

April 4, 1967

E. L. PARAMORE ET AL
METHOD OF REDUCING THE PERMEABILITY
OF PORTIONS OF BORE HOLES
Filed May 13, 1964

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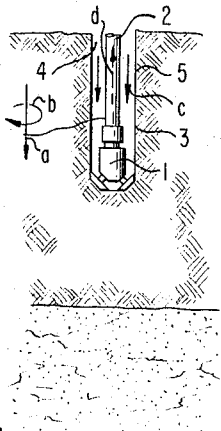


FIG. 1

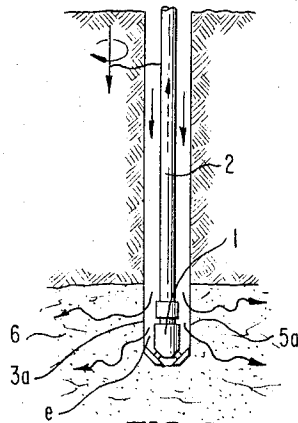


FIG. 2

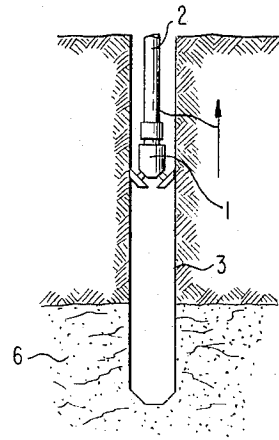


FIG. 3

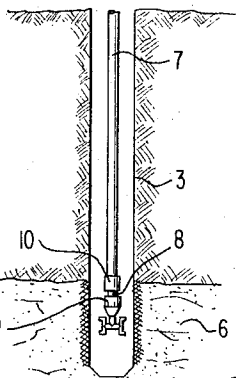


FIG. 4

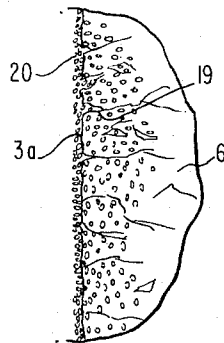


FIG. 5

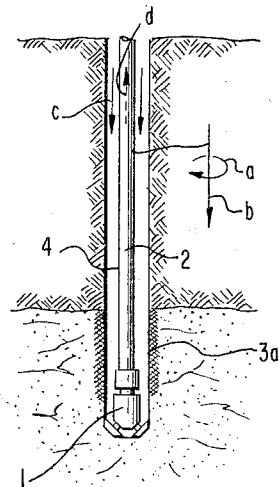


FIG. 6

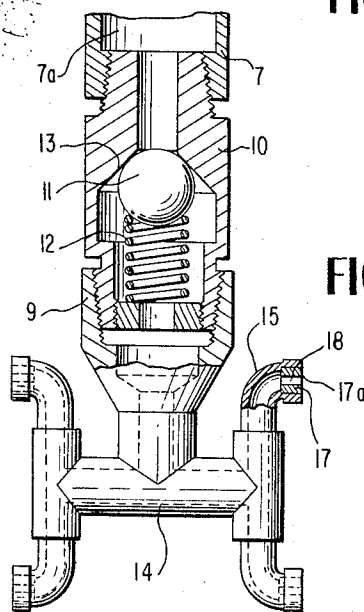


FIG. 7

INVENTORS
EDWIN L. PARAMORE
NEAL W. GLAZNER, JR.
RONNEY R. KOCH

BY
Burns, Doane, Benedict, Swecker & Mathis
ATTORNEYS

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METHOD OF REDUCING THE PERMEABILITY OF PORTIONS OF BORE HOLES

Edwin Lee Paramore, Dallas, Tex., Neal W. Glazner, Jr., Las Vegas, Nev., and Ronney R. Koch, Duncan, Okla., assignors to Halliburton Company, Duncan, Okla., a corporation of Delaware

Filed May 13, 1964, Ser. No. 367,915

6 Claims. (Cl. 175-72)

This invention relates to a method of reducing the permeability of a portion of a hole formed in an earthen mass. In particular it relates to a method of rotary drilling in which a gaseous fluid, such as air, is circulated into a hole being drilled.

