June 20, 1967 F. C. PITTMAN 3,326,288

METHOD AND APPARATUS FOR REDUCING THE PERMEABILITY OF PORTIONS OF BORE HOLES

Filed May 13, 1964 2 Sheets-Sheet 1

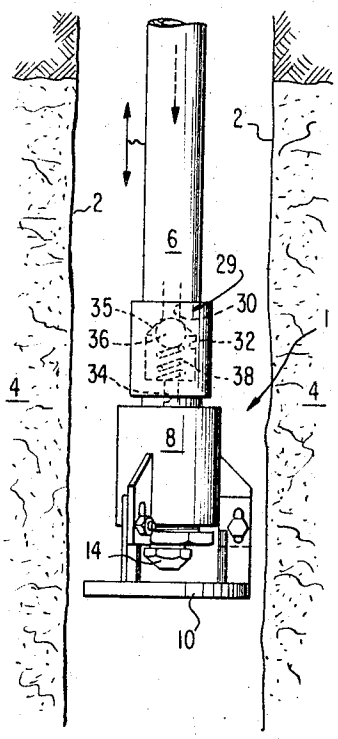


FIG. 1

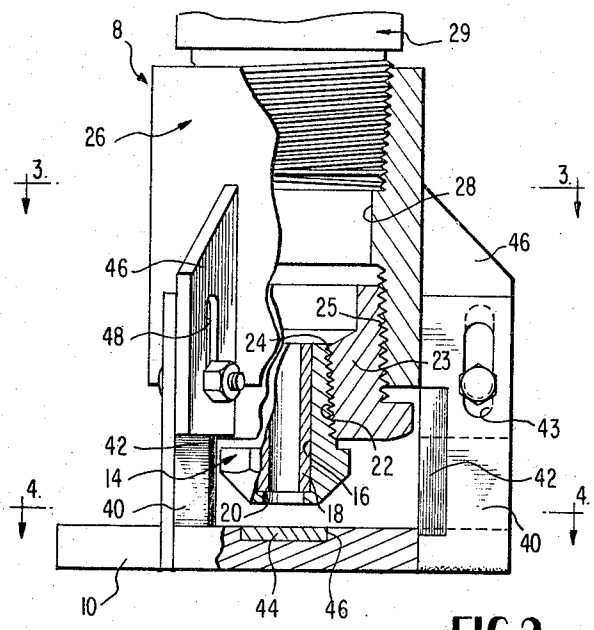


FIG. 2

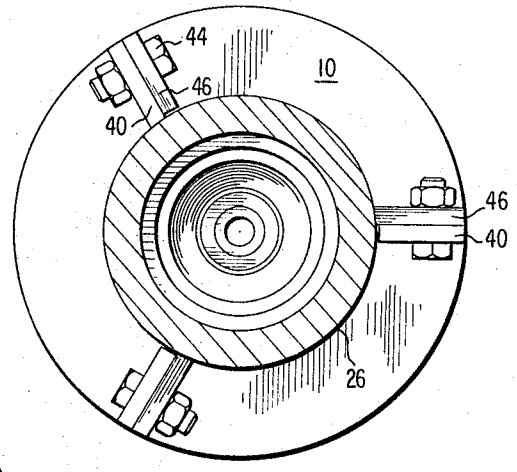
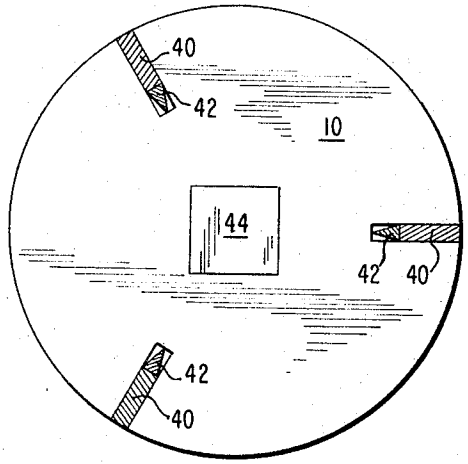


FIG. 3

FIG. 4



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METHOD AND APPARATUS FOR REDUCING THE PERMEABILITY OF PORTIONS OF BORE HOLES

