Dec. 13, 1966 D. E. WINKEL 3,291,226

APPARATUS AND MATERIAL FOR CORE ORIENTATION

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Fig. 1.

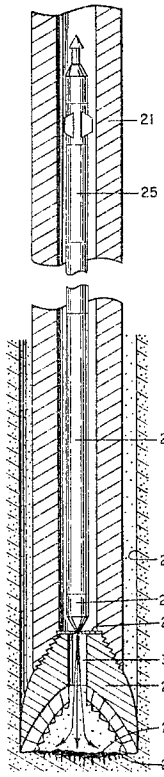



Fig. 2.

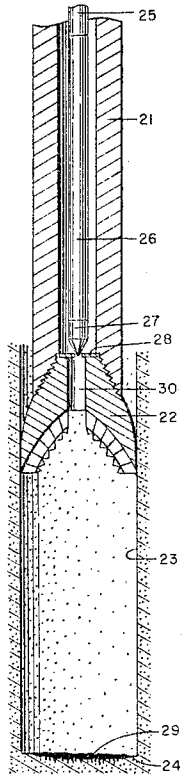



Fig. 3.

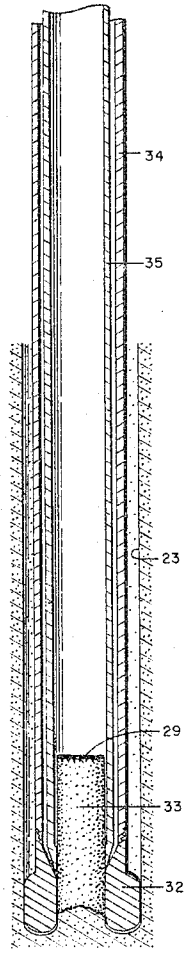
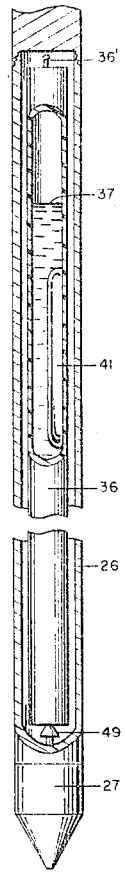



Fig. 4.



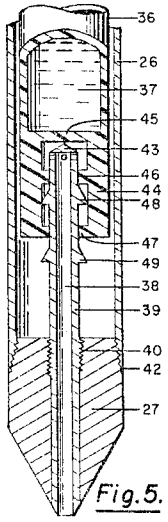




Fig. 5.

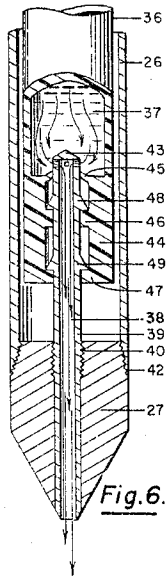



Fig. 6.

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APPARATUS AND MATERIAL FOR CORE ORIENTATION

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Fig. 7.

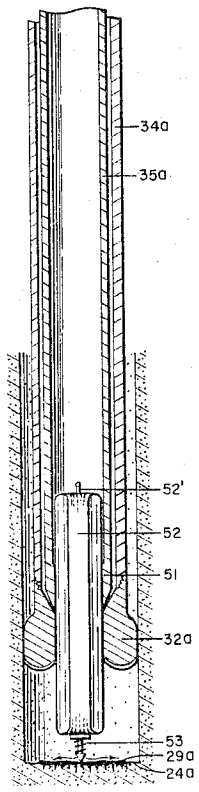



Fig. 8.

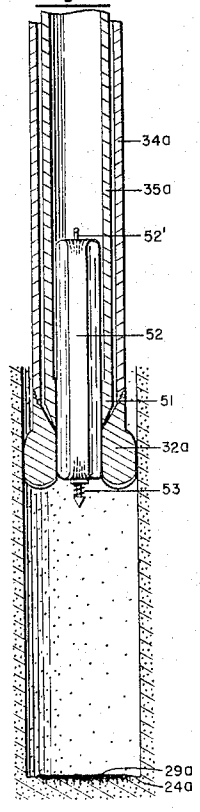
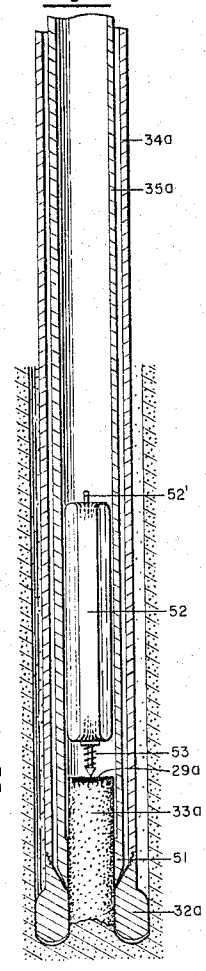



Fig. 9.



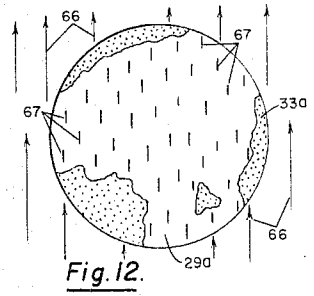




Fig. 12.

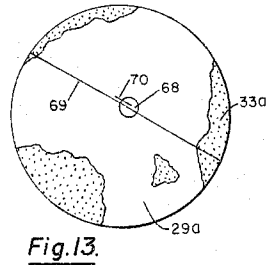



Fig. 13.

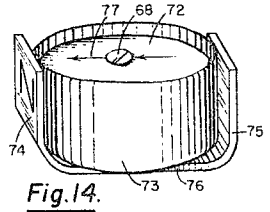



Fig. 14.

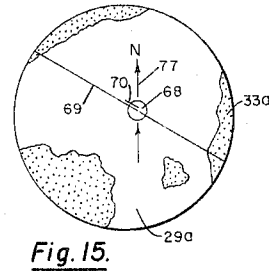



Fig. 15.

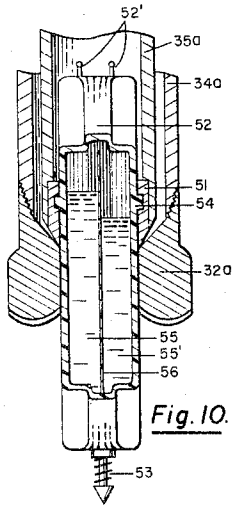



Fig. 10.

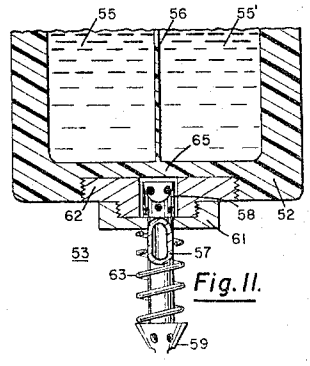



Fig. 11.