Conventional drilling techniques frequently entail the use of a rotary drill bit supported on a conduit string. A drilling fluid is ordinarily circulated between the interior of this conduit string and the annular space between the string and the bore hole wall to assist in the removal of cuttings, and to cool the bit.

Frequently a drilling mechanism will intersect an excessively permeable formation such that inordinate amounts of drilling fluid will pass into the formation so as to adversely affect or all together interrupt its circulation. The problem becomes particularly acute in the drilling of deep bore holes, such as oil and gas wells, and in the drilling of large holes into the earth which have a diameter of several feet.

A variety of techniques have heretofore been employed to seal off excessively permeable formations so as to allow drilling to continue without excessive losses of drilling fluid into the formation.

One conventional technique entails the setting of a section of casing adjacent the formation so as to provide a fluid impermeable seal lying against the formation face exposed within the bore hole. This technique, of course, is both time consuming and cumbersome and entails considerable expense.

Another proposal for sealing a permeable formation has entailed the wiping of sealant material against an exposed face or wall of a formation. This technique also entails considerable complexity and tends to consume an inordinate amount of time. In addition, it presents substantial difficulties from the standpoint of obtaining a uniform and reliable seal.

Other techniques proposed for sealing permeable formations have involved the filling of a bore hole with sealant material. After this sealant material has at least partially hardened, a hole is drilled through the sealant so as to form an annular sleeve of sealant material extending through the permeable formation to be isolated. This technique, of course, entails the significant drawback of requiring the removal of substantial quantities of excess sealant material. In addition, it involves the utilization of a considerably greater quantity of sealant material than that required to seal the formation face.

As a general observation, it might be noted that the previously known formation sealing techniques involve the forming of a relatively thick seal surface. Often this surface interferes with the movement of drilling apparatus through the drilled hole. In addition, such relatively thick-seal surfaces are vulnerable to abrasion caused by movement of cuttings suspended in drilling fluids.

Recognizing the problems associated with the prior attempts to seal off permeable formations in drilled holes,

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it is an object of the present invention to provide an improved technique which enables holes to be effectively drilled through and beyond permeable formations while substantially reducing the time and effort involved in effectively minimizing the permeability of these formations.

It is a particular object of the invention to provide such an improved technique which eliminates all together the need for the setting of casing adjacent a permeable formation.

It is another object of the invention to provide such an improved technique which minimizes the amounts of sealant material required to properly reduce the permeability of exposed formation faces.

Another principal object of the invention is to provide a technique by means of which a permeable formation may be adequately sealed without leaving a thick coating on the interior of a well bore which would impede the movement of drilling apparatus, be vulnerable to mechanical damage as a result of movements of drilling apparatus and be excessively vulnerable to the abrasive action of cuttings carried by drilling fluids.

It is likewise a principal object of the invention to provide such an improved technique by means of which a sealant may be effectively projected against a formation face so as to be at least partially imbibed by the formation face and to leave a relatively thin film of sealant on the formation wall.

Still another object of the invention is to provide such an improved technique by means of which the overall time required to drill holes extending through permeable formations is substantially decreased.

An additional object of the invention is to provide such a technique which substantially obviates the necessity for either drilling through a solidified mass of sealant material or attempting to remove significant quantities of sealant material entirely filling substantial portions of a drilled hole.

Yet another object of the invention is to provide such an improved technique by means of which the amounts of sealant material applied and the thickness of sealant material applied to a formation face may be substantially controlled and which obviates the necessity of wiping sealant material across a formation face to be sealed.