Filed May 13, 1964 2 Sheets-Sheet 2

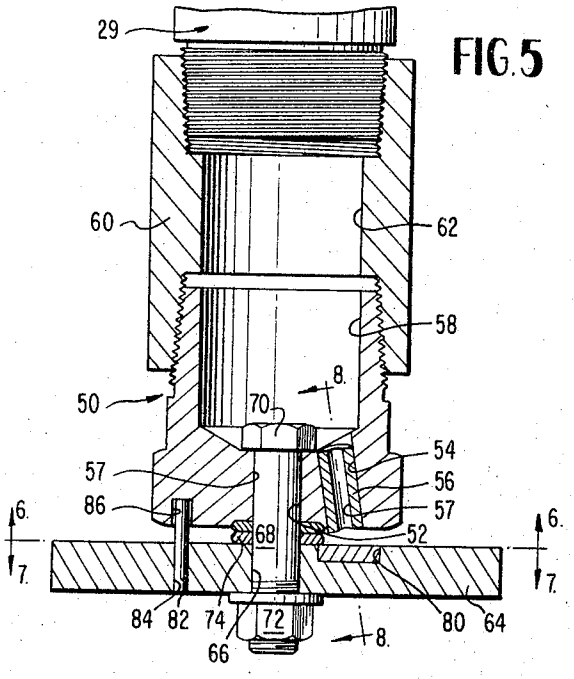


FIG. 5

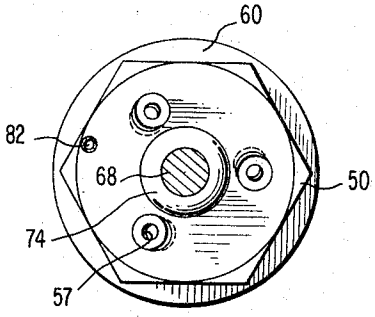


FIG. 6

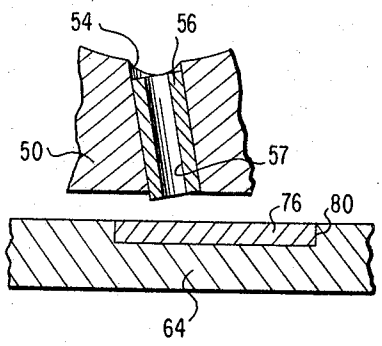


FIG. 8

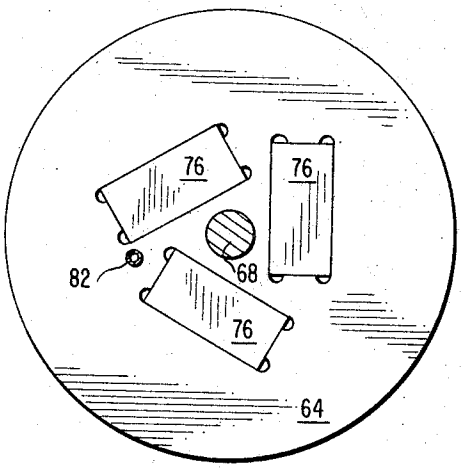


FIG. 7

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3,326,288

METHOD AND APPARATUS FOR REDUCING THE PERMEABILITY OF PORTIONS OF BORE HOLES

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Filed May 13, 1964, Ser. No. 367,000
8 Claims. (Cl. 166—27)

This invention relates to a method and apparatus for reducing the permeability of a portion of a hole formed in an earthen mass and is an improvement of the invention disclosed in a copending application of Edwin L. Paramore et al. entitled, "Methods of Reducing the Permeability of Portions of Bore Holes." In particular this invention relates to a method of and apparatus for applying sealant to said portion of said hole.

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

A variety of techniques have heretofore been employed to seal off an excessively permeable formation 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 permeable formation to be sealed. This technique also entails undue 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 the sealant material has at least partially hardened, a hole is drilled through the sealant so as to form in essence an annular casing 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 and, in addition, it involves the utilization of considerably greater quantities of sealant material than are required to form the formation-face-sealing operation.