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APPARATUS AND MATERIAL FOR CORE ORIENTATION

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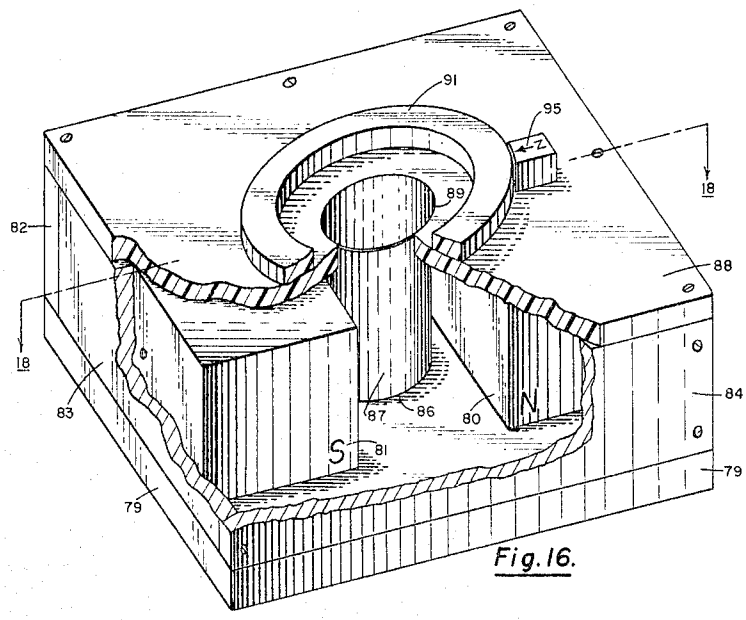



Fig. 16.

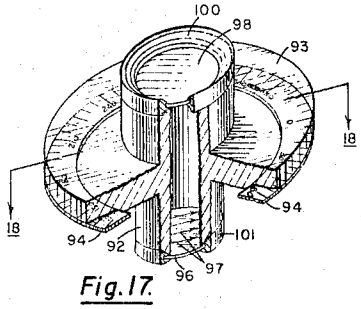



Fig. 17.

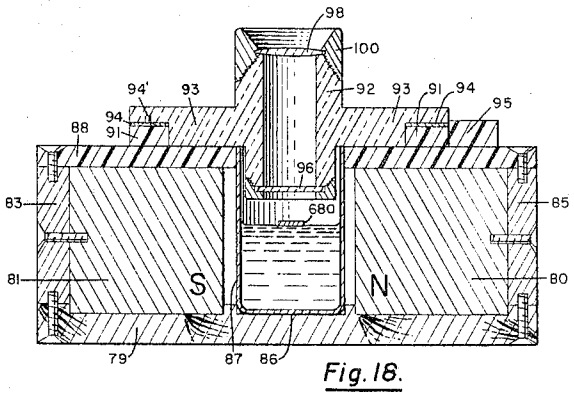



Fig. 18.

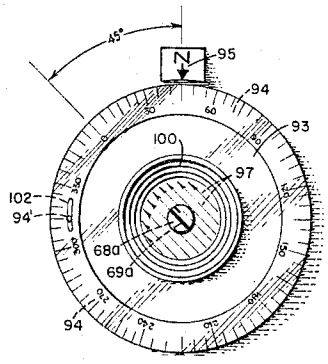



Fig. 19.

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APPARATUS AND MATERIAL FOR CORE ORIENTATION

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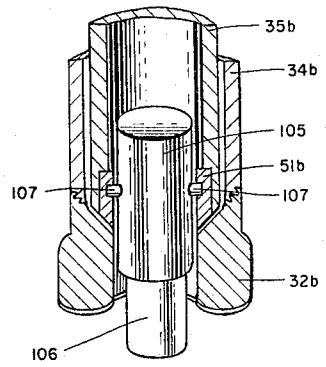



Fig. 20.

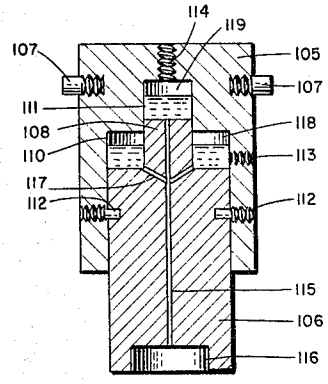



Fig. 21.

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Dec. 13, 1966 D. E. WINKEL 3,291,226

# APPARATUS AND MATERIAL FOR CORE ORIENTATION

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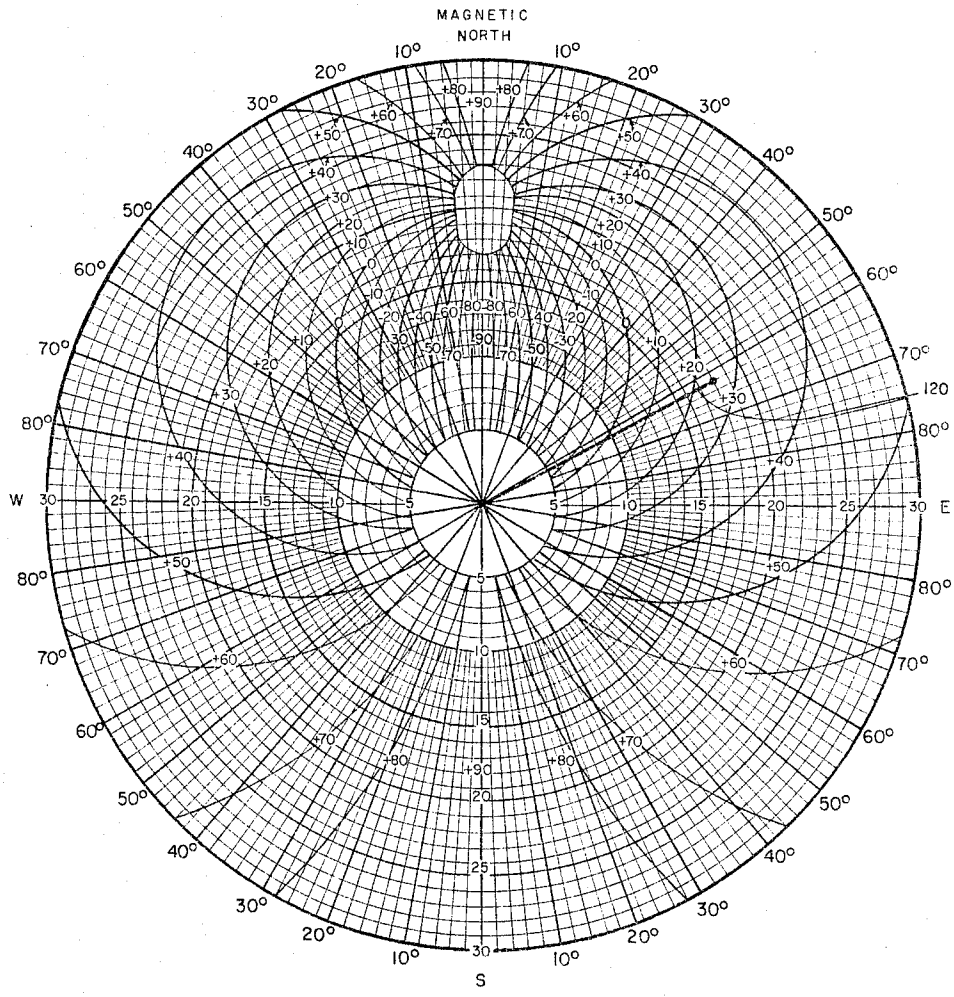



Fig. 22.

