and will indicate which variety of metal is at the moment under detection and location.

With the foregoing and other objects in view, the invention will be more fully described hereinafter, and will be more particularly pointed out in the claims appended hereto.

In the drawings, wherein like symbols refer to like or corresponding parts throughout the several views.

Figure 1 is a top plan view, with parts broken away, showing the improved hand instrument constructed according to the present invention.

Figure 2 is a vertical longitudinal section taken on the line 2—2 in Figure 1.

Figure 3 is a horizontal section taken on the line 3—3 in Figure 2.

Figure 4 is a transverse sectional view taken on the line 4—4 in Figure 1, and

Figure 5 is a circuit diagrammatic view showing one method of actuating the hand instrument and indicating the result produced in the hand instrument by the presence of metal.

Referring more particularly to the drawings, and for the present to Figures 1 to 4 inclusive illustrating the hand instrument, 6 and 7 designate counterparts or half sections of a casing or housing which may be fitted together, for instance along the line of division 8, and securely held in the assembled relation shown as by means of adhesive.

Within the casing are contained two induction coils 9 and 10 partially overlapped and relatively movable or adjustable whereby the degree of the overlap may be enlarged or diminished for the purpose of creating a balanced condition in the magnetic relative condition of the two coils.

Either coil may be the primary and either the secondary, the coils being alike in construction and characteristics. For convenience in description will designate the coil 9 as being the primary, and the coil 10 as the secondary or receiver.

One of the coils may be mounted in one section of the casing while the other is mounted in the other section. The primary 9 is contained in the upper casing section 7 and is slidably supported therein by being partly or wholly held in a groove 11 formed in the wall of the casing section 7. The secondary or receiver coil 10 is permanently or fixedly mounted in the lower casing section 6. This latter section may be conveniently formed with a groove 12 in which the secondary 10 is fitted and cemented. It is obvious that either one or both of the coils 9 and 10 may be slidable in their respective grooves 11 and 12; or, as shown in the drawings, one of the coils may be fixed or stationary and the other slidable. In the instance shown the primary 9 is shown to be the slidable coil, the same being freely movable back and forth in the partially-elliptical groove, as illustrated in Figure 3. The coils are shown to be partially elliptical but the shape of such coils and the corresponding shape of the grooves 11 and 12 which they occupy may be changed to suit any particular circumstances.

The coils 9 and 10 at their inner overlapping portions may be in the form of substantially straight bars 9^a and 10^a which bars overlap one another to greater or lesser extent in accordance with the position of the movable primary coil 9. This primary coil may be adjusted as to position by means of an adjusting lever 13 pivoted, as indicated at 14, in a housing 15 seated upon the upper

section 7 of the casing. The hollow interior portion 16 of the housing 15 communicates with the interior space of the casing through an opening 17 made in the upper casing section 7. Through this opening the forked lower end portion 18 of the actuating lever 13 extends for the purpose of loosely embracing the cross-bar 9a of the primary coil 9. The fork 18 preferably has a loose fit on the cross-bar 9a not only as to its sides but also upon the top portion thereof to permit the free rocking of the lever 13 about its fulcrum 14 in the act of shifting the primary coil back and forth. This rocking movement of the lever 13 is accomplished by means of an adjusting screw 19 threaded through one wall of the housing 15 with which it has threaded engagement. At its inner end the adjusting screw 19 freely abuts against the upper projecting part of the lever 13. Such part of the lever is constantly urged to this abutting relation with the said screw by the expansive action of a coil spring 20 seated in a recess 21 of the housing 15 and having its axis substantially in alinement with the axis of the adjusting screw 19, although this specific relation is not essential.

The leads to the primary coil 9 are indicated at 22 and 23.

The leads to the secondary coil 10 are represented at 24 and 25. These leads are wound into a cable and passed through a hollow handle 26 attached to the casing and forming a convenient means by which the casing may be manipulated, that is passed over various bodies or substances to be searched for metals.