The method presented through this invention for accomplishing the foregoing objectives involves the directing of a confined flow of pressurized sealant material, isolated from the periphery of a drilled hole, generally axially of the hole and toward a hole portion, the periphery of which is to be treated. This axial flow is constricted so that its velocity is increased. The constricted flow is passed through outlet means so as to form a spray of sealant material particles.

The spray of sealant material particles is projected from the outlet means toward the wall of the hole portion to be treated. The sealant material particles are impinged against the wall portion while maintaining a space between the outlet means and the wall portions substantially unoccupied by continuous phase liquid material. The thus impinged, sealant material is at least partially imbibed by the permeable formation and forms a relatively thin sealant coating on the wall portion within the well bore.

In practicing the preferred form of the invention, a gaseous fluid is employed as a drilling fluid and circulated into the hole portion to be treated so as to enter the per-

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meable formation through the wall of the hole portion against which the sealant particles are to be impinged.

In describing a preferred mode of practicing the invention, reference will be made to the accompanying drawings.

In these drawings:

FIGURE 1 is a fragmentary, partially sectioned, elevational and schematic showing of a bore hole within which a conventional drill mechanism is advancing into the earth toward a permeable formation;

FIGURE 2 is a view of the FIGURE 1 bore hole after the drill mechanism has penetrated a permeable formation and gaseous drilling fluid is passing to a substantial degree into this formation;

FIGURE 3 illustrates the withdrawal of the drilling mechanism from the hole which has intersected a permeable formation so as to enable the sealing or reducing of permeability of this formation;

FIGURE 4 is a partially sectioned, fragmentary, elevational, and schematic view of the FIGURE 2 bore into which a sealant-applying apparatus has been lowered on a conduit string;

FIGURE 5 is a fragmentary, enlarged, sectional, and schematic view of a portion of the permeable formation intersected by the FIGURE 2 drill hole and showing the manner in which sealant material, projected as particles against the exposed face of the bore hole, have been partially imbibed by the formation and formed a thin coating or film on the exposed formation face;

FIGURE 6 schematically illustrates the resumption of drilling subsequent to the formation-sealing operation illustrated in FIGURES 4 and 5; and

FIGURE 7 is an enlarged, fragmentary, sectional, and elevational view of one form of a sealant-material-disbursing apparatus which may be employed in the practice of this invention.

The overall drilling technique with which this invention is concerned is illustrated in FIGURES 1 through 6.

FIGURE 1 illustrates a drilling mechanism comprising a conventional rotary drill bit 1 supported upon a conduit string 2. As schematically represented by the arrows *a* and *b*, the conduit string 2 is advanced axially into the hole 3 being drilled and is concurrently rotated so as to form this hole.

While drilling is progressing, a gaseous fluid such as air, may be circulated within the hole 3 so as to remove cuttings formed by the bit 1 and to cool the bit. In the arrangement shown in FIGURE 1, air is circulated downwardly in the annular space 4 between the conduit string 2 and the wall 5 of the hole being drilled. This downward flow of air is schematically represented by the air flow direction arrows *c*. In a conventional and well understood fashion, this downwardly circulated drilling fluid will enter openings in the lower end of the bit 1 and pass upwardly through the interior of the conduit string 2 as schematically represented by the air flow direction arrow *d*.

It will be understood of course, that the drilling gas may also be circulated in an opposite direction i.e. downwardly through the interior of the conduit string 2 and upwardly through the annular space 4.

As drilling continues through the downward advancement of the conduit string 2 and drill 1, the bit 1 may intersect an excessively permeable formation 6. The portion 3*a* of the bore hole 3 which intersects the formation 6 will be characterized by an annular wall portion 5*a*. Drilling gas such as air will escape through wall portion 5*a* into the interior of the formation 6 as schematically represented by the flow direction arrows *e* in FIGURE 2.

If the permeability of the formation 6 is such that air escapes into its interior to such a degree as to impede the removal of cuttings, it then becomes necessary to seal off or reduce the permeability of the formation 6 in the vicinity of the drilled hole wall portion 5*a*.