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United States Patent Office 3,291,226
Patented Dec. 13, 1966



3,291,226

# APPARATUS AND MATERIAL FOR CORE ORIENTATION

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Filed Dec. 24, 1964, Ser. No. 421,062
15 Claims. (Cl. 175—44)

This invention relates to the determination of the orientation of core samples taken from the earth's crust and particularly to apparatus and materials for utilizing the earth's magnetic field in making such determination. This application is a continuation-in-part of my copending application Ser. No. 24,924, filed Apr. 27, 1960 for Core Orientation.

Core drilling is employed in various fields and particularly in the mining and petroleum industries in order to secure samples of the earth's crust at predetermined depths to secure subsurface geological data for the purpose of analysis and study. Full knowledge of the characteristics of a subsurface formation can be obtained only if the precise location and orientation of the core sample before it was taken can be determined. Many devices, methods and techniques have been employed for this purpose. Some are complicated and time-consuming, some are of limited accuracy, and others have not been entirely satisfactory for various reasons.

Some of these methods for core orientation have utilized the earth's magnetic field in effecting the determination of the position of the core sample. One such method employs cementitious material in a fluid state having finely divided particles of ferromagnetic material mixed therein, the mixture being deposited in a small cavity drilled in the bottom of the bore to be cored. While the mixture is still in a fluid state, the particles align themselves with the earth's magnetic field and are then locked in their position of alignment upon solidification of the cementitious material. Thereafter the core is drilled and taken with the body of solidified mixture remaining in position in the cavity at the top of the sample and a magnetometer is employed to determine the polarity of the magnetic particles in the core.

The present invention provides novel material and apparatus constituting improvements on the material and apparatus of the type for determining the orientation of core samples by employing a fluid mixture of solidifiable material and magnetic particles.

It is an object of this invention to provide an improved material comprising a mixture of solidifiable liquid and fine magnetizable particles for location on and adherence to rock and rock-like structures.

It is another object of this invention to provide an improved device for emplacing a solidifiable magnetic mixture on a well bottom or other remotely located surface.

It is another object of this invention to provide a device for emplacing a solidifiable mixture on a well bottom or other remotely located surface including an improved arrangement for utilizing the weight of the drill assembly for effecting such discharge.

Briefly, in carrying out the objects of this invention in one embodiment thereof a mixture of epoxy resin and finely divided ceramic magnetic material together with an agent for effecting solidification at the end of a predetermined period is provided and before use the ceramic particles are magnetized by subjecting them to a relatively strong magnetic field. The material is then lowered to the bottom of a well or drill hole and is discharged so that it spreads over the bottom and the drilling or emplacing equipment is then removed to take away any magnetic elements thereof. The magnetic particles in the liquid mixture then align themselves with the earth's magnetic field and at the end of the predetermined period the mixture solidifies, locking the particles in their aligned positions and affixing the solidified mass securely to the rock. The core sample is then taken with a drilled-out portion of the solidified mixture adhering tightly thereto.



At the surface the core sample is marked to provide an identifying line and a small fragment including an identifiable part of the marking is removed, floated on a liquid in a uni-directional magnetic field, and the direction of magnetization or polarity of the particles is determined. The core sample is then marked with the direction of the magnetic field indicating the direction of the North Magnetic Pole of the earth, this being determined by the known position of the fragment with respect to the core prior to its removal. One embodiment of the apparatus for depositing the solidifiable material on a well bottom comprises a charged container in which a mixture of resin and catalyst together with magnetic particles is prepared immediately before deposit and is then lowered into the bore. The container is constructed of flexible material such as plastic and a piercing device is provided which pierces the container by impact when the assembly strikes the bore bottom, thereby discharging the material. The assembly is then removed and the material allowed to harden.

In another embodiment the charged container is provided with two compartments, one containing the resin and the other the catalyst, and these are mixed on piercing and discharge, and in a further embodiment the liquids are contained within a rigid piston structure which strikes the bottom and actuates the piston to force the liquids outwardly onto the desired surface.

The features of novelty which characterize the invention are pointed out with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof may best be understood upon reference to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a sectional view of a well drill assembly at the bottom of the well in position during emplacement of liquid in accordance with the method employed with the apparatus of this invention;

FIG. 2 is a view similar to FIG. 1 showing the tool assembly withdrawn from position after emplacement of the liquid;

FIG. 3 is an illustration of the same portion of the well with the tool assembly removed and the coring bit in position during the coring operation;

FIG. 4 is an enlarged view of the liquid charged container employed in the equipment of FIG. 1;

FIG. 5 is an enlarged sectional view of the lower portion of the charged container in FIG. 4;

FIG. 6 is a view similar to FIG. 5 showing the container during discharge of the liquid;

FIGS. 7, 8 and 9 are views similar to FIGS. 1, 2 and 3, respectively, illustrating coring equipment provided with a liquid charged container embodying the invention shown during three steps in the method of the invention;

FIG. 10 is an enlarged view partly in section of the coring bit and container of FIG. 1;

FIG. 11 is an enlarged sectional view of the lower portion of the container;

FIG. 12 is a plan view of the bottom of the well bore having the solidified orientation material of the invention in position thereon and illustrating characteristics of the invention;

FIG. 13 is a view similar to FIG. 12 showing the top of the core after removal and illustrating a step in the method of the invention;

FIG. 14 illustrates a magnetic device for determining the orientation of particles in accordance with the invention;

FIG. 15 is a view similar to FIG. 13 illustrating the marking of a core in accordance with its determined orientation;

FIG. 16 is a perspective view partly in section of an instrument for facilitating the determination of the magnetic polarity of particles with a portion of the instrument removed for purposes of illustration;

FIG. 17 is a perspective view partly in section of the optical system and azimuth ring for the instrument of FIG. 16;

FIG. 18 is a sectional view along the line **18—18** of FIGS. 16 and 17 illustrating the optical system in position on the instrument;

FIG. 19 is a plan view showing the top of the instrument of FIG. 18;

FIG. 20 is an elevation view partly in section of the lower end of a core drill assembly showing a modified form of the liquid charge apparatus;

FIG. 21 is a sectional elevation view of the charge apparatus taken along the same central plane as that of FIG. 20; and

FIG. 22 is a chart for use in the method of the invention for determining the angular correction required for cores taken from deflected bores.

In the drawings the invention has been illustrated in connection with apparatus suitable for placing a charge of solidifiable liquid mixture including a dispersion of magnetic particles at the bottom of the well bore. The liquid is selected to solidify at the end of a known period of time and all magnetic materials are removed from the vicinity of the bottom of the well before the end of this time so that the magnetic particles in suspension in the liquid will align themselves only with the earth's magnetic field prior to solidification of the liquid. After solidification, a core sample is taken, the top end of the sample having the solidified liquid securely adhering thereto.

