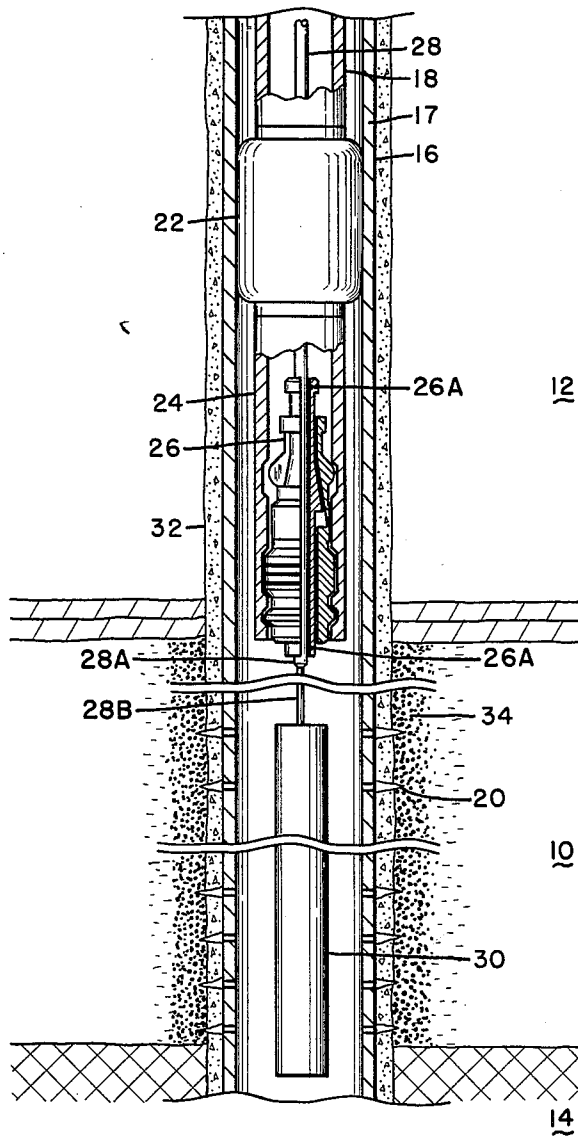


Filed Feb. 8, 1960

STABILIZING A FORMATION

5 Sheets-Sheet 1



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STABILIZING A FORMATION

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5 Sheets-Sheet 2

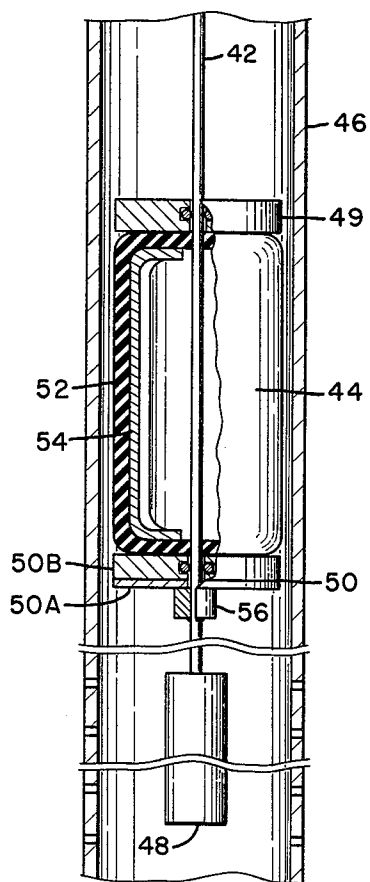


FIG. 2A

