

April 15, 1941.

D. H. NELSON ET AL

2,238,072

METHOD OF AND MEANS FOR LOCATING CONCEALED BODIES

Filed Feb. 26, 1938

4 Sheets-Sheet 1

FIG. 1

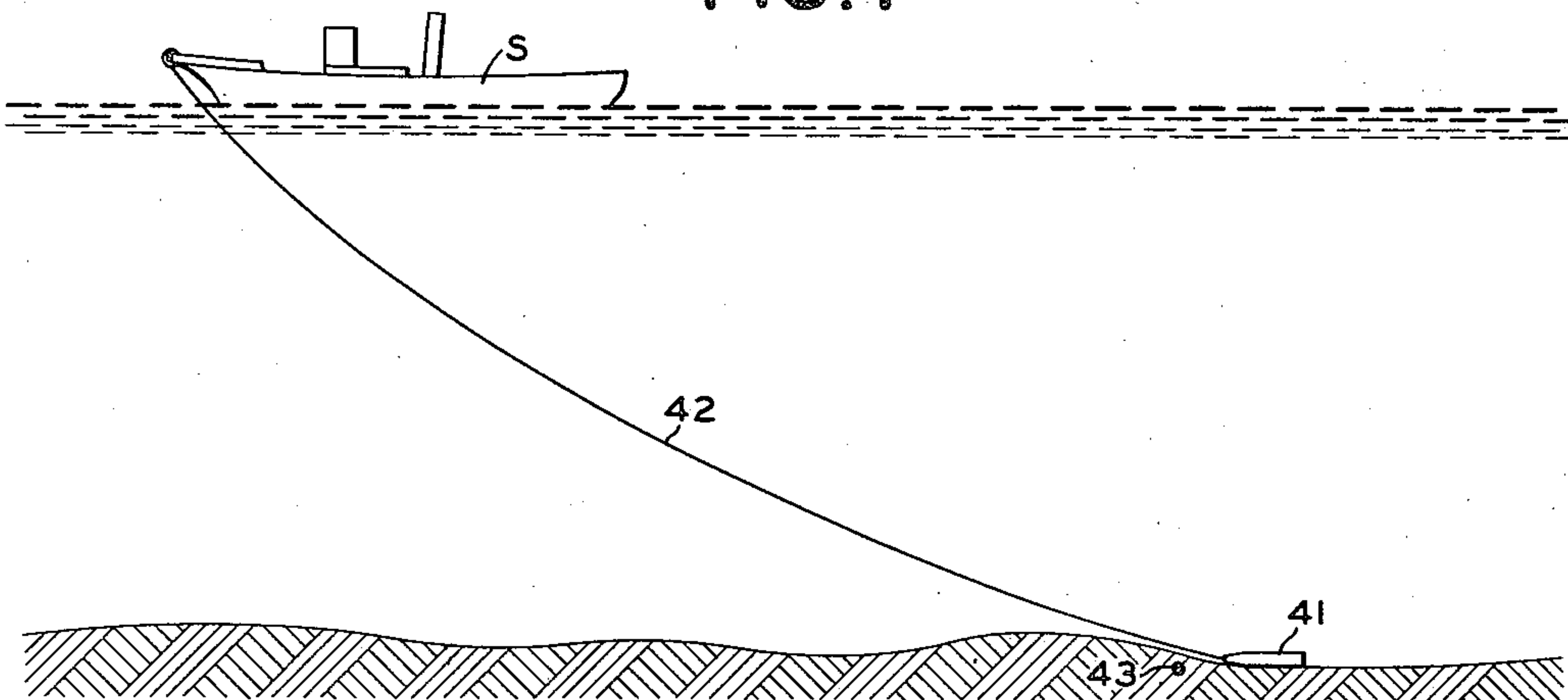


FIG. 4

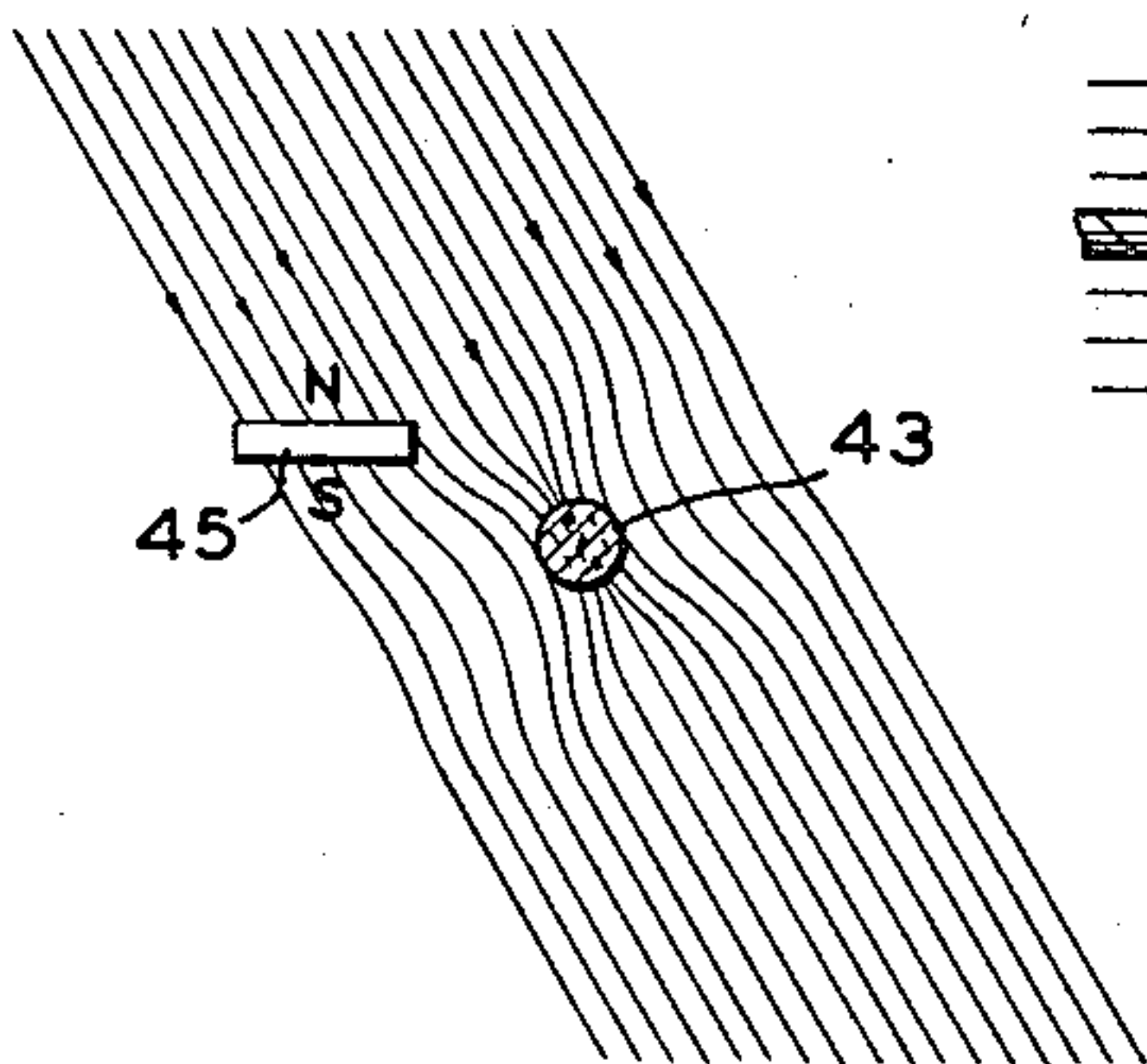


FIG. 2

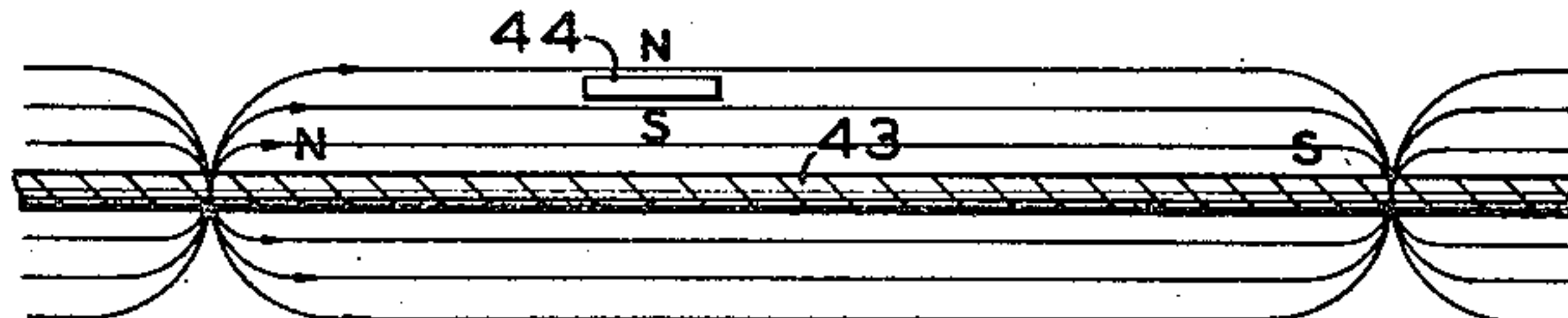


FIG. 3

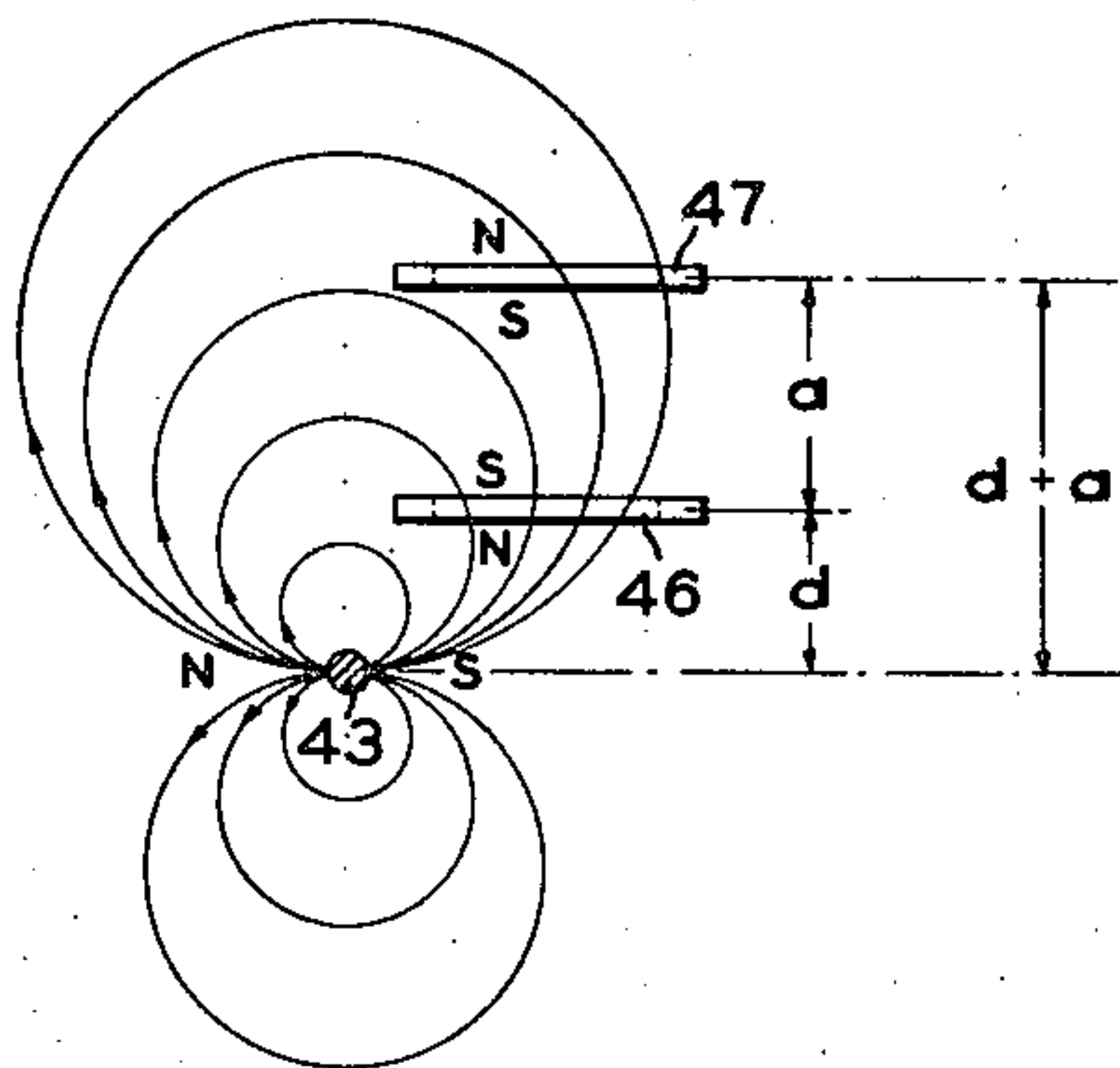


FIG. 5

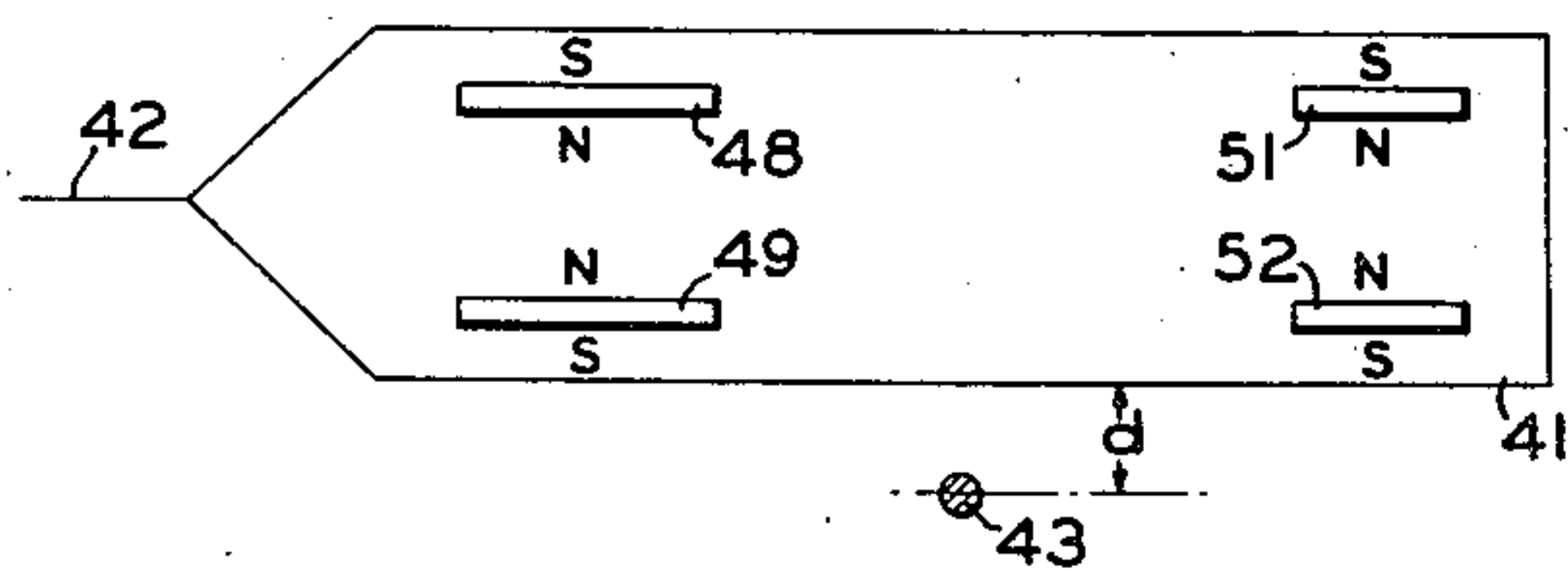
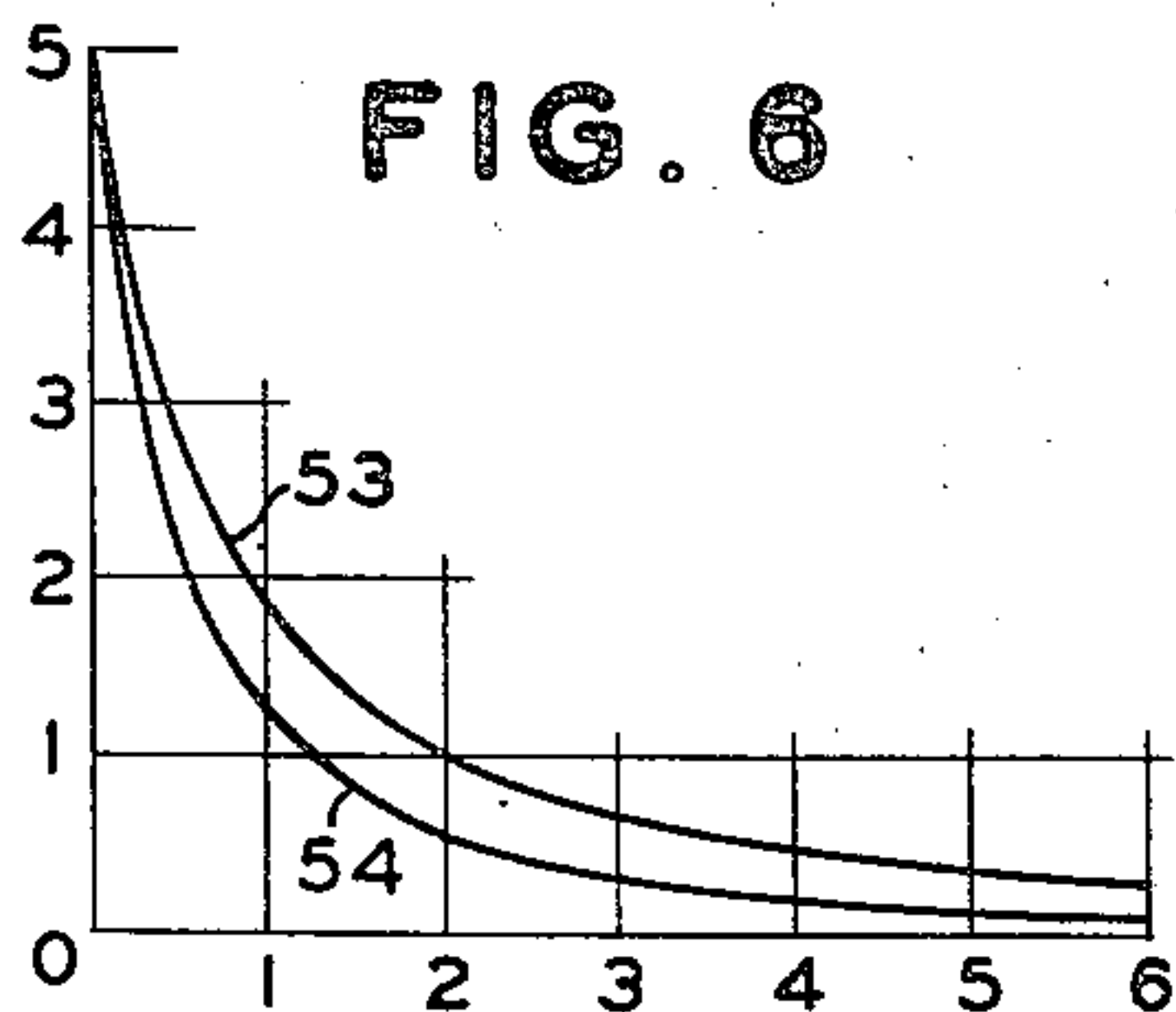


