Oct. 15, 1940. J. M. PEARSON 2,217,768

APPARATUS FOR ORIENTING CORES

Filed Nov. 5, 1937 5 Sheets-Sheet 1

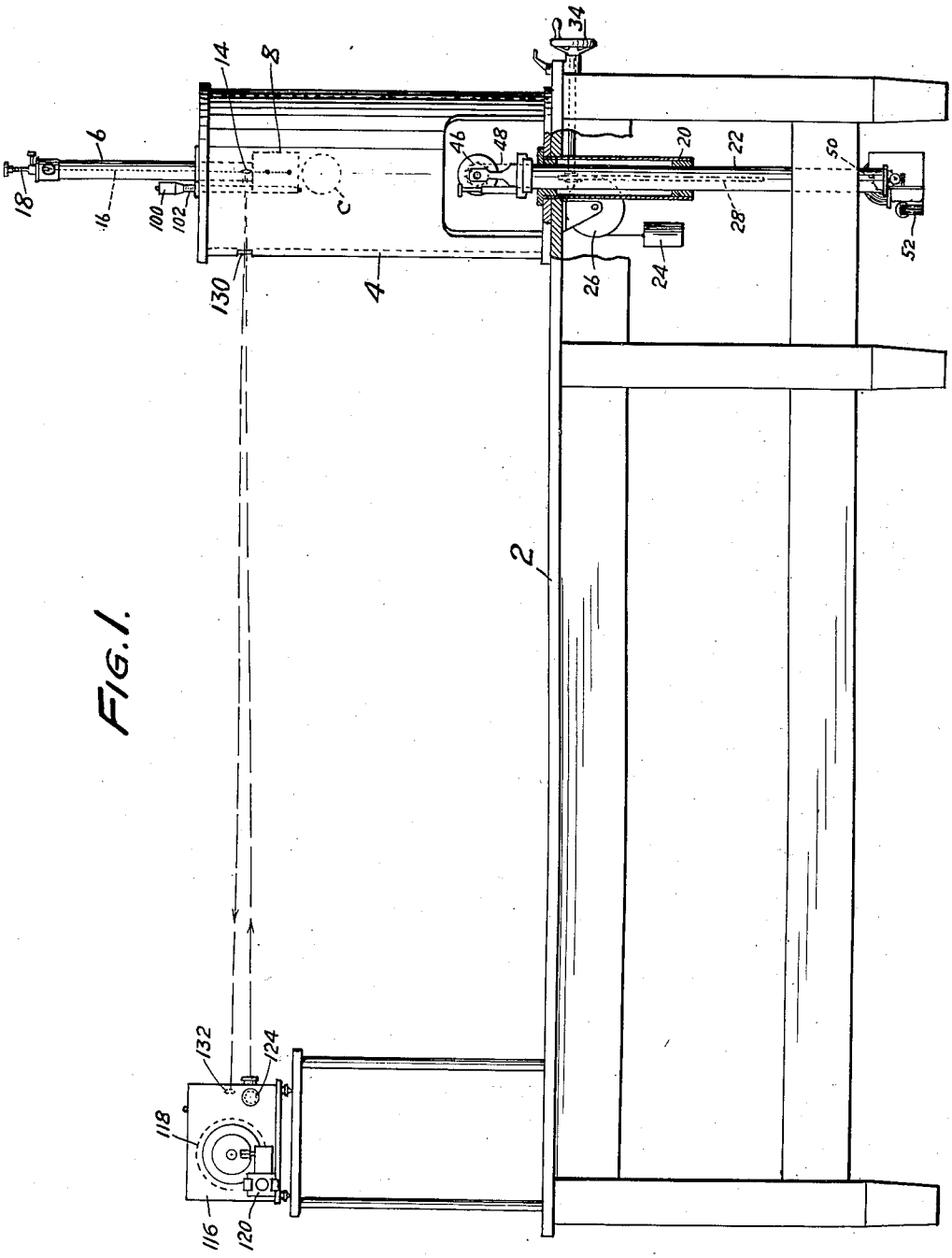



FIG. 1.

WITNESS:

Robt R. Ketchel

INVENTOR

John M. Pearson

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Bussey & Harding

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Oct. 15, 1940. J. M. PEARSON 2,217,768

APPARATUS FOR ORIENTING CORES

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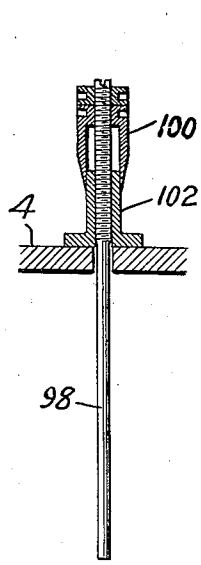



FIG. 4.

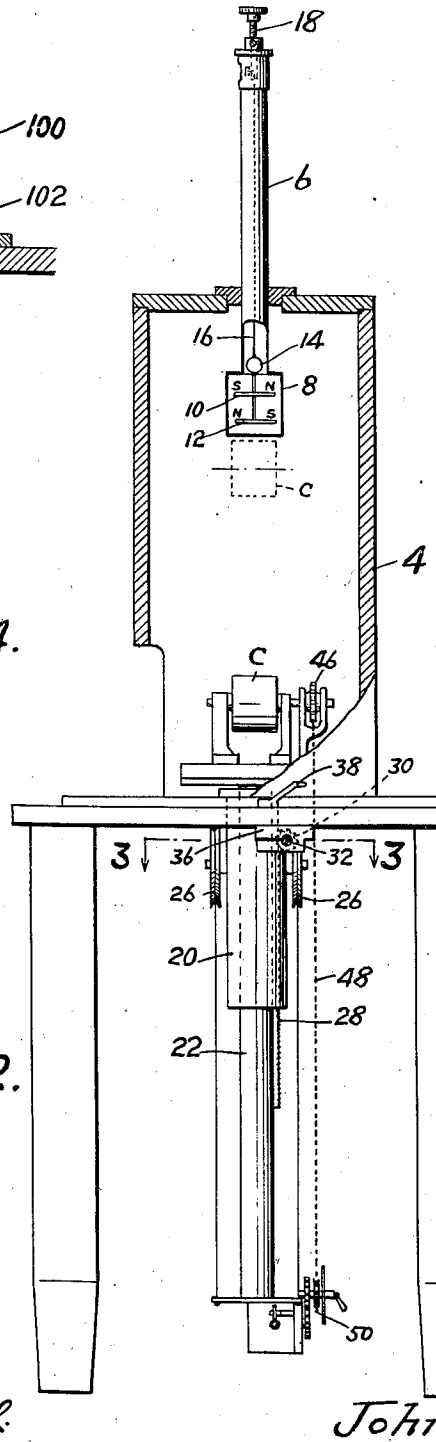



FIG. 2.