Various liquid mixtures may be employed in the apparatus of the invention and the particular mixtures and solidification times are selected depending upon the depth of the bore hole and the nature of the reservoir formation or rock surface on which the liquid is to be solidified and to which it must adhere securely when solidified. Coloring may also be added to facilitate recognition of the solidified liquid on the core. The solidified liquid must have the characteristics of adhering securely to the rock or other material to be cored. Various liquids are suitable for mixture with magnetized particles and may be selected depending upon the requirements of the specific application. It has been found that highly satisfactory results may be secured by employing epoxy resins with a polyamine as the cross-linking or solidifying agent; these resins have the property of wetting rock surfaces and are admirably suited for securing good attachment of the solidified material to the core. Furthermore, while various magnetic materials can be employed and give usable results, it has been found that ceramic magnetic materials commonly known as "ferrites" are especially useful in the practice of this invention. These ceramic magnetic materials have a high coercive force so that after being magnetized they cannot be demagnetized or remagnetized easily and thus provide substantially permanent records of their alignment after solidification of the liquid. Furthermore, the density of the ceramic materials is substantially lower than that of metallic magnetic substances such, for example, as iron and alnico particles, and as a result the ceramic materials provide magnetic particles which do not settle as readily in the liquid and therefore may be kept more uniformly distributed in the liquid and provide more uniform and reliable results. Furthermore, the ceramic materials are easily powdered and are particularly suitable to use in a finely divided state which provides the added advantage of greater sensitivity to alignment.

The nature, size and concentration of the magnetized particles are, as indicated, varied to meet the particular drilling conditions. For some applications the particles may be of visible size and may be sufficiently large for direct observation; for the purpose of direct observation the particles may be suitably colored or otherwise marked and relatively large particles may be marked by color or shape to indicate their polarity. However, for most of the applications herein contemplated, the particles will be of small size and direct visual observation of their orientation is not required.

In order to secure accurate and reliable placement of the liquid mixture at the bottom of the well to be cored, charged containers are provided which include the solidifiable liquid and the magnetizable particles mixed therein. The container may be charged with a gas under pressure; in another embodiment the liquid is contained in a chamber having a piston therein and is discharged by pressure produced by movement of the piston upon landing of the drill apparatus. When liquids such as epoxy resins are employed, the solidifying or cross-linking agent such as a polyamine may be isolated within the charged vessel by a frangible capsule or diaphragm which may be broken at the time it is to be mixed with the resin, the solidifying time running from the time of breaking the capsule or diaphragm. The magnetizable particles may be magnetized at any time. However, it is preferred for most applications not to magnetize the particles until they are about to be used, whereupon they can be magnetized by passing them through a magnetic field. The concentration of the magnetic particles may be varied according to the requirements of the particular application. However, for general purposes it has been found that a low concentration of magnetic particles provides a very practical type of mixture and avoids a tendency to obscure alignment with the earth's field which may result from magnetic interaction between the particles when they are in excessive abundance. For example, a solidifiable substance for the core orienting method of this invention may comprise an epoxy resin with a polyamine solidifying agent (preferably a higher polyamine) comprising the liquid and finely powdered ceramic magnetic material having a concentration of one-tenth to one gram per liter of the liquid. With this mixture, when a solidified fragment is taken from the core it has been found that this fragment may be as small as ten cubic millimeters and still provide an adequate indication of the orientation or polarization of the mass of particles produced by alignment with the earth's magnetic field.

For further purposes of illustration and not by way of limitation, another example of a practical mixture suitable for use in the method of this invention comprises an epoxy resin identified as resorcinol diglycidyl ether with a hardening agent sold by the Dow Chemical Co. as X–2654.4. This composition may be employed effectively with ceramic magnetic materials such as one sold under the trade name "Indox-1" and the chemical composition of which in $BaFe_{12}O_{19}$.

For storage purposes the charged containers may be kept cool, which increases the viscosity of the liquid and minimizes or prevents agglomeration of the contained particles. It is particularly desirable to use low temperature storage to keep the viscosity high when the particles have been magnetized before storage.

The solidification time for the liquid mixture may be changed selectively by varying the type or amount of epoxy resin or solidifying agent to provide periods from a fraction of an hour to many hours depending upon the application in which it is to be employed. In the case of charged containers provided with breakable capsules or diaphragms each container may be marked to indicate its solidification period, which will depend on the nature

of the resin and solidifying agent employed and the temperature within the particular well bore.

Referring now to the drawings, FIG. 1 illustrates a drill collar 21 carrying a drilling bit 22 within a well bore defined by walls indicated at 23, the bit 22 resting against the bottom of the bore indicated at 24. Within the collar 21 there is positioned a standard well survey tool 25 including a hollow anchor 26 and a landing shoe 27 secured to the bottom end of the anchor and resting in position against a baffle plate 28 at the top of the bit 22. This particular arrangement of the survey tool in the drilling equipment is commonly known as the "bottom-landing" type. The devices for emplacing the orienting substance herein described are equally applicable without modification in the survey tool arrangement known as the "top-landing" type, where the body of the survey tool passes through the plate and is arrested when an enlarged member of the top of the tool contacts the baffle plate.

The hollow anchor is provided with a charged container and in FIG. 1 a body of liquid mixture 29 has been shown during its discharge through a fluid port 30 in the bit 22. The liquid is discharged through the landing shoe 27 in a manner to be described below. After the liquid has been deposited as indicated in FIG. 1, the drill assembly is removed from the area as indicated in FIG. 2, the distance of removal being sufficient to prevent any interference with the effect of the earth's magnetic field on the magnetic particles within the discharged liquid.

In carrying out the method employing the material of the invention as illustrated in FIGS. 1, 2 and 3, the drill assembly is removed completely from the well or bore and a coring bit is then employed as illustrated in FIG. 3 to remove a core including a portion of the liquid 29 after it has solidified and has attached itself to the bottom of the bore hole 24. As shown in FIG. 3, a coring bit 32 is being operated to remove a core 33 from the bottom of the hole with a portion of the now solidified liquid 29 remaining on the top of the core. The coring bit 32 is attached to an outer core barrel 34 in the usual way and an inner core barrel 35 is provided in the usual way to receive and retain the core 33. The material 29 remains securely affixed to the top face of the core after having been solidified with the magnetic materials dispersed therein. These materials are aligned by the earth's magnetic field and provide a substantially permanent record for test purposes. After the core has been brought to the surface it may be positioned in accordance with the previously secured well data and oriented about its axis by the method of this invention as more fully described later herein.

The construction and arrangement of the charged container within the anchor section 26 of the standard type well survey tool is clearly shown in FIGS. 4, 5 and 6 where the anchor section is shown containing a charged vessel or pressurized cartridge 36. The cartridge 36 and anchor 26 are preferably constructed of a non-magnetic material which may, for example, be a molded synthetic resin or plastic. Other suitable materials include aluminum, magnesium, and plastics having glass fibers incorporated in them, all of which may be drilled away should they lodge in the bore. The cartridge is filled to a predetermined level with the solidifiable liquid 37 and is sealed with a volume of gas under pressure above the liquid. The cartridge may be fitted with a standard pneumatic valve 36' through which compressed air or other gas may be admitted to charge the container to the desired pressure.

Before the cartridge is sealed, a frangible or shatterable capsule, diaphragm or other container 41 filled with suitable solidifying or cross-linking agent for the resin or other liquid 37 is positioned in the cartridge and attached to the wall of the cartridge well below the surface of the liquid. This capsule has been shown unbroken in FIG. 4, although in normal use when the cartridge is inserted in the anchor section the capsule would have been broken and the catalyst mixed with the liquid 37 in order to start the solidification period. The capsule 41 may be broken by a sharp blow against the container.