FIG. 6



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FIG. 8

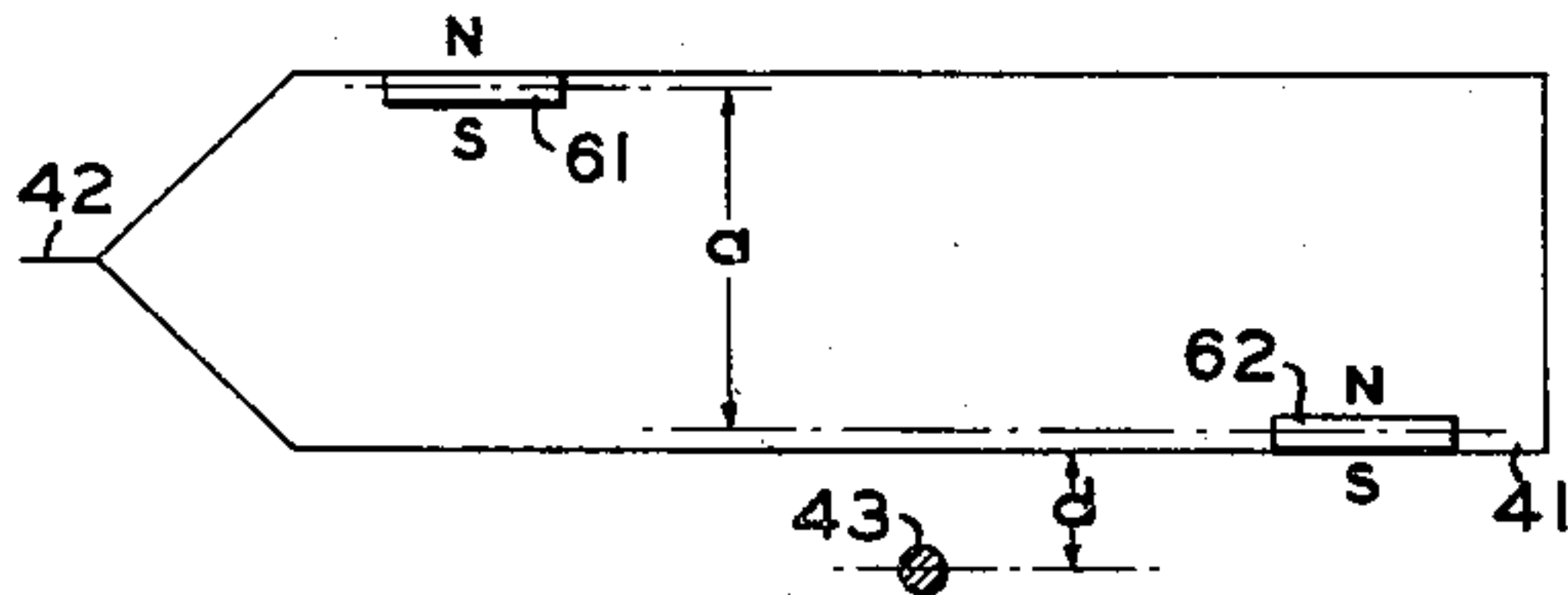


FIG. 7

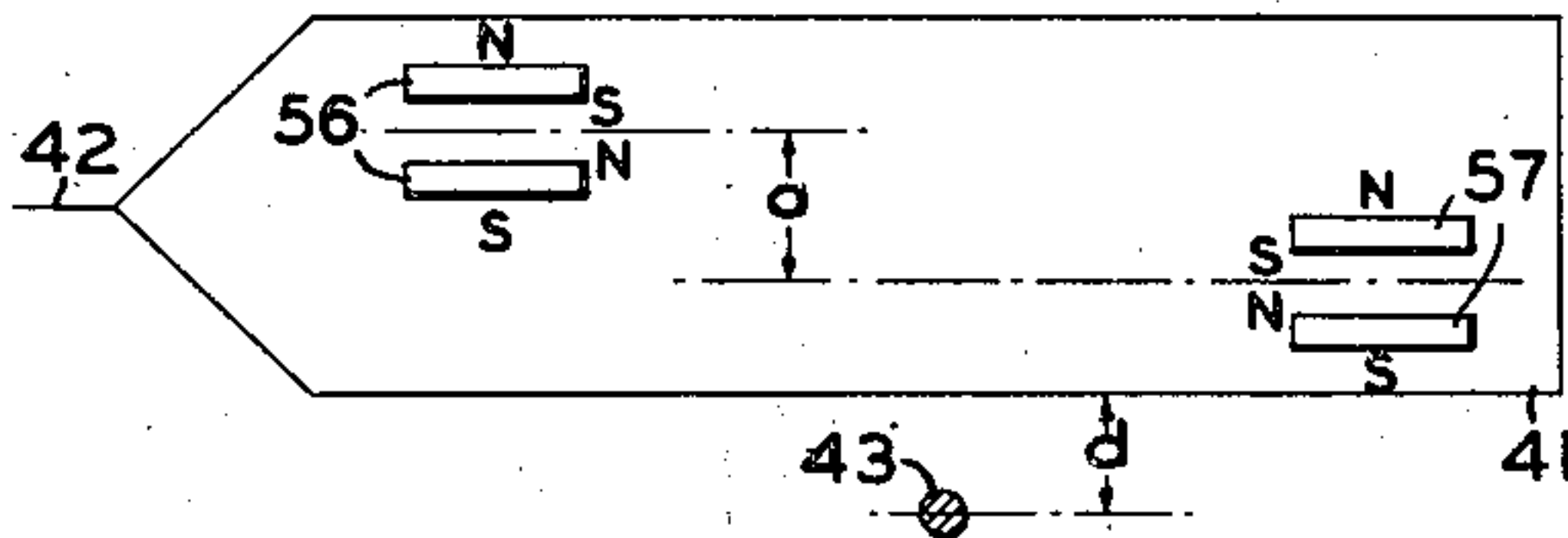


FIG. 9

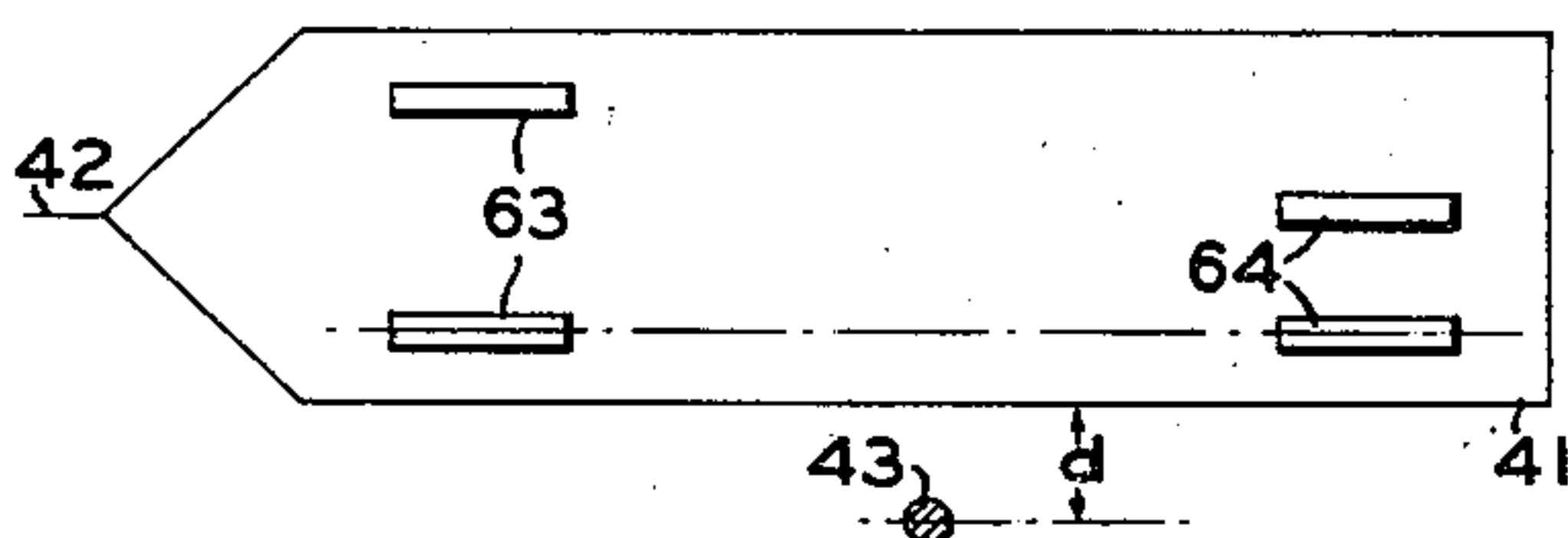


FIG. 10

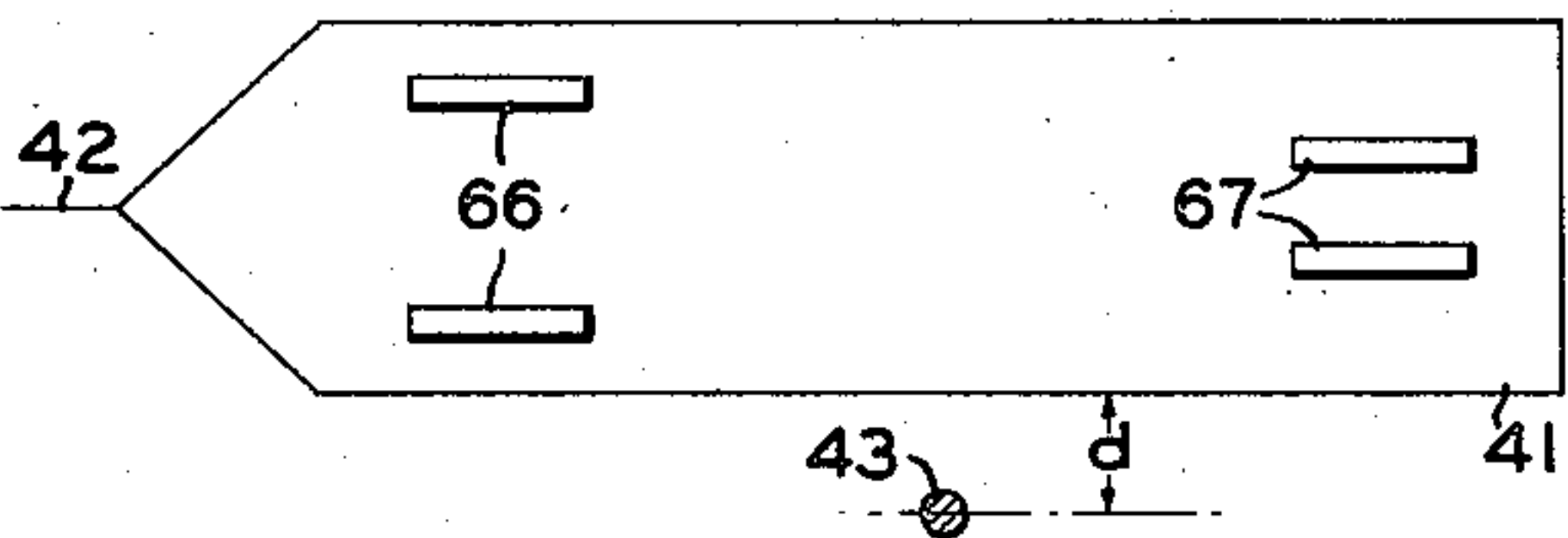


FIG. 12

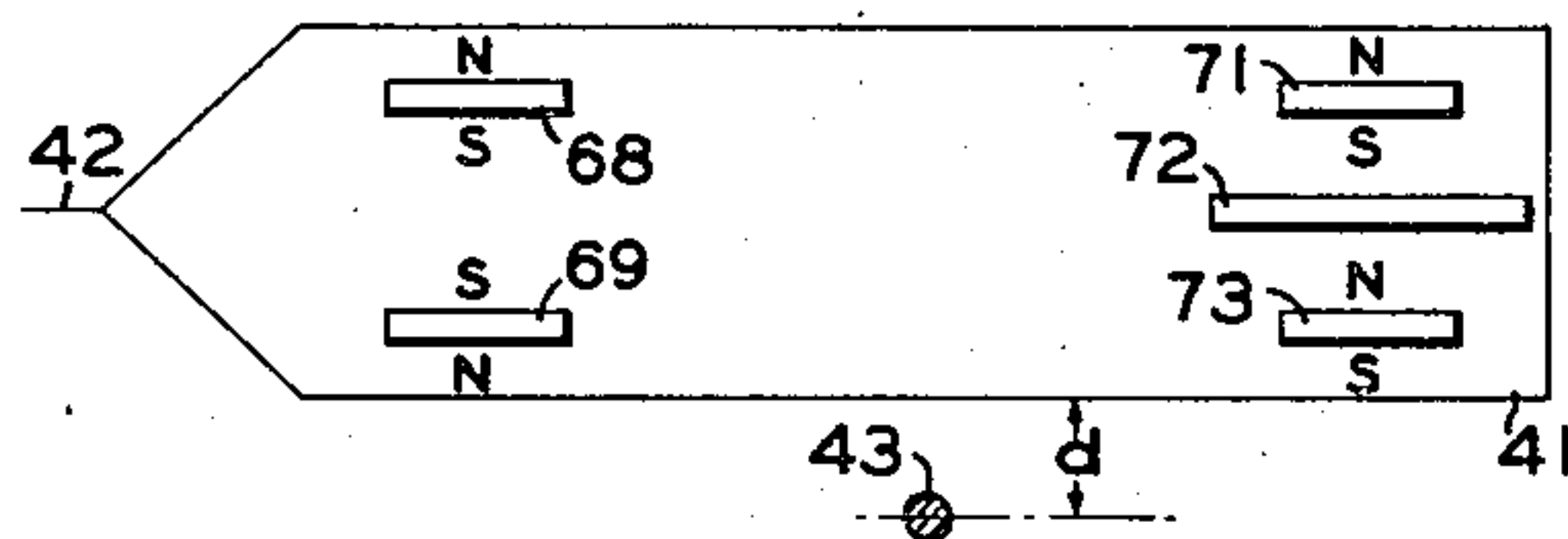


FIG. 11

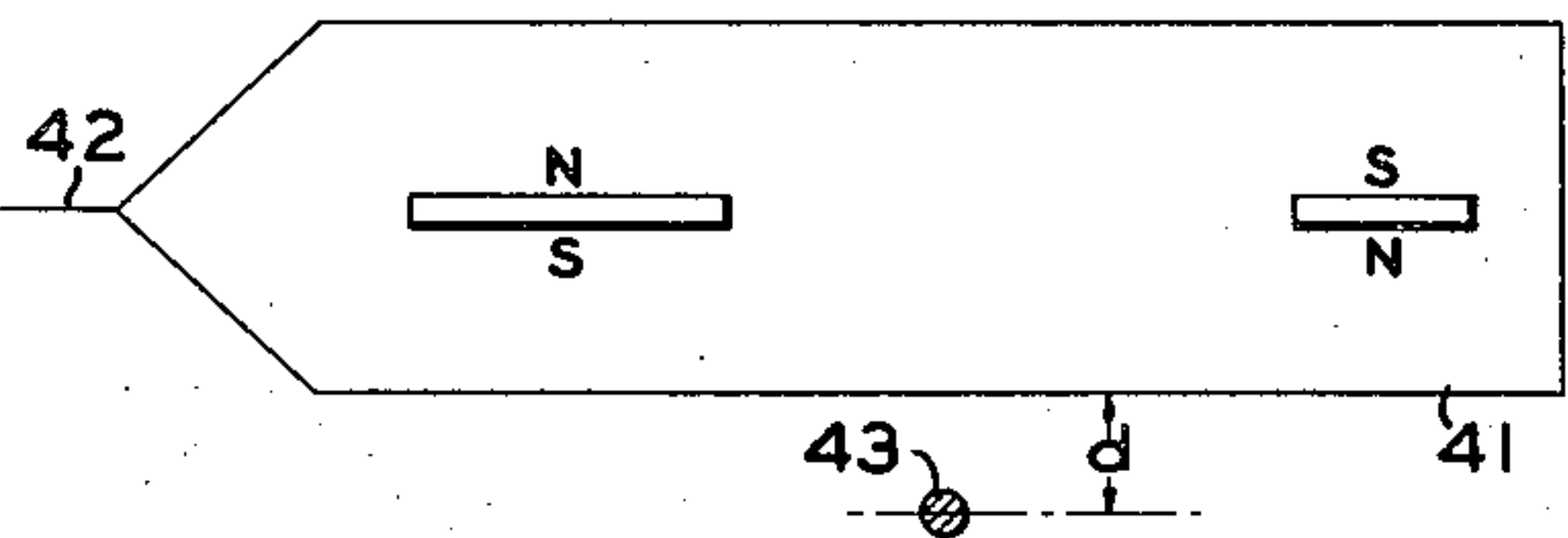


FIG. 13

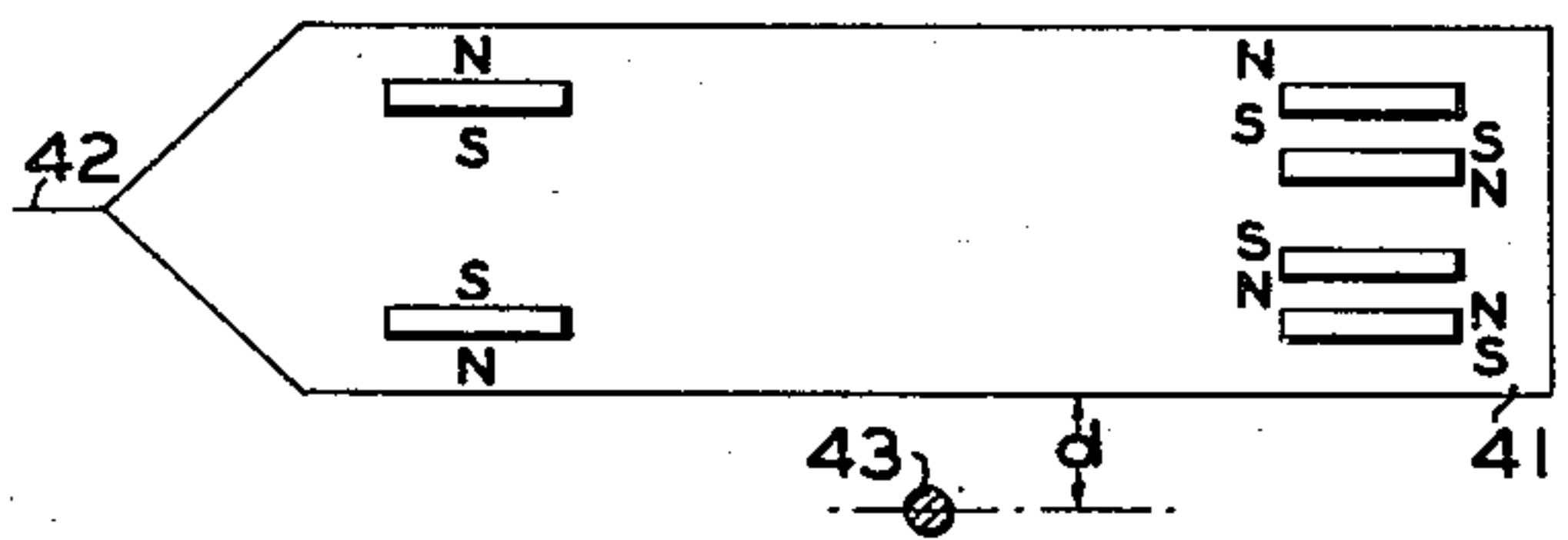


FIG. 14

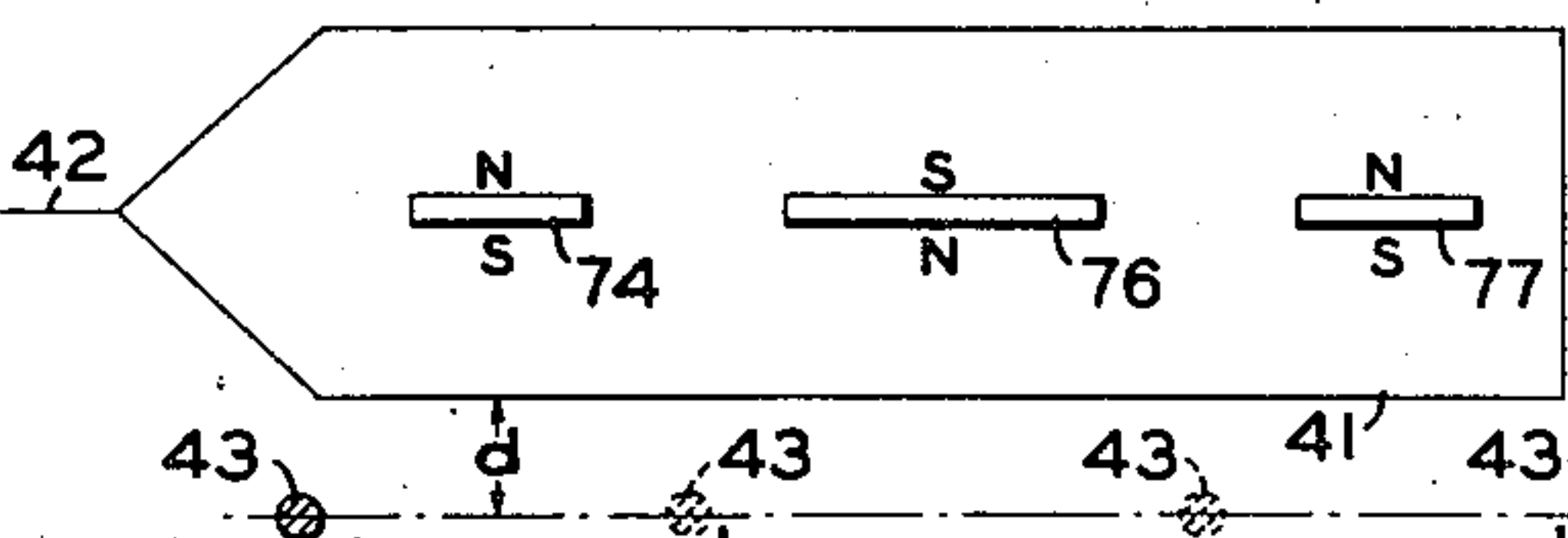


FIG. 15A

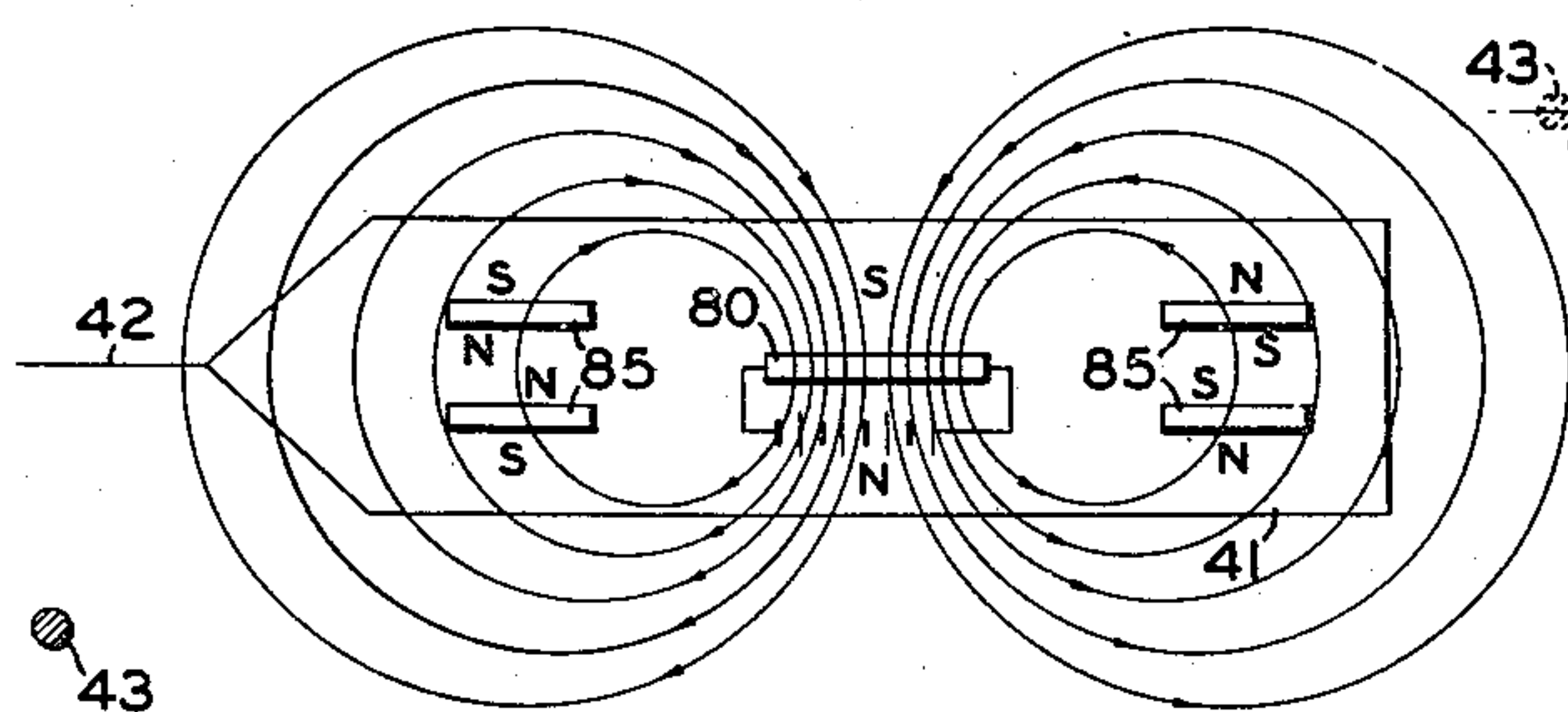