When it has been determined that the circulation of air is being reduced to an inordinate degree as a result of its

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flowing into the permeable formation 6, the conduit string 2 and its supported drill bit 1 are withdrawn upwardly from the drilled hole 3 as shown in FIGURE 3. Thereafter, a conduit string 7, which may comprise the conduit string 2 with the bit 1 removed, is lowered into the bored hole 3. Conduit string 7 supports on its lower end a sealant material distributing apparatus 8.

Under conventional drilling conditions, such as those encountered in the forming of oil well bore holes, the depth of the permeable formation 6 may exceed several hundred feet.

The internal structure of one form of a sealant material distributing apparatus 8 is schematically illustrated in FIGURES 4 and 7.

This apparatus 8 may comprise a spray head 9 and a check valve assembly 10 interposed between the spray head 9 and the conduit string 7.

Check valve 10, may assume a variety of forms and may be of the type which may be adjusted to open at a particular pressure differential. This pressure responsive valve 10 serves to allow a flow of sealant material from the interior of the conduit string 7 into the spray head 9 in response to the existence of the minimum predetermined pressure within the interior 7*a* of the conduit string 7 adjacent the check valve 10. Thus, in the schematically represented check valve arrangement shown in FIGURE 7, a spherical valve member 11 may be biased by a coil spring 12 against a generally conical valve seat 13. The compressive force of the spring 12 will be selected so as to hold the valve member 11 against the seal 13 until a predetermined, minimum fluid pressure is exerted against the upper end of the valve member 11. When this preselected minimum pressure is attained, the valve member 11 will be displaced from the seal 13 so as to allow a flow of sealant material into the spray head 9.

The spray head 9, as schematically shown in FIGURE 7, may comprise a body portion 14 supporting a plurality of spray nozzles 15 directed generally radially of the longitudinal axis of the conduit string 7. In the arrangement shown in FIGURE 7, the spray head 9 includes four nozzles 15. Each nozzle 15 may be provided with flow constricting means such as a hardened and abrasion resistant, tungsten carbide orifice tube 17 mounted generally as shown in FIGURE 7.

Hardened orifice tube 17 defines a constricted flow path 18 which will tend to substantially increase the velocity of sealant material, which may be somewhat viscous, as it passes from the interior of the spray head 9 to the orifice tube outlet 17*a*. The high velocity flow of sealant material issuing from the outlet 17*a* into the low pressure annulus 4 will cause the constricted sealant flow to diverge so as to form a spray of sealant material particles. Such particles of course may range in size from relatively large globules, through conventional droplets, to very fine mist-like particles.

The spray of sealant material particles issuing from each nozzle tube is projected against the walls 5*a* of the hole portion 3*a* which extends into or intersects the permeable formation 6.

In summary, it may be stated that the spray of sealant material particles is formed by directing flow of pressurized sealant material, isolated from the wall 5 of the bore hole 3 by virtue of its enclosure within the interior of the conduit string 7, so that it moves generally axially of the bore hole 3 toward the bore hole portion 3*a*. This flow of sealant material is constricted as it passes through the orifice tubes 18 so that the velocity of the sealant material is substantially increased. As the high velocity sealant flow issues from the orifice tube outlets 17*a*, a spray of sealant material particles is formed which is projected toward the wall portion 3*a*.

With a spray apparatus as schematically shown in FIGURE 7, it may be desirable to vertically reciprocate the spray head assembly 8 through the axial extent of the hole portion 3*a*. It may also be desirable to rotate the

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spray nozzle 9 by rotating the conduit string 7. Where the rotation and reciprocation of the spray nozzle are concurrently effected, the sprays issuing from the outlet means 17a will be moved in a generally helical pattern within the hole section 3a. This movement of the spray nozzle will cause sealant material spray particles to engage the formation wall portion 3a at a variety of impingement angles.