As a general observation, it might be noted that the previously noted 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 the drilling fluid.

The invention disclosed in the previously designated copending application of Edwin L. Paramore et al. presents a basic method and novel method for effectively sealing a bore hole in an excessively permeable formation. However, the sealant applicator disclosed in this copending application may require rotation to effectively seal the entire periphery of the hole in a permeable formation. Such rotation, whether performed mechanically or manually by rotation of the drill pipe, necessitates additional labor and introduces the possibility of an uneven application of sealant about the periphery of the hole because of possible variations in the speed of rotation of the applicator.

Recognizing the problems associated with the prior attempts to seal off permeable formations in drilled holes, 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 reducing the permeability or sealing excessively permeable formations.

It is a particular object of the invention to provide such an improved technique and apparatus for the practice of this technique which eliminated 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 and apparatus which minimizes the amount of sealant material required to properly reduce the permeability of exposed formation faces.

Another principal object of the invention is to provide a technique and apparatus by means of which a permeable formation may be adequately sealed without leaving 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 or be excessively vulnerable to the abrasive action of cutting carried by drilling fluids.

It is likewise a principal object of the invention to provide such an improved technique and apparatus 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 leave a relatively thin film of sealant on the formation wall defining a portion of a bore hole.

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 and apparatus 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 all together obviates the necessity of wiping sealant material across a formation face to be sealed.

It is still another object of the invention to provide such an improved technique and apparatus for its practice that eliminates the necessity of rotating the sealant applicator.

It is yet another object of the invention to provide an improved technique and apparatus for finely dividing the flow of sealant materials to be directed about the periphery of the hole in the permeable formation.

Another object of the invention is to provide a sealant applicator which is operable to provide an evenly distributed coat of sealant materials about the periphery of the hole in the permeable formation.

Additionally, it is an object of the invention to provide a sealant applicator that requires little maintenance when used with abrasive and/or gumming sealant materials.

The method presented through this invention for accomplishing the foregoing objectives involves the directing of a confined flow of 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 and impinged against an abutment surface so as to form a finely divided spray of sealant material particles.

The finely divided spray of sealant material particles is deflected so as to be projected generally transversely of the bore hole axis and outwardly from the abutment surface toward the wall of the hole portion to be treated in a substantially uniform and evenly distributed manner. The sealant material particles are impinged against, and evenly distributed about, the wall portion while maintaining a space between the outlet means and the wall portions substantially unoccupied by continuous phase liquid or solid 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.

To practice the method of this invention, a sealant applicator is provided which comprises nozzle means in fluid connection with a sealant materially carrying conduit string, abutment surface means cooperating with the nozzle, and connecting means connecting the abutment surface means in spaced relation to the nozzle means whereby the flow of sealant material directed from the nozzle means impinges against the abutment surface means and is deflected about the periphery of the hole in the permeable formation.

In describing a preferred mode of the invention and apparatus therefore, reference will be made to the accompanying drawings in which:

FIG. 1 is a fragmentary, elevational, and somewhat schematic view of one form of sealant-applying apparatus of the present invention which has been lowered on a conduit string into the drilled hole portion intersecting a permeable formation;

FIG. 2 is a fragmentary, elevational view of the spray head of the sealant applying apparatus shown in FIGURE 1;

FIG. 3 is a horizontal, cross-sectional view of the spray head of the sealant-applying apparatus shown in FIG. 2 and taken along line **3—3** therein;

FIG. 4 is a horizontal, cross-sectional view of the abutment surface disc of the spray head of the sealant-applying apparatus shown in FIG. 2 and taken along line **4—4** therein;

FIG. 5 is a fragmentary, vertical, cross-sectional view of a second embodiment of the sealant-applying apparatus of this invention;

FIG. 6 is a horizontal, cross-sectional view of the embodiment of the spray head of the present sealant-applying apparatus shown in FIG. 5 and taken along line **6—6** therein;

FIG. 7 is a horizontal, cross-sectional view of the abutment surface disc of the spray head of the sealant-applying apparatus shown in FIG. 5 and taken along line **7—7** therein; and

FIG. 8 is an enlarged, fragmentary, vertical, cross-sectional view of one orifice of the spray head of the sealant-applying apparatus shown in FIG. 5 and taken along line **8—8** therein.