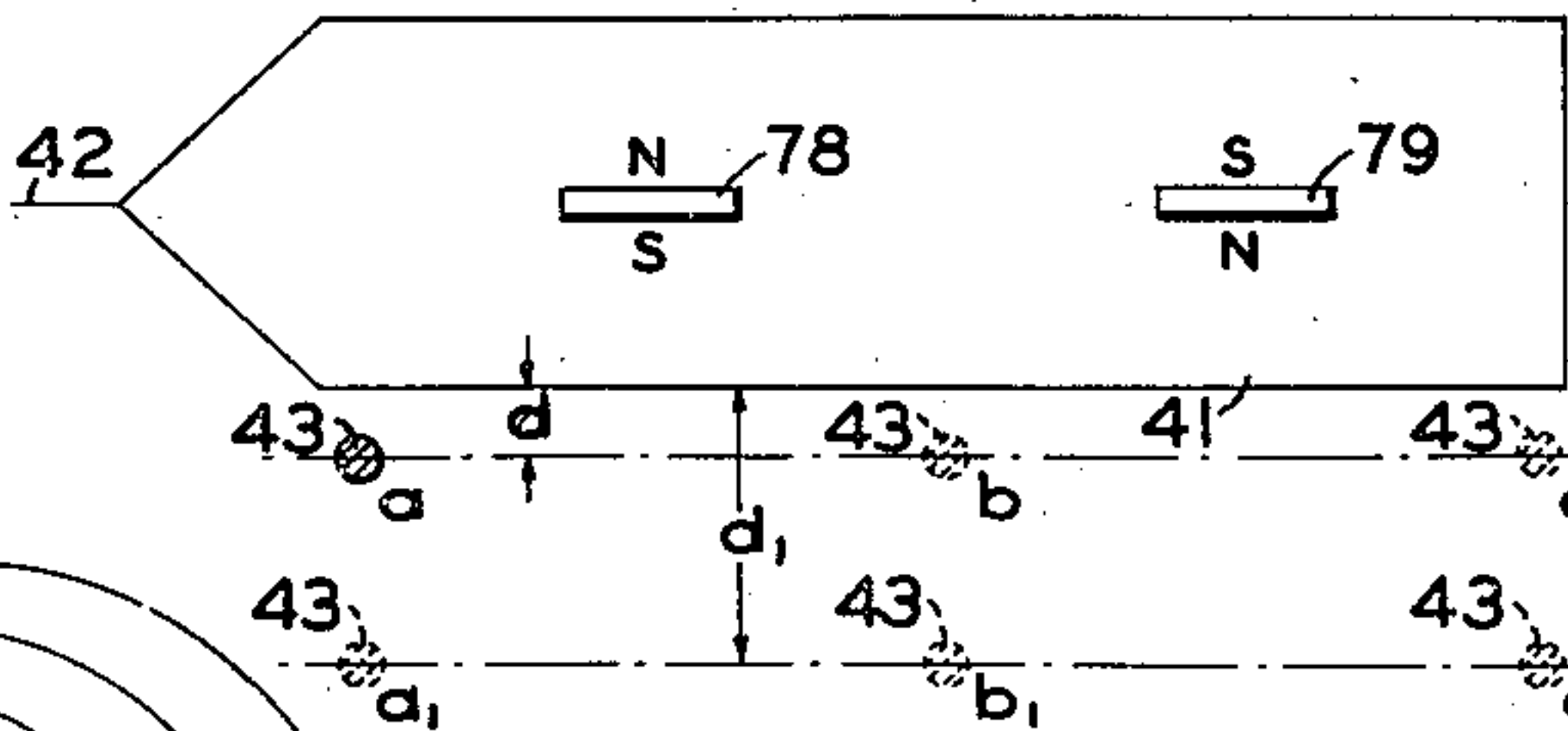


FIG. 15



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FIG. 16

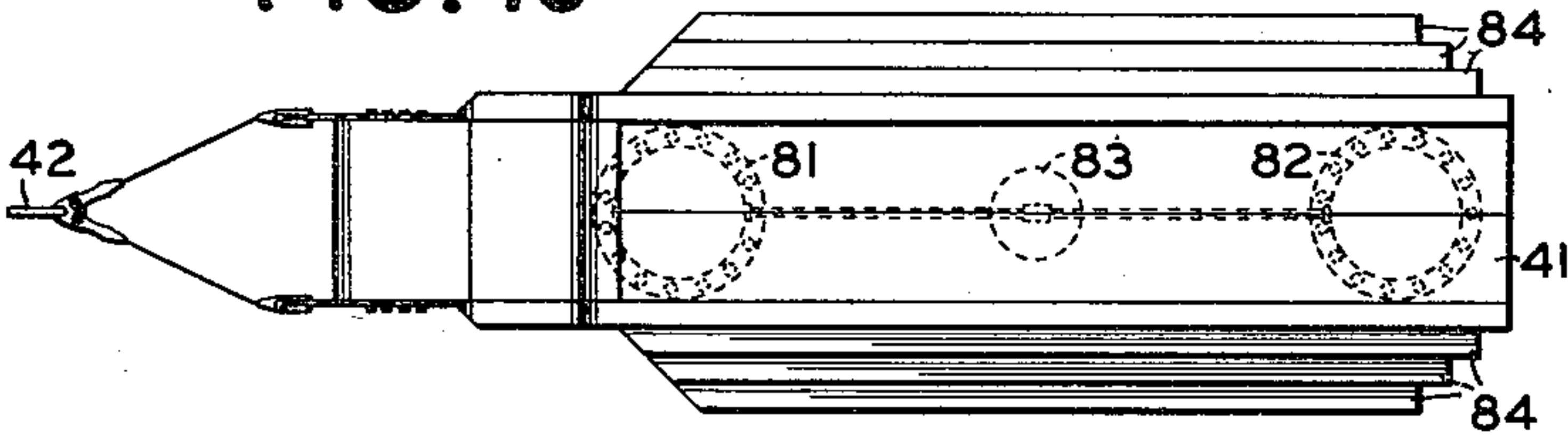


FIG. 19

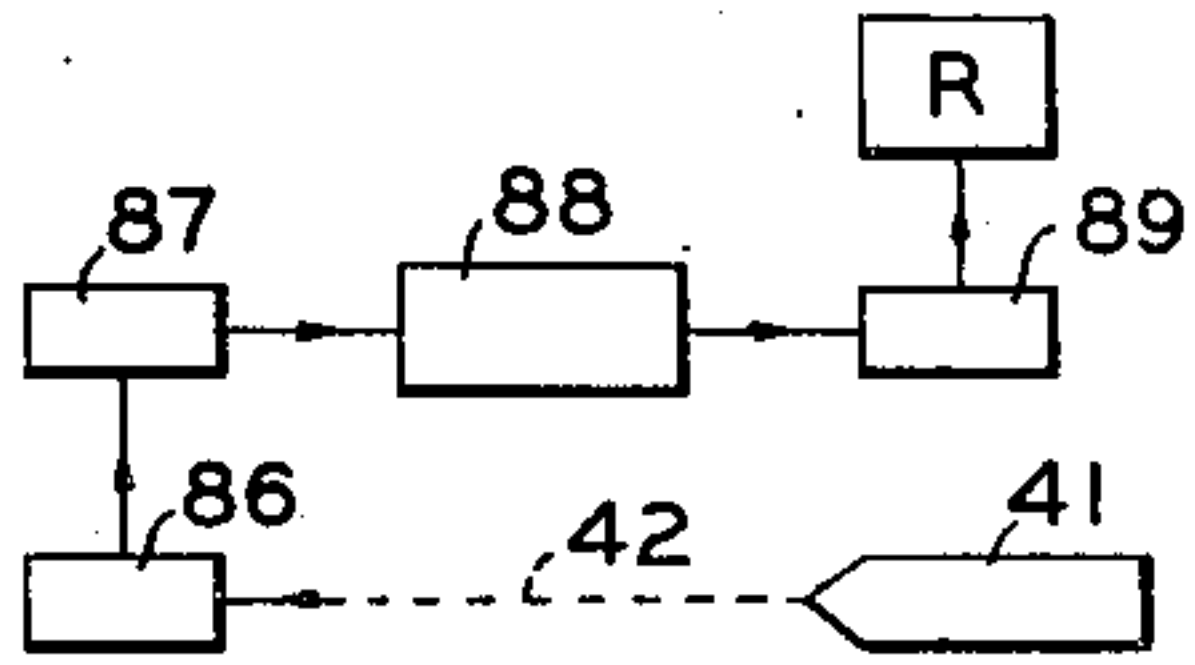


FIG. 17

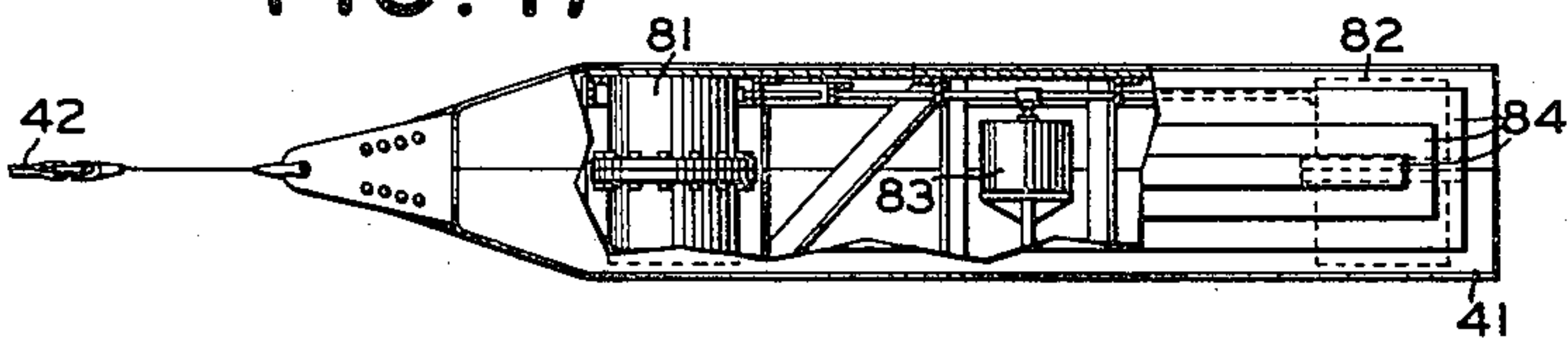


FIG. 18

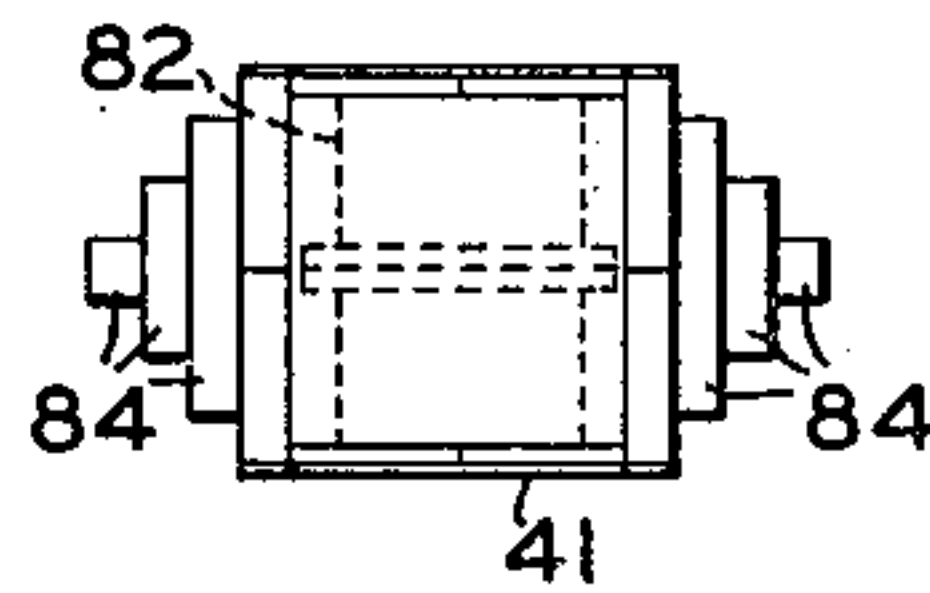


FIG. 20

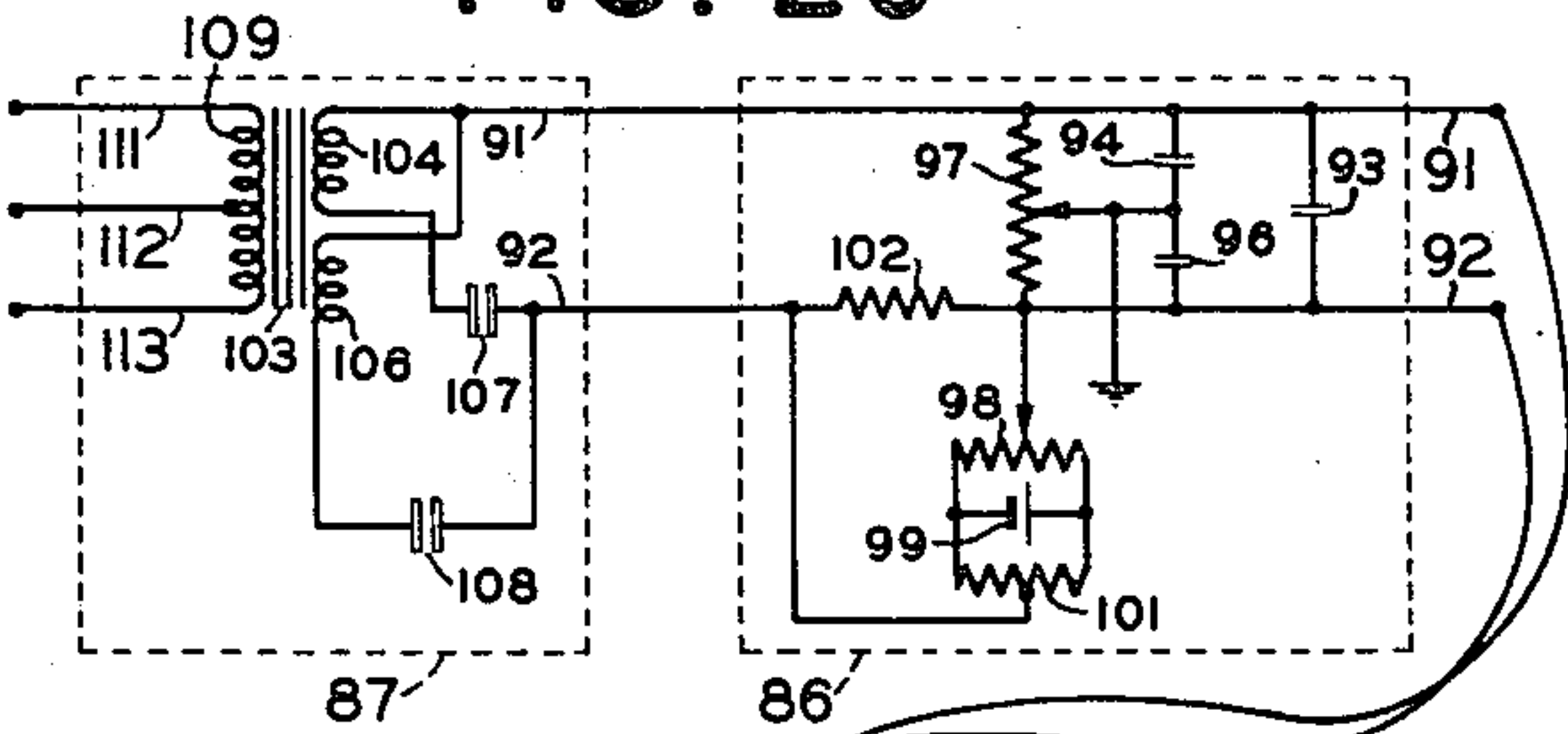


FIG. 21

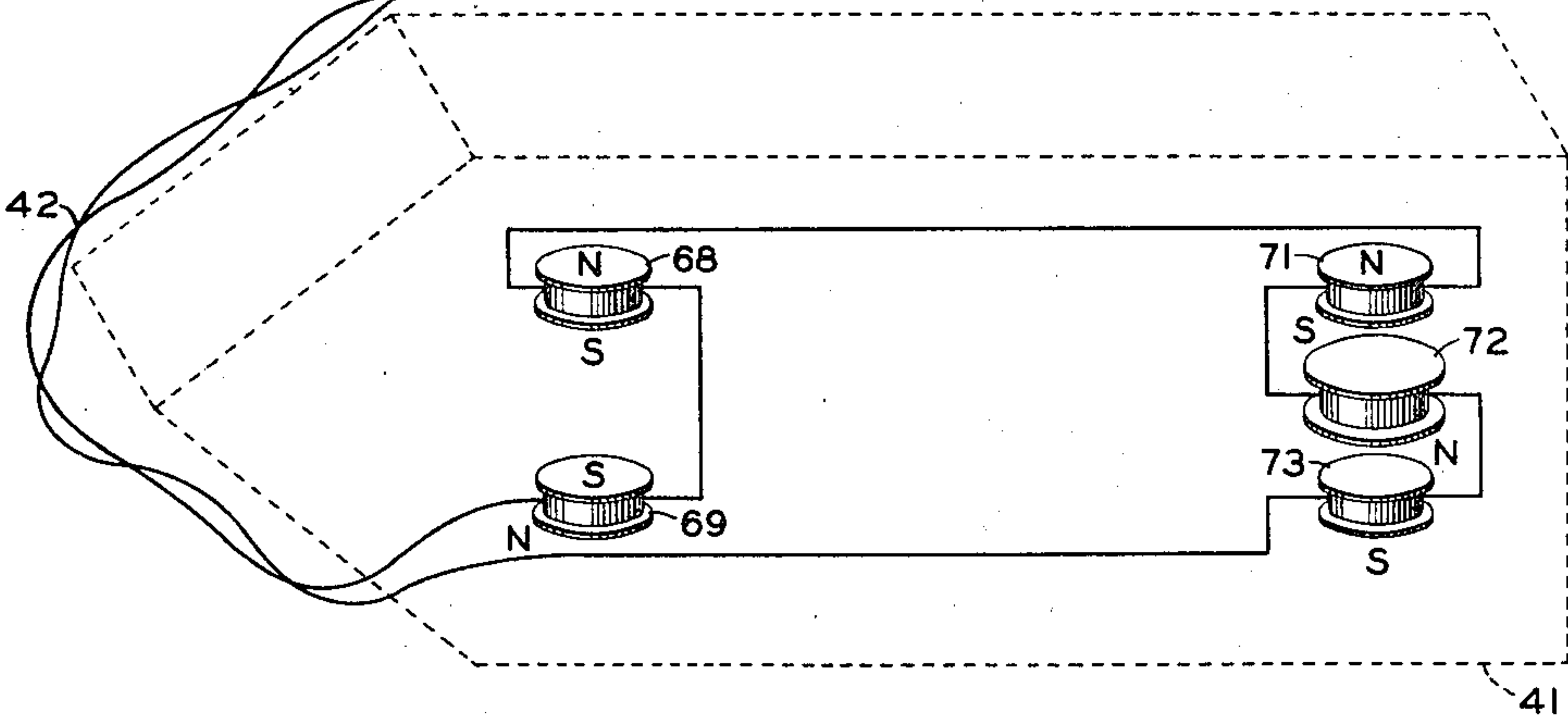
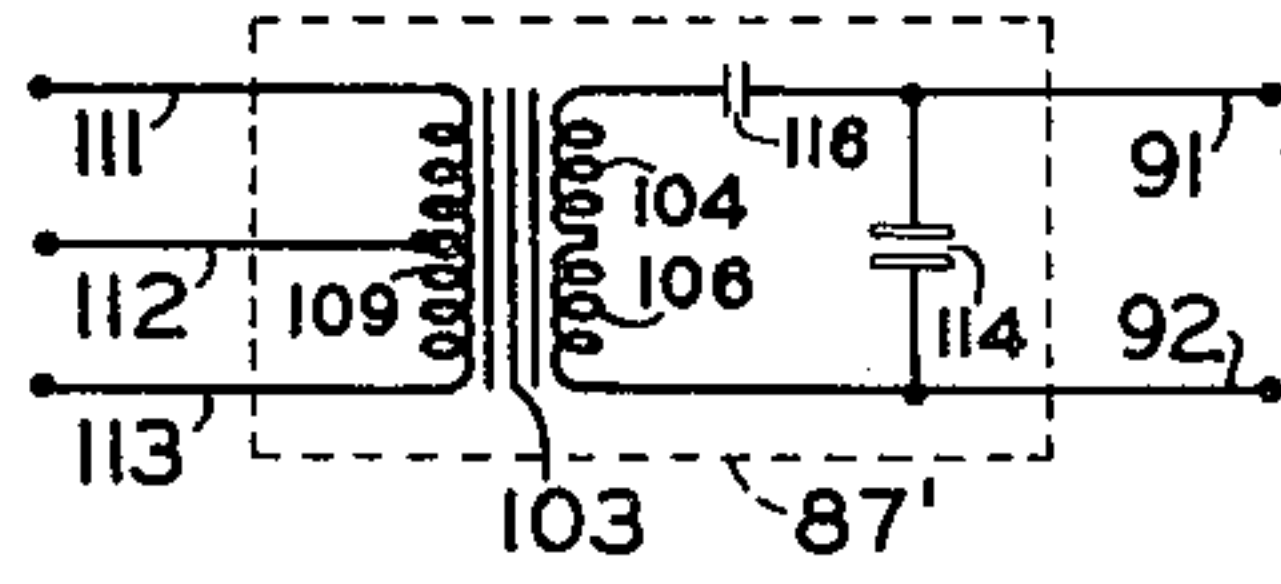
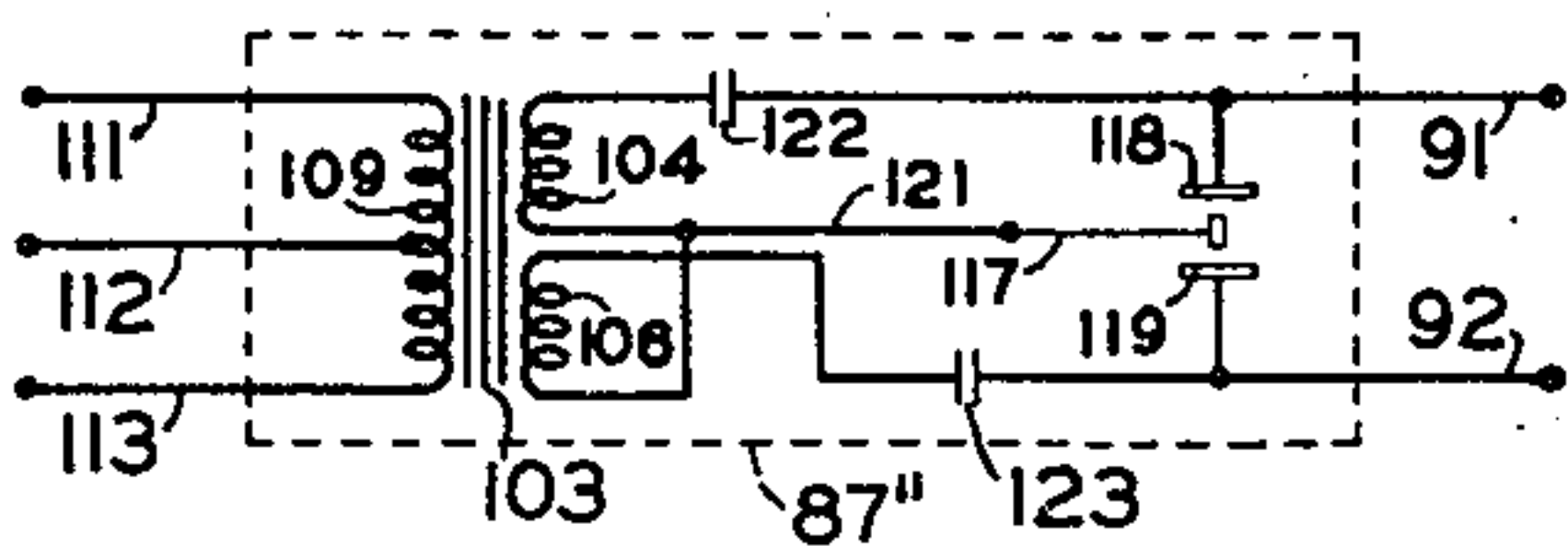


