FIP8011 XR 3,384,181

CROSS REFERENCE SEARCH ROOM
166
241

May 21, 1968 G. P. MALY ET AL 3,384,181

APPARATUS FOR DETECTING SAND ENTRAINMENT

Filed Jan. 25, 1966 2 Sheets-Sheet 1

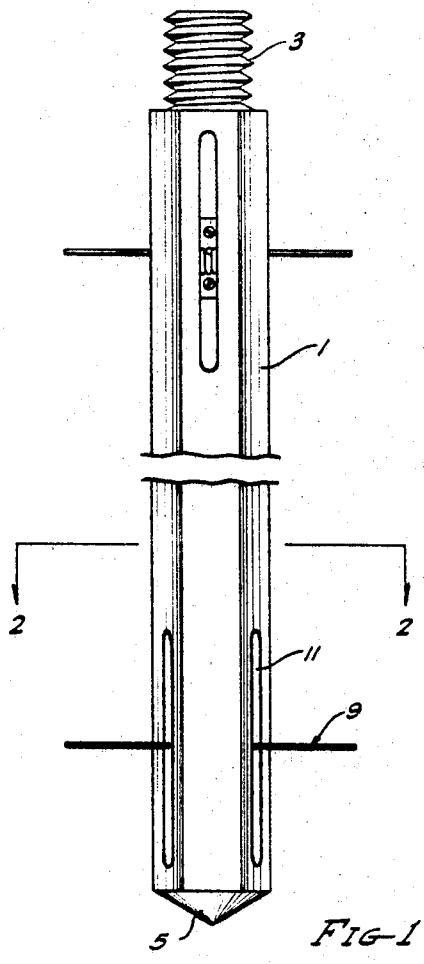


FIG-1

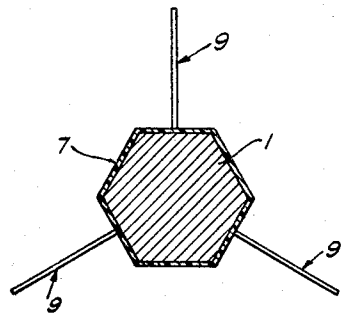


FIG-2

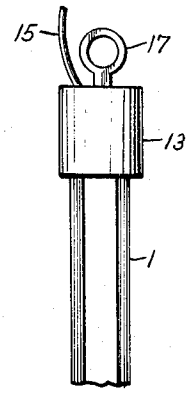


FIG. 6

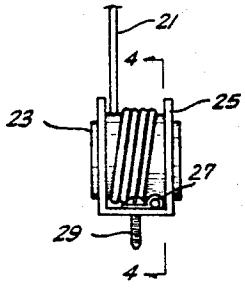


FIG-3

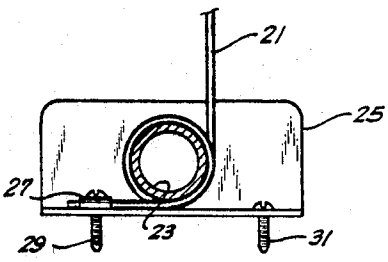


FIG-4

INVENTORS
GEORGE P. MALY
GEORGE M. HARPER JR.
BY
Dean Sandford
ATTORNEY

May 21, 1968 G. P. MALY ET AL 3,384,181

APPARATUS FOR DETECTING SAND ENTRAINMENT

Filed Jan. 25, 1966 2 Sheets-Sheet 2

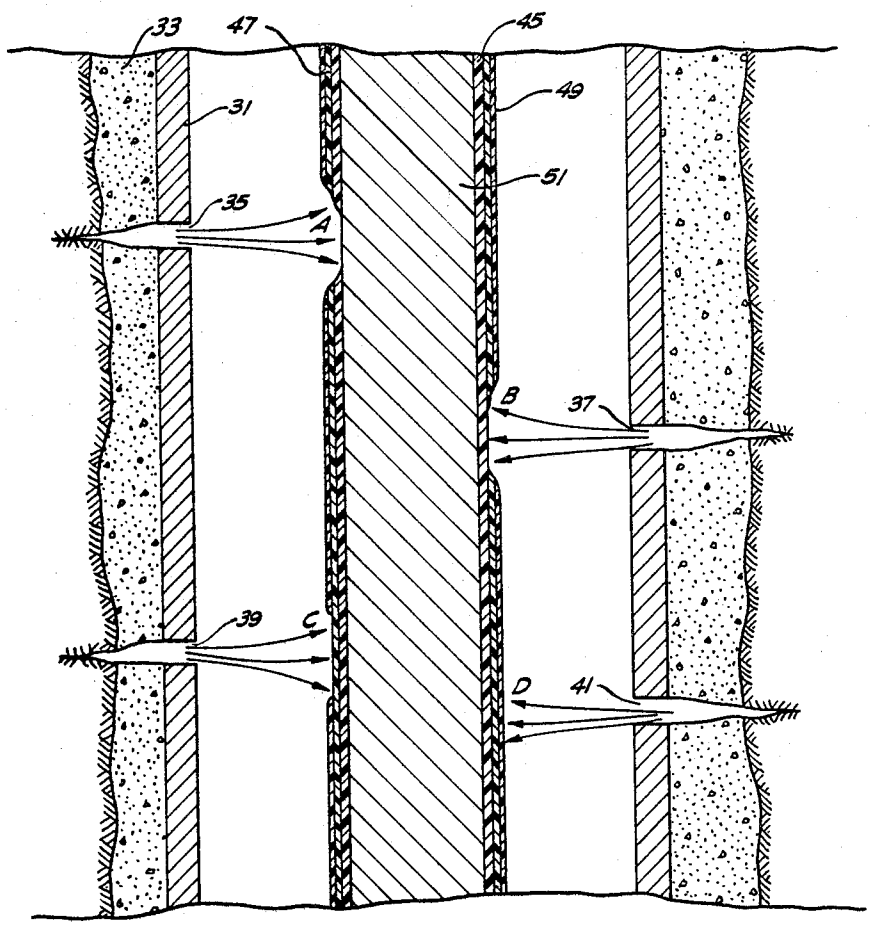


FIG-5

INVENTORS
GEORGE P. MALY
GEORGE M. HARPER JR.
BY
Dean Sandford
ATTORNEY

United States Patent Office 3,384,181 Patented May 21, 1968

3,384,181

APPARATUS FOR DETECTING SAND ENTRAINMENT

George P. Maly, Newport Beach, Calif., and George M. Harper, Jr., Abbeville, La., assignors to Union Oil Company of California, Los Angeles, Calif., a corporation of California

Filed Jan. 25, 1966, Ser. No. 522,901
14 Claims. (Cl. 166—241)

ABSTRACT OF THE DISCLOSURE

A device for detecting the entrainment of sand in fluid flowing into a well from a surrounding fluid-producing earth formation that comprises an elongated member having a polygon-shaped cross-section and which is covered with one or more coats of distinguishable abradable materials. The device is positioned in the well adjacent the fluid producing zones and the well produced in conventional manner for a period of time sufficient to effect at least partial erosion of said abradable material by the produced fluids.

This invention relates generally to the production of connate earth fluids from incompetent subterranean producing formations, and more particularly to an apparatus for detecting the entrainment of sand in fluid flowing from a subterranean fluid-producing earth formation into a well penetrating the formation.