It will also be noted that the spray of sealant material will be directed from the spray nozzle 9 across an annular space between it and the formation wall 3a which will remain substantially unfilled by continuous phase material such as a liquid or solid body which would impede the projecting of sealant material particles.

Sealant material particles, projected against the formation wall portion 3a, are impinged against this wall portion and form a seal as shown in the enlarged sectional and schematic view of FIGURE 5. Through the utilization of a latex containing sealing material, a formation sealing action will result by a part of the projected sealant spray being imbibed or drawn into formation pores or fissures and by a part remaining on the surface of the wall 3a so as to form a sealing film. Thus, some sealant particles, such as the particles 19, will be drawn into the formation 6 so as to seal formation pores, cracks and fissures, and reduce formation permeability. It is believed that this effective sealant material imbibition may result to a substantial degree from the prior flow of gaseous fluid into the formation. Other sealant particles 20 will collect or coalesce on the wall 3a so as to form a relatively thin sheathing or film on the bore hole periphery. The character of preferred sealant materials by means of which this dual sealing action may be accomplished without resorting to the use of special formation treating agents will be hereinafter described.

The stopping of the projecting of the spray of sealant material particles, i.e. the passing of sealant material through the orifice tubes 18, may be accomplished by stopping the application of pump pressure at the well head to the flow of sealant material passing downwardly into the bore hole 3 through the conduit string 7. When the surface pump pressure applied to the sealant material is removed, the fluid pressure force acting upon the spherical valving member 11 will entail only the hydrostatic head of sealant material contained within the conduit string 7. By knowing in advance the magnitude of the hydrostatic head, the compressive force of the spring 12 may be selected so as to cause the valve member 11 to sealingly engage the valve seat 13 when the pump pressure is so interrupted. When the pump pressure is thus interrupted, sealant material contained within the conduit string 7 will be effectively confined and prevented from moving out of the conduit string 7 into the bottom of the hole portion 3a.

Subsequent to the spraying of the formation wall portion 3a, and the withdrawal of the spray head assembly 8 and supporting conduit string 7, the drill conduit string 2 and drill bit 1 may be relowered into the bore hole 3 and drilling and air circulation resumed, as shown in FIGURE 6.

When drilling is resumed, as shown in FIGURE 6, the circulation of gaseous drilling fluid will cause this fluid to move through the annulus 4 past the spray coated or sealed bore hole wall portion 3a.

A particularly unique feature of the invention involves the nature of the preferred sealant material which is to be impinged against the exposed face or wall of a permeable formation.

Sealant materials to be used in the practice of this invention comprise latex compositions, i.e. compositions including a dispersion of resinous or rubbery polymers in water. Representative examples of such polymers include polyvinyl acetates, polyvinyl chlorides, butadiene

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styrene copolymers, acrylic copolymers, neoprenes, coumarone indenes, polyvinylidene chlorides and natural rubber latices.

Latex compositions of this type, when impinged as a spray against permeable formation walls are at least partially imbibed by the formation pores and by formation fractures, interstices, and other openings. Latex so imbibed by a formation and latex deposited on an exposed bore hole face tends to coagulate so as to form a resilient film. This film forming is facilitated when the sprayed latex compositions dry through exposure to a gaseous drying agent such as air. Air, which would be conventionally used as a drilling circulating fluid would define the drying environment in the bore hole even after drilling and air circulation were interrupted.

The tough, elastic, resilient film of sheath of polymerized material deposited upon permeable formation faces effectively withstands corrosive formation fluids and the abrasive action of fluid-circulated cuttings.

The relatively deep penetration of the latex sealant, resulting from its imbibition, forms an internal seal which is effectively removed from the formation surface so as to be altogether immune to damage caused by the manipulation of well tools or the abrasive action of circulated cuttings.