FIG. 22



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FIG. 25

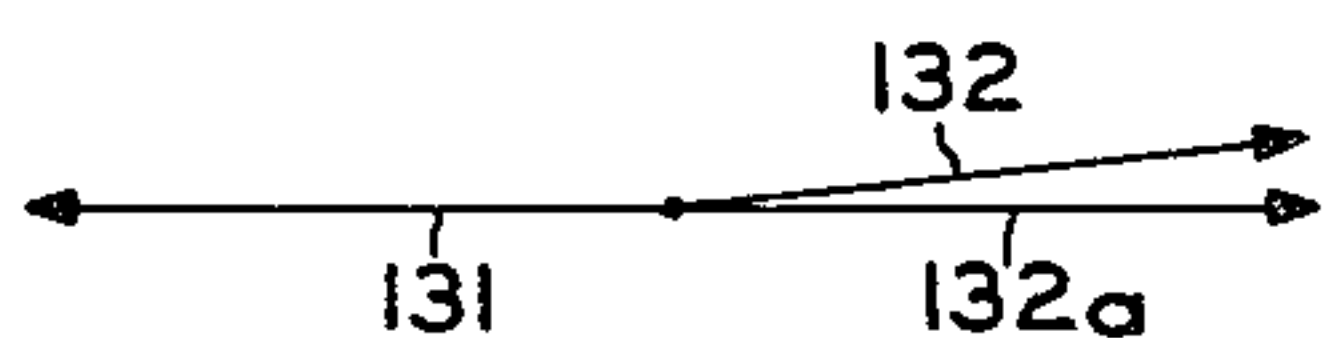


FIG. 24

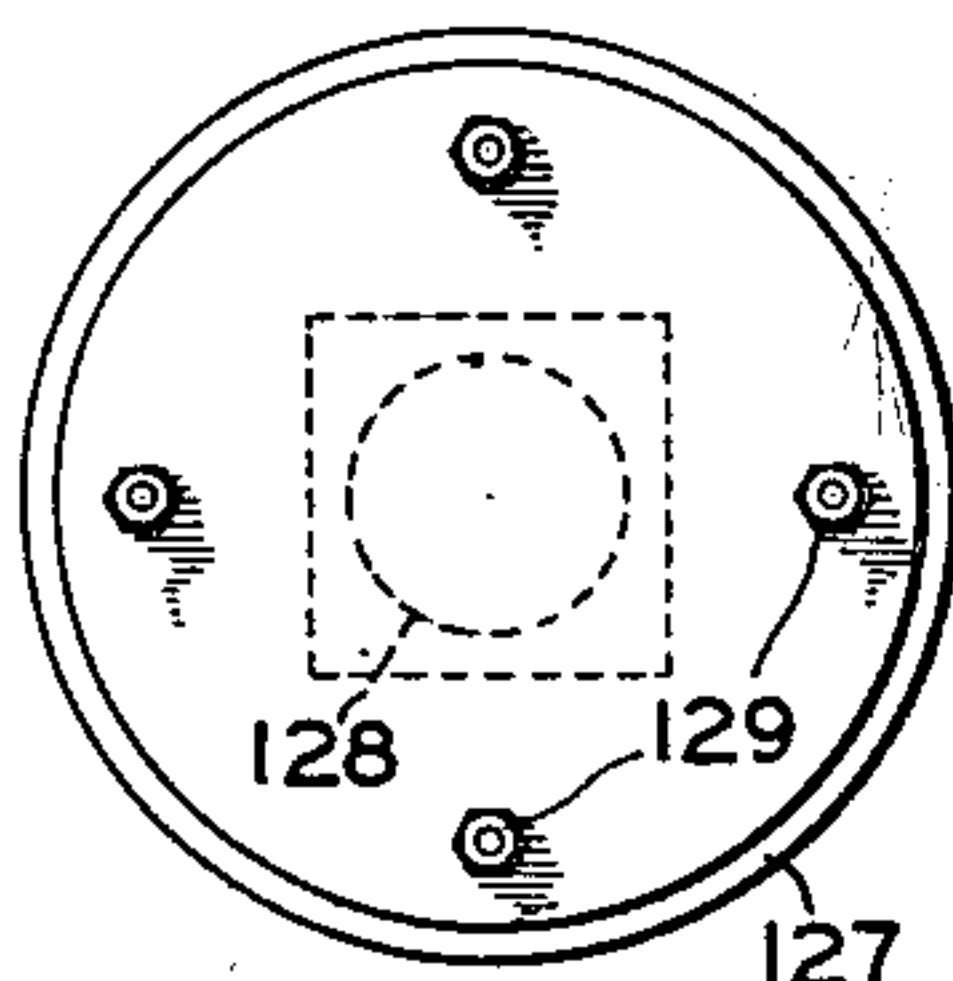


FIG. 23

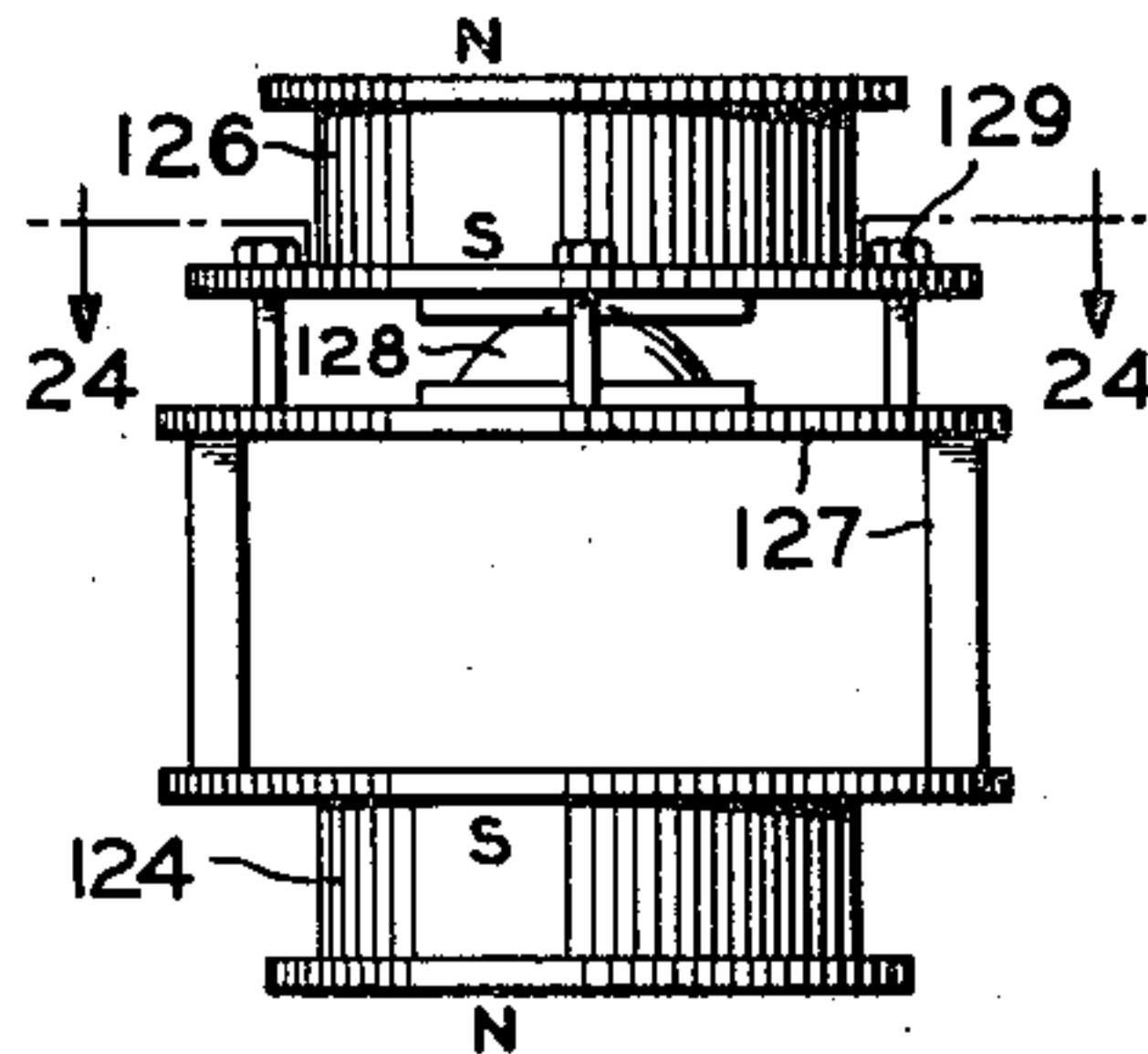


FIG. 26

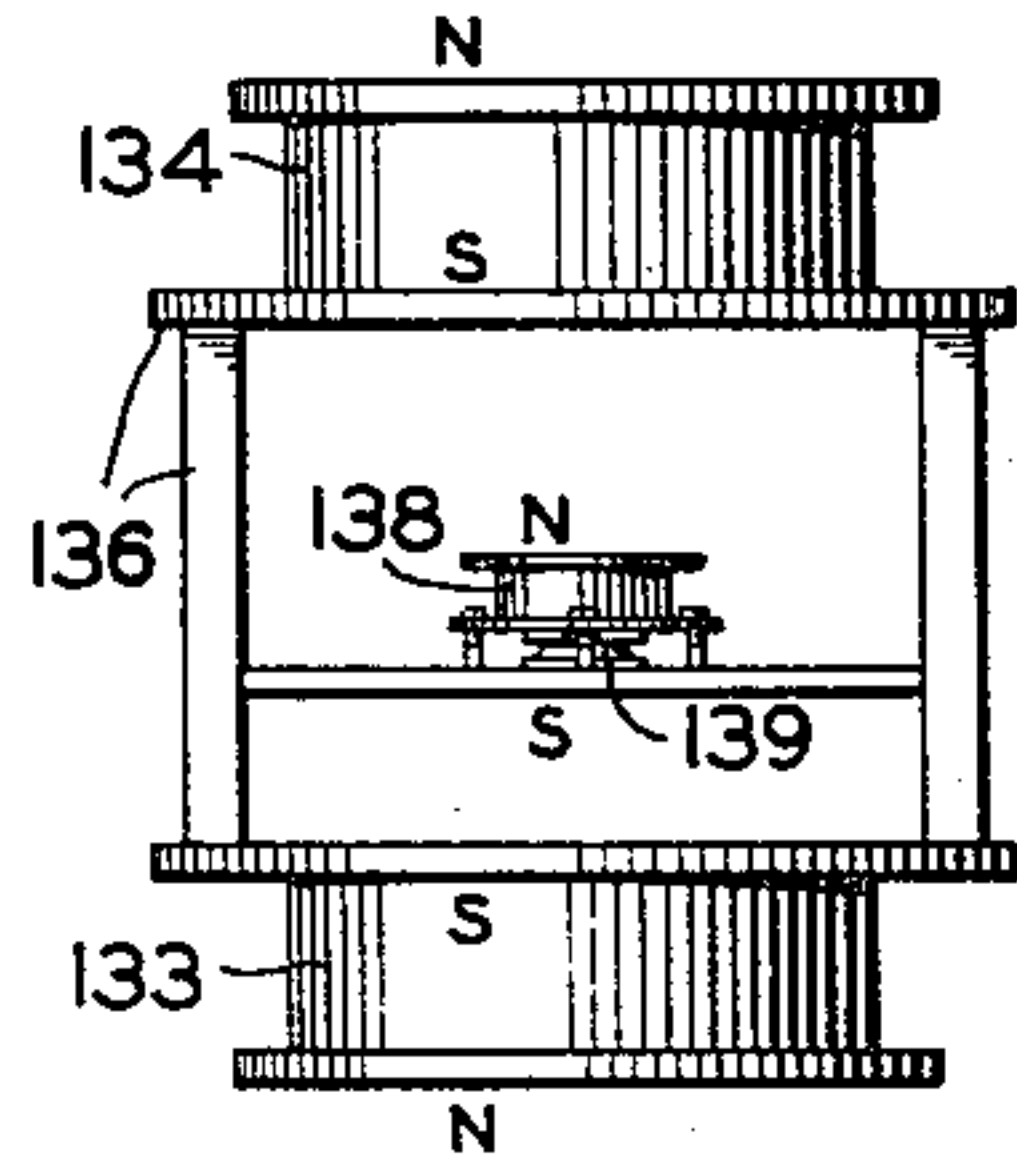


FIG. 27



FIG. 28

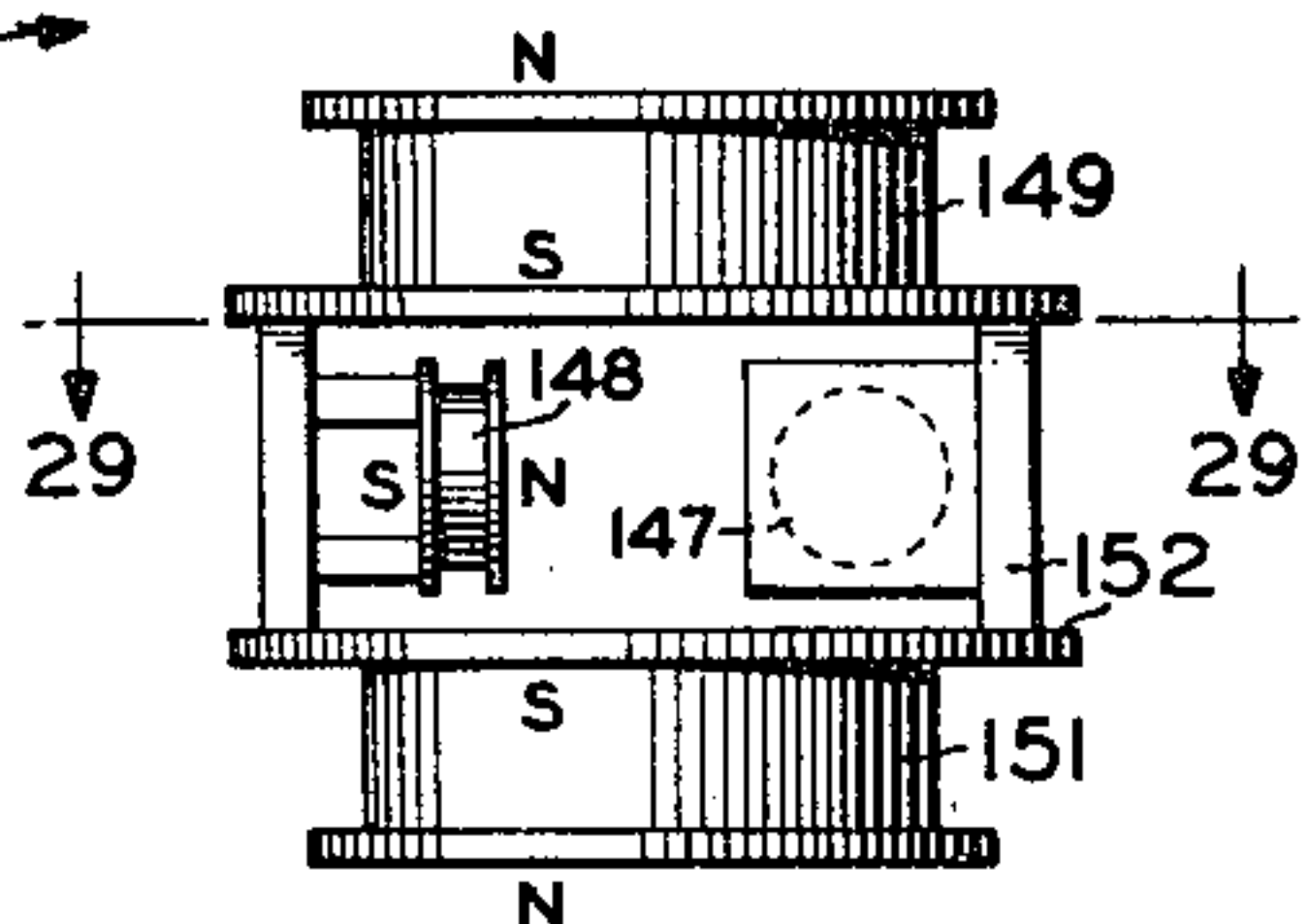


FIG. 29

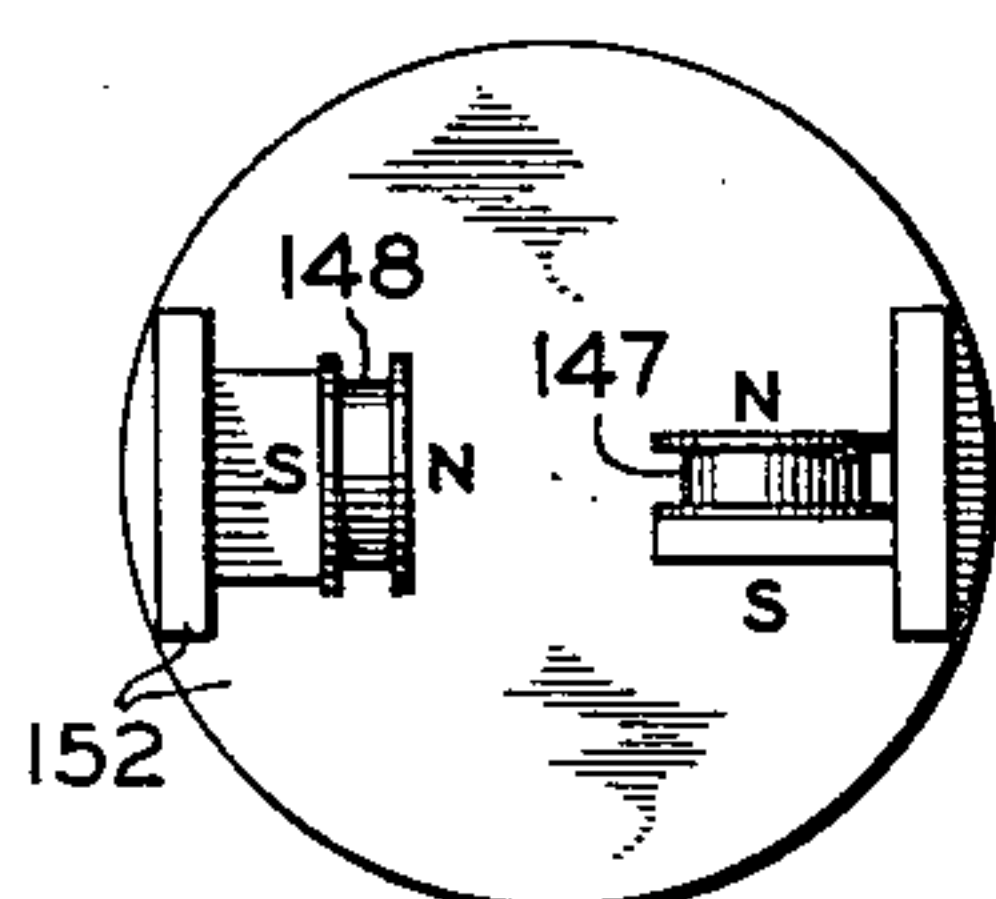


FIG. 30

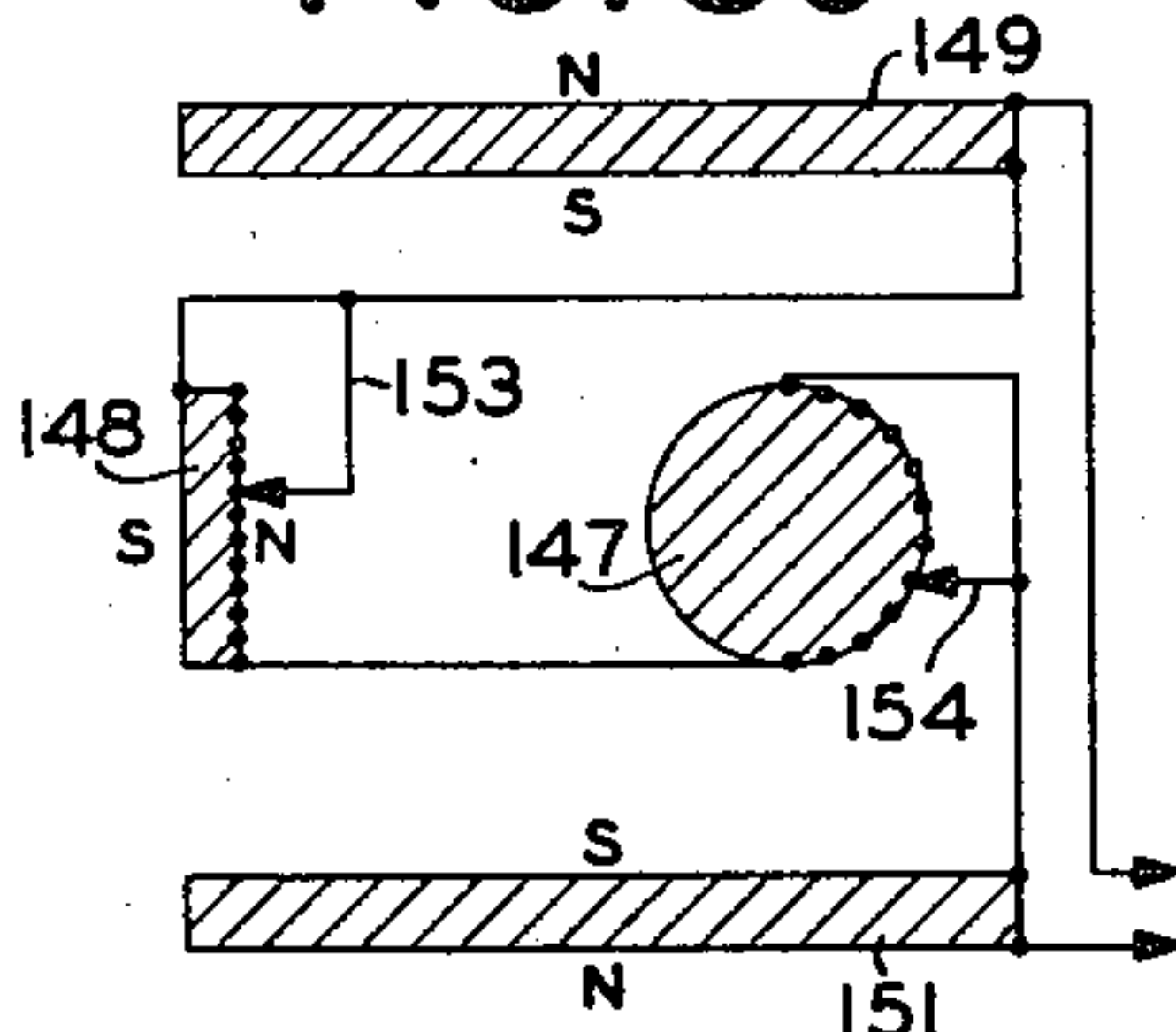


FIG. 31

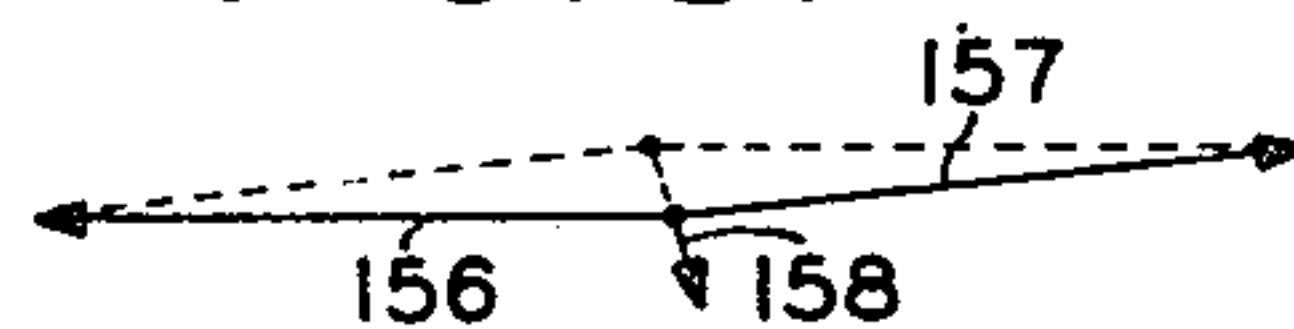


FIG. 32

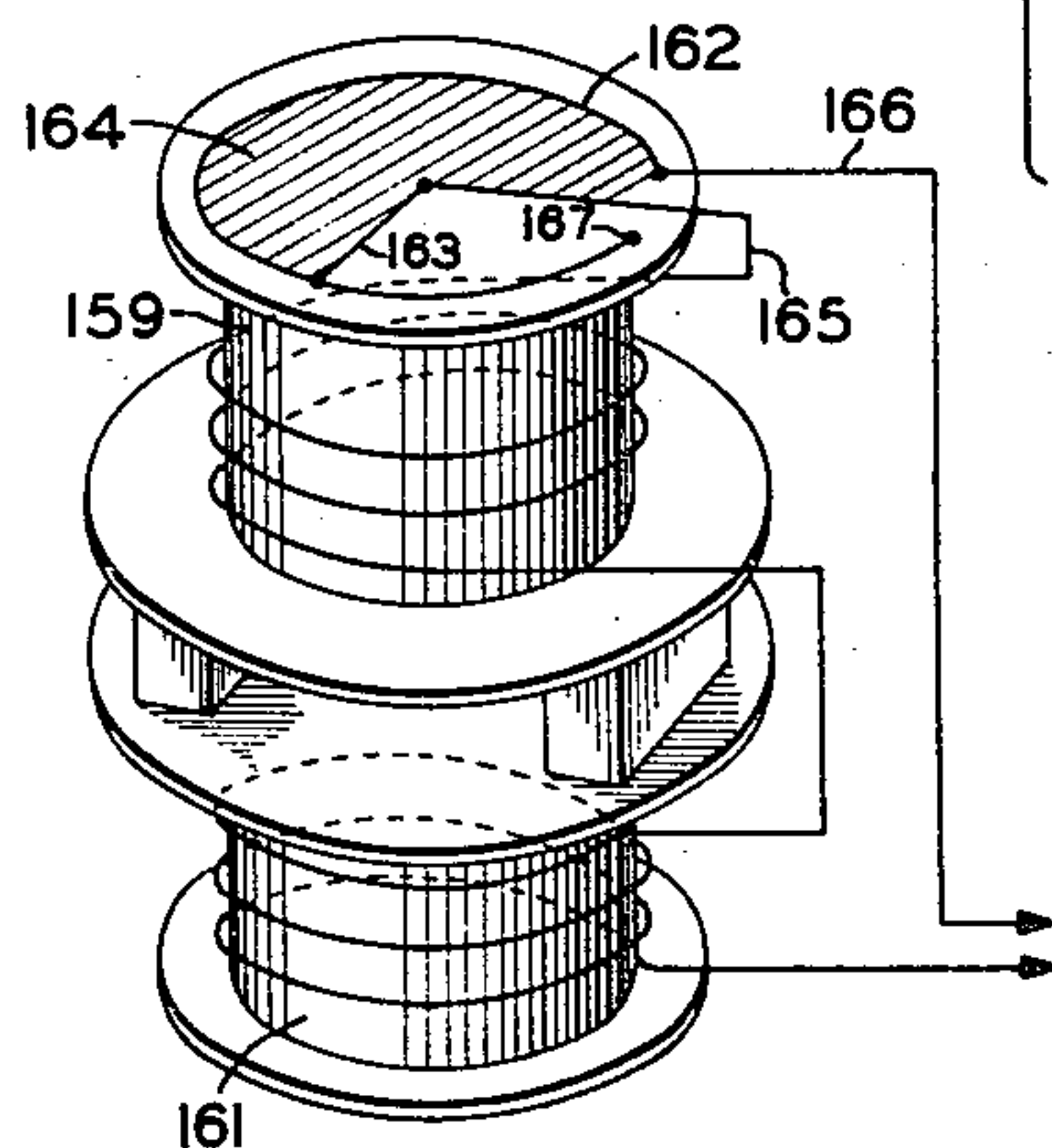
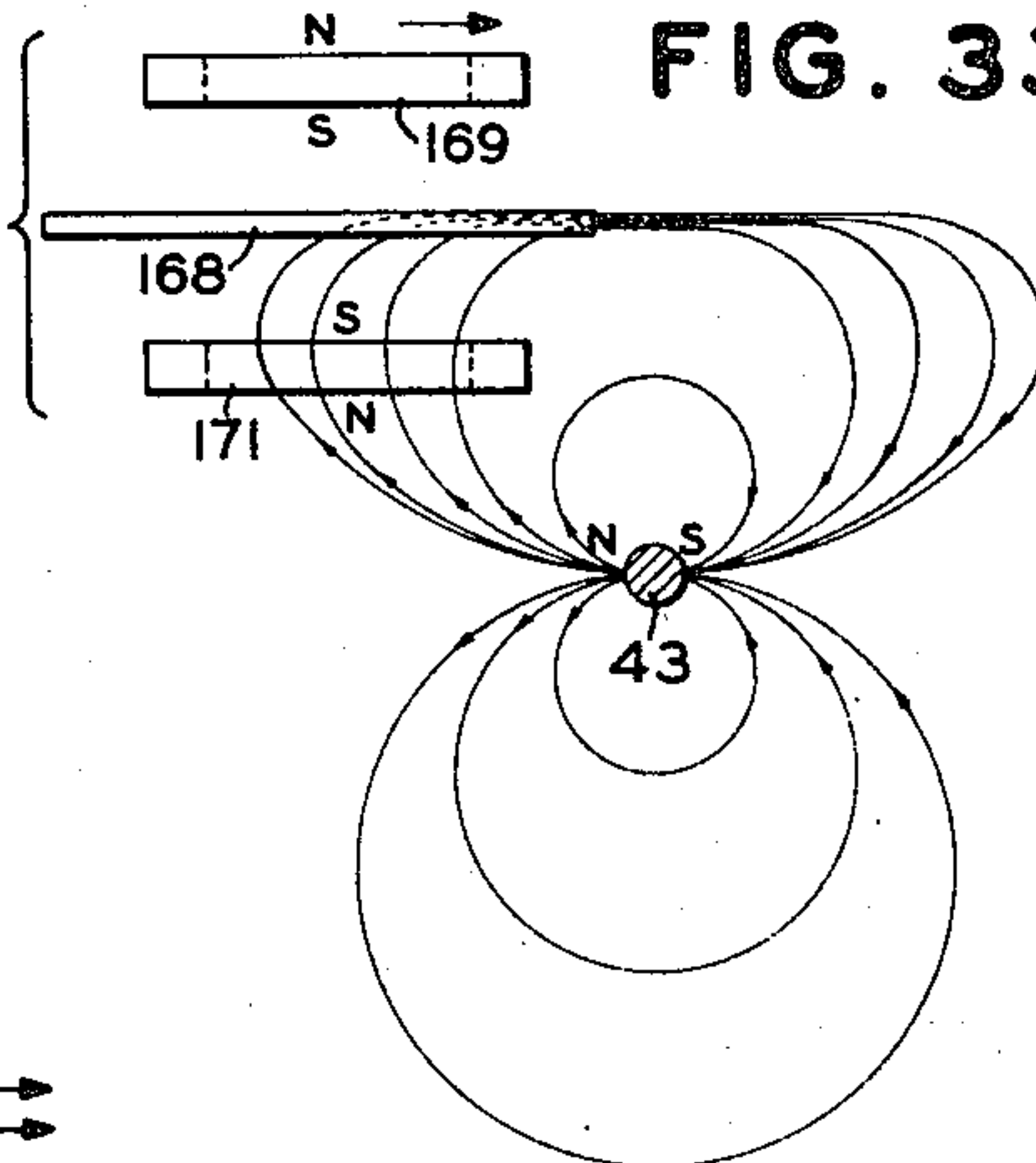


FIG. 33



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METHOD AND MEANS FOR LOCATING
CONCEALED BODIES

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Application February 26, 1938, Serial No. 192,770

48 Claims. (Cl. 175—183)

This invention relates generally to a method of and means for locating and determining the depth to which a cable, or other body capable of affecting, distorting and/or producing magnetic lines of force, is buried in the ground or otherwise concealed, and more particularly to locating and determining the depth to which submarine cables and the like are buried in the bed of the ocean or other body of water.

Submarine cables when laid on the bed of the ocean or other body of water through which they pass, are frequently fouled or dragged and sometimes are broken by otterboards of nets of fishing vessels or by ships' anchors and in the U. S. patent to Lawton and Bloomer No. 2,067,717, issued Jan. 12, 1937, and in the U. S. patent to C. S. Lawton, No. 2,099,527, issued Nov. 16, 1937, there are disclosed various forms of submarine cable plows for forming under water a trench in the bed of the body of water in which the cable is to lie and simultaneously placing the cable therein to embed the same so as to lessen the likelihood of the cable becoming fouled, injured or dragged. It is highly desirable to determine whether the cable has been properly buried, and the depth to which the cable is buried, in order to determine whether the submarine cable plow is working satisfactorily and also to ascertain whether the cable has been given the desired protection. After a cable has been buried for a length of time, ocean currents and/or other factors are likely to unbury it or to bury it deeper, and it is also desirable to determine these facts.

Among the objects of the invention is the provision of novel methods and apparatus for detecting or locating a submarine cable or other body capable of affecting, distorting and/or producing magnetic lines of force, lying on or buried in the bed of a body of water, or otherwise concealed from view, and/or for determining the depth to which such a body is buried or concealed.

Another object of the invention is to provide a device of the foregoing character which is adapted to engage and travel along on the bed of the body of water in which the cable or other body capable of affecting, distorting, and/or producing magnetic lines of force, lies, or is embedded, for accomplishing the above objects.

Another object of the invention is to provide a device of the character described which is adapted to produce signals which may be transmitted to a remote point, such as to a ship on the surface of the body of water, for indicating and/or recording the depth to which a cable or other body is buried in the bed of the body of water.

A further object of the invention is to provide a method of and apparatus for determining the depth to which a cable or magnetic material is buried in or concealed beneath a surface, and

which will give an accurate determination of this depth irrespective of the rate of movement of the device relative to the cable or magnetic material.

Still another object of the invention is to provide a device of the character described which will indicate the depth to which a body of paramagnetic or diamagnetic material is buried, which device utilizes the distortion in the earth's magnetic field caused by the paramagnetic or diamagnetic material, thereby to determine the depth to which the conductor is buried or otherwise disposed beneath the surface.

Still another object of the invention is to provide a method and apparatus for locating and/or determining the depth of a body of magnetizable material, such as an ocean cable, on or buried in the bed of a body of water regardless of the size of the magnetic body or cable, its degree of magnetization, or the variation of its degree of magnetization.

Still another object of the invention resides in the provision of novel methods and apparatus for detecting and determining the distance removed of any magnetic, paramagnetic or diamagnetic material which will distort or affect the earth's magnetic field.

A more specific object of the invention in accordance with the above is the provision of novel methods and apparatus for detecting and/or locating a body such as a submarine cable buried or otherwise concealed in the bed of a body of water, irrespective of the operating or non-operating condition of the cable.

Another more specific object of the invention in accordance with the above is the provision of novel methods and apparatus for detecting and/or locating a body such as a submarine cable buried or otherwise concealed in the bed of a body of water, independent of current in the cable.

A still further more specific object of the invention in accordance with the above is the provision of novel methods and apparatus for detecting and/or locating a body such as a submarine cable buried or otherwise concealed in the middle of a body of water where it is impossible or impractical to put an appreciable signal in the cable.

Other more specific objects of the invention in conjunction and in accordance with the above are the provision of a novel balancing circuit and arrangement, the method and manner of balancing two or more coils in order that they have equal flux linkage values and are parallel to one another, and the provision of an interrupting circuit and arrangement whereby the affect of any contact potential is reduced to a minimum.

The invention further resides in the method, features of combination, construction and arrangement hereinafter described and claimed.

For an understanding of the invention, and

for an illustration of some of the various forms it may take, reference is had to the accompanying drawings, in which:

Fig. 1 is a diagrammatic illustration of the preferred application of the invention in which a ship and a device towed along the bed of the body of water by the ship is employed for detecting and determining the depth to which a magnetic material, such as a submarine or ocean cable, a paramagnetic or a diamagnetic material is buried or concealed in the bed of the body of water;

Fig. 2 is a diagrammatic view showing the manner in which lines of flux are set up longitudinally in a comparatively long magnetic object, such as the sheath of an ocean cable;

Fig. 3 diagrammatically illustrates the manner in which magnetic poles are formed transversely of magnetic materials, such as the sheaths of ocean cables;

Fig. 4 illustrates diagrammatically the manner in which a magnetic object, such as the sheath of an ocean cable, causes concentration or warping of the earth's magnetic field;