Recoverable fluids, such as petroleum oil, gas and water, are frequently found in subterranean formations comprising unconsolidated, or loosely consolidated sand and sandstone. When such incompetent formations are pierced by a well bore, and the connate fluids therein removed, the loose or weakly bound sand particles become dislodged and are entrained in the fluid. Also, sand control problems can be encountered in otherwise competent formations due to excessively high fluid velocities, particularly in localized areas, or because of water invasion into the producing zone which destroys the bond between sand particles. In any case, some of the dislodged sand accumulates in the well bore and other flow areas causing plugging and reduced fluid flow, while other of the sand is carried to the surface with the withdrawn fluid. These entrained particles causes severe erosion of underground strainers and liners, the producing string, pressure control valves, chokes, pumps and flow lines. Substantial quantities of the entrained sand are deposited in field storage tanks causing cleaning and disposal probelms. In extreme cases, sufficient sand can be removed from the producing formation to create large underground zones of reduced pressure, which can collapse the casing and cause the loss of a well. Thus, fluid production from incompetent subterranean formations can result in restricted flow, increased production and well maintenance costs, and even destruction of the well.

Both the quantity of sand carried from the producing formation and the problems associated with handling fluids containing entrained sand particles are increased by higher fluid velocities. Thus, although sand entrainment is experienced in both oil and water wells, wells producing gas or liquid-gas mixtures are particularly plagued with severe sand entrainment.

The aforementioned sand entrainment can be wholly or partially eliminated by treating the producing zone with cement, plastic, or other adhesive binders to consolidate the incompetent sand sufficiently to prevent them from being carried from the formation into the well by the flowing fluid. While these techniques are more or less satisfactory in reducing sand entrainment, they necessarily cause a reduction in formation permeability. Thus, the benefits of consolidation must be balanced against reduced permeability, with it generally proving desirable to effect a lesser consolidation.

Usually sand entrainment will be experienced from only a few of the many strata penetrated by the well. However, because of inadequate methods of determining the exact location of the sand entrainment, it has heretofore been necessary to consolidate the entire producing formation to achieve sand control. Further, since in many cases a single consolidation treatment does not accomplish the necessary sand control, or because previously consolidated formations deteriorate sufficiently to allow entrainment of sand therefrom, it often becomes necessary to retreat the producing formation with one or more subsequent consolidation treatments, each of such treatments further reducing the formation permeability. Thus either in the case of original consolidation, or in subsequent treatment, it is highly desirable to precisely locate the source of sand entrainment so that treatment can be limited to only those strata from which entrainment is experienced.

Additionally, it is desirable that an approximation of the magnitude of entrainment for each of the sand producing zones be obtainable as it may be advantageous to defer consolidation of those formations suffering only minor sand entrainment. It is further advantageous to determine entrainment distribution as sand entrainment attributable to localized high velocities can frequently be reduced or eliminated by locating additional perforations within the high velocity zone.

Accordingly, it is a principal object of the present invention to provide an apparatus for locating those strata of a producing formation experiencing sand entrainment. Another object is to provide an apparatus for determining the location and approximate magnitude of sand entrainment from producing formations. Still another object is to provide apparatus for detecting sand entrainment which is capable of insertion into a well through conventional well equipment. A still further object is to provide a sand detecting device for insertion into a well bore capable of measuring the location of fluid streams entering the well which contain entrained matter, and of determining the approximate quantity of such entrained matter. Other objects and advantages of the invention will be apparent to those skilled in the art from the description which follows.

The above objects and related advantages can be realized by an elongated device or tool positionable within a well adjacent a fluid producing formation. This detector device comprises a rigid body member coated with one or more coatings of an abradable material which is eroded form the surface of the body member by impingement of a fluid containing entrained sand, but which is eroded to a lesser degree by the impingement of fluid not containing entrained sand. The location, extent and depth of the observed erosion is determinative of the location and magnitude of sand entrainment. By a proper choice of coatings, the location and approximate quantity of entrained water and hydrocarbon condensate can also be estimated.

The present invention can be more readily understood by reference to the accompanying drawings, of which:

FIGURE 1 is a side view illustrating one embodiment of the detector device of this invention.

FIGURE 2 is a cross-sectional view of the illustrated detector device taken along the line 2—2 of FIGURE 1.

FIGURE 3 is a detail showing the centralizing mechanism

FIGURE 4 is a cross-sectional view of the centralizer taken along the line 4—4 of FIGURE 3.