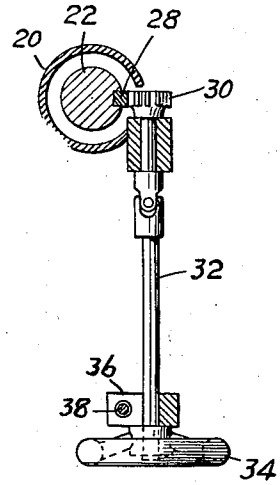



FIG. 3.

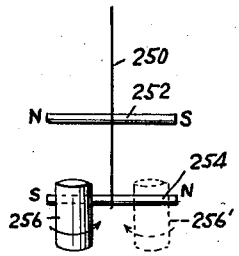



FIG. 16.

WITNESS:

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Oct. 15, 1940. J. M. PEARSON 2,217,768

APPARATUS FOR ORIENTING CORES

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FIG. 6.

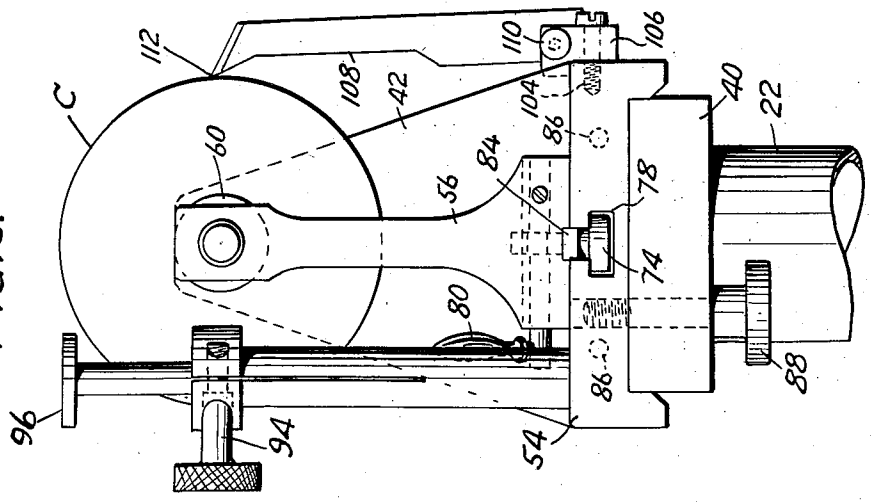
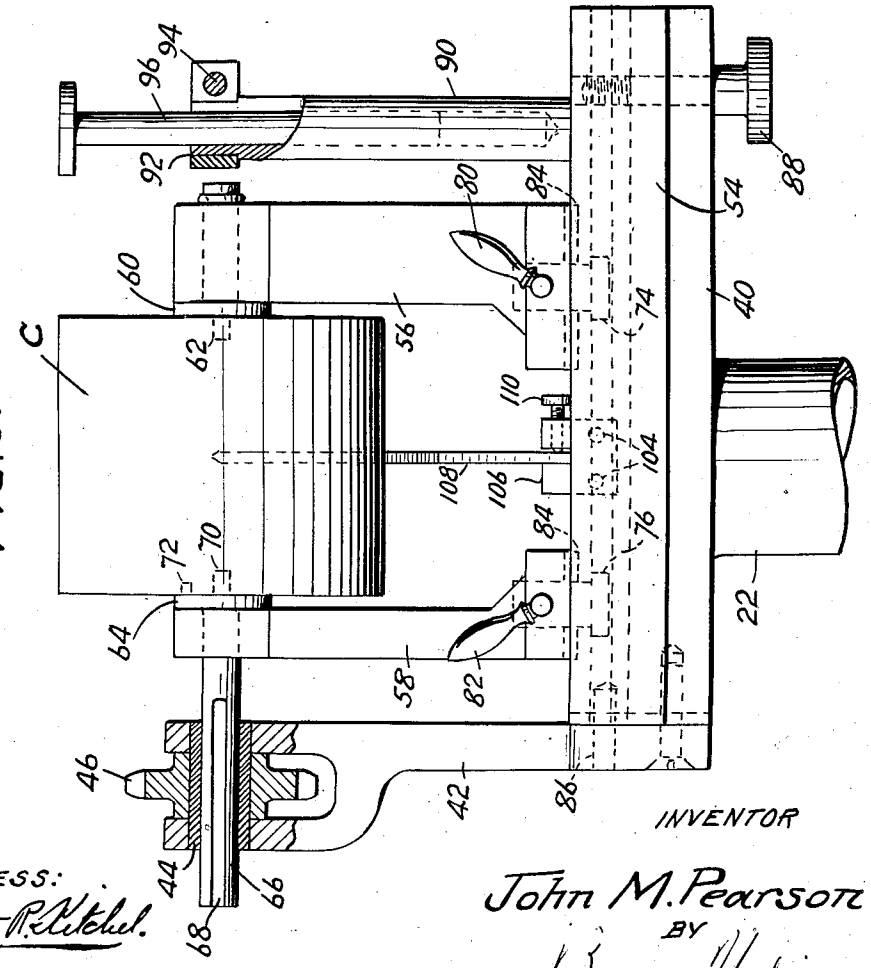



FIG. 5.




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WITNESS:

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Oct. 15, 1940. J. M. PEARSON 2,217,768

APPARATUS FOR ORIENTING CORES

Filed Nov. 5, 1937 5 Sheets-Sheet 4

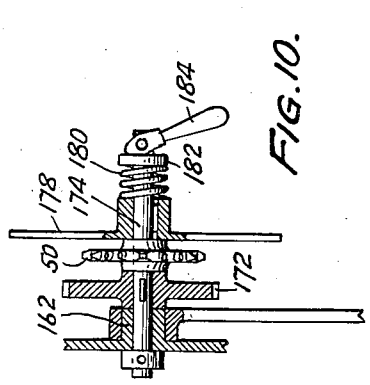



FIG. 10.