The lower end of the cartridge is provided with an arrangement for breaking a wall portion of the cartridge and discharging the liquid when the tool strikes the bottom of the hole. In cartridges having the frangible capsule or diaphragm attached to or near the bottom wall portion of the cartridge to be broken, the solidifying agent will be mixed with the solidifiable fluid during the interval of fluid discharge. The details of construction of the wall piercing and fluid discharging device are shown in FIGS. 5 and 6. As shown in these figures, the landing shoe 27 has a central passage 38 within a tubular fitting 39 which is threaded into the upper portion of the shoe as indicated at 40. The shoe is provided with external threads 42 at its upper end so that it can be threaded into corresponding internal threads at the bottom end of the anchor section 26. When the cartridge 36 is to be placed in the anchor section the shoe 27 is unscrewed and the upper pointed end of the tube 39, indiacted at 43, is pressed into a fitting 44 molded as an integral part of the cartridge. The fitting 44 is provided with a central opening or chamber below a bottom wall portion 45 of the cartridge and is provided with intermediate and bottom restrictions 46 and 47, respectively, which have central openings slightly smaller than the external diameter of the tube 39. The plastic material of the fitting is sufficiently flexible to be deformed and afford passage for an annular wedge member 48 on the tube 39 which thus enters the lower chamber formed between the restrictions 46 and 47. The pointed end 43 extends into the upper chamber and lies just below the cartridge wall 45. A second annular wedge 49 is provided on the tube 39 in a position to lie outside just below the fitting 44.

The cartridge with the landing shoe and tube 39 assembled in the fitting 44 is then inserted in the anchor section 26 and the shoe screwed into place at the bottom of the section. The assembly is then dropped or lowered into the drilling tools where it becomes positioned for discharge as shown in FIG. 1. When the survey tool and anchor 26 strike the baffle plate 28, the momentum of the cartridge presses the wall 45 against the pointed tube which then pierces the wall, the wedge 48 entering the upper shoulder of the fitting and the wedge 49 entering the lower, as indicated in FIG. 6. The shape of the annular wedges prevents their being withdrawn from the cartridge and holds the cartridge and tube in discharging position. The gas under pressure then forces the liquid downwardly through the tube and discharges it onto the surface at the bottom of the well as indicated by the arrows in FIGS. 1 and 6. Before dropping or lowering the survey tool and combined cartridge into position for emplacement of the liquid it may be necessary or desirable to circulate the drilling fluid to clear any chips or debris from the bottom of the bore.

After emplacement of the liquid the tool assembly is raised, as stated heretofore, to remove all magnetic material, and when the equipment has been raised the magnetic particles in the liquid are influenced solely by the earth's magnetic field and align themselves with the field. When the liquid has solidified the particles are locked in their aligned position and provide a positive indication of the direction of the earth's field through the zone at the bottom of the bore, and thus after coring provides this indication on the core which indication is not affected by any turning or twisting of the core during removal.

In the above described embodiment of the invention the liquid emplacing device has been employed with a standard surveying tool lowered in the usual manner through the drill stem or collar and it is thus not necessary to provide a modification of the standard drilling equipment.

The foregoing method using the material of this invention may also be practiced in connection with standard coring tools by utilizing the pressurized cartridge and

without modifying the coring tools for this purpose. FIGS. 7, 8 and 9 illustrate the same three steps of the method as FIGS. 1, 2 and 3 but with standard coring tools in all steps. In these figures a standard coring tool comprising an outer core barrel **34***a* having a coring bit **32***a* is employed, an inner core barrel **35***a* being arranged to receive the core in the usual manner. A suitable core catching and retaining means such as resilient stepped or shouldered fingers **51** are provided in the usual manner at the lower end of the inner barrel to grip and retain the core.

In this arrangement the charged container or cartridge is constructed substantially in the form of a standard core barrel plug or core marker so that it fits the coring tool and may be locked in place until the emplacement of the liquid has been effected. As shown in FIG. 7, a pressurized cartridge **52** is positioned and locked in the lower end of the coring tool and extends a substantial distance beyond the bit. The cartridge is provided with a discharge device **53** which is actuated upon striking the bottom of the bore **24***a* and deposits the liquid **29***a* in a manner similar to that of the first embodiment. The impact on striking the bottom also breaks the lock and allows the cartridge to move back into the core barrel **35***a* as indicated in FIG. 8 showing the coring bit raised after deposit of the liquid **29***a*. Then when the well is cored as indicated in FIG. 9 the spent cartridge is moved upwardly in the core barrel in the usual manner of a core marker by the core **33***a* which is being drilled.

The details of construction of the cartridge and discharge mechanism are shown in FIGS. 10 and 11. As shown in FIG. 10 the cartridge comprises a hollow container of plastic such as polyethylene or other easily drillable and non-magnetic material which is shaped to be adapted to the particular type of coring tool with which it is employed. In the illustrated arrangement the core catcher **51** is provided with recesses which receive integral shearing pins **54** formed on the outer wall of the container **52**; these pins lock the container in position and prevent its displacement until the unit strikes the bottom of the bore whereupon the contained fluid is ejected, as more fully described hereafter, and the pins are sheared off. The cartridge is charged with a solidifiable liquid **55** such as an epoxy resin and a quantity of magnetized ceramic magnetic particles and charged with gas under pressure, as through a pneumatic valve, in the same manner as that of FIG. 4. The cartridge is also provided with a longitudinal frangible diaphragm **56** separating the solidifiable fluid **55** from the solidifying agent **55'**. For purposes of charging, two standard pneumatic valves **52'** may be mounted at the top of the cartridge one in communication with a respective chamber on each side of the diaphragm. Thus the liquids are discharged under pressure when the device **53** strikes the bottom of the well bore.

As shown in FIG. 11, the device **53** comprises a tube **57** having upper and lower wedge-shaped ends **58** and **59** both of which have perforations providing open communication at the two ends of the tube. The upper wedge **58** is flat and is positioned transversely of the diaphragm **56** so that it will cut into both sides of the diaphragm and release both liquids. The tube is secured in position by a collar **61** threaded onto a boss or fitting **62** threaded or otherwise secured to the bottom of the container **52**. The upper wedge **58** fits in the central opening of the fitting **62** with its point below the wall **65** of the container and with its base resting on the collar **61** which holds it in position. The tube is also provided with a suitable ridge or key (not shown) to fit a complementary recess (not shown) at the side of the opening through the collar and prevent rotation of the tube. A compression spring **63** may be mounted about the tube between the cone **59** and the collar **61** to hold the cone **58** against the collar **61** and minimize the likelihood of accidental puncture of the cartridge.

The bottom wall of the container is relatively thin as indicated at **65**, and when the device **53** strikes the bottom of the well bore the upper wedge **58** pierces the wall **65** and ruptures the diaphragm **56** and allows the liquids **55** and **55'** to be discharged by the gas pressure, the liquids flowing through the tube, mixing therein, and out onto the rock surface. The broad base of the wedge **58** holds the wedge within the container during discharge against the pressure in the container which tends to force the tube outwardly.