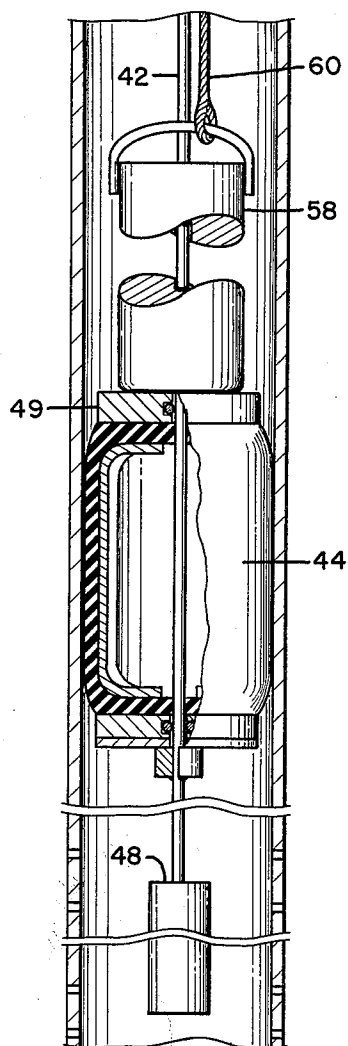


FIG. 2B

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5 Sheets-Sheet 3

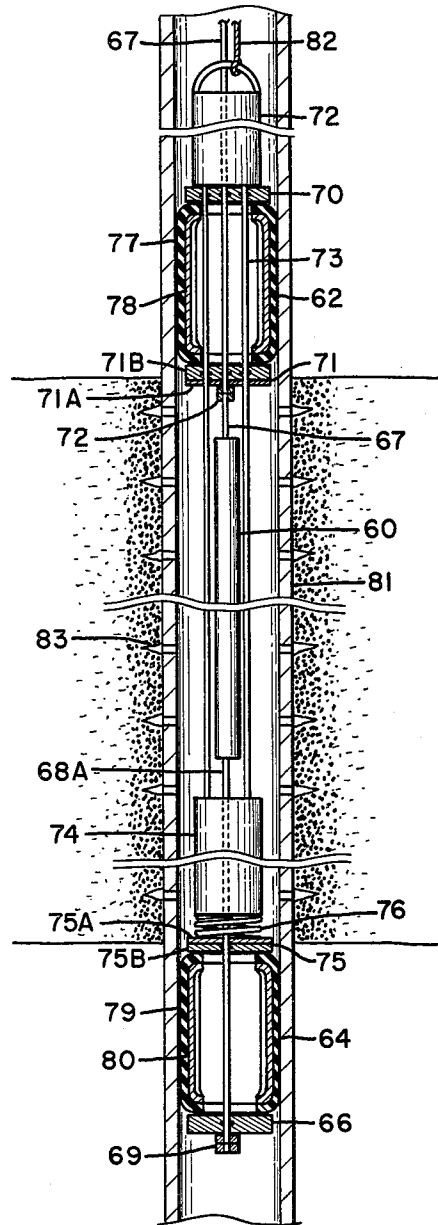


FIG. 3

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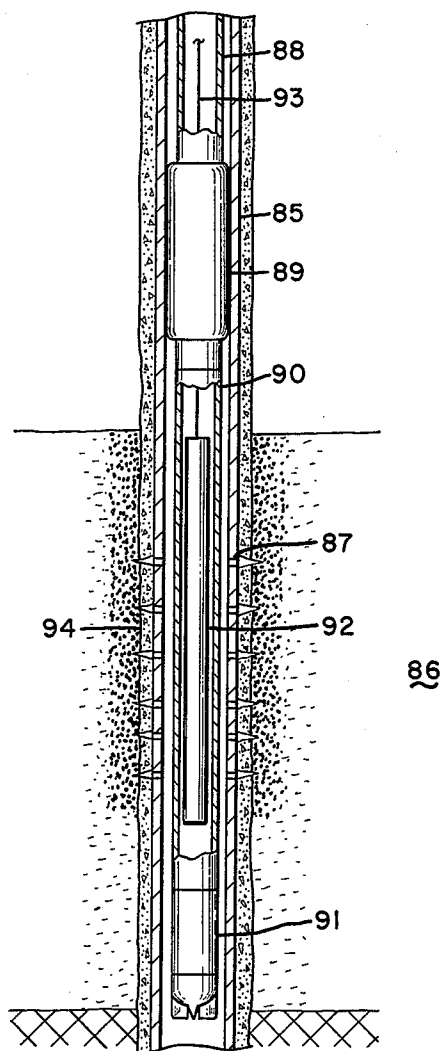
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3,104,705