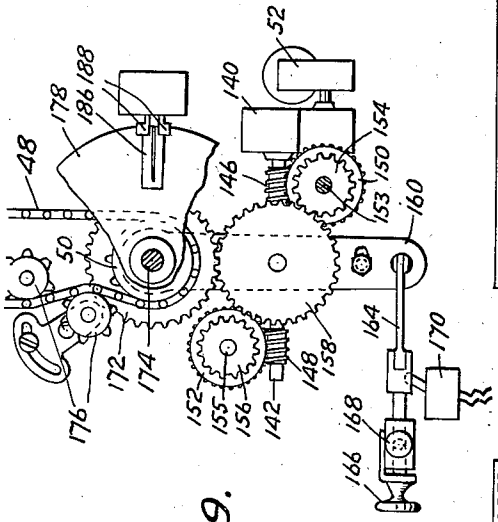



FIG. 9.

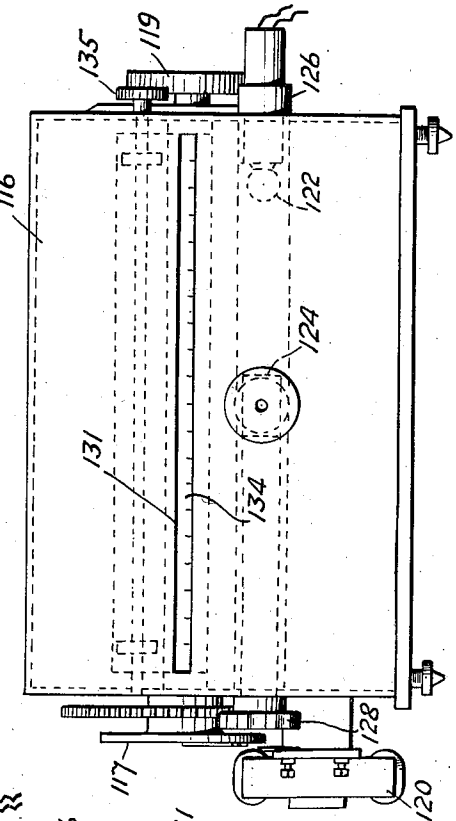



FIG. 7.

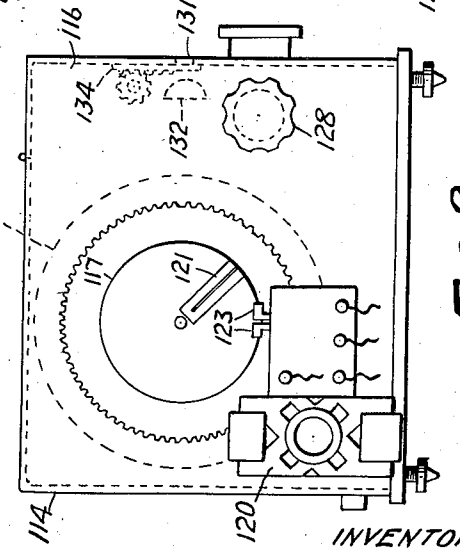



FIG. 8.

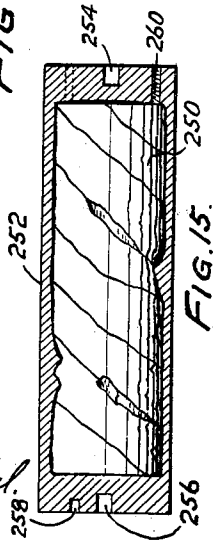



FIG. 15.

WITNESS:
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Oct. 15, 1940. J. M. PEARSON 2,217,768

APPARATUS FOR ORIENTING CORES

Filed Nov. 5, 1937 5 Sheets-Sheet 5

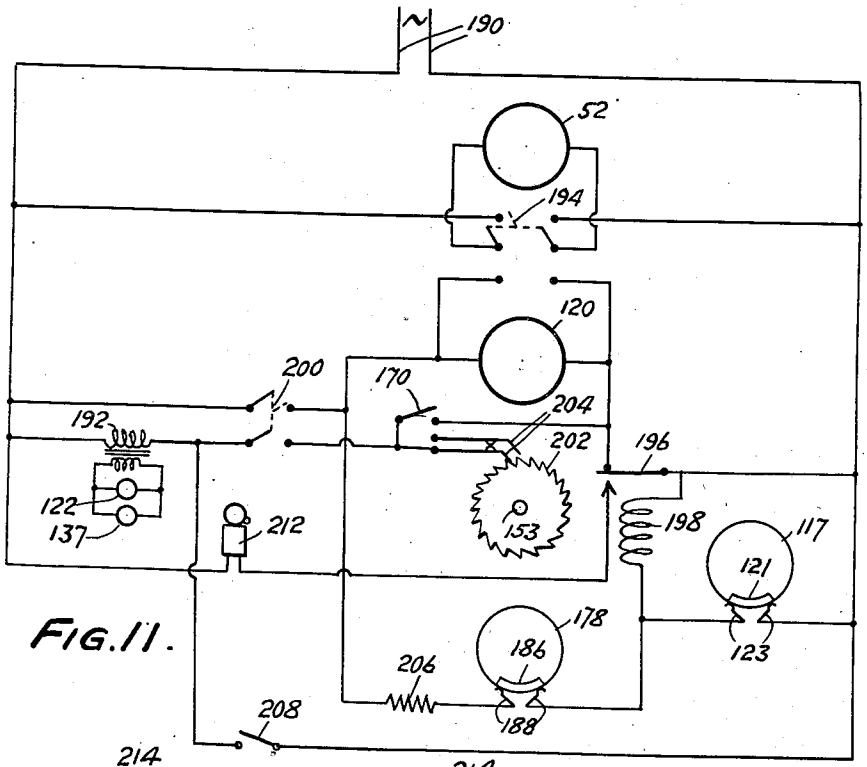



FIG. 11.

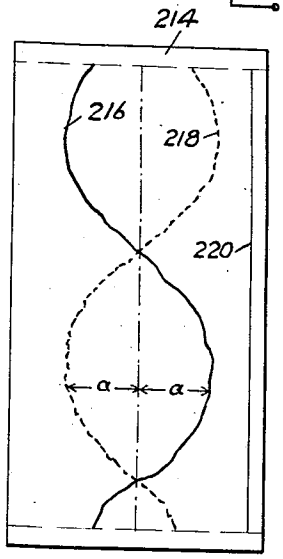



FIG. 12.