A representative latex sealant composition which may be employed in the practice of this invention may be formed from a base latex material of which 40 to 60 percent by weight comprises a polyvinyl polymer dispersed in water. In mixing the sealant to be pumped to the spray head within a well bore, the following mixing ratios have been employed: 100 gallons of the base latex material, 25 gallons of isopropanol, and 75 gallons of water.

A latex composition formulated as described above was sprayed through spray nozzle orifices having a diameter of approximately $\frac{3}{16}$ of an inch. The fluid pressure existing immediately above the check valve assembly is estimated to have been approximately 600 pounds per square inch. With a spray nozzle including four spray jets as shown in FIGURE 7, the latex sealant material was sprayed against an exposed, permeable formation face at a spray rate of approximately 6 gallons per minute and resulted in the applying of approximately $\frac{1}{10}$ of a gallon of sealant against each square foot of exposed formation wall being treated. However, it has been found that a satisfactory formation seal may be obtained by applying as little as $\frac{5}{100}$ of a gallon of sealant per square foot of exposed formation, depending upon the character of the formation.

Under certain conditions it may be desirable to employ sealant compositions which include both latex and gypsum cement components.

Gypsum cement constitutes a desirable seal-forming constituent owing to its relatively rapid setting properties and its ability to form a relatively rigid cement-lattice-work for supporting the elastic film formed by a deposited latex.

A satisfactory latex-gypsum cement composition may be formulated utilizing a base latex such as the polyvinyl polymer latex described above. A suitable mixing ratio for this particular sealing material may comprise 50 gallons of base latex, 50 gallons of water and approximately 1,250 pounds of gypsum cement.

A latex-gypsum cement sealant composition so formulated may have a representative initial viscosity on the order of 262 centipoises. This composition was effectively applied by being sprayed through nozzle orifices of approximately $\frac{3}{16}$ of an inch in diameter. The fluid pressure applied to force the composition through the check valve and spray nozzle assembly was estimated to have been on the order of 600 pounds per square inch.

The invention has been practiced and found to be particularly effective in sealing the exposed walls of relatively large diametered bore holes. With spray head assemblies

having lateral dimensions only on the order of several inches, bore holes having a diameter of 4 to 6 feet have been effectively treated. As will be appreciated, under these circumstances, the spray of sealant material particles is projected across a distance of two or more feet of open hole.

Subsequent to the spray coating of a permeable formation wall, conventional drilling may be resumed. The time which should elapse between the application of sealant material and the resumption of drilling depends upon the time required for the sealant material to sufficiently set or dry. As will be appreciated, drying time will be dependent upon a variety of sealant material and bore hole conditions including the adjacent formation temperature. However, in practice it has been found that a drying period of only 2 or 3 hours may suffice.

In describing the manner in which the preferred formation-sealing techniques are to be practiced, the overall and unobvious advantages of the invention have been demonstrated.

Of foremost consequence is the unexpected manner in which a latex-containing composition may be merely sprayed against a permeable portion of a bore hole so as to provide a sufficiently effective seal as to enable the relatively prompt resumption and continuation of drilling while using a gaseous circulating medium.

The advantageous manner in which sprayed latex compositions are at least in part imbibed by permeable formations so as to form a seal extending partially into a formation, as well as a film coating on the exposed formation face, provides an effective formation seal uniquely conducive to the continuation of drilling operations. The tough, elastic, and abrasion-resistant properties of this seal, resulting from its resinous or rubbery character and its penetration into a formation permits drilling to continue while the formation seal is subject to the abrasive action of gas-circulated, formation cuttings. The rigid lattice formed by the gypsum cement, when employed as a sealant constituent, provides a device for facilitating the adherence of a durable latex film to an exposed formation.

The relatively thin nature of the polymer film formed on the exposed face of the permeable formation virtually eliminates any interference by the seal with the movement of drilling tools through a bore hole.