The modifications of the invention described above may be employed with standard types of equipment as described. In some applications it may be desirable to drop or otherwise deposit a charged container or cartridge into the well after the drilling equipment has been removed and then to lower the coring tools, break the cartridge in position at the bottom thereby releasing the liquid, then withdrawing the tools as before and, after solidification of the liquid, drilling the cores, the cartridge casing being of drillable material and being drilled away in the coring process. The cartridges for this method of operation may, for example, be one of the cartridges **52** of FIG. 7 with the ejection device **53** removed as it is not required when the cartridge is to be broken by the drill. Other forms or shapes and sizes of the charged cartridges may be employed and, for example, may be relatively small spherical cartridges a plurality of which are dropped into the well or admitted with the drilling fluid. Such capsules may also be constructed with sufficient weight added that they will sink through the circulating medium or drilling fluid and settle to the bottom rapidly after the circulation has stopped. These containers which are to be broken by the drilling equipment need not be pressurized. However, pressure ejection and the forced discharging of the liquid will help in many cases to effect better emplacement of the liquid on the surface of the rock to be cored. Also when employing the plurality of small cartridges, some may contain the resin and ceramic magnetic powder while others contain the solidifying agent, the mixing being effected upon breaking of the cartridges at the bottom of the well.

After the core sample has been taken with the solidified liquid affixed to its end, it is necessary to determine the direction or polarity of the aligned particles. Fig. 12 illustrates the bottom of a well bore **24***a* with the solidified magnetic-particle mixture **29***a* covering a portion of the bottom. For purposes of illustration the earth's magnetic field at the bottom of the bore hole has been indicated by a plurality of parallel arrows **66** pointing in the same direction toward Magnetic North and the particles have been shown as short lines **67** in the material all parallel to the magnetic field or arrows. As mentioned heretofore, the particles may be visible and may even be colored or otherwise marked to indicate their north pointing poles; however, for most applications the magnetic particles will be in minute or powder form. The short straight lines of FIG. 12 nevertheless serve to illustrate the action with either type of particle.

The alignment of the particles may be determined by testing a very small fragment of the solidified plastic as already mentioned. In FIG. 13, which is a plan view of the central portion of the same rock formation as FIG. 12 after being cut and removed as a core, the core has been shown after the solidified mixture has been marked and is ready for the removal of a circular fragment **68**. The core has been marked by drawing a straight line **69** across the top of the solidified plastic and a second short parallel line **70** close to it. The fragment **68** is cut so that the line **70** extends only a short distance across it to serve as a position indicator. This short line thus identifies the position of the fragment on the core and facilitates correct placing of the fragment when it is returned to the core after determination of its polarity. The fragment is preferably cut or otherwise removed

so that it is taken from a plane substantially at right angles to the axis of the core.

After the fragment has been cut from the body of material it is tested in a simple magnetic device a basic form of which is shown in FIG. 14. The device provides a body of liquid 72 in a non-magnetic cup or vessel 73 which rests between north-attracting and south-attracting pole pieces 74 and 75, respectively, of a U-shaped magnet 76. The fragment 68 is floated on the liquid and remains substantially at the middle of the vessel due to surface tension forces of the liquid. The fragment is free to rotate and aligns itself with the relatively strong magnetic field of the magnet, the north-seeking pole of the fragment, as determined by the alignment of the contained magnetized particles, pointing toward the north-attracting pole of the magnet as represented by the arrow 77 indicated on the water surface. The angle between the straight lines on the fragment and the direction of the field is then measured as by observing a protractor (not shown) placed across the rim of the cup 73. For purposes of illustration the fragment 68 is shown in FIG. 15 replaced to its original position on the core and the magnetic north line 77 marked at the measured angle with respect to the line 69. In actual practice, however, only the angular difference between the lines 69 and 77 as described need be transferred to the core; the fragment need not be replaced. Any suitable system of marks or method of marking may be employed, the parallel lines being shown as one suitable and simple method by way of example.

An instrument for facilitating the more precise determination of the direction of alignment or polarity of the particles is shown in FIGS. 16 through 19. The instrument comprises a rectangular box having a base 79 of non-magnetic material on which are supported north-attracting and south-attracting magnetic pole pieces 80 and 81, respectively, and a return magnetic path comprising the four side walls 82, 83, 84 and 85 of the case. The poles 80 and 81 are spaced apart and a vessel or vial 87 is mounted centrally in the space between the poles, a circular recess 86 being provided in the base 79 to receive the vessel. The case is completed by a non-magnetic cover on top 88 having a circular central opening 89 which receives the upper end of the vessel 87. A ring 91 is fixed to the top 88 concentric with the opening 89 and acts as a seat or retainer for an optical system shown in FIG. 17.

The optical system comprises a vertical tube 92 having a flange 93 which fits on the ring 91 as shown in FIG. 18. The tube and flange have been shown as molded from a single piece of transparent material, the lower face of the flange being stepped or rabbeted to fit over the ring 91. A 360° azimuth ring or plate 94 is secured by a small screw 94' to the flange 93 at the stepped portion so that the azimuth ring may be read through the transparent plastic. A north index line or member 95 is secured to the top of the case at the center line of the north-attracting magnet so that it may register with the marking on the azimuth ring. The optical system is thus mounted so that it may be rotated about a vertical axis coinciding with the central vertical axis of the vessel 87.

The optical system includes a reticle 96 comprising a transparent disc marked with a plurality of spaced lines 97 parallel to the 0°–180° axis of the aximuth ring as shown in FIG. 19. A magnifying lens 98 is provided for viewing the reticle when aligning the lines 97 with marks on objects such as a floating fragment indicated at 68*a* which is similar to the fragment 68 of FIGS. 13 to 15. The lens 98 is held on the tube 92 by a threaded collar 100 and the reticle 96 is secured to the lower end of the tube 92 by a threaded collar or retainer 101.

The liquid in the vessel 87 is selected to provide the required buoyancy of the objects to be floated, and in the case of plastic fragments may be water. The body of liquid fills the vessel to a level fairly close to the position of the reticle to facilitate the registering of the reticle lines with identifying marks such as the line 69*a* on the fragment 68*a*. In the illustrated position of FIG. 19 the reference line 69*a* of the magnetized fragment is at 45° to the center line of the magnetic poles 80 and 81; thus, during solidification of the liquid, the earth's magnetic field is indicated to have passed through the core from which the fragment 68*a* was taken at an angle of 45° to the reference line marked on the core. The true line representing the direction of the earth's magnetic field on the core in its original position in the formation may now be marked on the core by drawing a line 45° to the original reference line 69*a*, essentially the same as the north arrow 77 of FIG. 15, the direction of the 45° polarity line being determined with respect to the fragment's original position on the core.

The azimuth ring 94 includes a concentric slot 102 to receive the attachment screw 94', which slot permits adjustments in the position of the azimuth ring to allow for minor corrections of alignment with the reticle lines and to compensate for the local declination of the earth's magnetic field if desired. Such declination adjustments are usual in survey tools and allow for direct determination of true north rather than magnetic north; however, such adjustments can be used only with cores taken from essentially vertical well bores.

This instrument provides a simple, rugged and accurate device for determining the polarity or magnetic field direction of small fragments of solid material.