As discussed in the heretofore identified copending application of Paramore et al., in drilling a bore hole, a conventional rotary drill bit supported by a conduit string is advanced axially into the hole being drilled and concurrently rotated so as to form this hole.

While drilling is progressing, a gaseous fluid such as air may be circulated within the hole being drilled so as to remove cuttings formed by the bit and to lubricate and cool the bit. Air is circulated downwardly in the annularly space between the conduit string and the wall of the

hole being drilled. In the conventional and well understood fashion, this downwardly circulating drilling fluid will enter openings in the lower end of the bit and pass upwardly through the interior of the conduit string, or vice versa.

As drilling continues through the downward advancement of the conduit string and the drill, the drill bit may intersect an excessively permeable formation. The portion of the bore hole which intersects the formation will be characterized by an annular wall portion through which the drilling fluid i.e., air, will escape into the interior of the formation. Under conventional drilling conditions such as those encountered in forming of oil well bore holes, the depth of the permeable formation may exceed several hundred feet with reference to the ground surface.

If the permeability of the formation 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 in the vicinity of the drilled hole wall portion. In the method herein disclosed, when it has been determined that the circulation of air is being reduced to an inordinate degree as a result of its flowing into the permeable formation, the conduit and its supported drill bit are withdrawn upwardly from the drilled hole. Thereafter, the bit is removed from the conduit string and is replaced by a sealant material distributing apparatus, the construction of which will be subsequently discussed.

To seal off the excessively permeable formation of a drill hole being formed, the present method includes spraying a finely divided flow sealant material about the periphery of the hole in the excessively permeable formation. The sealant material may be, advantageously, of a latex composition or a latex and gypsum cement, as disclosed in the heretofore designated copending application of Edwin L. Paramore et al.

Referring in more detail to FIGURE 1 of the drawings, in the present method a jetting tool **1** is lowered into the hole **2** in the permeable formation **4** and sealant material is directed downwardly under about 600 p.s.i. pressure through a conduit spring **6**. The flow of the sealant material is constricted as by a constriction in a spray head **8** of the jetting tool having a nozzle orifice size of approximately $\frac{3}{16}$" to thereby increase the velocity of the flow of sealant material urged in a downwardly direction. The forceful, high velocity, downward emission of the sealant material through the outlet of the spray head **8** is abruptly interrupted by an abutment surface disc **10**. The abutment surface disc functions to finely divide the flow of sealant material so as to form a partially mist-like spray and to redirect this spray in a radially uniform manner outward against the walls of the bore hole **2** in the permeable formation.

The spray of the sealant material is impinged against the bore walls and at least a portion thereof is imbibed in the pores of the permeable formation. This imbibition of the sealant material functions to increase the bond of the sealant material coating to the bore hole walls as disclosed in the heretofore designated Paramore et al. application. It is thought that the prior circulation of gaseous drilling fluid enhances subsequent imbibition of the sealant into the pores of the permeable formation and the consequential bond thereto.

One embodiment of the jetting tool, as shown in FIG. 2, includes a spray head **8** having a single, centrally disposed nozzle **14**. The nozzle includes a longitudinally-extending bore **16** having a hardened, abrasion- resistant tube **18**, of tungsten carbide or the like, positioned in the bore above a terminal orifice **20**. The outside upper periphery of the nozzle **14** is provided with threads **22** for connection with a longitudinally bored, collar-like nozzle adapter **23**, an inside bore **24** and outside upper periphery **25** of which is also threaded.

In threaded engagement the outside upper periphery of the nozzle adapter **23** is a couping **26** having a longi-

tudinally extending bore **28**, the upper and lower portions of which are also threaded.