The handle 26 may also conveniently embody a loop or arch 27 having its opposite end affixed to the casing. This arch or loop 27 also forms a convenient hand-grip. The construction also admits of a great amount of clearance above the top of the casing for freedom in manipulating the set screw 19 and also the adjusting cap 28. This adjusting cap 28 is threaded upon a stud 29 upstanding from the top portion of the casing, the cap 28 having an internal threaded socket with threads mating with those of the stud 29. These threads are preferably relatively fine in order to secure a micrometer adjustment. Accordingly as the cap 28 is turned in one or the other direction a metal washer 30 carried on the underside thereof and next to the casing will advance toward, or retire away from, the coils 9 and 10 within the casing; this for the purpose of securing a final and nice adjustment of the condition of balance between the coils 9 and 10.

Referring more particularly to Figure 5, the primary coil 9 is connected to the output of an oscillator circuit. This oscillator circuit is representative of any pulsating source of direct or alternating current. The oscillator circuit as shown includes the oscillator tube 31, a choke coil 32, which is in the plate circuit of the tube 31, an audio transformer 33, which is in the grid circuit of the tube 31, and the filament circuit 34. In the grid circuit is also a resistor 35 and a condenser 36 by-passing the resistor. Both the resistor 35 and the condenser 36 are in series with the primary 37 of the transformer 33. The primary coil 9 is attached to the secondary 38 of the transformer 33 through leads 22 and 23.

The arrangement shown is for use in connection with 110 volt alternating current which is plugged ing at 39. This incoming current is led to the primary of the transformer 40 and from the secondary of that transformer to the filament circuit 34 and to the rectifying circuit including the rectifying tube 41 and choke coil 42.

The other coil 10 in the hand instrument is coupled by the leads 24 and 25 to the primary of the input transformer 43. The pulsations in the primary induce similar current of higher amplitude in the secondary of this transformer 43 and such currents are impressed on the grid of the first audio amplifier tube 44. These alternating pulsations appear in the plate circuit of the tube 44 and are built up in the transformer 45 and impressed on the grid of the second audio amplifier or power tube 46. These alternating pulsations appear in the plate circuit of the power tube 46 and are induced into the secondary of the output transformer 47. From there the current is used to actuate any desired type of indicating instrument, such for instance the meter 48 or the loud speaker 49, there being a switch 50 for the purpose of cutting in either the meter or the loud speaker. The speaker field coil 50' is used as a filter choke coil in the rectifier circuit for the amplifier circuit. This rectifier circuit includes the rectifier tube 51 and power transformer 52 which receives its current from the source 39 and which transformer 52 also supplies the current for the filaments of the first and second audio tubes 44 and 46 and also the filament current for the rectifier tube 51.

In operation, an alternating current will be impressed upon the primary coil 9 in the hand instrument. This alternating current flowing through the primary 9 will ordinarily tend to induce in the secondary or receiving coil 10 a similar alternating current. The object is to initially balance these two coils 9 and 10. By balance I mean that the coils shall be so related that no electro-motive force will appear at the leads of the secondary 10. The electro-motive force induced in coil 10 by the magnetic field of coil 9 is in two directions at the same instant; meaning, there are two opposing electro-motive forces. When these two opposing electro-motive forces are made equal, no current can flow in coil 10, and this coil is in a condition of balance inductively. This result is made possible by placing coils 9 and 10 in an overlapping position. The magnetic field of coil 9 cuts through the turns of coil 10 in two directions at the same instant because of this overlapping position. If these coils were not overlapped, but were placed in a position side by side, coil 10 would be cut by the field of coil 9 in one direction only, and an electro-motive force would be induced in coil 10 with current flowing around the coil in one direction only at that instant and no balance could exist. However, by overlapping the coils, the magnetic field of coil 9 cuts the bar section of coil 10 in one direction and the circular section of coil 10 in the opposite direction at any particular instant. This results in electro-motive forces being induced in coil 10 of opposite directions. When these opposite electro-motive forces are made equal, by adjusting the amount of overlap, no current can flow in coil 10 and an induction balance is obtained in coil 10, while coil 9 continues to emit an oscillating magnetic field.

The magnetic field whirling around the bar section of coil 9, at the particular instant shown in the drawings, is downward through the bar of coil 10 and upward through the circular part of coil 10, thus inducing an electro-motive force in one direction in the bar of coil 10 and an electro-motive force in the opposite direction in the circular part of coil 10. The direction of current flow is found by the right hand rule shown in the drawings. The induced electro-motive force is

always opposite to, and opposed to, the electro-motive force causing the induction.