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5 Sheets-Sheet 5

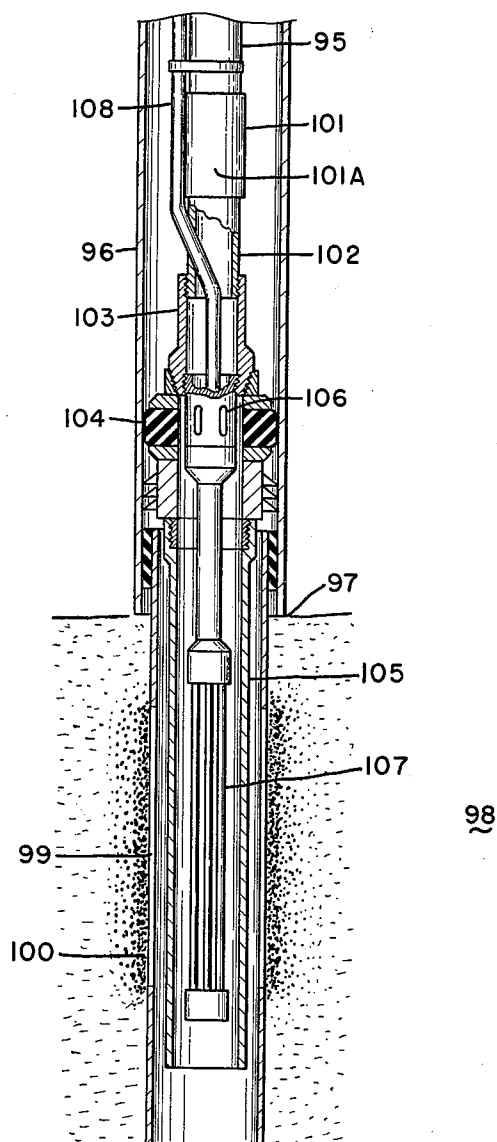


FIG. 5

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STABILIZING A FORMATION

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Filed Feb. 8, 1960, Ser. No. 7,458

13 Claims. (Cl. 166—39)

This invention generally relates to the production of fluids from unconsolidated formations. The invention especially concerns a method and apparatus for completing and producing a well that penetrates an unconsolidated formation wherein that portion of the formation in the immediate vicinity of the well is consolidated into a permeable self-supporting section.

In production of petroleum products from subterranean reservoirs, many wells are drilled into or through loosely cemented or unconsolidated formations. When such a well is placed on production sand is carried from the formation by the fluid and is deposited in the well bore. Some sand is usually entrained in the produced fluid thus causing severe erosion and damage in equipment which is employed in the production of the fluid. The production of the sand interferes with the normal production operations and gives rise to numerous operating problems. It can generally be said that in the production of a fluid from a loosely consolidated formation workovers are frequently necessary to remove sand from the bottom of the borehole. If the erosion of the sand around the casing in the bottom of a borehole is sufficiently great, it will leave the casing inadequately supported and the casing may eventually collapse. In some instances, the sand problem is so severe that the well has to be abandoned. The magnitude of the problem, then, is seen to be considerable.

Various methods have been attempted or suggested to date for solving the problem of sand production in wells that penetrate unconsolidated formations. Two commonly used practices are (1) gravel packing, and (2) plastic consolidation. In the gravel packing procedure, gravel is packed or otherwise placed so that all the oil produced must pass through the gravel pack before entering the production tubing. A common method is to pack the annulus between a slotted liner and the borehole wall. The gravel in effect acts as a filter permitting the oil to pass through but retaining the sand. The use of gravel packing to control the production of sand has proved in many cases to be quite helpful; however, gravel packing has many serious disadvantages. For example, the gravel packing operation is rather expensive. Considerable time and effort must be spent in properly preparing a well for setting a gravel pack therein. Future workovers in wells having gravel packs are quite expensive. For example, if a water shut-off operation is desired in an oil producing well it is necessary first to remove the gravel pack and its associated equipment before the workover can commence. After the workover has been completed it is necessary to again gravel pack before testing the success of the workover operations. These all add to considerable time and effort and in many cases wells are abandoned due to the cost of such operations.

Plastics such as phenol-formaldehyde has been used to consolidate the sand particles of the unconsolidated formations. Unfortunately, this system has a serious drawback in that the plastic injected into the formation is not evenly distributed; that is, the distribution is affected by the permeability variations throughout the section. In other words, most of the plastic goes into the more permeable zones with very little or none of the plastic going into the less permeable zones.