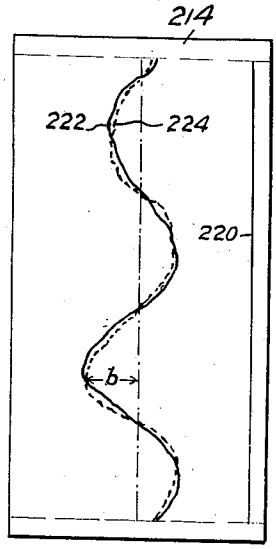



FIG. 13.

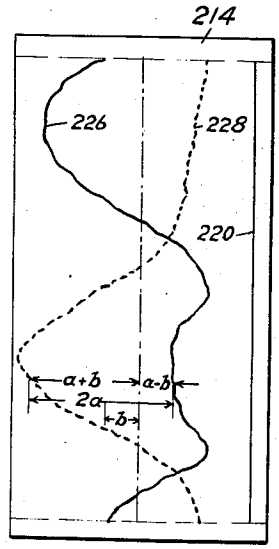



FIG. 14.

WITNESS:

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Patented Oct. 15, 1940

2,217,768

# UNITED STATES PATENT OFFICE

2,217,768

## APPARATUS FOR ORIENTING CORES

John M. Pearson, Swarthmore, Pa., assignor to Sperry-Sun Well Surveying Company, Philadelphia, Pa., a corporation of Delaware

Application November 5, 1937, Serial No. 172,988

7 Claims. (Cl. 175—182)

This invention relates to a method and apparatus for orienting cores by the determination of the magnetic characteristics thereof.

As described, for example, in Herrick Patent 1,792,639, dated February 17, 1931, it is possible to determine to a fair degree of accuracy the dip and strike of strata penetrated by a bore hole if measurements are made to ascertain the magnetic polarization of a core taken at the location of the strata.

The assumption borne out by observations is that in a magnetically polarized core the axis of polarization generally originally coincided in direction and sense with the earth's field and that in a core showing an axis of maximum susceptibility, that axis originally coincided in direction with the axis of the earth's field, though in the latter case the susceptibility axis is without sign.

In making such determinations, the magnetic polarity or axis of maximum susceptibility of the core may be determined by means of an apparatus of the type generally disclosed in said Herrick patent, which, briefly stated, constitutes a magnetometer capable of determining the magnetic north or susceptibility axis of the core. The magnetic polarity or susceptibility axis is marked on the core following the use of such apparatus, and by suitable measurements there can be then determined the apparent dip and strike of a bedding plane appearing in the core with respect to the magnetic north or susceptibility axis so indicated. Further calculations to determine the relation of dips and strikes to the earth may then be made, either numerically or by use of an apparatus such as that disclosed in my application Serial No. 146,739, filed June 7, 1937.

The present invention has two broad objects, first the improvement of apparatus for better determining the magnetic properties of cores and second an improved method of making determinations with such apparatus (including preparation of cores) whereby more thorough analysis of the magnetic properties of cores may be made than by methods heretofore used.

The improved apparatus may be briefly outlined as comprising an astatic magnet system, adjacent which the core may be mounted for slow rotation, together with a photographic recording means whereby movements of the astatic magnet system may be accurately recorded over a substantial period of time, the core rotating on its axis quite slowly in view of the delicacy and consequent long period of the magnet system. The objects of the invention relating to the apparatus are particularly concerned with various arrangements and details whereby the determinations may be carried out with a high degree of accuracy and particularly without influence due to extraneous magnetic fields. The invention also contemplates the provision in the apparatus of means for accurately supporting the core so as to provide for repeated observations consistent with each other. The accomplishment of these and other objects relating to the apparatus will become clear from the description which follows.

The primary object of the invention with respect to the method is to carry out measurements of the magnetic properties of cores in such fashion that the various magnetic properties may be individually determined and segregated from each other. In most cores it may be suspected that the magnetic properties might result first from definite polarization, secondly from a more or less uniform condition of anisotropic susceptibility which may exhibit itself as a general axis for the whole core and anisotropic susceptibility or polarization conditions, or both, resulting from local inclusions in the core of materials having magnetic properties differing substantially from the properties of the major portions thereof. If such a core is rotated about its axis through a single revolution below a suspended astatic magnetic system in which the axes of the magnets are generally parallel to the axis of the core, the deflection of the magnetic system as recorded on a sensitized paper in the type of apparatus hereinafter described will be an irregular line probably having more or less sinusoidal form. Such a line constitutes a rather uninterpretable record of the sum of the various properties of the core. In accordance with the present invention a second record is made by turning the core end for end and rotating it under the magnetic system, preferably (for simplicity of graphical calculation) in a direction opposite its former rotation. There is thus obtained another curve which, in general, may have little resemblance to the one first obtained. From the two curves, however, polarization effects may be readily segregated from the effects of anisotropic susceptibility, and in each of the sub-divisions of these effects there may be rather readily segregated those portions of the effects which are of interest from those which are strictly characteristic of the particular core and not of interest. This latter analysis is particularly true if runs are made on a series of cores taken close to each other in the same portion of the bore hole. Furthermore, by tak-

ing proper precautions in making the determinations, other matters of interest are deducible.

The various objects of the invention relating to the preparation of cores and the making of determinations and details of both methods and apparatus will be apparent from the following description read in conjunction with the accompanying drawings in which:

Figure 1 is a side elevation, partly in section, showing the general layout of the improved apparatus;

Figure 2 is an end view of the same, also partially in section, to show details;

Figure 3 is an enlarged sectional view showing details of the core raising mechanism;

Figure 4 is a vertical section showing the construction of a micrometer used to accurately locate a core with respect to the suspended magnetic system;

Figure 5 is a vertical elevation with certain parts in section, showing an improved core holding device;

Figure 6 is an end view of the same;

Figure 7 is a front elevation showing the improved recording camera;

Figure 8 is a side elevation of the same;

Figure 9 is a fragmentary view, partially in section, showing the driving mechanism for the core;

Figure 10 is a section of the same on a vertical plane;

Figure 11 is a wiring diagram illustrating the interconnections between various portions of the apparatus;

Figures 12, 13 and 14 are diagrams showing the types of records obtained in the apparatus, and their mode of analysis;

Figure 15 is a vertical section illustrating one method of preparing cores for determinations; and

Figure 16 is a diagrammatic illustration of an alternative method of making determinations.