A somewhat surprising aspect of the invention involves the ability to pump a latex composition through several hundred feet and then force it under a pressure of several hundred pounds per square inch through a relatively small orifice without causing undue coagulation of the latex prior to its impingement upon a formation face to be sealed.

Overall advantages of the invention entail the rapidity with which a permeable formation may be sealed, the minimized and controllable quantities of sealant utilized in formation spraying operations, the accuracy with which the spray coating may be applied and located, and the overall uniformity of the sprayed coating. As will be further appreciated, through this invention the necessity of setting casing to seal off a permeable formation or the necessity of utilizing cumbersome wiping tools or sheath forming tools within a well bore are altogether obviated.

While the invention has been described with reference to preferred embodiments, those skilled in the art and familiar with the disclosure of these preferred embodiments may recognize modifications of the invention as disclosed. Such modifications entailing additions, deletions, substitutions or other variations with respect to the disclosed operational sequences, sealant compositions, apparatus structure or dimensions, and areas of utilization of the invention are deemed to be embraced within the scope of the appended claims.

We claim:

1. A method of reducing the permeability of a por-

tion of a hole formed in the earth, said method comprising:

directing a confined flow of sealant material, isolated from the periphery of said hole, generally axially of said hole and toward said hole portion, said sealant material comprising a composition including latex and gypsum cement materials;

constricting said axial flow of sealant material so that its flow velocity is increased;

passing said constricted flow through outlet means so as to form a diverging spray of sealant material particles; and

projecting said spray of sealant material particles from said outlet means toward the wall of said hole portions;

said sealant material being impinged as particles against said wall portion while maintaining a space between said outlet means and said wall portion substantially unoccupied by continuous phase liquid material; and said thus impinged sealant material being, at least in part, imbibed by said permeable formations.

2. A method of drilling comprising:

supporting drill means on conduit means and advancing said drill means into the earth to form a hole while circulating a gaseous fluid between said drill means and the exposed wall of said hole;

continuing the advancing of said drill means until said drill means forms a hole portion intersecting a permeable formation and said circulating gaseous fluid enter said permeable formation through the exposed wall of said hole portion;

withdrawing said drill means from said hole;

directing a confined flow of pressurized sealant material, isolated from the periphery of said hole, generally axially into said hole and toward said hole portion;

constricting said axial flow of sealant material so that its flow velocity is increased;

passing said constricted flow through outlet means spaced from at least a portion of said wall of said hole portion so as to form a diverging spray of sealant material particles; and

projecting said spray of sealant material particles from said outlet means toward said wall of said hole portion, said sealant material particles being impinged as particles against said wall portion while maintaining the space between said outlet means and said wall portion substantially unoccupied by continuous phase liquid material;

said thus impinged sealant material being at least in part imbibed by said permeable formation;

allowing sealant material on the wall of said hole portion to dry in a substantially gaseous environment; and

thereafter renewing the advancing of said drill means and circulating gaseous fluid past said permeable formation wall portion against which said sealant material particles were impinged.

3. A method as described in claim 2 wherein said sealant material comprises a latex composition.

4. A method as described in claim 3 wherein, while said sealant material is passing through said outlet means and being projected toward the wall of said hole portion, said outlet means is reciprocated axially within said hole portion.

5. A method as described in claim 4 wherein, prior to the renewing of the advancing of said drill means, the projecting of said spray of sealant material particles and the passing of said sealant material through said outlet means is stopped by interrupting said flow of sealant material adjacent said outlet means in response to a reduction in the pressure applied to said confined flow of sealant material.

6. A method as described in claim 5 wherein said sealant material comprises a dispersion of latex in water,

said confined flow of sealant material extending for at least several hundred feet, with there being a pressure applied to said sealant material, adjacent said outlet means, of at least several hundred pounds per square inch.

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CHARLES E. O'CONNELL, *Primary Examiner.*

J. A. LEPPINK, *Assistant Examiner.*