2

Briefly, in a preferred manner of operation of this invention, the steps for one system of consolidating a loosely consolidated formation includes: positioning a heater assembly in the well bore opposite the formation to be consolidated, isolating the heater in the well bore opposite the formation to be treated, heating the fluid in the well bore so that heat will be transferred into the formation, removing the heater from the well bore, and establishing fluid communication between the formation and the surface so that fluid may be produced from such formation. Heat from the heater vaporizer fluid in the well bore surrounding the heater and as vaporizing continues, the pressure goes up and the vapors are driven into the formation. Heating in the well bore is continued until that portion of the formation immediately surrounding the heater is raised to a temperature sufficient to cause the residual hydrocarbons to solidify and bond the unconsolidated particles of the sand together. Under usual reservoir conditions the formation particles are consolidated by a coke-like material when the formation is raised to a temperature from about 700° F. to about 1500° F. The portion thus consolidated has sufficient strength and rigidity to prevent movement of loose sand into the well bore. Furthermore, the consolidated portion retains a high permeability.

The process of this invention has many advantages over the methods heretofore used for stopping the production of sand. For example, it has also been observed that any difference in permeability along the zone being treated has no effect upon obtaining complete consolidation of the section being treated. In other words, the process is not selective as is the plastic injection process. The cost of consolidating a portion of a formation immediately surrounding the well bore as disclosed herein is much less than the cost of using gravel packs, for example. The initial cost of consolidating a formation by the method disclosed herein may be as little as 1/40 or less of the cost of gravel packing a similar well; the amount thus saved may run into the tens of thousands of dollars per well. It should also be noted that the consolidation of a formation as disclosed herein does not hinder future workover operations, inasmuch as the inside of the casing is left clean.

For many years, heaters have been used in well bores to treat wells as for example to reduce oil viscosity, and remove paraffin. In these processes, temperatures generated were usually quite low, normally being in the range of 250° F. to about 500° F. None of these systems teach or suggest use of heaters in a process for stabilizing the formation in the vicinity of the well bore in unconsolidated subterranean reservoirs as disclosed herein by applicants.

The invention and its objects may be better understood by reference to the drawings taken in conjunction with the following detailed description.

FIG. 1 is a diagrammatic illustration showing a heater isolated in a well bore opposite the formation to be treated;

FIG. 2A is similar to FIG. 1 except it shows a different type packer;

FIG. 2B is similar to FIG. 2A except the packer is shown in an expanded position;

FIG. 3 shows a heater suspended in a well bore opposite the formation to be treated and isolated by packers above and below the heater;

FIG. 4 illustrates diagrammatically a heater within a liner suspended from a liner packer; and

FIG. 5 illustrates another embodiment of apparatus suitable for carrying out this invention.

According to the drawing in FIG. 1 in particular, there is illustrated a vertical cross-section or profile of a por-

tion of the earth showing an unconsolidated oil bearing formation 10 which lies vertically intermediate an upper impervious formation 12 and a lower impervious formation 14. A well 16 is shown as extending from the earth's surface to the unconsolidated formation. Casing 17 extends through the unconsolidated formation 10 and has perforations 20 through the casing and cement 32. Tubing 18 is shown within casing 17 and terminating just above the top of the formation 10 and has attached to its lower end a casing packer 22 which is adapted to seal off the annular space between the casing and the tubing. A suitable casing packer is commercially available and designated as Baker Model E casing packer and is described on page 532 of the Composite Catalog, 23rd (1958-50) Revision, published by World Oil, P.O. Box 2608, Houston, Texas. Connected to the lower end of packer 22 is a nipple 24 and plug 26. A suitable nipple and plug assembly is designated as Type S, Otis Landing Nipple and Otis Plug and is described on pages 3970-3971 of the aforesaid Composite Catalog. The plug described therein has been modified to permit an electrical conducting supporting cable 28 to slidably pass therethrough in a sealingly fluid-tight relationship as shown in FIG. 1.