Referring first to Figures 1 to 4, inclusive, the various portions of the apparatus are illustrated as supported upon a sturdy table 2 arranged to prevent vibration to a maximum degree, and preferably carefully leveled to properly support a magnetic system. This table carries a magnetic shield 4, for example, of steel of considerable thickness, provided with a window at its lower end of sufficient size to permit entry of a core and its holder. Fixed in the upper portion of this shield is a magnetometer housing 6 consisting of a torsion wire enclosing tube and a lower damping housing 8, both formed of non-magnetic material. Within this housing there is located a pair of bar magnets 10 and 12, of equal dimensions and supported upon a suitable mounting carrying a mirror 14, the whole structure being supported by a torsion wire of suitable length adjustable about its axis by means, generally indicated at 18, of the type usually provided on sensitive galvanometers. Such suspensions for astatic magnetic systems are well known and need not be further described. Windows are provided in the housing 6 and the shield 4 opposite the face of the mirror.

Extending downwardly through the table is a tube 20 in which is slidably mounted a tube 22 carrying a core holder and counter-balanced by weights 24 supported by pulleys 26. A rack 28 carried by the tube 22 acts as a spline with respect to the bearing portions of the tube 20 to prevent rotation of tube 22 about its axis. The teeth of this rack mesh with a pinion 30 adapted to be driven by a hand wheel 34 through a shaft 32 arranged to be clamped in fixed position by clamping means 36, actuated by a clamping screw 38. The parts just described are accurately arranged so as to definitely align a core carried by the holder with respect to the magnetic system.

The core holder is shown in detail in Figures 5 and 6. The tube 22 at its upper end carries a base plate 40 at one end of which there is located a standard 42 in which is journalled a sleeve 44 carrying a sprocket 46. Over this sprocket is trained a chain 48 which extends downwardly through the table and passes about a sprocket 50 arranged to be driven by a motor 52 through reduction gearing, as hereafter described.

The core holder proper, which is removable from base plate 40, comprises a base 54 on which are adjustably mounted two standards 56 and 58. The former of these has journalled in its upper end a face plate 60 provided with an axially extending pin 62 adapted to enter a hole formed in one end of a core C. The second standard 58 is provided with a face plate 64 carried by a shaft 66 which is slotted, as indicated at 68, to receive a key carried by the sleeve 44 with the result that the shaft 66 and the face plate 64 are rotated with the sprocket 46. Due to the key and slot construction, the shaft 68 is removable lengthwise from the sleeve 44. The face plate 64 carries not only a central pin 70 corresponding to the pin 62, but in addition an eccentric driving pin 72 arranged to engage an eccentric hole in the core C and thereby drive the same.

In order to clamp the standards 56 and 58 in fixed position they are provided, respectively, with headed members 74 and 76, arranged to slide in a T-slot 78. Handles 80 and 82 are connected to transverse pins having eccentric portions engageable within openings in the members 74 and 76 so that manipulation thereof will effect clamping and definite location of the standards in fixed position. Each of the standards is provided with key members 84 engageable within the narrow portion of the T-slot 78 for accurate guidance. The base 54 is adapted to be maintained accurately fixed relative to the base plate 40 by having holes therein arranged to engage pins 86 carried by the standard 42 and by being arranged to be clamped on the base plate by means of a clamping screw 88.

The base 54 is provided with a tubular standard 90 having a split portion at its upper end arranged to be clamped by a collar and clamping screw arrangement 94 upon an anvil member 96. This anvil member is adjustable to a definite height, preferably that of a horizontal plane tangent to the upper side of the core and is arranged when the core is located adjacent the magnetometer to abut the lower end of a micrometer screw 98, the longitudinal position of which is determined by the relationship of a head 100 with respect to the supporting nut 102. By the proper location of the anvil with respect to the core and the adjustment of the micrometer screw, the position of the core with respect to the magnetic needles is determined to a high degree of accuracy.

It is also important that the core should be arranged symmetrically with respect to the axis of suspension of the magnets. To attain this end tapped holes 104 are located in the base 54 to receive screws holding a block 106 against the

base 54. Pivotally mounted in the block 106 is a blade 108 adjustably clamped by a screw 110 and provided with a point 112 adapted to be located in close proximity with the surface of the core C. The standards 56 and 58 are adjusted with the core between them until a line representing the center of the core between its end faces is lined up with the point 112. After the core is clamped in such adjusted position, the blade 108 may be removed.

All of the various parts associated with the core holder must be free of all traces of magnetic material. This remark applies not only to the various parts illustrated in Figures 5 and 6, but the driving chain 48 as well. Freedom from magnetic materials may be readily determined by a test run with a non-magnetic dummy core. If magnetic materials are present even in minute quantities noticeable deflections of the magnetometer will be observed.

The recording camera is generally illustrated at 114 and in greater detail in Figures 7 and 8. It comprises a light-tight box 116 in which is mounted a drum 118 arranged to receive a sheet of photographic paper which is clamped by a clamping member extending lengthwise of the drum. The drum is driven through reduction gearing by means of a synchronous motor 120 and its shaft is provided with an insulating disc 117 carrying conductor 121 adapted to engage and thereby connect with each other contact members 123. The object of this arrangement will be described hereafter. A knob 119 is connected to the drum and serves to move it, with the disc 117, relative to its driving gearing which is provided with a slipping connection therewith. The knob 119 is preferably provided with a pointer moving adjacent a fixed scale so that the position of the drum may be readily determined.

Illumination for the magnetometer recording is provided by means of a lamp 122 carried within a tube 126 extending transversely across the camera box 116 and arranged for angular adjustment by means of a knob 128. Adjacent the central portion of this tube and mounted within the same is located a reflecting prism 124 arranged to reflect a beam of light from the lamp to the mirror 14 through an aperture in the box 116. A lengthwise extending opening 131 is provided in the camera box and is adapted to be covered by a shutter 134, which is normally in position closing the box against the entrance of light, and when in such position, renders visible a scale carried by it to facilitate adjustment by observing the position of a spot of light thereon. When a record is being made, this shutter is manually raised by manipulation of knob 135, so that the beam may enter the box.