FIGS. 20 and 21 illustrate an embodiment of the apparatus of this invention wherein the liquid resin and solidifying agent are maintained separately and not under pressure until the apparatus reaches the bottom of the drill hole. Upon reaching the bottom, both liquids are discharged under pressure by a piston device and are mixed and placed on the bottom wall of the drill hole. In FIGS. 20 and 21 this embodiment of the invention is illustrated as secured in a conventional core drilling assembly like that of FIGS. 3 and 10, and corresponding parts of the drill assembly have been designated by the same numerals with the suffix letter "*b*."

The liquid emplacing device indicated at 105, and which is of generally cylindrical configuration and provided with a plunger 106 at the bottom end thereof, is mounted in engagement with the shouldered fingers 51*b* of the core catching and retaining means at the lower end of the core barrel 35*b*. Displacement of the apparatus 105 is prevented by two shear pins 107 positioned diametrically of each other and engaging the recesses in opposite ones of the fingers 51*b*. As shown in FIG. 21, the pins 107 are threaded into the cylindrical body 105.

The plunger 106 comprises a cylindrical piston body having a concentric reduced portion 108 at its upper end. The main body is slidably mounted in a cylindrical chamber 110 formed within the block 105 and the reduced section 108 enters and is slidably mounted in a piston chamber 111 of correspondingly reduced cross section. The plunger 106 is secured within the block 105 on oppositely positioned shear pins 112 having their outer ends threaded into threaded passageways in the walls of the body 105. The shear pins 112 are weaker than the pins 107 and are sheared on impact when the assembly bottoms on the drill hole and the plunger 106 strikes the bottom wall. Thus the piston 106 moves upwardly in the block 105 which remains latched in position at the end of the core barrel 35*b*.

In order to charge the chambers formed by the pistons 106 and 108, screw plugs 113 and 114, respectively, are unscrewed and the liquid injected into the chambers while the plunger 106 is secured in position by the pins 112.

The resin with fine magnetic particles dispersed therein is injected into the chamber 111 and the solidifying agent into the chamber 110. A passage 115 connects the chamber 111 with a recess 116 in the end of the plunger 106

and inclined passages **117** connect the chamber **110** with the passage **115**.

It will be apparent that when the piston **106** moves upwardly in the block **105** liquid is forced out of the chambers **110** and **111** and discharged through the passages **115** and **117**. The liquids are thus mixed and discharged together into the recess **116** and thus onto the bottom of the drill hole. The drill assembly is then moved away from the bottom of the bore and the material with its magnetic particles allowed to solidify to retain the particles in their positions of alignment with the earth's magnetic field.

The chambers **110** and **111** are charged with liquid, but some air is left in them and forms top air spaces indicated at **118** and **119**, respectively. The air in the chambers is compressed upon actuation of the pistons and not only reduces the shock on impact but results in a discharge of air through the passages **115** and **117** after the liquid has been discharged and thereby facilitates the cleaning of the passages for recharging.

After the material has solidified, the drill assembly is again lowered to the bore bottom. The lowering provides sufficient weight to shear the pins **107**, and as drilling proceeds the apparatus **105** enters the core barrel and thus is retrieved with the core. If desired, this shearing action may be effected before withdrawal of the assembly to allow solidification of the liquid. In this case, the cylinder **105** may be provided with a shoulder to assure its being caught above the shoulders on the core fingers **51***b* after shearing of the pins **107** so that the device does not drop into the bore hole when the assembly is withdrawn for solidification of the liquid.

In order to prevent mixing of the resin and solidifying agent before the apparatus reaches the bottom of the bore, a temporary stopper of suitable material may be released at the inlets of the passages, the stopper being driven out through the passages under the piston pressure; however, for most purposes the small size of the passages together with the sealing of the chambers **110** and **111** will prevent leakage of the liquid. Furthermore, the solidification time may be selected to be such that the liquids will not solidify even should they mix in the passages during the relatively short period after filling of the chambers and before the drill assembly reaches the bottom of the bore.

In the foregoing description of the methods and apparatus for determining the orientation of cores taken from the earth's crust, it has been assumed that the core was taken from a substantially vertical well bore. In practice the bore or well may lie at very substantial angles of deflection from the vertical. Because the earth's magnetic field may also be inclined below the horizontal by widely different angles depending on the location on the earth's surface, it becomes necessary whenever the deflection of a bore hole exceeds say 5° from the vertical to introduce a correction in the determination of core orientation by the method of this invention.

It is common practice in surveying bore holes to determine the amount of deflection from the vertical and the direction of such deflection. This information is thus available from the standard well surveys. The amount of correction required for deflected bores may be determined as an angle with respect to the horizontal at which the orientation polarity line, determined as fully described heretofore, marked across the flat end of a core must be set to effect correct orientation of the core. The correction factor can be computed for any magnetic dip and any angle and direction of the bore hole deflection for use with the orientation method of this inevntion by means of the following formula:

$$\tan C=(\cos I)\ (\tan S)+\frac{(\sin I)\ (\tan D)}{\cos S}$$

where

$C$=desired correction angle in degrees,

$I$=deflection in degrees of bore hole from vertical near depth of cored rock,

$D$=dip in degrees of earth's magnetic field below horizontal at location of well,

$S$=magnetic direction of bore hole deflection, established as:

0° at east and west
−90° at north, and
+90° at south

FIG. 22 is a chart prepared by using the above equation and indicates the correction factors for a location where the earth's magnetic dip or inclination is 70°. The chart has been drawn in four quadrants, east of north, west of north, east of south and west of south, respectively. The radial lines thus represent the magnetic compass direction of the deflection of the well bore. The amount of deflection of the bore is indicated in degrees by concentric circles and on this chart bore deflections up to 30° are indicated, as designated along the horizontal axis of the chart. The correction factors in degrees as calculated by the formula are indicated by the curved lines. In utilizing these correction factors, the core is positioned according to the data obtained from the well survey and, where the bottom of the bore is deflected in the western two quadrants, the core and the north end of the polarity line are rotated clockwise below the horizontal by the amount of the positive correction factor and counter-clockwise above the horizontal by the amount of the negative correction factor. Conversely, where the bottom of the bore hole is deflected in the eastern two quadrants, the core and north end of the polarity line are rotated counter-clockwise below the horizontal for positive correction factors and clockwise above the horizontal for negative correction factors. This positions the north end of the polarity line at the proper rotational position according to the direction of the bore hole deflection with respect to the vertical north-south magnetic plane. The zero correction or horizontal position of the polarity line on the core is represented by a curved line marked zero in the central part of the upper two quadrants of FIG. 22. All correction factors within these zero arcs are negative and those outside positive.

By way of illustration, a line **120** has been drawn on FIG. 22 representing a bore deflected north 62° east. The deflection of the bore as determined from well survey data is assumed to be 18°, the line thus terminating at the 18° circle. This point is about halfway between the +20° and +30° correction curves so that a correction factor of +25° will be necessary to correct for the deflected bore hole. The orientation polarity line, for example **77** of FIG. 15, is determined as described in detail heretofore and the core is positioned in the attitude of the bore hole as determined from the usual well survey. Since the bore hole is deflected in an eastern quadrant and the correction factor is positive, the core is then rotated counterclockwise about its axis so that the north end of the polarity line is directed 25° below the horizontal, thus completely orienting the core in the position it occupied at the bottom of the deflected bore hole used as an example.