FIGURE 5 is a schematic illustration of a detector device, shown in cross-section, in position within a well penetrating a fluid producing formation.

FIGURE 6 is a side view of the detector device equipped with a location detecting device.

Referring now to FIGURES 1 and 2, the detector tool comprises elongated body member **1** having threaded end **3**. Body member **1** is formed of either a solid rod or bar, or a hollow member such as a length of pipe, and can be of circular or elliptical cross-section. However, in a preferred embodiment the body member has a cross-sectional configuration shaped as a polygon, and particularly as a regular polygon having from **3** to about **8** sides. The advantage of the polygonical shape is that the body member will tend to contact the tubing, or other apparatus through which it is inserted, only along the edges formed by the vertices of the polygon, thus minimizing wear and abrasion of the coating during the process of inserting or otherwise handling the detector device. It is preferred that body member **1** comprise an elongated member having a cross-sectional configuration in the shape of a regular polygon of less than eight sides, such as a triangle, square, pentagon, hexagon, heptagon, or an octagon; the illustrated device of FIGURES 1 and 2 having a regular hexagonal cross-section.

No matter which cross-sectional configuration is employed, body member **1** must be of sufficiently small cross-sectional dimension to be easily insertable into the well. Since in the conventional application the device is inserted through the production tubing to a position adjacent the producing zone, the maximum diameter of body member **1** must be less than the inside diameter of the tubing. Accordingly, body member **1** is usually less than 2 inches in diameter, and conventionally has a diameter of from about 1 inch to about 2 inches.

Body member **1** can be of any convenient length, limited only by the length of member which can be inserted through available lubricators, or by the length of member which can traverse crooked or offset sections of the well. Body member **1** can be of any length from about 1 to about 60 feet, and conventionally will be of a length from about 4 to about 200 ft. It is desirable that the detector have a length somewhat in excess of the thickness of the producing zone. However, in the case of thick producing zones, successive measurements can be made, as will be more fully described. One end of member **1** is threaded at **3** to engage a cable or wire line head or other threadably engageable tool holder. In the illustrated device, the opposite end **5** of member **1** has a slight point. End **5** can also be flat, or often is desirably fabricated with male threads to engage a coupling, or with female threads to directly engage another section of detector device or other tool. Thus, an elongated detector device can be formed of two or more detachable sections so that the body length can be varied to accommodate different applications and also for convenient handling and storage.

The exterior surface of body member **1** is covered with one or more coatings **7** of adherent abradable material. This adherent covering can comprise one or more coats of paint, varnish, plastic, porcelain, ceramic, or metal; preferably completely coating body member **1** about its periphery and extending substantially the length of the member. Thus, in the simplest embodiment, the exterior surface of body member **1** is covered by a single coating of an abradable material of substantially uniform thickness. It is also desirable to select a coating easily distinguishable from the metal surface of body member **1** so that the abraded portions will be readily apparent. A coating material having a distinct color, or texture can be selected, or where the coating material is clear or otherwise not easily distinguishable from the metal surface, a distinctive pigment or color body can be included.

In another embodiment, the coating comprises a plurality of layers of abradable material, each of which layers is of substantially uniform thickness, although individual layers can be of different thicknesses. Different coating materials can be employed for each layer, or at least two readily distinguishable materials can be alternately applied. In any case, the thickness of individual coatings is in the range of from about 5 mils to about ¼ inch, primarily depending on the type of coating material. As previously mentioned, individual coating layers are preferably of a substantially uniform thickness, although different layers can be of different thickness within the aforementioned range.

In one preferred embodiment, the coating comprises two or more coats of adherent material having different abrasion characteristics. The material having the greater resistance to abrasion is applied first as an inner coat, with a less resistant coating being applied as an outer layer. In this manner, the adherent coating can comprise a plurality of coats of different abrasion resistances, varying from an inner or first coat of highly resistant material to an outer, or final coat of a material having the lowest abrasion resistance. Thus, commencing at the outer coating, each successive coating will be of a material having increased abrasion resistance. A somewhat similar effect can be obtained by varying the thickness of the coats, with the thickest application being made first and each progressive application being of somewhat reduced thickness.