Suspended at the lower end of cable 28 is a heater 30. Heater 30 may be any heater capable of generating sufficient heat to raise the formation immediately surrounding heater 30 to a temperature whereby the formation will be consolidated or cemented. It can generally be said that heater 30 is preferably an electrical resistance type heater thermostatically controlled. Cable 28 is a multiple purpose cable. In addition to conducting electricity to heater 30 it also supports heater 30. Cable 28 also has separately insulated lead wires therein for connection to control and information instruments in heater 30 such as thermocouples, for example. An example of such a cable is the Amergraph 3-H-7 cable manufactured by the American Steel and Wire Division, United States Steel Corporation, Cleveland, Ohio. A suitable heat resistant cable for use directly above the heater and connected to the above cable is a copper covered cable designated as Type MI Cable and sold by General Cable Corporation of 420 Lexington Avenue, New York 17, N.Y.

Having thus briefly described and enumerated the various structural components shown in FIG. 1, attention is now directed toward consideration of the manner in which the apparatus shown therein functions in carrying out the present invention. In this connection, with the description, it will be assumed that the formation 10 is a relatively high pressure oil bearing formation which is uncemented or unconsolidated and which cannot satisfactorily be produced by conventional production procedures. It will also be assumed that a sheath of cement 32 surrounds casing 17. It will be further assumed that the apparatus has been lowered into the well bore so that heater 30 is positioned opposite formation 10 which is to be consolidated. Casing packer 22 is set in the conventional manner within casing 17. When packer 22 is set, the borehole below packer 22 and a nipple 24 then is isolated from the space above packer 22 both within tubing 18 and casing 17. It will be assumed that the well bore is free of any sand. It will further be assumed that casing 17 below packer 22 is substantially filled with formation fluid which has entered therein through perforations 20. It will further be assumed that the formation fluid contains adequate residual hydrocarbons to consolidate the formation upon proper heating. After packer 22 has been set, electricity is generated by any convenient method at the surface and is conducted through cable 28 to heater 30. Heater 30 then is caused to heat up. As heater 30 radiates heat to the liquid surrounding it, the liquid vaporizes. As additional liquid is vaporized the pressure beneath packer 22 then builds up considerably. As this pressure increases above the formation pressure, fluid is forced outwardly through perforations 20. The hot vapors tend to heat the portion of the formation 10 immediately surrounding casing 17. Heat from

the vapors and from heater 30 causes the formation immediately surrounding the well bore to be heated sufficiently to cause a coke-like deposit to form, thus bonding the particles of sand together into a permeable consolidated mass or zone as illustrated at 34. To accomplish this, it has been found that heater 30 should be raised to a temperature generally from about 800° F. to about 1600° F. A preferred range is from about 1,000° F. to 1500° F. and an especially preferred range is from about 1200° F. to 1400° F. This temperature of the heater should be maintained long enough for the section immediately surrounding the well bore to reach a temperature approaching that of the heater. The thickness of the consolidated shell need not be great, indeed it has been found that a consolidated shell from as thin as one to two inches is sufficient to support most formations adequately. In general, it can be said the temperature of the portion of the formation to be consolidated should be raised to a general range of from about 700° F. to about 1500° F., a preferred range is from about 900° F. to about 1300° F. and an especially preferred range of about 1000° F. to about 1200° F. The time required for the formation immediately surrounding the well bore to reach this temperature depends largely upon the diameter of the heater, the diameter of the borehole and the type completion. For example, if cement is behind the casing a greater period of time will be required than if cement is not present. The required time can be determined through calculations or experiments.

The minimum temperature at which "consolidation" by this process occurs will vary depending on such factors as type of oil in the reservoir and the reservoir pressure. In general, it has been found that very little, if any, consolidating of the formation occurs below about 700° F. In one test, a heater having a 3" diameter and approximately 10 feet long was placed inside a 4½" liner in a borehole lined with 7" casing. The casing was covered with cement ½" thick. The borehole had a 14" diameter and was about 25 feet deep. The annular space between the casing and the borehole was filled with loose Bayou Choctaw, Louisiana sand saturated with Bayou Choctaw 18° API gravity crude oil (to a height above the position of the heater). The casing had perforations in its lower portion opposite the Bayou Choctaw sand. The borehole above the packer was closed. The heater was energized for a period of approximately 28 hours. The maximum temperature of the outside of the cement shell was 740° F. and the maximum temperature of the Bayou Choctaw sand in the annular space 3" from the cement shell was approximately 580° F. Good consolidation occurred at the cement shell where the maximum temperature was 740° F., but no consolidation occurred at 3" from the cement shell. Consolidation ended about 1½ to 2" from the cement shell where by extrapolation the temperature was approximately 660° F. to 685° F.