Fig. 5 diagrammatically illustrates one arrangement of the pickup coils in the towed device;

Fig. 6 is a graph showing the voltages induced in a set of pickup coils with an arrangement of coils such as shown in Fig. 5 as they are moved relative to a magnetic object, such as an ocean cable, at various distances therefrom;

Figs. 7 to 15 diagrammatically illustrate various arrangements and numbers of pickup coils in the towed device;

Fig. 15A diagrammatically illustrates the lines of force set up in the vicinity of the towed device by a local D. C. coil;

Fig. 16 is a plan view of one form of the device adapted to be towed along the bed of a body of water in accordance with the invention;

Fig. 17 is a side view, in elevation, of the device of Fig. 16, with certain portions broken away;

Fig. 18 is a rear end view of the device of Figs. 16 and 17;

Fig. 19 is a diagrammatic view of the arrangement of the elements of the invention;

Fig. 20 shows schematically the manner in which the pickup coils in the towed device are connected through a balancing circuit arrangement to an interrupter and input transformer;

Figs. 21 and 22 are modifications of the interrupter and input transformer circuits;

Fig. 23 diagrammatically illustrates one method of obtaining parallelism between a set of pickup coils;

Fig. 24 is a sectional view taken substantially on line 24—24 of Fig. 23;

Fig. 25 illustrates vectorially how the pickup coils with an arrangement of Figs. 23 and 24 are balanced;

Fig. 26 diagrammatically illustrates an alternate method of obtaining parallelism between a set of pickup coils;

Fig. 27 illustrates vectorially how the pickup and balancing coils arranged as in Fig. 26 are balanced;

Fig. 28 diagrammatically illustrates a third method of obtaining parallelism between a set of pickup coils;

Fig. 29 is a sectional view taken substantially on line 29—29 of Fig. 28;

Fig. 30 illustrates diagrammatically how the pickup and balancing coils of Figs. 28 and 29 are connected;

Fig. 31 illustrates vectorially how the pickup and balancing coils arranged as in Figs. 28, 29 and 30 are balanced;

Fig. 32 illustrates diagrammatically how a set of pickup coils is balanced so as to make their flux linkage vectors numerically equal; and

Fig. 33 illustrates diagrammatically how a magnetic material placed between two pickup coils affects the paths of magnetic lines of force from a magnetic source such as an ocean cable.

This invention consists in general, as fully described in detail hereinafter, of the method and means for locating and/or determining the distance removed of any magnetic, paramagnetic or diamagnetic material, or the origin of any magnetic field (in the case of a magnetic field generated by an electrical current) which will cause or create a magnetic field and/or cause or create a disturbance of the earth's magnetic field. The principles of the invention are hereinafter described in detail, as applied in locating and determining the distance of a submarine cable below the bed of a body of water, but it should be kept in mind that its application is not so limited. In accordance with the above, as diagrammatically illustrated in Fig. 1, a device, such as 41, hereinafter referred to as the sled, wherein are predeterminedly arranged so-called pickup coils, is adapted to be towed or dragged along the bed of a body of water by some such means as a ship or vessel on the surface of the body of water. The sled 41 in passing over a buried cable such as 43, causes a signal, or a series thereof, to be generated which is transmitted to the ship S indicating the location and depth below the bed of the body of water of the cable, in a manner hereinafter described. The ship S and the sled 41 are shown connected by a cable 42 which serves as a combined messenger and tow cable, although separate cables for each purpose could be employed if desired.

This invention, in its described application, makes use of the fact that submarine cables and particularly ocean cables have a protective sheath of iron or steel wires wrapped around their core and insulation. As this sheath is of magnetic material, it has been found that it is quite likely to form or have magnetic poles located at various points along the length of the cable, as diagrammatically illustrated in Fig. 2. These magnetic poles are relatively far apart, setting up comparatively weak magnetic field with the magnetic lines of force close to and generally parallel to the cable. Such magnetism is hereinafter referred to as longitudinal magnetization of the cable sheath. A cable sheath is also generally found to have magnetic poles set up on opposite sides of the cable with the lines of force of the associated field substantially at right angles to the cable. Such magnetization, called transverse magnetization, is diagrammatically illustrated in Fig. 3. The poles of such a magnetic field tend to line up in the direction of the earth's field, but are shown in a horizontal plane in Fig. 3. Such a field, with the lines of force substantially circular, is comparatively strong close to the cable, rapidly decreasing as the distance from the cable increases. Also, the low reluctance of a highly magnetic object such as the iron or steel in the sheath of an ocean cable causes a concentration or warping of the lines of force of the earth's magnetic field in the immediate neighborhood as diagrammatically illustrated in Fig. 4. This effect decreases rapidly as the distance from the

sheath increases; however, it is sufficient to be effective within the desired distances.

This invention also is based on the fundamental electrical phenomena that moving a conductor so as to cut magnetic lines of force causes a voltage to be induced in the conductor, and in order to increase the induced voltage, a coil is employed, called a pickup coil. The pickup coil is rigidly mounted in the sled 41, as hereinafter described, with the plane thereof substantially horizontal and the voltage or signal induced therein as it is moved over a cable is caused by any one or a combination of all three of the magnetic fields or effects mentioned above. As the plane of a pickup coil, such as 44, Fig. 2, is generally parallel to the cable 43, very few, if any, of the lines of force of the longitudinal magnetic field are cut as the coil moves across it. Hence, the longitudinal magnetic field does not cause an appreciable signal to be induced in the pickup coil. However, it is evident that by moving a pickup coil, such as 46 or 47, Fig. 3, across a cable 43, lines of force established by the transverse magnetization will link with the turns of the coil and consequently produce a signal. Also, moving a coil such as 45, Fig. 4, across the cable 43, causes it to link with the warped lines of force of the earth's field and produce a signal which will affect the resultant signal induced in the pickup coil. Obviously, the nearer a pickup coil is to the cable 43, a larger number of lines of force will be cut, and other things being equal, a large signal will be produced. And, as the signal is the first derivative of the number of lines of force with respect to the time, the induced voltage signal in a pickup coil can be algebraically expressed as,

$$e = K \frac{d\phi}{dt}$$

where e is the induced voltage and ϕ the lines of force through the coil.