Another embodiment of the detector device having an outer or final coating of water or oil soluble material has particular application in the testing of gas wells. Since the outer coating will be solubilized and removed by liquid water or hydrocarbon, depending upon the nature of the coating selected, without removal of subsequent nonsoluble layers, the strata can be located from which a gas is being produced which contains entrained water or condensate. It is not desirable that the coating to be highly soluble in oil or water, so as to be removed on contact, but instead suitable materials are only slightly soluble in the solvent so that the combined action of the solubilizing effect of the solvent and the scouring action of the impinging fluid stream is required to remove the coating. Thus, it is within the purview of this invention to employ as an outer coating a material which is slightly soluble in either liquid water, or in liquid hydrocarbon.

The above-described coating materials are applied in conventional manner depending on the nature of the coating material selected. Accordingly, the paints and some plastics can be applied by brushing, spraying or dipping; glasses, ceramics and porcelain are applied by conventional glazing and porcelainizing methods wherein the coating is heated, usually to temperatures in the range of 800–1400° C.; and the metal coatings can be applied by anodizing, by electroplating, by galvanizing or by metal spray and vacuum deposition techniques. Where possible, it is desirable to employ the more simplified methods of application which can be performed in the field by relatively unskilled personnel.

Although not essential to the operability of the above-described detection device, it is usually advantageous to provide body member **1** with centralizers to maintain the detector device more or less centrally positioned within the conduit through which it is inserted. Fitting the device with centralizers will minimize abrasion or damage to the coating material as the device is inserted into well, and also will more favorably locate the detector at the center axis of the well during the actual test. Any conventional centralizer can be employed which has the capability of sufficient compression to permit the detector to be inserted and lowered through the small diameter tubing without undue frictional drag, yet also has sufficient expandability to provide centralization of the device within the larger diameter casing.

The detection device illustrated in FIGURES 1 and 2 is provided with centralizing means **9** particularly adapted to function within conduits having varying in-

side diameters of from slightly larger than that of body member **1** up to several times the diameter thereof. The arms of centralizing means **9** normally protrude perpendicular to the principal axis of body member and normal to the exterior surface thereof. Centralizing means **9** are biased so as to be movable in an axial direction by application of external force sufficient to overcome the bias. On application of sufficient force, the bias will be sufficiently compressed so that the protruding arm of mechanism **9** can be forced into slot **11** in body member **1**. Centralizer **9** is so biased that it can be forced into slot **11** in either axial direction. On removal of the external force maintaining the bias compressed, the centralizer arm will return to the normal perpendicular position. Desirably, three or more centralizers are positioned about the periphery of body member **1** at each of several locations along its length. In the illustrated device, three centralizers are located adjacent the threaded end **3** of body member **1**, and three centralizers are located adjacent end **5** which are oriented 60 degrees removed from those adjacent end **3**.

The construction of centralizer **9** is shown in detail in FIGURES 3 and 4. A length of spring wire **21** has one end coiled to fit around shaft **23**, which can comprise a hollow or solid cylinder. Shaft **23** is supported by bracket **25**. The clearance between the ends of shaft **23** and the sidewalls of slot **11** are less than the distance between this wall and bracket **25** so that shaft **23** is maintained in the bracket assembly without lateral retainers. The nonprotruding end of spring **21** is fastened to bracket **25** by clip **27** and bolt **29**. The centralizer assembly is fitted within slot **11** and secured to body member **1** by bolts **29** and **31** which fit into tapped holes in member **1**. Assembly of centralizer **9** can be conveniently made by inserting shaft **23** through spring **21** and slipping this assembly into bracket **25**. Clip **27** is added and the assembly attached to body member **1** by bolt **29** and **31**. Because of this simplicity of installation, broken or damaged centralizers can be replaced in the field, usually by merely replacing spring **21**.