Threadedly engaged in the upper portion of the bore **28** of the coupling **26** is a valve housing and coupling **29**, the lower end of which is in threaded engagement with the upper bore portion of the coupling **26**. The upper end of the housing and coupling **29** is connected to the conduit string **6**. The valve housing and coupling **29** is provided with a longitudinally extending bore **30** the mid-portion of which is enlarged to form a check valve-receiving chamber **32**, below which a lower bore **34** is provided to place the check valve housing and coupling in fluid connection with the nozzle adapter coupling bore **28**. Positioned in a frustoconical upper extremity **35** of the enlarged chamber **32** is a spherical closure or ball **36**, urged in an upwardly direction by a coil spring **38** or the like to thereby provide a pressure responsive closure.

It has been determined that the check valve should be so constructed so as to unseat upon the occurrence of from 400 to 500 p.s.i. pressure in the conduit **6** but to close upon the occurrence of reduced pressure to thereby eliminate the possibility of sealant material drippage and waste. Further, by the provision of this pressure responsive valve fouling of the spray head and the bore hole from sealant material drippage when the device is in the inoperative condition is likewise elilminated.

To divide and deflect the high pressure and high velocity flow of sealant material from the nozzle **14**, an abutment surface disc **10** is adjustably connected subjacent the nozzle **14**. It should be noted that the disc **10** should be maintained in a horizontal position if even spray distribution is to be achieved. Positioned about the periphery of the disc **10**, and spaced at approximately 120°, are three vertically extending legs **40**, the upper ends of which contiguous with the periphery of the coupling **26** and provided with slots **43** for receiving threaded bolt and nut **44**, or the like, therein.

Fixedly connected about the periphery of the coupling **26** are three vertically and generally radially extending legs **46** also positioned at 120° so as to flushly engage the generally radially extending legs **40**. The lower ends of the legs **46** are provided with slots **48** for reception of the threaded bolts **44** or the like. In this manner, the vertical spacing between the nozzle and the abutment surface disc may be adjusted to vary the degree of flow division afforded by the disc.

The vertically extending surfaces of the legs **40** most closely adjacent the nozzle **14** are provided with knife-shaped inserts **42** of tungsten carbide or other similar hardened materials so as to cut the spray of sealant materials deflected by the disc **10** with a minimum disturbance to the radial uniformity of the spray and a minimum of wear on the legs **40**.

Positioned immediately subjacent the nozzle **14** is a replaceable, square wear plate **44** also constructed of tungsten carbide or the like. The wear plate **44** is received in a rectangular recess **46** in the disc **10** so that its upper surface is flush with the upper surface of the disc.

In operation, as the sealant material is pumped through the conduit **6** and the pressure therein exceeds the 400–500 p.s.i. setting of the check valve **36**, the valve is opened permitting flow through the coupling **26**. The velocity of the sealant material is increased upon encountering the constriction formed in the flow course by the nozzle adapter **23** and the nozzle **14** and such flow, as it is emitted from the orifice **20**, is of such an increased velocity that, upon striking the abutment plate **10**, the flow particles become finely divided and deflected outwardly in a radially uniform and evenly distributed manner to thereby coat the walls of the bore hole **2** of the permeable formation **4**. The degree of flow division and the direction of spray deflection may be adjusted by adjustment of the vertical and angular orientation of the disc **10**. Also, it will be seen that uniform radial sealant flow distribution is achieved without rotation of the conduit string or the spray head.

In the embodiment of the present invention shown in FIG. 5 a plural orifice nozzle **50** having a central bore **52** therein is provided. Positioned in symmetrical arrangement about the central bore **52** are three orifice tube receiving bores **54**, the lower extremity of each of which is offset both outwardly and forwardly from the upper extremity in the direction which the sealant material is to be propelled. Positioned in each of the bores **54** is an abrasion-resistant tubular insert of tungsten carbide or other similar hardened material. As shown, the axis of these bores **54** are skewed both outwardly and forwardly at an angle of about 15 degrees in relation to the longitudinal axis of nozzle **50**.

The upper end of the nozzle **50** is provided with an enlarged, longitudinally extending bore **58** and the outside upper periphery of the nozzle is in threaded engagement with the nozzle adapter **60** having a longitudinally extending bore **62** therein. The nozzle adapter bore **62** in threaded engagement with the valve housing and conduit **29**, as shown in FIG. 1.