Before releasing plug 26 it is preferred that the bottom of the well bore be cooled. The heater, casing and other bottom hole equipment as well as the consolidated section should be cooled sufficiently before producing oil from the well so that oil produced would not coke up the perforations tending to block such perforations or "stick" the heater to the casing or well bore, for example. The bottom of the borehole may be cooled by simply turning off the heater and allowing heat to dissipate into the formation or a cooling fluid may be introduced in a controlled manner from the surface. If plug 26 were released while the temperature of the equipment in the bottom of the well was still high, fluid in relatively large quantities from above plug 26 coming into contact with the hot equipment could, in some instances, cause pressures sufficient to fracture the consolidated shell. Normally, it is therefore preferred to permit the bottom of the well bore to cool, as can be measured as the heater or casing temperature, to about 300° F. before plug 26 is

5

released. Means for introducing fluid from the surface can conveniently be provided. For example, section 28A is sized to sealingly fit within seals 26A in plug 26. Section 28B is of smaller diameter than section 28A. Fluid may be introduced from tubing 18 to below plug 26 by raising heater 30 until the smaller section 28B passes through seals 26A. A preferred cooling fluid is water as it will form steam upon contact with the hot bottom hole equipment. The pressure buildup of the steam will prevent movement of fluid from the formation into the well bore.

After the zone 34 has been consolidated the well is ready to be placed on production. To accomplish this, plug 26 is released from nipple 24 by pulling the heater upwardly against the plug. Plug 26 and heater 30 are then removed to the surface of the earth. Sand-free production is then produced through consolidated section 34, perforations 20, and upwardly through tubing 18 to the surface of the earth.

Various modifications of the process described above for consolidating loosely consolidated formations may be made. For example, it has been found to be advantageous to add a catalyst to the formation fluid in the well bore. Suitable catalysts include metallic ions such as ferric oxide, ferric chloride, iron, nickel, cobalt and hydrochloric and sulfuric acids which are broadly included as metallic ions. The use of catalysts shortens the time required to form the consolidated section 34 thus making the operation even more practical and inexpensive. It also tends to increase the thickness and strength of the coked zone.

FIG. 2A is similar to FIG. 1 except for the novel packer which is set by wirelines. A heater 48 is suspended on a cable 42 which passes through packer 44 which is used to seal casing 46 at a point just above heater 48. Packer 44 includes an upper plate means 49 and a lower plate means 50. In a preferred embodiment, lower plate means 50 includes a heat reflection plate 50A which may be made of steel and supported thereon a heat resistance plate 50B which may be made, for example, out of asbestos. An elastic sleeve 52 is sealingly connected at one end to plate 49 and at the other end to plate means 50. Sleeve 52 may be made of silicon rubber or asbestos, for example. Resilient means such as springs 54 may conveniently be placed or embedded in sleeve 52 to aid in the expansion and retraction thereof.

Plate 49 is sealingly and slidably mounted about cable 42. Plate 50B is likewise sealingly and slidably mounted on cable 42. Securely fixed to cable 42 is stop 56. Heater 48 which is supported at the lower end of cable 42 is similar to heater 30 in FIG. 1 and in operation is likewise positioned opposite that part of the unconsolidated formation which is desired to be consolidated.