The detector device of this invention can be used to determine sand entrainment into well bores lined with conventional perforated casings, slotted liners, or screens. The device has application in determining the location and approximate magnitude of entrainment in fluid streams carrying entrained sand, water or condensate into the well bore through established perforations or slots, and also in locating holes in damaged or corroded screens and casing.

However, in any of the foregoing applications the detector device is used in a substantially similar manner. The well is shut in and the detector inserted into the well and positioned adjacent a producing zone. The detector device is lowered into the well bore and supported adjacent the producing formation by means of a wire line, electric cable, or on a drill stem, as may be convenient. The well is then produced at normal rates for a period sufficient to effect abrasion of the coating material by entrained sand particles, and once again shut in for removal of the detector device. The detector is removed and inspected for abrasion and the well returned to normal production.

Since, in the usual application, the well is under an elevated pressure and cannot be opened to the atmosphere for insertion of the detector, a conventional sealed lubricator can be used to insert the detector device into the well. This lubricator comprises a chamber which is attachable to the well head and equipped with a pressure retaining packed gland through which the wire line or cable passes. Thus, the method of determining sand or liquid entrainment in accordance with the present invention comprises the steps of shutting in production from the well and fitting the well head with a lubricator in conventional manner. A properly coated detector tool is suspended on a wire line or cable and inserted into the lubricator, the wire passing through the packed gland. The detectors is then lowered through the tubing or casing to the producing zone in conventional manner. On properly positioning the detector device at the location to be tested, the well is opened to production at normal rates for a period of from about 15 minutes to about 4 hours in the usual case, or for such other period as necessary to effect abrasion of the coating material by entrained said particles. The well is then again shut in and the detector device passed upwardly from the well and into the lubricator. The lubricator is isolated and depressurized, and the detector device removed therefrom. The location and magnitude of entrainment is determined by observation of the erosion suffered by the abradable coating. Alternatively, the extent of erosion can be determined by measuring the thickness of the remaining coating.

FIGURE 5 illustrates the use of the detector device of this invention in determining sand and water entrainment in connate fluids flowing from a subterranean fluid-producing formation into a well. Steel casing **31** is positioned within a bore hole penetrating a typical unconsolidated earth formation and cemented in place at **33** in conventional manner. Casing **31** and cement **33** are perforated at **35**, **37**, **39** and **41** to permit fluids to flow from the adjacent earth formation into the interior of casing **31**. A short intermediate section of the detector device is shown positioned within casing **31**, approximately at the center axis thereof. Elongated solid body member **51** is shown covered by three adherent coats of abradable material illustrated at **45**, **47** and **49**. First, or inner coating **45** and intermediate coating **47** are selected from the above-described materials. The material used in coating **45** is selected for a somewhat higher abrasion resistance than the material of coating **47**. Outer coating **49** is slightly water soluble so that it will be removed by impingement of entrained water.

Typical moderately heavy sand entrainment is illustrated at A where the effect of the sand particles entrained in the fluid stream entering the well through perforation **35** is to erode coatings **45**, **47** and **49** to expose the surface of body member **51**. Under conditions of heavy entrainment body member **51** can also suffer heavy erosion. B illustrates a lesser degree of sand entrainment, since under the same conditions of exposure, sand particles entrained into the well with fluids passing through perforation **37** are only sufficient to erode coatings **47** and **49**, leaving more abrasion resistant coating **45** relatively undamaged. The situation where the impinging fluid stream contains only water droplets is illustrated at C wherein only outer coating **49** is removed in the area of impingement without appreciable erosion of coating **47**. D represents a case where the fluids entering the well through perforation **41** and impinging the detector at D contain neither entrained sand nor water as evidenced by the coatings suffering substantially no erosion damage. It is to be understood that outer coating **49** could be formed of an oil soluble material so as to provide detection of hydrocarbon condensate entrained in a produced gas.