The three hereinbefore described magnetic effects created by the cable sheath are likely to be comparatively small in relation to the earth's magnetic field and with a single pick-up coil sufficiently sensitive to respond to movement through these magnetic fields, a very large interfering voltage would be induced in the coil by its movement through the earth's field. It is therefore advantageous to employ a second coil which has the same inductive characteristics or flux linkage value with respect to the earth's field as the first coil and rigidly mount the second coil parallel to the first coil to prevent any relative motion between the two coils. The coils are poled oppositely, i. e., they are differentially connected with the result that the voltages induced in the two coils by motion through a substantially uniform earth's field are in opposite directions in the circuit hereinafter described and cancel one another. As long as the requirements of parallelism and equal inductive characteristics with respect to the earth's field are met, the location of the coils need not be exacting, but for practical purposes they should be substantially on the same vertical axis and not too close together as the induced voltages generated by their movement through the magnetic fields around the cable sheath would nearly cancel. A more detailed description of the requirements in the arrangements of the coils, together with the manner in which parallelism and equal inductive characteristics or flux linkages between two or

more coils are obtained will be found in the following paragraphs.

From the above it will be apparent that two coils parallel to one another and with equal inductive characteristics with respect to a uniform magnetic field will respond to a magnetic disturbance caused by a cable sheath of magnetic material and still not respond to any motion relative to the earth's magnetic field. Two such coils 46 and 47, Fig. 3, are shown passing through the transverse magnetic field of the cable 43. These coils are assumed to be moving in a horizontal plane across the cable and are separated from one another by a vertical distance represented by a and the lower coil separated from the cable by a vertical distance represented by d . The approximate signal generated in a coil, such as 46, is proportional to

$$\frac{K}{d^2}$$

where d is the distance from the cable sheath to the coil. Thus the net response for two coils such as 46 and 47 parallel to one another and differentially connected is equal to

$$\frac{K}{d^2} - \frac{K}{(a+d)^2}$$

For assumed values of a and d each equal to ten inches, the induced signal would be

$$\frac{K}{10^2} - \frac{K}{20^2}$$

or 0.0075 K . With the same distance between coils and the vertical distance d of the lower coil to the cable sheath reduced to five inches, the net response of the two coils would be

$$\frac{K}{5^2} - \frac{K}{15^2}$$

or 0.0356 K . Thus it is evident that a change in the value d produces appreciable changes in the net responses of the two coils and as the distance d decreases, the induced voltage of the two coils increases very rapidly. Thus it is evident that to be able to read small and large signals with equal accuracy, it is advantageous to employ an automatic volume control or current limiting device of the types well known in the art in conjunction with the amplifier, as will be hereinafter described.

In view of the facts set forth above, it is obvious that a set of coils being moved relative to a cable sheath will have signals induced therein which are proportional, other things being equal, to the vertical distances between the cable sheath and the coils. From experimental data and/or calculations a curve can be plotted with the responses as a function of the distance between the cable sheath and the coils. Then, provided several other variable factors are controlled or accounted for, the distance between the cable sheath and the coils for any signal response, between certain limits, can be determined. Some of the factors would have to be controlled or accounted for in the above method are the speed and direction at which the coils move relative to the cable sheath, the amount of magnetic material in the cable sheath, its degree of magnetization, the gain in the amplifier and the strength and direction of the earth's field. It is possible to determine the first two factors with considerable degree of accuracy and make corresponding corrections in the signal responses therefor, whereas the other variable factors could be fairly accurately approximated for cer-

tain set conditions and various types of cables. Thus it can be seen that this method of employing a single pair of parallel coils with equal flux linkage has several obvious difficulties and disadvantages in its application. However, it is fundamentally sound and would give very satisfactory results under certain conditions.

In order to make it unnecessary to compensate for the speed of towing the sled and other factors more or less difficult to evaluate, a second pair of coils may be used and such is the case in the application of the preferred embodiment of the invention. With the second set of coils so disposed and/or constructed so that its signal response plotted against distance from the cable sheath is different from that of the first pair or set of coils, the ratio of the signal responses of the two sets of coils will be a function only of the distances from the cable to the sets of coils and will be independent of the variable factors such as speed, permeability of the cable, etc., thus making it unnecessary to take these factors into account. The coils can be constructed to have different response curves by making their geometries different, such as for example, having the coils of one set in a thin flat or "pancake" form and having the other set of coils with their turns concentrated at the outer diameter of the coil.

With such an arrangement having two sets of coils with different geometries, one set being mounted at the front of the sled 41, and the other at the rear of the sled so as to have signals induced therein in sequence when passing over the cable, the approximate response e_1 of the first set of coils for small values of d , may be algebraically expressed as:

$$e_1 = \frac{(H+m)(N_1 A_1)vk}{d^n}$$

where H is the strength of the earth's field, m is the strength of the magnetization of the cable, $N_1 A_1$ is the product of the turns and area of the first set of coils, v is the velocity perpendicular to the cable, k is a constant involving the size and permeability of the cable, d is the distance between the cable sheath and the center of the coil nearest the cable, and n is the power of the distance to which the first set of coils responds, dependent on the geometry of, and the distance between the coils.

Similarly, the response of the second set of coils may be expressed as follows:

$$e_2 = \frac{(H+m)(N_2 A_2)vk}{d^q}$$

where q is the power of the distance to which the second set of coils responds, being dependent on the geometry of these coils. The ratio of the signal responses then becomes

$$R = \frac{e_1}{e_2} = \frac{(H+m)(N_1 A_1)vk d^q}{(H+m)(N_2 A_2)vk d^n} =$$

or

$$= \frac{(N_1 A_1) d^{(q-n)}}{(N_2 A_2)}$$

The ratio of $N_2 A_2$ to $N_1 A_1$ is known or can be accurately determined and is constant and may be called K . Rewriting the above equation;

$$d = \frac{(q-n)\sqrt{RK}}{R}$$

There is no need for evaluation of the factors q , n and K as a calibration curve showing the relationship between the distance and the ratio of the

first and second sets of coil responses can easily be obtained from experimental data.

Fig. 5 diagrammatically illustrates two such sets of coils mounted in the sled 41 which are assumed to have different inductive characteristics for uniform distances of the sled from the cable sheath with one set located adjacent the forward end of the sled and the other set adjacent the rear end of the sled. The sets of coils are separated sufficiently so that there is no appreciable flux linkage of the magnetic fields of the cable sheath in both sets of coils at the same time. The forward set of coils in accordance with the above comprises two coils 48 and 49 parallel to one another with equal inductive characteristics and preferably on a common vertical axis and are of the thin flat or pancake type. The aft set comprising coils 51 and 52 also have equal inductive characteristics, are parallel to one another, have a common vertical axis and have their turns concentrated at their outer diameters. Each set of coils is mounted symmetrically about a longitudinal axis of the sled 41 so that the same signal responses are received with the sled being dragged on its top or bottom surface. If the forward set of pickup coils 48 and 49, Fig. 5, is determined by experimentation and calculations to have a signal response proportional to

$$\frac{k}{d^{1.5}}$$

where d is the distance from the lower coil 49 to the cable 43, for a certain set of conditions of speed of the sled, degree of magnetization of the cable sheath, etc., then its responses, relative to the distance of the sled from the cable sheath may be represented by some such curve as 53, Fig. 6, where d is the abscissae and the response the ordinates of the curve. If the aft set of coils 51 and 52, Fig. 5, are determined to have a response proportional to

$$\frac{k}{d^2}$$

for the same set of conditions of the speed of the sled, etc., then its response, relative to the distance of the sled to the cable may be represented by a curve such as 54, Fig. 6. It is obvious that any change in the conditions affecting the response of one set of coils will cause a proportional change in the response of the other set of coils unless the change is rapid and occurs after the front set has crossed the cable and before the aft set crosses, such a change being very unlikely to happen. For example, doubling the speed of the sled crossing the cable would substantially double the ordinates of both curves without changing the ratio for any given value of d . Let it be assumed that a response of two units is received from the first set of coils and a response of one for the aft set, giving a ratio of two to one which, when applied to Fig. 6, is found to correspond to a value of d equal to approximately two units. Thus the distance of the sled 41 to the cable 43 is found to be two units, where d is preferably calibrated in inches. It will be noted that for this arrangement and hereinafter the distance d represents the vertical distance from the bottom of the sled 41 to the cable sheath and not the distance from the cable to the center of the lower coil or set of coils as above. As hereinbefore pointed out, the individual coils of each set are poled oppositely and the signal response from a set of coils is the net effect of the voltages induced in the individual coils and therefore the coils of either set may

be connected in series or in parallel as long as the signals generated in the two coils of a set cancel one another when the set moves through a uniform magnetic field. Also, as the sets of coils are sufficiently separated to make the signal response of one set practically independent of the other set, the sets may be connected in series or in parallel. Similarly, the balance and polarity of one set of pickup coils is independent of the balance and polarity of the other set. Although both the forward and aft sets of coils as shown in Fig. 5 have the south pole of the upper coils of each set at the top, it is obvious that either one or both of the top coils of each set may be turned over to place the north pole on the top, provided the associated lower coil is also turned over so that the coils of a set will be oppositely poled. As hereinafter apparent, the coils of Figs. 7, 12 and 13 may be likewise changed.

Where two sets of pickup coils with different geometries are employed as in Fig. 5, their geometries have to be widely different in order to make an appreciable change in their signal responses and therefore, under certain conditions it might be advantageous to employ two similar sets of pickup coils and dispose them differently within the sled 41. Such an arrangement is shown in Fig. 7 with the forward set 56 similar to the aft set 57, with the center of the sets of coils separated by the vertical distance represented by a and the sled separated from the cable 43 by the distance represented by d . With such an arrangement of the similar sets of coils 56 and 57 as in Fig. 7, it is obvious that for small values of " d " the response from the rear set of coils 57 is much larger than that from the forward set 56, whereas for larger values of d where the relative distances of the two sets of coils from the cable sheath are more nearly the same, the ratio of the signal response approaches unity.

Fig. 8 shows another embodiment of the invention as to the disposition and number of pickup coils employed. In the arrangement only two coils 61 and 62 are employed which have equal inductive characteristics with respect to the earth's field and are poled oppositely to one another. Obviously, the two coils 61 and 62 must be parallel to one another in order that the signals generated therein in passing through the earth's field completely cancel one another. With these conditions met the individual coils 61 and 62 operate to produce signals of different values in passing over a cable in substantially the same manner as the similar sets of coils 56 and 57, Fig. 7. However, as the individual coils 61 and 62, Fig. 8, have to be horizontally separated by a considerable amount, the problem of rigidity between the two coils is more or less difficult to overcome as any slight variation out of true parallelism would have an appreciable effect towards increasing interference.

Another arrangement of the pickup coil within the sled 41 is illustrated in Fig. 9. Here the location of the coils is not symmetrical with respect to the longitudinal center axis of the sled and consequently a different calibration exists when the sled is being dragged on opposite sides whereas with the coils arranged as in Figs. 5, 7 and 8, the same signal response ratio is received when the sled is dragged on either side. However, the sequence of the larger and smaller individual responses may be reversed when the sled is dragged on opposite sides. With the pickup coils arranged as in Fig. 9 and the sled being dragged on its lower side, the front set of coils 63 and the rear

set 64 will have approximately the same signal response for small values of d . As the distance d increases, the response from the rear set of coils 64 is relatively small due to the small separations between the individual coils, nearly an equal number of lines of force passing through each coil whereas the net response from the front set of coils 63 will be relatively larger due to their wider separation. Fig. 10 illustrates an arrangement of coils which are mounted symmetrically about the axis of the sled 41 with the forward set 66 widely separated and the rear set 67 comparatively close together. If the rear coils are wound considerably higher than the forward set, i. e. have greater flux linkage, it is possible to obtain a signal response from the rear coils which is higher than that of the forward coils for small values of d , in spite of the spacial arrangement of the rear coils. However, the response from the rear coils decreases much more rapidly with increasing values of " d " than does that of the forward coils. Thus the ratio of the responses may be made to pass through unity which is desirable, in that the signals can be more easily amplified, as hereinafter apparent.

From the above descriptions and discussions of the coil arrangements illustrated in Figs. 7 to 10, it is evident that similar coils and/or similar sets of coils may be employed which are differently arranged in the sled to give different responses and that from the ratio of the responses the depth of the cable can be determined. Thus the geometries of the coils do not have to be unsymmetrical.

Fig. 11 illustrates an arrangement wherein only two coils are employed and arranged symmetrically along the axis of the sled 41, the two coils having the same flux linkage characteristics with respect to the earth's field but different geometries. With this arrangement the difficulty of maintaining rigidity between the two coils is encountered as any variation out of true parallelism between the two coils would cause appreciable interference when moved in the earth's magnetic field.

Fig. 12 diagrammatically illustrates an arrangement of coils wherein five coils are employed, two 68 and 69 in the first set and three 71, 72 and 73 in the rear set. In the front set the coils 68 and 69 are similar and have the same flux linkage characteristics. In the rear set the top and bottom coils 71 and 73 respectively have equal flux linkage characteristics and are poled alike while the middle coil 72 is equal to the sum of coils 71 and 73 in flux linkage and is poled oppositely. Thus the effect of the earth's field is balanced out when all three coils are parallel and poled as shown. By providing the rear set of coils with a higher inductive flux linkage than the front set, the response from the rear set of coils is greater than that of the front set of coils for small values of d whereas for large values of d the response from the rear set will decrease to nearly zero while the response from the front set is still appreciable. This arrangement gives a ratio of response which passes through unity which has the advantage of being more easily and accurately amplified.

A modification of the arrangement of Fig. 12 is shown in Fig. 13 and involves the use of six coils, four in the rear set and two in the front. In effect the middle rear coil 72 of Fig. 12 has been divided and the two halves separated and each associated with one of the other coils of the set. This arrangement has the advantage in

that all four coils of the rear set may be alike with the upper set of coils and the lower set of coils independent of each other in regard to parallelism.

Another modification of the method of arranging the pickup coils in the sled is diagrammatically illustrated in Fig. 14. In this arrangement three coils, 74, 76 and 77 are employed and are all located along the longitudinal center axis of the sled. The front and rear coils 74 and 77 respectively have equal inductive characteristics and are poled as shown in the same direction, whereas the middle coil 76 has an inductive characteristic equal to both the front and rear coils and is poled in the opposite direction so that with the three coils connected together and parallel with each other, any inductive effect caused by moving the sled through the earth's field will be cancelled as hereinbefore described. As the sled passes over the cable and is approximately in a longitudinal position relative thereto as denoted by the letter *a*, the peak signal response of the first coil 74 will be reached, as at this point the flux is increasing most rapidly through the first coil and the signal will return to zero when the flux reaches the maximum. With the coils reasonably close together, about eighteen to thirty inches center to center, as the flux through the first coil 74, decreases, the flux through the center coil 76 will increase, and as these two coils are poled oppositely, the induced voltage in the two coils will assist each other. This results in a second peak signal which occurs with the cable in approximately the position denoted by the letter *b* with respect to the sled, and as this second peak response is the result of the flux change through both coils 74 and 76 it will be greater than that which could be obtained through the middle coil 76 alone. With the cable in the position denoted by the letter *c* with respect to the sled, a third peak response identical to that received at position *b* will be obtained which will be caused by the combined effect of the flux decreasing through the middle coil 76 and increasing through the rear coil 77. A fourth response identical to the first at *a* is obtained when the cable is in the position denoted at *d* with respect to the sled, and this response is due to the decrease of the flux through the rear coil 77 alone. With this arrangement as shown in Fig. 14, and with small values of *d*, the response from each of the three coils is so great that the effect of the neighboring coil is very small and the ratio of the peak responses therefore is approximately 1 to 2 to 2 to 1. However, with greater distances of *d*, the effect of the neighboring coil is of importance at points *b* and *c* and the relative values of the signal responses at *b* and *c* will increase. The ratio of the second peak, at *b*, to the first peak, at *a*, will thus increase as the distance *d* increases. From these ratios and other experimental data the distance of the sled from the cable can be calibrated.

Another modification of the arrangement of the coils is shown in Fig. 15 employing only two coils 78 and 79. These two coils are parallel, have the same inductive characteristics, the same shape and are poled oppositely. They are spaced comparatively close together, about eighteen to thirty inches apart, along the longitudinal center axis of the sled. With the sled 41 at a comparatively small distance *d* from the cable 43 and in the position indicated at *a* relatively thereto, a peak signal due to the flux change through the first coil 78 is received, which is due almost

entirely to the first coil. With the cable halfway between the two coils as denoted in the position *b*, the flux through the first coil 78 is decreasing while the flux through the second coil 79 is increasing. As the two coils are poled oppositely, the individual responses will add and result in a second peak response for this position of the cable. A third peak response identical with the first response is received when the cable is in the position *c* relative to the sled, caused almost entirely by the flux decreasing through the second coil 79. At greater distance between the sled and the cable, such as denoted by *d*₁, the effective distance of the two coils from the cable is more nearly the same. Thus with the cable in approximately the position *a*₁ relative to the sled, the flux will increase in both coils and as they are differentially connected, the induced voltages in them tend to cancel one another. Consequently the first response will be comparatively small. With the cable in the position *b*₁ relative to the sled, the flux is decreasing through the first coil and increasing through the second coil, and as the coils are poled oppositely, the induced voltage is the sum of the induced voltages in the two coils, giving a comparatively large signal peak response. The third peak response, which is identical with the first, is obtained with the cable in approximately the position *c*₁, with respect to the sled. With the above arrangement of disposing the coils, the ratio of the first or third peak response to the second peak response is in the neighborhood of ten for small values of *d*, decreasing to unity as *d* increases, and reverses with a value of about 0.2 for larger values of *d*. This arrangement is very simple and gives large ratio changes for varying distances between the sled and the cable. The ratio depends on the horizontal distances between centers of the coils in this arrangement and the arrangement of Fig. 14 and obviously when the sled passes over the cable at an angle of any other than 90°, the distance between coil centers measured in a direction perpendicular to the cable would be less than that on which the calibration was based. Therefore, the application of this arrangement could be advantageously employed only where the angle, at which the sled crosses the cable can be controlled.

Although the preceding paragraphs have described the method and means for determining the distance between a cable and a sled by means of employing the ratio between induced voltages as a most advantageous application of the invention, it should be kept in mind that a single pair of coils differentially or otherwise connected, as pointed out above, could be employed and that the response therefrom read as a function of the distance from the magnetic material after due allowances for factors of speed of the sled, permeability of the cable, etc. were made.

Generation of a signal in the pickup coils depends entirely, in the above described arrangements, upon the magnetization of the cable sheath and the warping or concentrating effect on the cable sheath of the earth's magnetic field. However, instead of depending on these magnetizations, the installation of an additional coil or and additional balanced set of coils in the sled and energized with a steady direct current establishing a magnetic field in the vicinity of the sled may be employed. With such an arrangement as shown in Fig. 15A, where the D. C. coil 80 sets up lines of force in the vicinity of the sled 41 as the sled moves over a magnetic object,

such as an ocean cable, the lines of force are disturbed. This disturbing effect causes a change in the flux through the pickup coils such as 85 in the sled, which induces signals therein proportional to the distance between the sled and the magnetic object in much the same manner as described above. These signals would be due to a combination of the distortion of the created field, warping of the earth's field by the cable sheath, and the inductive effect of the cable sheath's own field on the pickup coil. In the same way an object of diamagnetic material may be detected and its distance below the bed of a body of water determined as it would also have a disturbing effect in the earth's field and/or a created field. Obviously, the establishment of the local field in the vicinity of the sled by the D. C. coil or coils could be employed in any of the coil arrangements shown and described.

The preferred method of arranging the coils in the sled 41 is to rigidly mount them in separate pots of Everdur metal such as 81 and 82, Figs. 16, 17 and 18 which is a non-magnetic alloy, and have the pots in turn rigidly attached to the sled adjacent the ends thereof. As the sled is to be placed in water of considerable depth where large pressures are encountered, the pots are completely filled with an oil, such as castor oil, which is not easily compressible and therefore reduces the pressure differential between the inside and the outside of the pots to a low value. To compensate for the different temperature coefficients of expansion between the Everdur metal and the material and liquid in the pots, syphon bellows 83 are employed to permit expansion or contraction of the oil. One bellows being employed for both of the pots in the preferred embodiment of the invention. Figs. 16, 17 and 18 show the stepped flanges 84 on the sides of the sled to prevent it from being dragged on its sides.

The above paragraphs have described the various arrangements of the pickup coils in the sled and the advantages of each as compared to the others together with the manner in which the signals are generated. A description of the arrangement and operation of the rest of the apparatus entering into the invention will now be given. As diagrammatically illustrated in Fig. 19, the signals generated in the sled 41 are transmitted to the ship over the messenger 42 where they progressively encounter a balancing circuit 86, an interrupter and input transformer 87, an amplifier 88, a current limiting device 89 and a recorder R. The signal generated in the pickup coils, as hereinbefore described, is essentially an alternating current signal of very low frequency. The frequency is so low, however, being in the neighborhood of one-half to one cycle per second, depending on the speed of the sled and the distance between pickup coils, that ordinary transformer coupled amplifiers cannot be employed and it is necessary to treat the signal as a direct current signal of changing polarity.

Referring to Fig. 20 a schematic arrangement of the pickup coils 68, 69, 71, 72 and 73, in the sled similar to that of Fig. 12 is shown and one method of connecting them (all five coils in series) to the messenger cable 42. However, the method of connecting the pickup coils with the sled may be varied, such as having the individual coils in a set connected in parallel and/or having the sets in parallel as described. The two wires of the messenger cable 42 connect to conductors 91 and 92 of the balancing circuit enclosed within the dot-dashed rectangle 86, Fig.