In the operation of the device shown in FIG. 2A the packer and heater are lowered through casing 46 until the heater 48 is positioned properly. At this point, a weight 58 slidably mounted around cable 42 and shown in FIG. 2B is lowered against the upper surface of upper plate 49. Lower plate 50 is held in position by tension being applied to the cable 42. The weight 58 applied on plate 49 causes plate 49 to move downwardly. The downward movement of plate 49 while plate 50 remains stationary causes sleeve 52 to expand against the inner wall of casing 46. The heater is then energized in a manner similar to that described above for the apparatus shown in FIG. 1 to produce a hard, durable, solid residue on the particulate sand grains thus bonding them together to form a consolidated permeable mass. When it is desired to release packer 44, weight 58 is lifted by wireline 60 and packer 44 and heater 48 may then be removed from the well bore or heater 48 may be repositioned at another position as may be required. Or, heater 48 can be moved to a new position without resetting the packer if desired; this is desirable, for example, when the vertical dimension of the section to be consolidated is greater than the length of the heater.

6

Referring now to FIG. 3, there is illustrated means for isolating the heater by forming a seal within the casing both above and below the heater. The upper packer in FIG. 3 is very similar to the packer 44 shown in FIG.

2A. Shown in FIG. 3 are heater 60 positioned between upper packer 62 and lower packer 64. Packers 62 and 64 are very similar to packer 44 of FIG. 2A. Packer 64 is positioned beneath heater 60 and its lower plate 66 is supported from heater 60 by cable 68A with stop 69 below plate 66.

Packer 62 has upper plate 70 and lower plate means 71 having a reflection plate 71A and an insulation plate 71B similarly as plate means 50 of FIG. 2A. Conductor cable 67 passes slidably through weight member 72 and sealingly passes through upper plate 70 and lower plate means 71. Stop 72 on conductor cable 67 supports lower plate means 71. Extending downwardly from weight 72 are elongated members 73 which slidably and sealingly pass through upper plate 70, sleeve 77 and lower plate means 71 of packer 62 to a lower weight 74.

Packer 64 has an upper plate means 75 having a heat reflection plate 75A and a heat resistance plate 75B through which supporting cable 68A is passed in a slidable and sealing relationship. Positioned between weight 74 and plate means 75 is a resilient member such as spring 76. Resilient member 76 is used to insure that both packers will be fully expanded. Weight 74 contacts resilient member 76 before weight 72 contacts upper plate 70 thus insuring that lower packer 64 is expanded before upper packer 62. Further downward movement of upper weight 72 and lower weight 74 expands upper packer 62 and further compresses resilient member 76. Packer 62 has sleeve element 77 reinforced with resilient members 78 which are similar to elements 52 and 54 shown in FIG. 2A. Packer 64 likewise has sleeve element 79 having resilient means 80. It is also to be noted that casing 81 is preferably set through the unconsolidated sand formation and has perforations 83.

Having described the structural features of FIG. 3, attention will now be directed toward how the device may be lowered into position opposite the formation to be treated. The device is lowered into the well bore through casing 81. During the lowering operations sufficient tension is maintained on wireline 82 to prevent weights 72 and 74 exerting sufficient force on plate means 70 and 75, respectively, to cause packers 62 and 64 to set prematurely. When the device has been lowered such that heater 60 is positioned opposite the formation to be consolidated the downward movement of plate means 71, plate 66 and heater 60 are stopped by holding conductor supporting cable 67. At this point, the tension on wireline 82 is released so that the weight 74 compresses resilient member 76. This causes plate means 75 to move downwardly while plate 66 remains substantially stationary. This causes sleeve element 79 to be expanded against the inner walls of casing 81. Just prior to contact between sleeve 79 and casing 81, weight 72 contacts upper plate 70 and causes it to move downwardly while plate means 71 remains substantially stationary. This causes upper sleeve 77 to expand against casing 81. Lower weight 74 moving in fixed relationship with upper weight 72 merely compresses resilient means 76 further after sleeve 79 contacts casing 81. After packers 62 and 64 have been set, heater 60 may be energized similarly to the manner described above in FIG. 1. After the formation has been treated, the removal of the apparatus from the well or to another position is comparatively easy. First the wireline 82 is pulled taut to lift the weights 72 and 74 from plate 70 of packer 62 and plate means 75 of packer 64. The packer elements then are disengaged from the wall of the casing aided by resilient members 78 and 80 and may be withdrawn by withdrawal of conductor cable 67 and wireline 82.