The optical system is of substantially conventional form. The beam of light from the prism 124 passes through a lens 130 (Figure 1) to the mirror 14 by which it is reflected back through the lens 130 and through the slot 131. The lens 130 is a cylindrical lens having its axis vertical and is of such focal length that the beam of light in traversing it twice would be focused to a very thin vertical line at the position of the paper on the drum 118. However, there is placed behind the slot 131 a long cylindrical condensing lens 132 having a horizontal axis. This condensing lens is of short focal length and serves to reduce the thin vertically extending beam which impinges upon it to a fine and very intense point of light on the sensitized paper. As a result of this arrangement, it will be obvious that with the shutter closed there will appear on the scale of the shutter a vertical line, and adjustments may be made using this spot as a guide to the condition of the instrument. When the shutter is open a corresponding point of light is projected upon the paper.

Inasmuch as a single determination may take a time of the order of one-half to two hours, the apparatus is preferably made as automatic as possible in order to avoid the necessity for constant attendance. Furthermore, adjustments must be possible and for this reason there are provided certain details, as illustrated in Figures 9 and 10 and the wiring diagram of Figure 11.

The apparatus for driving the core through the chain 48, briefly referred to heretofore, is illustrated in greater diagrammatic detail in Figures 9 and 10. The motor 52 drives through reduction gearing, indicated at 140, a shaft 142 carrying worms 146 and 148. These worms mesh, respectively, with worm wheels 150 and 152, respectively, secured to shafts 153 and 155, to which are secured pinions 154 and 156. A gear 158, journalled on a pin carried by a lever 160 is adapted to mesh selectively with the pinions 154 and 156 when the lever 160 is swung into alternative positions about a boss 162 carried by a portion of the frame which mounts these elements, and at the lower end of the tube 22. The adjustment of the lever and its alternative positions is effected by means of a link 164 joining it to a manually operable knob 166 which may be held in its adjusted position by a clamping screw 168. The knob 166 is operatively connected to the actuating lever of a switch 170 which is arranged to be closed when the lever 160 is in one position and opened when the lever 160 is in its other position.

The gear 158 meshes with a gear 172 which is keyed to a shaft 174 mounted in the boss 162 and held against axial movement with respect thereto. The sprocket 50 is journalled on the shaft 174 to freely turn thereon, and about it is trained the chain 48 which is held taut by an adjustable idler arrangement of sprockets, indicated at 176. Splined to the shaft 174 there is the hub of a disc 178 of insulating material adjacent which and surrounding the shaft 174 is a spring 180 adapted to be compressed against the disc through the medium of a collar 182 and a cam lever 184, pivoted to the outer end of the shaft 174. When the cam 184 is in the position shown in Figure 10, the spring is relieved of compression and the sprocket 50 may turn freely about the shaft 174 so that the position of the core may be adjusted independently of the driving gearing. On the other hand, if the cam lever 184 is moved outwardly, the spring 180 is compressed, clamping the sprocket wheel 50 between the gear 172 and the disc 178 and thus causing it to be driven by the gear.

The disc 178 carries a bridging conductor arrangement 186 adapted to connect contacts 188, thereby forming a switch. This arrangement is similar to that heretofore described and comprising the elements 121 and 123.

Referring now to the wiring diagram of Figure 11, various elements heretofore mentioned will be recognized therein. Power for the entire system is derived from an alternating current line 190. In view of the fact that both the core driving motor 52 and the camera driving motor 120 are synchronous motors driven from this same line, it is obvious that the rotation of the core and camera drum will accurately correspond. How-

ever, the core and the camera drum are not driven at the same rotary rate. When the core makes a complete revolution the camera drum turns through only 350 degrees. In such fashion, a record corresponding to a complete rotation of the core is confined to a clear portion of the photographic paper on the camera drum, 10° being allowed for the overlapping and clamping of the paper thereon. Desirably, the scale heretofore referred to in connection with the knob 119 is graduated in terms of core positions rather than drum positions. In other words, 350° is graduated to correspond to 360° of the core rotation.

The contact members 186 and 121 of the discs 178 and 117, respectively, are also arranged to correspond with each other. The former, which may be designated the magnetometer limiting switch is so related to the contacts 188, which are conventionalized in Figure 11, as to short these contacts between 359° and 1° of a core revolution. The zero position of a core should correspond to a mid position of this shorting contact. The camera limiting switch, on the other hand, is so arranged that the conductor 122 shorts the contacts 123 between 355° and 5° of the camera drum rotation.

The electrical relationships of the various parts will be generally clear from the wiring diagram of Figure 11 without detailed description. A double pole double throw switch 194 is so arranged that the motor 52 may be driven for adjustment and testing purposes independently of the motor 120 or simultaneously therewith, while both are under control of the relay contact 196, arranged to be opened through energization of the relay coil 198. When opening of the motor circuits takes place due to energization of the coil 198, a contact is made to energize a warning bell 212, which indicates to an attendant that the determination has been completed.

A transformer 192 supplies the low voltage for the energization of the lamp 122 and also for a lamp 137 which, though not shown in Figure 7, is arranged to produce a trace down one side of the photographic paper so as to give an indication of the proper position of the paper when interpretations are made. A switch 200 serves to control various circuits, as indicated.

Mounted on the shaft 153 there is a toothed cam member 202, adapted to control a quick make and break switch 204. The arrangement is such that during rotation of the cam member 202 contact is made for short periods and broken for still shorter periods so as to produce a dotted record on the photographic paper. The switch 170 referred to heretofore and illustrated in Figure 9 is arranged to short the contacts 204 during a forward run, so that the record made during a forward run will be a continuous, unbroken line, while during a reverse run, a dotted line will be produced.

Additionally, on the wiring diagram there will be noted a protective resistance 206 and a switch 208 serving to energize the lamps 122 and 137 independently of the rest of the apparatus.

In the use of the apparatus, the core is first carefully prepared, for example, by having its cylindrical face turned down and its ends ground at right angles to its axis with due precaution to avoid the inclusion in the core of any magnetic materials such as iron chippings or the like. The core thus prepared is mounted in the holder, illustrated in Figures 5 and 6, and centered in predetermined position by means of the member 108. There is also marked on the core a zero indication from which angular reference about the axis may be made.