This induction balance is easily disturbed by the smallest particle of metal, but the ability of this instrument to distinguish between magnetic and non-magnetic metals is due to the fact that a magnetic metal has an attraction for magnetic lines of force and non-magnetic metals have no such attraction. Non-magnetic metal disturbs the induction balance by receiving an induced current from coil 9 when brought within the field of said coil. The induced current in said metal object, as in all cases of mutual induction, is of such polarity as to oppose the force causing the induction. The opposing force in this case is the magnetic field emanating from the metal object, and is the result of the induced current in the metal object. This opposing force causes a number of the magnetic lines of force from the field of coil 9 to pass out of their natural circular path to go around this obstruction. This change or distorting of the field of coil 9 causes an unbalance in coil 10 or a current flow in said coil, this current being induced by coil 9.

A magnetic metal attracts a number of the lines of force of the magnetic field of coil 9, and the field is distorted, causing coil 10 to be unbalanced and allowing a current to flow in said coil 10. It is to be noted, however, that, in this case, the field is distorted by magnetic attraction instead of magnetic opposition.

To distinguish between these two kinds of metal, it is necessary to adjust coils 9 and 10 to a point where a small amount of current flows in coil 10 or a slight unbalance is obtained. Then a magnetic metal brought in the field of coil 9 will distort the field in such direction as to correct this unbalanced condition in coil 10, or bring said coil back to a condition where no current flows therein. When, however, a non-magnetic metal is brought in the field of coil 9 during this condition of unbalance in coil 10, the field of coil 9 is distorted in such direction as to further increase the unbalanced condition in coil 10, causing a greater induced current to flow in said coil 10. Any decrease or increase in the induced current in coil 10 is shown on a meter after having been amplified. It can be seen, therefore, that due to the different properties of the different metals in affecting a magnetic field in different directions, this fact can be used to distinguish between the different metals. This is an actual accomplishment of this instrument.

The extreme sensitivity of this instrument is due to the fact that the coil 10 is inductively balanced in a position close to coil 9, or in such a position as to receive a high induced electro-motive force when unbalanced. A further reason is that the coils are both on the same plane, their fields being in one direction. The theory of the operation of the metal washer 30 is that this washer receives an induced current which has its resultant opposing magnetic field. By adjusting this washer closer or farther from the coils, the amount of induced current is varied to a point where the opposing magnetic field resulting from the induced current is just enough to compensate for amount of unbalance caused by any difference in the electrical characteristics of coils 9 and 10. In this condition of balance coil 9 is continuously throwing out an oscillating magnetic field; while coil 10 is in a neutral condition, and therefore no magnetic field emanates from the secondary coil 10. These coils remain in this condition until the magnetic field of coil 9 is interrupted by a metallic object. When this occurs an alternating electro-motive force is induced into said metal object. This induced current has its own magnetic field, which is of such polarity as to oppose the magnetic field of coil 9, which causes the induction. This opposing magnetic field surrounding said metal object causes a number of the magnetic lines of force emanating from coil 9 to pass out of their natural circular path to go around this obstruction. This distortion of the magnetic field of coil 9 causes a disturbance of the induction balance, and induces an alternating electro-motive force in coil 10, which is amplified to any degree necessary to operate a loud speaker, galvanometer, or other suitable indicating device.

When a metallic object is encountered as by moving the bottom of the casing over a body or substance, and the condition of balance in the two coils 9 and 10 is disturbed or destroyed, then an electro-motive force will immediately begin to flow in the coil 10. Such electro-motive force will immediately set up a magnetic field in the secondary coil 10 which will invade and envelop the metallic object, thus creating a further electro-motive force therein and a magnetic field as a result of that force. In this way the disturbance of the balance normally existing between the two coils 9 and 10 will be increased or enhanced and consequently the arrangement provides for immediately establishing in the receiver circuit an electro-motive force of relatively high voltage such as to promptly and effectively actuate the loud speaker, meter or other indicating device. The sensitivity of the locator is thus increased by the relative arrangement of the coils 9 and 10 both of which are disposed flatwise with reference to one another; or in other words both coils are so related, the one to the other, that the magnetic fields of both will extend out in the same direction and not at right angles to one another as proposed in certain prior detecting devices, which have little or no sensitivity, especially where minute metallic objects are concerned, or where the metallic object is relatively remote with respect to the primary coil.