20. The purpose of the balancing circuit is to balance out the direct current flowing in the circuit arising from thermo-electric, contact potential and galvanic phenomena by introducing a small direct current potential of correct polarity and magnitude. In the balancing circuit a condenser 93 across the conductors 91 and 92 acts as a reservoir during the time, as hereinafter described, the interrupter contacts are open. Two filter condensers 94 and 96 are connected across the conductors 91 and 92 to ground to serve as by-passes for various forms of interference and a 50,000 ohm potentiometer 97 also across the conductors 91 and 92 allows a ground to be placed in the most advantageous position for minimum noise. A second 50,000 ohm potentiometer 98 in conjunction with a small voltage battery 99 and a comparatively large resistance 101 is connected around a comparatively small resistance 102 in the conductor 92 as shown in Fig. 20 and provides the means for applying and varying a balancing direct current to the circuit. Such an arrangement obviously eliminates the effect of any contact potential of the potentiometer 98 in the signal circuit which would likely be of substantial magnitude when compared to the signal picked up in the sled.

The conductors 91 and 92 after passing through the balancing circuit 86, continue on to the interrupter and input transformer circuit represented within the dot-dashed rectangle 87, Fig. 20. Here the signal is interrupted at a desired constant frequency and fed to the primary of the input transformer 103. The input transformer 103 has two primaries 104 and 106, one for each of a set of two interrupter contacts 107 and 108, respectively. The contacts 107 and 108 may be cam operated and the sequence of operation, starting with both contacts open, is as follows. The contact 107 closes and allows current to pass through the primary winding 104 for less than one-half of the interrupter cycle. During this interval the contact 108 is open and consequently no current flows through the primary winding 106 of the transformer 103. At the end of this period contact 107 opens to break the current in the primary winding 104 with the result that a sharp peaked secondary voltage is induced in the secondary windings 109 of the input transformer 103. Contact 108 is still open and no induced current flows through the primary winding 106 to reduce the sharpness of the flux change. This second interval during which both contacts 107 and 108 are open is relatively short in duration and at the end of the second interval contact 108 closes, establishing a current through winding 106. The establishment of this current through primary winding 106 is relatively slow and very little secondary voltage is induced in the secondary winding of the transformer. At the end of the third interval which is the same length as the first, contact 108 opens with the result that another sharp peaked secondary voltage is induced in the secondary winding 109. During the fourth interval both contacts 107 and 108 are open and no induced current will flow through the primary winding 104 to reduce the sharpness of the flux change. This fourth interval which is the same length as the second, is followed by a repetition of the entire cycle. The circuit from the secondary winding of the transformer 103 is continued to the amplifier 88 by conductors 111, 112, 113.

Figs. 21 and 22 show modifications of the interrupter and input transformer circuits enclosed within the dot-dashed rectangles 87' and

87" respectively. In these modifications elements similar to and connected as those in Fig. 20 have the same reference numerals. In Fig. 21 a periodically operated contact 114 is connected across the conductors 91 and 92 and a condenser 116 is connected in the conductor 91, as shown. The operation of this modification, assuming positive potential to have appeared on the conductor 91 and negative potential on the conductor 92 and contact 114 open, is as follows. Positive current will charge the condenser 116 and flow in a downward direction through the primary windings 104 and 106 of the transformer 103. This will be accompanied by a voltage in the secondary winding 109 of the transformer which will be greatest at approximately the time the current is charging most rapidly in the primary windings 104 and 106. The next operation occurs when the contact 114 closes, allowing the charge of condenser 116 to dissipate in an upward direction through the primary windings of the transformer. As before, a voltage will appear in the secondary winding 109 which will be at maximum at the time the current is charging most rapidly in the primary windings. The voltage generated in the secondary winding 109 during the charging of the condenser 116 is very much less than that generated during the discharge of the condenser as the discharge path is of very low resistance. Accordingly, the predominating frequency of the voltage generated in the secondary winding 109 is the frequency at which the contacts are operated, i. e., the complete cycle of opening and closing the contacts 114 causes one complete alternation of the voltage in the secondary 109.

In the modification shown in Fig. 22, a tongue 117 vibrates between two contacts 118 and 119 connected to the conductors 91 and 92 respectively. The tongue is connected by the conductor 121 to the lower terminals of the primary windings 104 and 106 of the input transformer 103. Condensers 122 and 123 are inserted in the conductors 91 and 92, respectively, to the upper terminals of the windings 104 and 106 of the transformer 103. Assuming positive potential to have appeared on the conductor 91, negative potential on conductor 92, and the tongue 117 on the contact 118, the operation is as follows. The condenser 123 will be charged by a positive current which flows in an upward direction through the primary winding 106. Simultaneously, the condenser 122, which carried a charge from the previous cycle, (negative on the transformer side) will discharge through the primary winding 104 with positive current flowing in an upward direction therethrough. These two currents in the primaries 104 and 106 occur substantially at the same time and assist one another in the establishment of an induced voltage in the secondary winding 109 of the transformer. This voltage is obviously greatest at approximately the moment the combined current in the primary windings 104 and 106 is changing most rapidly. The second operation occurs when the tongue 117 makes with the contact 119. At this time the charge on the condenser 123 will be allowed to dissipate through the primary winding 106 with positive current flowing in a downward direction. Simultaneously the condenser 122 is charged, accompanied by positive current flowing in a downward direction through the primary 104. As before, the currents in the two primaries 104 and 106 are in the same direction through the primary 104. As before, the currents in the two

primaries 104 and 106 are in the same direction and assist one another in inducing a voltage in the secondary winding 109 which will obviously be in an opposite direction to that established during the interval the tongue 117 was on contact 118. Similarly, the predominating frequency of the voltage generated in the secondary 109 is the frequency at which the tongue makes one complete vibration, i. e., from contact 118 to 119 and back to 118. In Figs. 20, 21 and 22, the contacts 107, 108, 114, 118 and 119, and the tongue 117 may be either commutator, cam, or relay operated.

The advantages of the above described arrangements in regard to the manner in which contact potential has little or no effect in inducing a voltage in the secondary winding 109 of the transformer, will now be described. Let it be assumed that a contact potential exists between the tongue 117 and the contact 118 and that the conductors 91 and 92 are connected by a resistance and/or inductance, as is the case when they are connected to the pickup coils in the sled, and that no voltage is being generated by this resistance and/or inductance. While the tongue 117 makes with the contact 118, the contact potential existing therebetween will be effective to charge the condenser 122 and when the tongue 117 leaves contact 118 and makes with contact 119, this charge will tend to discharge through the resistance and/or inductance connected to the conductors 91 and 92. However, since this resistance and/or inductance is high, very little of the charge is drawn from the condenser or is drawn at such a slow rate that very little voltage is induced in a secondary winding 109 of the transformer. As the tongue 117 remakes with the contact 118 on the next cycle, the contact potential therebetween is effective to bring the condenser 122 up to its associated charge. During this time very little current will flow through the primary winding 104 as the condenser 122 was not completely discharged during the time the tongue 117 was in contact with contact 119. In the same manner contact potential existing between the tongue 117 and contact 119 charged the condenser 123 which is allowed to slowly discharge through the primary winding 106 while the tongue is in contact with contact 118. Potentials set up across the conductors 91 and 92, however, by the resistance and/or inductance charge the condensers 122 and 123, which are then allowed to discharge through very low resistance circuits to cause large voltages in the secondary windings 109 of the transformer. With this arrangement a contact potential of the order of several volts may exist between the tongue 117 and the contacts 118 and 119 and generate no appreciable voltage in the secondary winding 109 after the tongue 117 has passed through several cycles whereas the application of a voltage on the order of 10^{-5} on the conductors 91 and 92 will generate an appreciable voltage in the secondary winding.

In the same manner any contact potential existing between the contacts 114, Fig. 21, is effective to charge the condenser 116 which is slowly drained off through the high resistance circuit during the interval the contacts are open. However, charges on the condenser 116 due to potential across the conductors 91 and 92 quickly discharge through the low resistance circuit of the primary windings 104 and 106 inducing appreciable secondary voltages.

As stated hereinbefore, in order that no voltage be generated in the pickup coils as they move through the earth's field, it is necessary that the coils be arranged parallel to one another and have the same flux linkage. The various methods by which these conditions are obtained will now be described. In a pickup coil arrangement comprising two coils, such as 124 and 126, Fig. 23, the lower coil 124 is rigidly secured to a frame structure such as 127 while the upper coil 126 rests upon a ball and socket universal joint 128 between the frame structure 127 and the upper coil. A set of screws or bolts such as 129, Figs. 23 and 24, holds the upper coil 126 to the frame structure 127 and by means of adjusting the bolts or screws 129, the upper coil may be adjusted in any plane, within limits, relative to the frame structure and the lower coil 124. Where more than two coils are employed in a set, all but one are rigidly fastened to the frame structure and the adjustment for parallelism made with one movable coil. The one movable coil compensates for lack of parallelism between itself and each of the rigid coils and also between each other of the rigidly fastened coils. Figure 25 illustrates the flux linkage vectors of a two-coil arrangement such as that of Fig. 23. In Fig. 25 the vector 131 represents the flux linkage value of the coil 124 and the vector 132 the flux linkage value of the coil 126. Moving the upper coil 126 so that its vector 132 assumes the position 132a results in a balanced parallel condition between the two coils with the sum of the vectors equal to 0. Where more than two individual coils are employed in a pickup arrangement, the vector 131 will represent the vectorial sum of the rigidly fastened coils, while the vector 132 represents that of the movable coil.

Figure 26 shows a modification of the method for obtaining parallelism between two or more coils. Here two main pickup coils 133 and 134 are rigidly fastened substantially parallel to one another to a frame structure 136 with a small third balancing coil 138 mounted by means of a ball and socket universal joint 139 to the frame structure 136. The balancing coil 138 need only be in the vicinity of the other coils, the only requirement being that it be maintained in a fixed position relative to the main coils after the balance is made. In Figure 27 the vectors 141, 142 and 143 represent the flux linkage values of the coils 133, 134 and 138, respectively, with the vector 144 representing the sum of the vectors 142 and 143. To obtain the balance it is necessary to make an angular adjustment of the balancing coil 138 so that its vector assumes a position such as 146, with the sum of the three vectors equal to 0. The balancing coil 138 is of smaller flux linkage value compared to either of the two main pickup coils 133, 134, and therefore requires a relatively large angular adjustment to compensate for small angular differences between the two rigidly fastened main coils. For example, if the balancing coil 138 has a flux linkage value of 1% of the lower coil and the two main coils 133, 134 are out of true parallelism by an angle of 1'. It would require an angular adjustment of approximately 100' of the balancing coil to make the vector sums of the three coils equal to 0. Thus a very accurate balance between the two main coils is easily accomplished. Obviously it is necessary that the vector representing the flux linkage value of the balancing coil and the value of the flux linkage vector of one of the main coils which

points in the same general direction, be equal to that of the other main coil.

Another modification of a balancing arrangement is shown in Figs. 28 and 29 employing two small balancing coils such as 147 and 148. These two balancing coils together with the two main coils such as 149 and 151 are rigidly secured to a frame structure 152 with the balancing coils substantially at right angles to one another and substantially at right angles to the main coils. The balancing coils 147 and 148 are arranged so that any portion of the coils from 0 to 100% may be included in the circuit of the two main coils. This is preferably accomplished as shown in Fig. 30 by the short-circuiting arms 153 and 154 which short-out the unwanted portion of the balancing coils.

Figure 31 vectorially illustrates the manner in which parallelism in the above arrangement is obtained, with the vectors 156 and 157 representing the flux linkage vector values of the main coils 149 and 151, respectively, and 158 and that of either one of the balancing coils 147 and 148. To obtain a balance the vector 158 is increased or shortened by lengthening one of the short-circuiting arms 153 or 154 until the sum of the vectors equals 0. The other one of the balancing coils not represented by the vector 158 is employed in obtaining a balance in a plane at right angles to that shown in Fig. 31. As the unbalance between two or more coils may exist in two planes at right angles to one another, all balancing arrangements as in the above must take this into account.

All the described systems of balancing are applicable to a set of pickup coils comprising more than two individual coils and in such systems the vectors of Figs. 25, 27 and 31 represent the flux linkage values of one or more coils in that direction. A modification of balancing involving the features of the methods shown in Figs. 26 and 28 may be employed wherein two small balancing coils such as 147 and 148 at right angles to one another are each angularly adjustable in one plane.

In making the flux linkage values numerically equal, the coils in a two-coil system are adjusted to the nearest turn. In a two-coil system, such as that of the two coils 159 and 161, Fig. 32, one coil, such as 159 has a conducting ring 162 on the upper surface thereof. The ring 162 is open and has one end connected to the outgoing circuit conductor 166, an arm 163 pivoted at the center of the ring 162 to cooperate therewith is connected by a conductor 165 to the coils 159 and by moving the arm 163 any portion of a complete turn may be added or subtracted from the coil 159. As shown in Fig. 32, the shaded area 164 represents the vector flux area added to the coil 159. By changing the connection of the conductor 166 to the other end 167 of the conducting ring 162, the unshaded area within the ring 162 will be subtracted from the vector flux pickup area of the coil 159. Thus it is possible to make flux linkage vector values numerically equal within a small fraction of one turn. As pointed out above and shown in the figures, the pickup coils are connected in series and it will be apparent that the method of balancing and making the flux linkage vectors equal is also adaptable to a set of coils comprising two or more coils connected in series and/or in parallel.

From the above it is apparent that the pair of pickup coils should be separated by a discreet distance and be differentially connected and balanced in order that they respond to magnetic

disturbances caused by an object such as a cable sheath and not respond as the result of motion of the earth's field. Obviously, the net signal response of a pair of coils such as 46 and 47, Fig. 3, is the result of the different number of lines of force cut by the coils. The placing of a magnetic object such as an iron or steel plate 168, Fig. 33, between two coils such as 169 and 171 of a pickup set will reduce the passage of the magnetic lines of force through the upper coil 169 and tend to increase those through the lower coil 171. Such an arrangement obviously results in a large difference in the lines of force being cut by the coils, thus giving a considerably stronger signal. The addition of the magnetic object 168 has no effect on the described methods of balancing and making the flux linkage vectors equal.

It is obvious that various other modifications and applications of the invention shown and described herein may be made without departing from the spirit or essential attributes of the invention, and it is desired therefore that only such limitations shall be placed thereon as are imposed by the prior art or specifically set forth in the appended claims.

What is claimed is:

1. The method of locating a concealed body, capable of distorting the lines of force of a magnetic field, by detecting means affected by said lines of force, which comprises the steps of causing relative movement between said detecting means and the body in the vicinity of said body and producing during such movement successive electrical responses, said responses being dependent upon the degree of distortion of said lines of force by said concealed body in the path of said detecting means, determining the ratio of the respective magnitudes of said successive electrical responses, and determining from said ratio the location of said body.

2. In the art of locating a body capable of distorting the lines of force of a magnetic field and concealed by a surface, by moving detecting means along said surface in the vicinity of the body, the method of determining the distance from the surface to the concealed body, irrespective of the rate at which the detecting means is moved along the surface, said method comprising the steps of causing the detecting means to produce successive electrical signals which are dependent upon the degree of distortion of said lines of force in the path of movement of said detecting means by the concealed body during the movement of the detecting means along said surface, computing the ratio of the respective magnitudes of such successive signals, and determining from said ratio the distance from said surface to said concealed body.

3. The method of determining the distance from a surface to a body concealed by said surface, said body being capable of distorting the lines of force of a magnetic field, said method comprising the steps of simultaneously moving detecting means and a magnetic field along said surface in the vicinity of the body and producing during such movement successive electrical responses dependent upon the degree of distortion of said lines of force of said magnetic field by said concealed body in the path of said detecting means, determining the ratio of the respective magnitudes of said successive electrical responses, and determining from said ratio the distance from said surface to said concealed body.

4. In the art of locating a body capable of dis-

torting the lines of force of a magnetic field and concealed by a surface, by moving detecting means along said surface in the vicinity of the body, the method of determining the distance from the surface to the concealed body, irrespective of the rate at which the detecting means is moved along the surface the size of the body and the degree of distortion of the magnetic field, said method comprising the steps of causing the detecting means to produce successive electrical signals each a function of the degree of distortion of said lines of force in the vicinity of said detecting means by the concealed body during the movement of the detecting means along said surface, determining the ratio of the respective magnitudes of such successive signals, and computing from said ratio the distance from said surface to said concealed body.

5. The method of determining the distance from a surface to a body capable of distorting the lines of force of a magnetic field concealed by said surface, said method comprising the steps of moving detecting means along said surface in the vicinity of the body and producing during such movement an electrical response dependent upon the degree of distortion of said lines of force in the vicinity of said detecting means by said concealed body, applying correcting factors to said electrical response and determining from said corrected electrical response the distance from said surface to said concealed body.

6. The method of determining the distance from a surface to a body concealed by said surface, said body being capable of distorting the lines of force of a magnetic field, said method comprising the steps of moving detecting means along said surface in the vicinity of the body and producing during such movement successive electrical responses dependent upon the degree of distortion of said lines of force at different distances from said surface, determining the ratio of the respective magnitudes of said successive electrical responses, and determining from said ratio the distance from said surface to said concealed body.

7. Means for locating a body concealed beneath a surface and capable of distorting the lines of force of a magnetic field, comprising a device and means for causing the device to move along said surface, said device having means for producing successive electrical responses as the device as moved into and out of the distorted lines of force of said magnetic field in the vicinity of said concealed body, and means employing said successive electrical responses for determining the location of said concealed body.

8. In a system for locating submarine cables buried in the bed of a body of water and capable of distorting the lines of the force of a magnetic field, comprising a device and means for causing the device to move along the bed of the body of water in which the cable lies, said device having means for producing a succession of electrical responses as it passes over said cable, means for determining the ratio of the respective magnitudes of said electrical responses and means dependent on said ratio for determining the distance of said cable below the bed of said body of water.

9. Means for locating a body concealed beneath a surface and capable of affecting the lines of force of a magnetic field, comprising a device adapted to be moved along said surface in the vicinity of said body, means associated with said device for producing during such movement suc-

cessive electrical impulses a function of the degree of distortion of said lines of force by said concealed body at different distances removed from said surface and means for determining from the magnitudes of said successive electrical impulses the distance of said concealed body from said surface.

10. In an apparatus for locating a body concealed beneath a surface capable of affecting the lines of force of a magnetic field comprising a device and means for moving the device along said surface in the vicinity of said body, means associated with said device for producing during such movement successive electrical impulses dependent upon the degree of distortion of said lines of force by said concealed body at a predetermined distance from said surface and means for determining from the ratio of the respective magnitudes of said successive electrical impulses the distance of said concealed body from said surface.

11. In an apparatus for locating a body concealed beneath a surface capable of affecting the lines of force of a magnetic field, comprising a detecting means adapted to be moved along said surface in the vicinity of said body, a first means associated with said detecting means for establishing a magnetic field in the vicinity thereof and a second means associated with said detecting means adapted to measure the degree of distortion of said magnetic field by said concealed body during relative movement therebetween and produce a series of relative electrical impulses, the ratio of the respective magnitudes of which is a function of the distance of said concealed body from said surface.

12. In a device of the character described, said device comprising a plurality of pickup coils disposed in spaced relation, means for adjusting the relative position of said pickup coils with respect to one whereby individual induced voltages of said coils when moved through undisturbed lines of force of a magnetic field cancel one another and when moved through the lines of force of a disturbed portion of said magnetic field, the individual induced voltages of said coils produce a resultant signal the net value of which is proportional to the degree of distortion of the lines of force of said magnetic field at said pickup coils and means employing said resultant signal for determining the distance between said pickup coils and the origin of the disturbance of the disturbed portion of said magnetic field.

13. In a device of the character described, said device comprising a plurality of pickup coils in spaced relation, a balancing coil and a circuit connecting said coils, each of said coils being adapted to generate a voltage when moved so as to cut the lines of force of a magnetic field, means for making the product of the turns by the area of the coils adapted to generate a voltage in one direction in said circuit equal to those adapted to generate a voltage in the opposite direction for a uniform set of conditions and means for adjusting the position of said balancing coil whereby during movement of all of said coils through the lines of force of an undisturbed portion of the earth's magnetic field no net voltage is generated in said circuit.

14. In a device of the character described, said device comprising a plurality of pickup coils in spaced relation, a balancing coil and a circuit connecting said coils, each of said coils being adapted to generate a voltage when moved so as to cut the lines of force of a magnetic field,

means for making the product of the turns by the area of the coils adapted to generate a voltage in one direction in said circuit equal to those adapted to generate a voltage in the opposite direction for a uniform set of conditions and means for adjusting the position of said balancing coil whereby during movement of all of said coils through the lines of force of an undisturbed portion of the earth's magnetic field no net voltage is generated in said circuit while movement thereof through the lines of force of a disturbed portion of the earth's magnetic field causes the generation of a net voltage, the value of which is of function of the distance between said coils and the origin of the disturbance of the disturbed portion of the earth's field.

15. In a device of the character described, said device comprising a plurality of pickup coils, a plurality of balancing coils disposed at right angles to each other and a circuit connecting all of said coils, each of said coils being in relatively fixed spaced relation to one another and adapted to generate a voltage when cutting the lines of force of a magnetic field, means for making the product of the number of turns by the area of the coils adapted to generate a voltage in one direction in said circuit equal to those adapted to generate a voltage in the opposite direction in said circuit for a given set of conditions and means for varying the product of the turn by the area of said balancing coils whereby the movement of said coils through the lines of force of an undisturbed portion of the earth's magnetic field produces no net voltage in said circuit.

16. In a device of the character described, said device comprising a plurality of pickup coils, a circuit connecting said coils and a frame structure, one of said pickup coils being attached to said frame structure so as to permit movement thereof in any plane relative thereto, the other of said pickup coils being rigidly attached to said frame structure, each of said pickup coils being adapted to generate a voltage when cutting the lines of force of a magnetic field, means for making the product of the number of turns by the area of each coil adapted to generate a voltage in one direction in said circuit equal to those adapted to generate a voltage in the opposite direction in said circuit for a uniform set of conditions and means for adjusting the position of said movable pickup coil relative to said frame structure and the others of said pickup coils whereby movement of said coils through the lines of force of an undisturbed portion of the earth's magnetic field generates no net voltage in said circuit.