The somewhat egg-shaped zone about the intersection of the 0° north radial line and 20° deflection circle is an area of substantial coincidence of the inclination or dip of the earth's magnetic field and the bore hole deflection so that the lines of the earth's field run substantially along the core and no reliable indication of direction or orientation of the core may be secured in this zone. When survey data indicate that the well bore is within this zone, it is, of course, necessary to determine the orientation of the core by other methods than relying on the earth's magnetic field.

From the foregoing it is readily apparent that the material of this invention together with the apparatus thereof makes possible a simple, quick and reliable method for determining core orientation which requires minimum interruption of the operation of the standard drilling or coring procedures or equipment. This method greatly short-

ens the time for determining core orientation and is readily adaptable to use in the field.

While the invention has been described in connection with specific forms of the method employed therewith and embodiments of the material and apparatus, various modifications and other applications will occur to those skilled in the art. Therefore it is not desired that the invention be limited to the specific methods and constructions illustrated and described and it is intended by the appended claims to cover all modifications which fall within the spirit and scope of the invention.

I claim:

1. A material for use in the determination of the direction of weak magnetic fields which comprises a liquid having the property of solidifying at the end of a predetermined time and a mass of finely divided magnetizable ceramic particles mixed in said liquid, said particles being substantially permanently magnetized upon subjection to a relatively strong magnetic field whereby after magnetization of said particles and when said liquid and mixed ceramic particles are subjected to a weak magnetic field the particles will align themselves with the field and upon solidification of the liquid will be retained in such alignment.

2. A material for use in the determination of the direction of weak magnetic fields which comprises a liquid polymerizing resin and a mass of finely divided magnetizable ceramic particles therein and a setting agent, said particles being substantially permanently magnetized upon subjection to a relatively strong magnetic field whereby upon agitation of said material and the addition of the setting agent said particles will align themselves with whatever magnetic field they are subject to and upon setting of the resin will be retained in such alignment.

3. A material for use in the determination of the direction of weak magnetic fields as set forth in claim 2 wherein said ceramic particles are in powdered form and are of a low concentration in said liquid resin.

4. A material for use in the determination of the direction of weak magnetic fields as set forth in claim 2 wherein said setting agent is a higher polyamine.

5. A material for use in the determination of the direction of weak magnetic fields as set forth in claim 2 wherein said resin is an epoxy resin.

6. A material for use in the determination of the direction of weak magnetic fields as set forth in claim 5 wherein said ceramic material is in finely powdered form and is of a concentration of one-tenth to one gram per liter of said epoxy resin.

7. In the art of determining the orientation of a remote object with respect to a weak magnetic field and employing the orientation of magnetic particles with respect to such field, a fluid-charged device comprising a closed container of non-magnetic material and a body of solidifiable liquid in said container, said liquid having the property of solidifying at the end of a predetermined period, a mass of finely divided particles of magnetizable ceramic material in said liquid, and means for discharging the mixture whereby the solidification of the mixture may take place outside of the container.

8. In the art of determining the orientation of remote objects, a fluid-charged device as set forth in claim 7 wherein said container is charged under pressure and includes a rupturable portion and said discharge means includes a release element positioned to pierce said portion and release the pressurized charge when said element is pressed against said portion of said container.

9. In the art of determining the orientation of remote objects, a fluid-charged device as set forth in claim 8 wherein said container is of a size and shape to fit within and constitute a portion of a well tool assembly and said element is positioned and arranged to release said charge upon bottoming of the tool assembly.

10. In the art of determining the orientation of a remote object with respect to a weak magnetic field and employing the orientation of magnetic particles with respect to such field, a fluid-charged device comprising a closed container of non-magnetic material and a body of solidifiable liquid resin in said container, a mass of finely divided particles of magnetizable ceramic material in said liquid resin, means for maintaining a charge of solidifying agent in said container out of contact with said resin, means for releasing said solidifying agent and mixing said resin and said agent, and means for discharging the mixture whereby setting of the mixture may take place outside the container.

11. In the art of determining the orientation of remote objects, a fluid charged device as set forth in claim 10 wherein said container has flexible walls and said solidifying agent maintaining means includes a frangible member within said first mentioned container which may be broken by force applied to the walls of said first container to release the solidifying agent into the liquid resin.

12. A liquid discharge device arranged to be mounted in a core drill assembly or the like for the emplacement of solidifiable material on the bottom of a drill hole or the like comprising a body having a cylinder chamber therein and a piston slidably mounted in said chamber, said body being movable through the core barrel of a core drill, a first frangible means for securing said body in a core drill assembly, a second frangible means for securing said piston in spaced relation to the end of said cylinder chamber for providing a space for the storage of a liquid to be discharged, a foot member connected with said piston and extending below said body and beyond a core drill assembly when said body is mounted therein, said device including passage means communicating with said chamber and the lower portion of said device for directing liquid discharged from said chamber downwardly onto a surface contacted by said foot member, said first frangible means being weaker than said second frangible means whereby upon engagement of said member with a surface the downward force of the drill assembly first releases said piston to discharge the liquid and releases said body from said drill assembly upon application of increased force whereby said body is moved upwardly upon coring and may be removed with the core.

13. A liquid discharge device for mounting in a drill assembly or the like for the emplacement of solidifiable materials on the bottoms of drill holes and the like comprising a body having a plurality of chambers for holding charges of liquid therein, liquid discharge means including pistons in said chambers, a surface engaging foot extending beyond said body for urging said pistons into said chambers when the drill assembly bottoms on a drill hole or other surface, means locking said pistons in fixed spaced relationship to the ends of said chambers, said locking means being disengaged for releasing said pistons from said body upon application of a predetermined force urging said pistons into said chambers, and means for securing said body in a drill assembly with said foot extending beyond the assembly whereby force may be applied to said locking means when said portion strikes a drill hole bottom or the like and said locking means thereby released, said device having fluid passage means communicating with said chambers for directing fluid discharged from said chambers onto a surface contacted by said foot when the weight of the assembly rests thereon.

14. A liquid discharge device as set forth in claim 13 wherein said fluid passage means comprises a discharge passage extending through said piston and opening adjacent said foot and branch passages connecting respective ones of said chambers with said discharge passage whereby the fluids from said chambers are mixed in said discharge passage and the mixture is discharged adjacent said foot onto the surface struck thereby.

15. A liquid discharge device for mounting in a drill assembly or the like for the emplacement of solidifiable materials on the bottoms of drill holes and the like comprising a rigid body having a cylindrical opening therein,

said opening having a cylindrical extension of smaller diameter concentric therewith, a piston slidably mounted in said cylinder and having a reduced concentric cylindrical portion for sliding movement in said cylinder extension, frangible means for retaining said piston in a position spaced from the end of said cylinder and said extension and providing first and second chambers respectively for accommodating separate charges of liquid, means in said piston providing communication with said chambers and including a common discharge passage for mixing the liquids discharged from said chambers and directing the mixture downwardly toward the bottom of said piston, means for mounting said body in a drill assembly or the like with said piston extending beyond said assembly



whereby said piston may be struck to break said frangible means and to move into said chambers and discharge liquid through said common passage.

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