An alternative mode of preparation of the core for mounting in the apparatus is illustrated in Figure 15. It sometimes happens that cores as obtained from a core barrel are broken and may have rather irregular surfaces, breaks and hollows occurring along or adjacent to the lines of separation of the various strata. The cores in such cases may be rather fragile and even though major breaks are mended by the use of a magnetically neutral adhesive, such as casein glue, there may be danger of breakage if the core is subjected to turning and boring preparatory to mounting.

Additionally, there may be some question of demagnetization or magnetization in a strong electric field such as that of the earth if the core is subjected to much shock during its preparation. The turning accomplished by a grinding wheel may possibly affect its magnetic properties, and the same is true of the provision of holes at the ends for mounting purposes. These various difficulties may be avoided by encasing the core in a plaster of Paris cylinder in such fashion that the core itself is not subjected to any appreciable vibration. The core in such case, after cementing with glue if that is necessary, may be sand blasted to remove from its surface any particles of magnetic materials which it may be carrying accidentally. The use of a sand blast, in view of the extremely small mass of the particles of sand, does not appreciably vibrate the core to such extent as to affect its magnetic properties. Following such sand blast, the core is set upon end upon three adjusting screws threaded into a baseboard. By the adjustment of these screws the axis of the core may be brought to accurate perpendicularity with respect to the base, whereupon it is surrounded concentrically by an internally smooth cylindrical mold and surrounded by plaster of Paris, which is permitted to set. The mold may then be removed and the adjusting screws threaded out of the plaster of Paris with the result that there remains a smooth cylindrical surface concentric with the axis of the core. The plaster of Paris ends may then be bored to receive the mounting and driving pins. Figure 15 illustrates a core 250 which is shown as involving various surface defects. This is surrounded by the case 252 of plaster of Paris, which is bored at 254, 256 and 258 to receive the mounting and driving pins. The screws on which the core was originally supported will leave holes, as indicated at 260, but these are of no consequence. The plaster of Paris is so soft that the mounting and driving holes may be formed therein without any substantial vibration of the core.

When the core and its holder are located on the member 40 with the shaft 66 splined to the sprocket 46, the core may be located in predetermined relationship with the magnetic system, the lamp 122 turned on and the core rotated by hand manipulation of the chain 48 to determine whether the position is such that the beam of light will remain on the scale 134 during the complete revolution and also that the beam is properly centered. Centering may be effected through the manipulation of the adjustment 18 for the magnet suspension, while if greater or less sensitivity is desired the support may be lowered, the micrometer reset and the core again brought into the position determined by the new setting of the micrometer. In general, it is desirable that

the throw of the beam of light on the scale should be the maximum consistent with maintaining it within the scale limits.

Such adjustments having been effected, and photographic paper located on the drum 118, a zero line is traced by hand rotation of the camera drum with the elevator lowered, switch 208 being closed. The drum is then brought to its zero position with the respective contacts 121 and 123 centrally located with respect to each other and adjustment is also made in the driving arrangements, indicated in Figures 9 and 10, to secure a correspondence of the zero position of the core and the location of the contacts 186 and 188, as shown in Figure 9. The gear 158 is meshed with the gear 154 to produce a forward rotation of the core with the result that the switch 170 is closed to short circuit the dotting switch 204. The room containing the apparatus may then be darkened and the shutter 134 raised to expose the paper through the slot 131.

With the switch 194 in its lower position, the switch 200 is closed, initiating the operation of the apparatus. At the time of this initiation of the operation, it will be noted that the contacts of both the magnetometer and camera limit switch will be closed. The contacts of the camera limit switch 117 short circuit the relay coil 198 so that the latter will not attract its armature 196, and the switch 200 will, therefore, initiate rotation of both motors 42 and 120 and will also energize the transformer 192, the switch 208 being open at this time. The resistance 206 prevents a short circuit of the line. Switch 123 opens its circuit before switch 188 opens its circuit so that the operation is not stopped.

As the core rotates, the magnet system will be deflected causing a spot of light to move across the sensitized paper on the camera drum and thus trace a record. At the same time, the lamp 137 produces a mark serving to indicate the right side of the photographic record. The core is preferably very slowly driven in order that the magnets may follow it and in order that temporary jarring of the beam of light due to causes other than the magnetic conditions of the core will fail to record because the exposures corresponding to them will be very short. Since the dotting switch is shorted a solid line record will be made.

When the core has rotated 359° the contact 186 will bridge the contacts 188. At the same time, however, the contact 121 will not have bridged the contacts 123 because the camera will have rotated only about 349°. Accordingly, the relay 198 is energized, opening the motor and lamp circuits and at the same time energizing the warning bell 212. The operator will then close the shutter 134, thus ending the record of the forward run.

The core is then removed from its support, turned end for end and replaced in the same position relative to the magnets as before, this position being determined accurately by the micrometer. The gear 158 is then meshed with the pinion 156 and the core and camera drum reset in their zero positions as before. Simultaneously with the adjustment of the gear 158, the switch 170 is opened. The shutter 134 may now be raised and the switch 200 closed to provide a reversed rotation of the reversed core. The record at this time will be dotted by reason of the interruption of the lamp circuit by the switch 204, and consequently may be later distinguished from the record produced during the forward run. Automatic stopping takes place as before.

After development of the paper on the drum 118, the curves thereon may be interpreted to secure the desired information relative to the magnetic characteristics of the core. Figures 12, 13 and 14 indicate the types of records which may be obtained and their interpretation, though it will be understood that individual cores will show peculiar results in the curves made therefrom which may have special significance.

Consider first the record illustrated in Figure 12, made on a sheet 214. As illustrated, this record would be of the type obtained from a core showing polarization only and in which the polarization was fairly uniform. The record made during the forward run is indicated at 216 and that during the reverse run at 218. The line 220 is the line traced by the lamp 137 during both runs.

With a core of the type just mentioned the two curves will be substantially symmetrically located about the mean axis. Theoretically, if uniform polarization existed a smooth sinusoidal curve would result from both runs and the two would be identical in shape but located oppositely on the paper. The irregularities normally obtained are due to lack of symmetry in the polarization. If polarization alone is present, the curves will intersect each other at the central axis and will exhibit a single cycle on the record sheet.