17. In a device of the character described, said device comprising a plurality of pickup coils, two balancing coils, a circuit connecting said coils and a frame structure, each of said coils being rigidly attached to said frame structure with said balancing coils disposed at right angles with respect to one another and each of said coils being adapted to generate a voltage when cutting the lines of force of a magnetic field, means for making the product of the number of turns by the area of the coils adapted to generate a voltage in one direction in said circuit equal to those adapted to generate a voltage in the opposite direction in said circuit for a given set of conditions, means for varying the product of the turn by the area of said balancing coils whereby the movement of said coils through the lines of force of an undisturbed portion of the earth's magnetic field produces no net voltage in said circuit.

cuit, and movement thereof through the lines of force of a disturbed portion of the earth's magnetic field causes the generation of a net voltage in said circuit the value of which is a function of the distance between said coils and the origin of the disturbance of the disturbed portion of the earth's field.

18. In a system for detecting submarine cables buried in the bed of a body of water and capable of distorting the lines of force of the earth's magnetic field, a device adapted to be moved along the bed of the body of water in the vicinity of said buried cable, said device having substantially rigidly mounted therein in longitudinal spaced relation a plurality of sets of pickup coils, each of said pickup coils being capable of generating a voltage when cutting the lines of force of a magnetic field, and a circuit connecting said pickup coils, means for adjusting said pickup coils whereby during movement of said device through an undisturbed portion of the earth's magnetic field substantially no net voltage is generated in said circuit by said pickup coils and means whereby on movement of said device through the distorted portion of the earth's magnetic field caused by said cable, a succession of voltages is produced in said circuit the ratio of the respective magnitudes of which is a function of the distance of the cable below the bed of said body of water.

19. Means for locating a concealed body capable of affecting the lines of force of a magnetic field, comprising a device and means for causing the device to move relative to the concealed body in the vicinity thereof, said device having a forward and a rear set of pickup coils mounted therein in longitudinal and vertical spaced relation, each set comprising an equal number of similar coils with the coils separated from one another by substantially the same amount and means dependent on the vertical spaced relation of said pickup coil sets whereby relative movement of said device in the vicinity of said body produces a series of electrical impulses the ratio of the respective magnitudes of which is a function of the distance between said device and said body.

20. In a system for detecting submarine cables buried in the bed of a body of water and capable of distorting the lines of force of the earth's magnetic field, a device adapted to be moved along the bed of the body of water in the vicinity of said buried cable, said device having substantially rigidly mounted therein in longitudinal spaced relation a plurality of sets of pickup coils, each of said pickup coils being capable of generating a voltage when cutting the lines of force of a magnetic field, and a circuit connecting said pickup coils, means for adjusting said pickup coils whereby during movement of said device through an undisturbed portion of the earth's magnetic field substantially no net voltage is generated in said circuit by said pickup coils, means whereby on movement of said device through the distorted portion of the earth's magnetic field caused by said cable, a succession of voltages is produced in said circuit the ratio of the respective magnitudes of which is a function of the distance of the cable below the bed of said body of water, and means involving the disposition of the individual coils of each set with respect to one another whereby the curve of the generated voltage of each set of coils with respect to the distance between the device and the cable

as it crosses the cable is different for each set of coils.

21. In a system for detecting submarine cables buried in the bed of a body of water and capable of distorting the lines of force of the earth's magnetic field, a device adapted to be moved along the bed of the body of water in the vicinity of said buried cable, said device having substantially rigidly mounted therein in longitudinal spaced relation a plurality of sets of pickup coils, each of said pickup coils being capable of generating a voltage when cutting the lines of force of a magnetic field, and a circuit connecting said pickup coils, means for adjusting said pickup coils whereby during movement of said device through an undisturbed portion of the earth's magnetic field substantially no net voltage is generated in said circuit by said pickup coils, means whereby on movement of said device through the distorted portion of the earth's magnetic field caused by said cable, a succession of voltages is produced in said circuit the ratio of the respective magnitudes of which is a function of the distance of the cable below the bed of said body of water, and means involving the geometrics of the coils of each set whereby the curve of the generated voltage of each set of coils with respect to the distance between the device and the cable as it crosses the cable is different for each set of coils.

22. In a system for detecting submarine cables buried in the bed of a body of water and capable of distorting the lines of force of a magnetic field, a device adapted to be moved along the bed of the body of water in the vicinity of said cable, said device having substantially rigidly mounted therein in longitudinal spaced relation a plurality of sets of pickup coils each of said pickup coils being capable of generating a voltage when cutting the lines of force of a magnetic field, and a magnetic field generating means, the lines of force of which are adapted to be distorted when said device is moved in the vicinity of said cable, a circuit connecting said pickup coils, means for adjusting said pickup coils whereby the movement of said device through the lines of force of the earth's magnetic field produces no substantial net voltage in said circuit and means employing the distortion to the lines of force of the generated magnetic field as said device moves in the vicinity of said cable for causing said pickup coils to generate a succession of voltages, the ratio of the values of which is a function of the distance of said cable below the bed of the body of water.

23. In a system for detecting submarine cables buried in the bed of a body of water and capable of distorting the lines of force of a magnetic field, a device adapted to be moved along the bed of the body of water in the vicinity of said cable, said device having substantially rigidly mounted therein in longitudinal spaced relation a plurality of sets of pickup coils each of said pickup coils being capable of generating a voltage when cutting the lines of force of a magnetic field, and a magnetic field generating means, the lines of force of which are adapted to be distorted when said device is moved in the vicinity of said cable, a circuit connecting said pickup coils, means for adjusting said pickup coils whereby the movement of said device through the lines of force of the earth's magnetic field produces no substantial net voltage in said circuit, means employing the distortion to the lines of force of the generated magnetic field as said de-

vice moves in the vicinity of said cable for causing said pick coils to generate a succession of voltages, the ratio of the values of which is a function of the distance of said cable below the bed of the body of water, and means involving the geometrics and the disposition of the individual coils of each set whereby the curve of the generated voltage of each set of coils with respect to the distance between the device and the cable as it crosses the cable are different for each set of coils.

24. Means for locating a concealed body capable of affecting the lines of force of a magnetic field, comprising a device and means for causing the device to move relative to the concealed body in the vicinity thereof, said device having a forward and a rear set of pickup coils located symmetrically about the longitudinal center axis adjacent the forward and rear ends respectively of said device, each set comprising an equal number of individual pickup coils in superimposed relation and separated by substantially equal distances, the pickup coils of each individual set being similar to one another and having different geometrics from those of the other set, and means dependent on the different geometrics of said pickup coils whereby relative movement of said device with respect to a body capable of affecting the lines of force of a magnetic field in the vicinity thereof produces a series of electrical impulses, the ratio of the respective magnitudes of which is a function of the distance between the device and said body.

25. Means for locating a concealed body capable of affecting the lines of force of a magnetic field, comprising a device and means for causing the device to move relative to the concealed body in the vicinity thereof, said device having a forward and a rear pickup coil substantially rigidly mounted therein with respect to one another adjacent the forward and rear ends respectively of said device, said pickup coils being similar to one another and mounted in different horizontal planes and means dependent on the vertical and longitudinal spaced relation of said pickup coils whereby relative movement of said device in the vicinity of said body causes the production of a succession of electrical impulses, the ratio of the respective magnitudes of which is a function of the distance between said device and said body.

26. Means for locating a concealed body capable of affecting the lines of force of a magnetic field, comprising a device and means for causing the device to move relative to the concealed body in the vicinity thereof, said device having a forward and a rear set of pickup coils mounted therein in longitudinal spaced relation, each set comprising an equal number of similar individual pickup coils in superimposed relation to one another and separated from one another by different vertical distances, a circuit connecting all of said coils, means for adjusting said coils whereby voltages induced in said coils during movement of said device through the lines of force of an undisturbed portion of the earth's magnetic field are substantially balanced out and means dependent on the different vertical distances between the individual coils of each set whereby relative movement of said device in the vicinity of said body capable of affecting the lines of force of a magnetic field produces a succession of electrical impulses in said circuit the ratio of the respective magnitudes of which is a function of the distance between said device and the body.

27. In a system of the type described for locating a concealed body, said system comprising a recording station and a detecting means remote from said recording station, said detecting means being adapted to generate signals when moved relative to said concealed body in the vicinity thereof, a circuit between said detecting means and said recording station, a source of constant potential, a potentiometer, and a plurality of resistances predeterminedly connected in said circuit at said recording station and means comprising said source of potential, said potentiometer and said resistances whereby substantially steady currents induced and present in said circuit between said detecting means and said recording station due to thermo-electric, contact potential and galvanic phenomena have substantially no effect on the signals produced by said detecting means.

28. Means for locating a concealed body capable of affecting the lines of force of a magnetic field, comprising a device and means for causing the device to move relative to the concealed body in the vicinity thereof, said device having a forward and a rear set of pickup coils located adjacent the forward and rear ends respectively of said device, each set comprising an equal number of similar individual pickup coils in superimposed relation with the coils of one set having different geometrics and separated from one another by different vertical distances from those of the other set, a circuit connecting all of said coils, means for adjusting each set of pickup coils whereby the voltages induced in said circuit during movement of said device relative to the lines of force of an undisturbed portion of the earth's magnetic field substantially balance one another, and means jointly dependent on the different geometrics of the coils of each set and the different vertical distances separating the coils of each set whereby relative movement of said device in the vicinity of a body capable of affecting the lines of force of a magnetic field produces a succession of electrical impulses in said circuit the ratio of the respective magnitudes of which is a function of the distance between said device and said body.

29. In a device of the character described, said device having substantially rigidly mounted therein in the same horizontal plane a forward and a rear pickup coils, said coils having different geometrics and each being adapted to generate a voltage when cutting the lines of force of a magnetic field, a circuit connecting said coils, means for adjusting said coils whereby the voltages induced in said circuit during movement of said device so as to cut the lines of force of an undisturbed portion of the earth's magnetic field are in opposite directions and substantially cancel one another and means dependent solely on the different geometrics of said pickup coils on movement of said device so as to cut the lines of force of disturbed portions of the earth's magnetic field for generating a series of electrical impulses the ratio of the respective magnitudes of which is a function of the distance between said device and the origin of the disturbance of the disturbed portion of the earth's field.

30. Means for locating a concealed body capable of affecting the lines of force of a magnetic field, comprising a device and means for causing the device to move relative to the concealed body in the vicinity thereof, said device having a forward and a rear pickup coil substantially rigidly mounted therein with respect

to one another adjacent the forward and rear ends respectively of said device and in the same plane, said pickup coils having similar inductive characteristics and poled in opposite directions, and means effective by the longitudinal spaced relation of said pickup coils whereby relative movement of said device in the vicinity of said body causes the production of a succession of electrical impulses, the ratio of the respective magnitudes of which is a function of the distance between said device and said body.

31. Means for locating a concealed body capable of affecting the lines of force of a magnetic field, comprising a device and means for causing said device to move relative to the concealed body in the vicinity thereof, said device having a forward and a rear set of pickup coil devices, at least one of said devices having three individual pickup coils in superimposed relation with the upper and lower coil having similar inductive characteristics and jointly equal to the inductive characteristic of the center coil, a circuit connecting all of said coils, means for adjusting said coils whereby the voltages induced in said circuit during movement of said device so as to cut the lines of force of an undisturbed portion of the earth's magnetic field are in opposite directions and substantially cancel one another, and means dependent upon the disposition of the individual pickup coils of said pickup devices whereby on movement of said device so as to cut the lines of force of disturbed portions of the earth's magnetic field, a series of successive electrical impulses are generated by the forward and rear sets of pickup coil devices, the ratios of the respective magnitudes of which is a function of the distance between said device and the origin of the disturbance of the disturbed portion of the earth's magnetic field, said ratio being greater than unity for distances greater than a predetermined distance between said device and the origin of the disturbance and less than unity for distances less than said predetermined distance.

32. In a device of the character described for producing successive signals when moved in the vicinity of a body capable of disturbing the lines of force of the earth's magnetic field, said device having a plurality of sets of electrically connected pickup coil devices in longitudinal spaced relation, at least one of said devices having four individual pickup coils of similar inductive characteristics and disposed in superimposed relation, the upper two and the lower two of said individual coils being parallel to one another whereby on movement of said device so as to cut the lines of force of an undisturbed portion of the earth's magnetic field no net voltage is produced and on movement thereof through a portion of the earth's field disturbed by a body a series of successive electrical impulses are produced, the ratios of the respective magnitudes of which are a function of the distance between said device and said body.

33. In a device of the character described for producing successive signals when moved in the vicinity of a body capable of affecting the lines of force of the earth's magnetic field, the ratios of the magnitudes of the respective signals being a function of the distances between the said device and the body, said device having three electrically connected pickup coils arranged in longitudinal spaced relation and substantially in the same plane, the end coils of said device having similar inductive characteristics and poled in the same direction, the middle coil having

an inductive characteristic equal to twice either of the other coils and poled oppositely therefrom, whereby no net voltage is produced by said device when moved so as to cut the lines of force of an undisturbed portion of the earth's magnetic field and movement thereof through the lines of force of the earth's field disturbed by a body produces a succession of electrical impulses the ratio of the magnitudes of which is a function of the distance between said device and the body.

34. The method of locating a concealed body, capable of distorting the lines of force of the earth's magnetic field, by detecting means affected by said lines of force, which comprises the steps of causing relative movement between said detecting means and the body in the vicinity of said body and producing during such movement successive electrical responses which are dependent upon the degree of distortion of said lines of force by said concealed body, in the path of movement of said detecting means, determining the ratio of the respective magnitudes of said successive electrical responses, and determining from said ratio the location of said body.

35. The method of determining the distance from a surface to a body concealed by said surface, said body being capable of distorting the lines of force of a magnetic field, said method comprising the steps of moving detecting means along said surface in the vicinity of the body and producing during such movement successive electrical responses dependent upon the degree of distortion of said lines of force in the vicinity of said detecting means by said concealed body, determining the ratio of the respective magnitudes of said successive electrical responses, and determining from said ratio the distance from said surface to said concealed body.

36. The method of locating a concealed body, capable of establishing a magnetic field, by detecting means affected by lines of force of said magnetic field, which comprises the steps of causing relative movement between said detecting means and the body in the vicinity of said body and producing during such movement successive electrical responses which are a function of the least distance between said detecting means and said concealed body during the movement of said detecting means, determining the ratio of the respective magnitudes of said successive electrical responses, and determining from said ratio the location of said body.

37. The method of locating a concealed body, capable of establishing a magnetic field, the lines of force of which react with the lines of force of the earth's magnetic field, by detecting means affected by said reacted lines of force, which comprises the steps of causing relative movement between said detecting means and the body in the vicinity of said body and producing during such movement successive electrical responses dependent upon the degree of reaction of the lines of force of said concealed body with the lines of force of the earth's field in the path of movement of said detecting means, determining the ratio of the respective magnitudes of said successive electrical responses, and determining from said ratio the location of said body.

38. In the art of locating a body capable of distorting the lines of force of a magnetic field and concealed by a surface, by moving detecting means along said surface in the vicinity of the body, the method of determining the distance from the surface to the concealed body, irrespec-

tive of the rate at which the detecting means is moved along the surface, and the degree of distortion of the magnetic field, said method comprising the steps of causing the detecting means to produce successive electrical signals dependent upon the degree of distortion of said lines of force in the path of movement of said detecting means by the concealed body during the movement of the detecting means along said surface, determining the ratio of the respective magnitudes of such successive signals, and computing from said ratio the distance from said surface to said concealed body.

39. In an apparatus for locating a body concealed beneath a surface capable of affecting the lines of force of a magnetic field comprising a device and means for causing the device to move along said surface in the vicinity of said body and means associated with said device for producing during such movement a succession of electrical impulses the ratio of the respective magnitudes of which is a function of the distance of said concealed body from said surface.

40. In an apparatus for locating a body concealed beneath a surface capable of affecting the lines of force of a magnetic field, comprising a detecting means adapted to be moved along said surface in the vicinity of said body, a first means associated with said detecting means for establishing a magnetic field in the vicinity thereof and a second means associated with said detecting means adapted to indicate the degree of distortion of said magnetic field by said concealed body during relative movement therebetween at various distances from said surface by producing a succession of relative electrical impulses and means employing the ratio of the magnitudes of respective electrical impulses for determining the distance of said concealed body from said surface.

41. In a device of the character described, said device comprising a plurality of pickup coils, means for making the inductive characteristics of said pickup coils equal with respect to one another, means for adjusting the relative position of said pickup coils whereby said coils are substantially parallel and the voltages induced therein during movement thereof through the lines of force of a substantially uniform magnetic field are substantially equal, and means for disposing said coils with respect to one another whereby the movement thereof through the lines of force of a disturbed portion of said magnetic field produces unequal signals in said pickup coils.

42. In a device of the character described, said device comprising a plurality of pickup coils, a plurality of balancing coils disposed at right angles to each other and a circuit connecting all of said coils, each of said coils being in relatively fixed spaced relation to one another and adapted to generate a voltage when cutting the lines of force of a magnetic field, means for making the product of the number of turns by the area of the coils adapted to generate a voltage in one direction in said circuit equal to those adapted to generate a voltage in the opposite direction in said circuit for a given set of conditions, means for varying the product of the turn by the area of said balancing coils whereby the movement of said coils through the lines of force of an undisturbed portion of the earth's magnetic field produces no net voltage in said circuit and movement thereof through the lines of force of a disturbed portion of the earth's

magnet field causes the generation of a net voltage in said circuit the value of which is a function of the distance between said coils and the origin of the disturbance of the disturbed portion of the earth's field.

43. In a device of the character described, said device comprising a plurality of pickup coils, a balancing coil, a circuit connecting said coils and a frame structure, said pickup coils being rigidly attached to said frame structure and said balancing coil being attached thereto so as to permit movement thereof in any plane relative thereto, each of said coils being adapted to generate a voltage when cutting the lines of force of a magnetic field, means for making the product of the number of turns by the area of each coil adapted to generate a voltage in one direction in said circuit equal to those adapted to generate a voltage in the opposite direction in said circuit for a uniform set of conditions and means for adjusting the position of said balancing coil relative to said frame structure and said pickup coils whereby movement of said coils through the lines of force of an undisturbed portion of the earth's magnetic field generates no net voltage in said circuit.

44. In a system for detecting submarine cables buried in the bed of a body of water and capable of distorting the lines of force of the earth's magnetic field, a device adapted to be moved along the bed of the body of water in the vicinity of said buried cable, said device having substantially rigidly mounted therein a set of pickup coils each of said pickup coils being capable of generating a voltage when cutting the lines of force of a magnetic field, and a circuit connecting said pickup coils, means for adjusting said pickup coils whereby during movement of said device through an undisturbed portion of the earth's magnetic field substantially no net voltage is generated in said circuit by said pickup coils and means whereby on movement of said device through the distorted portion of the earth's magnetic field caused by said cable, a voltage is generated in said circuit the magnitude of which is a function of the distance of the cable below the bed of the body of water.

45. In a system for detecting submarine cables buried in the bed of a body of water and capable of distorting the lines of force of the earth's magnetic field, a device adapted to be moved along the bed of the body of water in the vicinity of said buried cable, said device having substantially rigidly mounted therein in longitudinal spaced relation a plurality of sets of pickup coils, each of said pickup coils being capable of generating a voltage when cutting the lines of force of a magnetic field, and a circuit connecting said pickup coils, means for adjusting said pickup coils whereby during movement of said device through an undisturbed portion of the earth's magnetic field substantially no net voltage is generated in said circuit by said pickup coils, means whereby on movement of said device through the distorted portion of the earth's magnetic field caused by said cable, a succession of voltages is produced in said circuit the ratio of the respective magnitudes of which is a function of the distance of the cable below the bed of said body of water, and means involving the geometrics and the disposition of the individual coils of each set whereby the curve of the generated voltages of each set of coils with respect to the distance between the device and the cable

as it crosses the cable is different for each set of coils.

46. In a system for detecting submarine cables buried in the bed of a body of water and capable of distorting the lines of force of a magnetic field, a device adapted to be moved along the bed of the body of water in the vicinity of said cable, said device having substantially rigidly mounted therein in longitudinal spaced relation a set of pickup coils, each of which is capable of generating a voltage when cutting the lines of force of a magnetic field, and a magnetic field generating means the lines of force of which are adapted to be distorted in proportion to the distance between said cable and said device, and means employing the change in the degree of distortion of the lines of force of said generated magnetic field as said device moves in the vicinity of said cable for causing said set of pickup coils to generate a voltage the value of which is a function of the distance of said cable from the bed of the body of water.

47. In a system for detecting submarine cables buried in the bed of a body of water and capable of distorting the lines of force of a magnetic field, a device adapted to be moved along the bed of the body of water in the vicinity of said cable, said device having substantially rigidly mounted therein in longitudinal spaced relation a plurality of sets of pickup coils each of said pickup coils being capable of generating a voltage when cutting the lines of force of a magnetic field, and a magnetic field generating means, the lines of force of which are adapted to be distorted when said device is moved in the vicinity of said cable, a circuit connecting said pickup coils, means for adjusting said pickup coils whereby on movement of said device through the lines of force of the earth's magnetic field no substantial net voltage is produced in said circuit, means employing the distortion to the lines of force of the generated magnetic field as said device moves in the vicinity of said cable

for causing said pickup coils to generate a succession of voltages, the ratio of the values of which is a function of the distance of said cable below the bed of the body of water, and means involving the disposition of the individual coils of each set with respect to one another whereby the curve of the generated voltage of each set of coils with respect to the distance between the device and the cable as it crosses the cable is different for each set of coils.

48. In a system for detecting submarine cables buried in the bed of a body of water and capable of distorting the lines of force of a magnetic field, a device adapted to be moved along the bed of the body of water in the vicinity of said cable, said device having substantially rigidly mounted therein in longitudinal spaced relation a plurality of sets of pickup coils each of said pickup coils being capable of generating a voltage when cutting the lines of force of a magnetic field, and a magnetic field generating means, the lines of force of which are adapted to be distorted when said device is moved in the vicinity of said cable, a circuit connecting said pickup coils, means for adjusting said pickup coils whereby the movement of said device through the lines of force of the earth's magnetic field no substantial net voltage is produced in said circuit, means employing the distortion to the lines of force of the generated magnetic field as said device moves in the vicinity of said cable for causing said pickup coils to generate a succession of voltages, the ratio of the values of which is a function of the distance of said cable below the bed of the body of water, and means involving the geometrics of the coils of each set whereby the curve of the generated voltage of each set of coils with respect to the distance between the device and the cable as it crosses the cable is different for each set of coils.

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