It has been observed by me in the use of the instrument that the arrangement of the coils 9 and 10 produces a line of maximum sensitivity and that this line runs transversely across the casing near to the minor axis of such parabolic casing. The fact that this zone of maximum sensitivity runs in a line across the casing is due to the fact that the bar members 9^a and 10^a of the coils extend across the casing at or about this point. On this line of maximum sensitivity is provided an opening 60 through both the bottom and top portions of the casing, through which a pencil 61 may be thrust. The upper portion of the pencil is received through a coil spring 62 attached at its lower end to the top of the casing and carrying at its upper end a plate or cap. This plate or cap engages the upper end of the pencil and the coil spring 62, which is extended in the act of moving the pencil into position and against the cap, will react to force such pencil downwardly with its point against a surface beneath or near which the metallic object is embedded or located. By moving the hand implement across the surface in one direction a line may be produced on such surface. Then by turning the hand implement at right angles with the pencil point still upon the surface at the point where the maximum indication is given and the instrument moved back and forth along a line at right angles to that previously reproduced on the surface, a graph is produced

consisting of intersecting lines on such surface, at the intersection of which will be indicated the point nearest to the metallic object. In this way the device is useful not only in detecting the fact that a metallic object is present in some undetermined locality adjacent the indicator, but the improved device goes further and points out the precise locality in which such object may be found. The instrument will thus be found particularly useful by physicians in determining the precise location of extraneous objects in the human body, which will aid greatly in the expeditious removal of such foreign objects.

Now in originally placing the instrument in a condition for detection, the set screw 19 may be rotated in one direction or the other to cause the relative movement of the primary coil 9 with respect to the secondary coil 10, thus either increasing or diminishing the degree of overlap between these coils. This adjustment is done experimentally until a point is reached where either a condition of balance is reached or such a near condition as it is found possible to secure.

Thereupon the cap 28 is rotated first in the one and then in the other direction in an experimental way to cause the washer 30 to approach or recede from the coils 9 and 10. This magnetic washer has an effect on the magnetic lines of force emanating from the coils and it will be found that this washer exerts a very great influence in finely adjusting the balance between the two coils.

It is obvious that various changes and modifications may be made in the details of construction and design of the above specifically described embodiment of this invention without departing from the spirit thereof, such changes and modifications being restricted only by the scope of the following claims:

What I claim is:

1. In a metal locator, a flat shallow casing, a bunch wound coil substantially shorter than the casing and having a straight portion, said coil being disposed within said casing with the straight portion extending transversely of the casing intermediate its ends, a second bunch wound coil substantially like the first coil and disposed within the casing with the straight portion thereof in proximity to the straight portion of the first coil, and a fork pivoted to the top wall of the casing for swinging longitudinally thereof and engaging one of the said straight portions whereby the coils may be moved relatively to change the inductive balance thereof.

2. In a metal locator, a flat hollow closed casing, a bunch wound coil substantially shorter than the casing and having a straight portion, said coil being fixedly disposed in the casing with the straight portion extending transversely of the casing intermediate the ends thereof, a second bunch wound coil substantially like the first and movably disposed in the casing above the first coil with the straight portions of the two coils in proximity to one another, a forked lever extending through an opening in the top wall of the casing and pivoted on an axis transverse thereof, the lower end of said lever being engaged with the straight portion of said second coil, an operating member engaging the upper end of said lever whereby to swing the lever and move the second coil relatively to the first.

3. In a metal locator, a rigid casing, a bunch wound semi-elliptical coil with a straight portion disposed in one end of the casing with the straight portion across the casing about the middle thereof, a second coil substantially like the first disposed in the opposite end of the casing overlapping the first coil a substantial amount with the straight portion overlapping and parallel to the straight portion of the first coil, whereby current passing through one of said coils creates lines of force cutting the other coil in two directions to induce opposed electromotive forces in the latter, and means for varying the inductive balance of the coils.

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