Positioned subjacent the nozzle **50** is an abutment surface disc **64** having a centrally disposed bore **66** therein. A bolt **68** having an enlarged head **70** is positioned in the bore **52** of the nozzle **50** and the lower end of the bolt **68** is directed through the bore **66** in the disc **64** and is provided with a nut **72** to maintain the vertically spaced relationship between the nozzle and the disc as well as the horizontal orientation of the disc. A plurality of washers **74**, the number of which may be varied, are positioned between the nozzle **50** and the abutment disc **64** to achieve the desired spacing therebetween.

Positioned immediately subjacent each orifice **57** is a rectangular, abrasion resistant wear plate **76**. The wear plates **76** of the spray head shown in FIGURE 5 are received in rectangular recesses **80** of the disc **64** and fixed therein by brazing, silver soldering, or the like, as in the embodiment shown in FIGURE 2. The recesses **80** are so dimensioned so as to position the upper surface of the wear plate **76** in a flush condition with the upper surface of the abutment disc **64**. To further assist in maintaining the desired orientation between the nozzle **50** and abutment disc **64**, a vertically extending dowel **82** is positioned in a bore **84** which is offset from the longitudinal axis of the central bore **66** in the disc **64**. The upper end of the dowel **82** is received in a vertically extending recess **86** in the lower face of the nozzle **50**.

It should be noted that the instant method and apparatus are applicable at bore hole depths and diameters and at sealant viscosity and pressures disclosed in the heretofore designated Paramore et al. application.

It will be seen that by utilization of the present method and either embodiment of the spray head disclosed hereing, a radially uniform spray pattern is achieved without rotation of the overall device. Further, the flow of sealant from the nozzle is directed to the walls of the bore hole in a finely-divided state facilitating a thin but uniform seal coat on the walls.

The unique three legged, deflector plate supported heretofore described enables deflector plate adjustments to be made while maintaining this plate absolutely perpendicular to a nozzle longitudinal axis.

The skewed, multiple orifice nozzle arrangement is noteworthy as it provides a spray swirling action, i.e. a generally tangential spray component, which yields an unusually effective coating action in a bore hole environment.

By the provision of a pressure responsive valve in the sealant carrying conduit, sealant drippage and waste, as well as unnecessary spray head and bore hole fouling is eliminated.

Through the utilization of an adjustably mounted abutment surface disc, not only may even spray distribu-

tion be maintained, but also flow dispersion may be regulated.

Various other modifications and alterations will suggest themselves readily to persons skilled in the art. It is intended, therefore, that the foregoing be considered as exemplary only, and that the scope of the invention be ascertained from the following claims.

Having thus described my invention, I claim:

1. A method of coating an exposed wall portion of a drilled hole intersecting a permeable earthen formation, said method comprising:

circulating gaseous fluid adjacent an exposed wall portion of a drilled hole which intersects a permeable formation such that at least a portion of said gaseous fluid enters said formation through said exposed wall portion;

directing a confined flow of sealant material, isolated from the periphery of said drilled hole, generally axially into said hole;

constricting said axial flow of sealant material so that its flow velocity is increased in passing said constricted flow through outlet means;

impinging said constricted flow of sealant material against abutment surface means, said abutment surface means being spaced from said outlet means and extending generally transversely of the longitudinal axis of said drilled hole;

said constricted flow of sealant material being impinged against said abutment surface means so as to form divided particles of sealant material which are deflected generally transversely of the longitudinal axis of said drilled hole and projected generally transversely of this axis as an at least partially mist-like spray against the exposed wall portion of said permeable formation.

2. A method of coating an exposed wall portion of a drilled hole intersecting a permeable earthen formation, said method comprising:

directing a confined flow of sealant material, isolated from the periphery of said drilled hole, generally axially into said hole;

constricting said axial flow of sealant material so that its flow velocity is increased in passing said constricted flow through outlet means; and

impinging said constricted flow of sealant material against abutment surface means, said abutment surface means, being spaced from said outlet means and extending generally transversely of the longitudinal axis of said drilled hole;

said constricted flow of sealant material being impinged against said abutment surface means, divided into particles, and deflected thereby generally transversely of the longitudinal axis of said drilled hole as an at least partially mist-like spray against the periphery of the exposed wall portion of said permeable formation.