Particularly where the detector is used on a wire line, it is desirable to attach the wire line to the detector by means of a rotary head to permit free rotation of the detector. Otherwise the tangential forces imparted to the detector by the impinging fluid streams could cause severe twisting of the wire line. In such cases, the eroded area appears as a concentric ring about the periphery of the detector, rather than as a spot which is the usual case with a nonrotatable detector.

Determining the exact location of the detector within the well is important in interpreting the erosion observed, and in conducting remedial operations to reduce detected sand entrainment. The precise location of the detector can be determined by any one of several conventional techniques, such as for example by measuring the distance off bottom, or from a set packer positioned below

the point of measurement. The position of the retector can be ascertained with reference to collars, the location of which can be determined with conventional magnetic collar locators. These magnetic collar locators will also indicate the location of perforations made by expendable perforating guns. The installation of a location detector on the detection device of this invention is illustrated in FIGURE 6 wherein magnetic detector **13** having electric cable connection **15** and eye **17** is shown threadably mounted on body member **1**. Also, the detector position can be measured in reference to known anomalies by conventional electric and radiation logging techniques.

While particular embodiments of the invention have been described, it will be understood, of course, that the invention is not limited thereto since many modifications can be made, and it is intended to include within the invention any such modifications as fall within the spirit and scope of the claims.

The invention having been fully described, we claim:

1. A device for detecting the entrainment of sand in fluid flowing into a well from a surrounding fluid-producing earth formation comprising an elongated body member having a polygon-shaped cross-section that can be positioned within said well adjacent said fluid producing zone, said body member having its outer surface substantially uniformly covered with an adherent coating of a distinguishable abradable material.

2. The device defined in claim **1** wherein said elongated body member is from about 1 to about 60 feet in length and less than about 2 inches in diameter.

3. The device defined in claim **1** wherein at least one end is threaded to threadably engage a holding device.

4. The device defined in claim **1** wherein said elongated body member has a cross-sectional shape in the form of a regular polygon of less than eight sides.

5. The device defined in claim **1** including flexible positioning means attached to said body member for centering said device in said well.

6. The device defined in claim **1** including means for determining the location of said device in said well.

7. The device defined in claim **1** wherein said coating comprises a plurality of separate adherent layers of individually distinguishable abradable material.

8. The device defined in claim **7** wherein said individual separate adherent layers are formed of materials having varying resistances to erosion, said innermost of said layers being the most resistant to erosion and each subsequent layer progressively decreasing in abrasion resistance.

9. The device defined in claim **7** including a substantially uniform outer coating of an abradable material which is soluble in liquid hydrocarbon.

10. The device defined in claim **7** including a substantially uniform outer coating of an abradable material which is water-soluble.

11. A device for detecting the entrainment of sand in fluid flowing into a well from a surrounding fluid-producing earth formation comprising an elongated body member that can be positioned within said well adjacent said fluid producing zone, said body member having its outer surface substantially uniformly covered with an adherent coating comprising a plurality of separate adherent layers of individually distinguishable abradable material.

12. The device defined in claim **11** wherein said individual separate adherent layers are formed of materials having varying resistances to erosion, said innermost of said layers being the most resistant to erosion and each subsequent layer having a progressively decreased abrasion resistance.

13. The device defined in claim **11** including a substantially uniform outer coating of an abradable material which is soluble in liquid hydrocarbon.

14. The device defined in claim **11** including a substantially uniform outer coating of water-soluble abradable material.

References Cited

UNITED STATES PATENTS

2,439,542	4/1948	Hunt	166—113 X
2,606,793	8/1952	Suter	166—241
2,628,682	2/1953	Wright	166—241 X
2,696,112	12/1954	Griffith	73—155
3,034,912	5/1962	Flowers	166—243
3,070,166	12/1962	Knauth	166—46
3,070,171	12/1962	Rike et al.	166—243
3,075,582	1/1963	Morse et al.	166—46
3,187,567	6/1965	O'Brien et al.	73—155
3,220,437	11/1965	Safford	166—242 X

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

DAVID H. BROWN, *Examiner.*