Figure 13 illustrates the type of record which would be produced from an unpolarized core, but one exhibiting anisotropic susceptibility only. If the anisotropic susceptibility was of a uniform nature, exhibiting a definite axis throughout the core, the curve to be expected on a record such as that of Figure 13 would be a smooth sinusoidal curve consisting of two cycles on the length of the record. Furthermore, the records formed during the forward and reverse rotations would coincide. Actually, due to local irregularities, non-coincident records, as indicated at 222 and 224, will be produced, while, furthermore, the curve will not exhibit sinusoidal symmetry about its axis due to lack of symmetry of its anisotropic susceptibility about any axis.

The two records so far discussed are rather more theoretical than actual. Actually, both polarization and susceptibility are most likely to be present. To exhibit the type of record obtained in such a case, and in order to make it comparable with the others, there is illustrated in Figure 14 the type of record which would result if a single core had the polarization which would give rise to Figure 12 if it existed alone, and the anisotropic susceptibility which would give rise to Figure 13 if that existed alone. It will be noted that in the case of Figure 14, the forward and reverse curves 227 and 228 bear no recognizable relationship to each other. However, these two curves taken together may be interpreted to give separate information relative to polarization and anisotropic susceptibility. Consider, for example, the spacing of the curves transverse to their axis at any particular point, as, for example, at the point indicated in Figure 14 where this spacing is $2a$. One-half of this spacing, namely, $a$, is the corresponding deviation from the axis due to polarization. On the other hand, the quantity $b$, representing the deviation from the axis due to anisotropic susceptibility may be readily determined by noting the deviation from the axis of the center point

of the line indicated at 2a in Figure 14. The figures will make clear how the two results superimpose to produce the record of Figure 14, and how that record may be analyzed to give the deviations due to the two causes. By plotting from Figure 14 the curves such as those in Figures 12 and 13, which are deducible from Figure 14, there may be obtained the still further information which may be derived from the irregularities and lack of symmetry of these curves. For example, a small inclusion of a particle of magnetic material may, if the material is polarized, exhibit itself by a sharp deviation from smoothness of either one or both of the derived curves.

It will be noted that the careful marking of the core to indicate its zero position will enable the record to be correlated with the core in such fashion that there may be marked on the core or tabulated for it the various magnetic and susceptibility axes and the like which may be of interest for the purpose of interpreting the conditions of the sub-surface where the core was taken. Desirably, to determine conditions in any local region, a number of cores from that region should be examined so that in the interpretation only the factors common to that region may be given weight and proper disregard taken of the properties which are solely characteristic of the individual cores. As indicated above, the principal matter of interest is to determine the polarization axis or the axis of maximum susceptibility which may be deduced to lie in the general direction of the magnetic field of the earth. The orientation of strata shown in the cores may be deduced therefrom.

In Figure 16 there is illustrated an alternative arrangement for securing the type of information indicated above. In this case, the astatic magnetic system supported by a suspension wire **250** comprises magnets **252** and **254**. A core **256**, located as illustrated, with its axis substantially parallel to the axis of the suspension, may be rotated to produce a first trace on the record sheet. The core is then moved to the position indicated at **256'** so that its axis is located at a distance from the axis of suspension the same as before with the core at the same vertical height with respect to the magnetic system and at the same distance as before from the lower magnet and similarly spaced from the opposite end of the magnet. If the core in the position **256'** is on the same side of the magnet **254** as in the position **256**, its rotation should be in the opposite direction to secure records of the types indicated in Figures 12 to 14. On the other hand, if it is on the opposite side of the magnet, its direction of rotation should be the same in both cases. Under these circumstances, the results will be of the same general type as those described heretofore, and a similar analysis may be made.

What I claim and desire to protect by Letters Patent is:

1. In combination, a suspended magnetic system, means for mounting a core from a bore hole for rotation about an axis perpendicular to the axis of suspension of said system, means for providing a photographic record of deflections of said system, means for rotating in both directions a core so mounted, and means for distinguishing records of deflections produced during rotation of a core in one direction from those produced during rotation of the core in the opposite direction.

2. In combination, a suspended magnetic system, means for mounting a core from a bore hole for rotation about its axis adjacent to said system, means for providing a photographic record of deflections of said system, means for rotating in both directions a core so mounted, and means for distinguishing records of deflections produced during rotation of a core in one direction from those produced during rotation of the core in the opposite direction.

3. In combination, a suspended magnetic system, means for mounting a core from a bore hole for rotation about an axis perpendicular to the axis of suspension of said system, means for providing a photographic record of deflections of said system, means for rotating in both directions a core so mounted, and means for distinguishing records of deflections produced during rotation of a core in one direction from those produced during rotation of the core in the opposite direction, the last named means being automatically controlled by reversal of the direction of rotation of the core.

4. In combination, a suspended magnetic system, means for mounting a core from a bore hole for rotation about its axis adjacent to said system, means for providing a photographic record of deflections of said system, means for rotating in both directions a core so mounted, and means for distinguishing records of deflections produced during rotation of a core in one direction from those produced during rotation of the core in the opposite direction, the last named means being automatically controlled by reversal of the direction of rotation of the core.

5. In combination, a suspended magnetic system, means for mounting a core from a bore hole for rotation about an axis perpendicular to the axis of suspension of said system, means for providing a photographic record of deflections of said system, means for rotating in both directions a core so mounted, and means for distinguishing records of deflections produced during rotation of a core in one direction from those produced during rotation of the core in the opposite direction, the last named means acting by periodically interrupting a recording beam of light during rotation of the core in one direction.

6. In combination, a suspended magnetic system, means for mounting a core from a bore hole for rotation about its axis adjacent to said system, means for producing a photographic record of deflections of said system, means for rotating in both directions a core so mounted, and means for distinguishing records of the deflections produced during rotation of a core in one direction from those produced during rotation of the core in the opposite direction, the last named means acting by periodically interrupting a recording beam of light during rotation of the core in one direction.

7. In combination, a suspended magnetic system, means for mounting a core from a bore hole for rotation about an axis perpendicular to the axis of suspension of said system, and means carrying said mounting means for movement towards or from said system, the mounting means being removably slidably mounted with respect to said carrying means at right angles to the direction of said movement towards or from said system.

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