3. In combination:

a drilled hole;

an exposed wall portion of a permeable formation intersected by said drilled hole;

a conduit string extending generally longitudinally of said drilled hole;

pump means for supplying a liquid sealant material under pressure to said conduit string;

nozzle means carried by and in fluid communication with said conduit string for directing a flow of sealant material;

abutment surface means located adjacent to said exposed wall portion of said permeable formation; and

connecting means connecting said abutment surface means in axially spaced relation to said nozzle means whereby a flow of sealant material directed from said nozzle means impinges against said abutment surface means and is divided into particles of sealant material and deflected as an at least partially mist-like spray generally toward the periphery of said exposed wall portion of said permeable formation.

4. A combination as described in claim 3, said combination including:

selectively adjustable connecting means mounting said abutment surface means for selective axial adjustment relative to said nozzle means;

coupling means connecting said nozzle means to said conduit string, and including pressure responsive valve means operable to prevent a flow of sealant material from said conduit string to said nozzle means when the pressure of sealant material within said conduit string has been reduced; and

replaceable wear plates removably mounted on said abutment surface means so as to be deflectingly impinged upon by sealant material issuing from said nozzle means.

5. In combination:

a drilled hole;

an exposed wall portion of a permeable formation intersected by said drilled hole;

a conduit string extending generally longitudinally of said drilled hole;

pump means for supplying a liquid sealant material under pressure to said conduit string;

nozzle means in fluid communication with said conduit string for directing a flow of sealant material;

abutment surface means located adjacent said exposed wall portion;

connecting means adjustably connecting said abutment surface means in axially spaced relation to said nozzle means whereby the flow of sealant material directed from said nozzle means impinges against said abutment surface means and is divided into particles and deflected as an at least partially mist-like spray toward the periphery of said exposed wall portion of said permeable formation; and

an abutment surface guide means carried by said conduit string;

said connecting means including at least three leg means each slidably and peripherally engaging abutment surface guide means carried by said conduit string.

6. A combination as described in claim 5:

wherein each leg means includes a sharpened portion disposed radially outwardly of but facing the longitudinal axis of said conduit string, each said sharpened portion being constructed of harder material than the remainder of its associated leg means;

wherein said abutment surface means includes at least one, removably mounted, hardened wear plate upon which sealant material issuing from said nozzle means deflectively impinges, and

wherein said combination further includes pressure responsive valve means disposed upstream of said nozzle means and operable to prevent a flow of sealant material from said conduit string to said nozzle means when the pressure of sealant material within said conduit string has been reduced to a predetermined level.

7. A spray head for a jetting tool, said spray head comprising:

nozzle means including a plurality of orifices distributed about the longitudinal axis of said nozzle means;

said orifices each being formed by a hardened tubular member, the longitudinal axis of which is non-parallel to the longitudinal axis of said nozzle means;

pressure responsive valve means adapted to prevent fluid flow to said orifices when said flow is beneath a predetermined pressure level;

abutment surface means;

connecting means positioned coaxially with the longitudinal axis of said nozzle means and radially adjacent said orifices;

said connecting means connecting said nozzle means in

spaced relation to said abutment surface means whereby fluid issuing from said nozzle means is divided by, and deflected generally outwardly from, said abutment surface means.

8. In combination:

a drilled hole;

an exposed wall portion of a permeable formation intersected by said drilled hole;

a conduit string extending generally longitudinally of said drilled hole;

pump means for supplying a liquid sealant material under pressure to said conduit string;

nozzle means carried by and in fluid communication with said conduit string for directing a flow of sealant materials;

abutment surface means located adjacent to said exposed wall portion of said permeable formation;

connecting means connecting said abutment surface means in axially spaced relation to said nozzle means whereby a flow of sealant material directed from said nozzle means impinges against said abutment surface means and is deflected as an at least partially mist-like spray generally toward the periphery of said exposed wall portion of said permeable formation; and

said nozzle means comprising a plurality of generally tubular passages, the longitudinal axes of which are skewed in relation to the longitudinal axis of said conduit string.

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