Attention is now directed toward another embodiment of the apparatus suitable for carrying out this process of

the present invention, which is illustrated in FIG. 4. Shown in FIG. 4 is a casing 85 extending through the unconsolidated formation 86 with perforations 87 through the casing 85 and cement 94. Suspended within casing 85 is tubing 88. Attached to the lower end of tubing 88 is a liner hanger packer assembly which includes a packing element 89 and a liner 90 at the lower end of packer 89. The lower end of liner 90 is enclosed by a liner shoe 91. Positioned within liner 90 is heater 92 which is similar to heater 30 of FIG. 1. Heater 92 is supported from the surface by conductor cable 93 which is similar to conductor cable 28. Packer 89 is of the type that permits the passage of heater 92 therethrough. It is to be noted that the interior of casing 85 which is in communication with the formation 86 is isolated from the space above packer 89. In other words, the fluid below packer 89 which is heated by heater 92 is isolated from the fluid in the well bore above the formation being treated. This is accomplished preferably by setting packer 89 as near as practical to the upper boundary of formation 86, for example. It will be noted that this isolation occurs in all the embodiments shown herein and is a very important step. If the fluid in the casing 85 which is opposite the formation being treated were not isolated from the remainder of the borehole to the surface, the operation of a heater would be most inefficient. In the treatment of deep formations, for example, where the borehole is substantially full of liquid, it is not believed that sufficient heat could be generated to consolidate the formation as desired. For example, if the well was 10,000 feet deep, as the heater started to heat the liquid in the bottom of a well the gas vapors formed would rise as bubbles in the well bore only to be condensed by the cooler liquid higher in the borehole. The heat thus absorbed would in turn be passed to the formation. In effect, then, there is nearly two miles of heat exchanger or a cooling coil that prevents the liquid in the bottom of the borehole from being heated.

In the operation of the device shown in FIG. 4, liner shoe 91 is attached to liner 90 which in turn is attached to the lower end of packer 89. Packer 89 is attached to the lower end of tubing 88 and is lowered into the well bore in a conventional manner. To set packer 89 it is only necessary to rotate and lower the tubing in a conventional manner to collapse the packer. A suitable liner hanger assembly is a type LH liner hanger packer described on page 4848 of the aforesaid Composite Catalog, and manufactured by Texas Iron Works, Inc.

FIG. 5 illustrates another embodiment of an apparatus suitable for practicing this invention. Illustrated is a tubing 95 suspended from the surface by conventional means (not shown) within a casing 96 which is set at 97 at the top of the formation 98 to be treated. A smaller diameter casing which is commonly referred to as a slotted liner 99 is suspended from casing 96. Slotted liner 99 extends from the bottom of the borehole 100 to where casing 96 is set.

At the lower end and suspended from tubing 95 is a landing nipple 101 and a short tubing nipple 102. A suitable landing nipple 101 is an Otis Type S shown and described on page 3971 of the aforesaid Composite Catalog. Inside the landing nipple 101 is a plug 101A. A suitable plug is shown on page 3965 of the aforementioned Composite Catalog. Attached to tubing nipple 102 and at its lower end is a liner setting tool 103 which has attached thereto liner hanger and packer 104; a suitable liner hanger and packer is illustrated on page 4848 of the aforesaid Composite Catalog. Suspended from liner hanger and packer 104 is an open-ended liner 105. Mounted within liner hanger and packer 104 is a slotted nipple 106. Suspended at the lower end of slotted nipple 106 is electric heater 107. Electric heating cable 108 is clamped to the outside of tubing 95 and passes sealingly through the wall of tubing nipple 102 at some point below nipple 101 and above liner setting tool 103 and continues through slotted nipple 106 to heater 107.

In the operation of the device shown in FIG. 5, the assembly less plug 101A is mounted substantially as shown on the lower end of tubing 95 and lowered to the extent necessary to heater 107 opposite the formation desired to be consolidated. The slots in the slotted nipple 106 facilitate lowering the assembly in the well bore by providing ample flow path for the fluid in the well bore as the assembly is lowered. The slotted nipple also permits circulation of fluid to remove loose sand from the well bore prior to consolidation. At that point, liner hanger and packer 104 is operated to sealingly engage casing 96. Plug 101A is then lowered and seated in the conventional manner in landing nipple 101. At that point, the heater is isolated from that portion of the well bore above packer 104 and the portion of the tubing above landing nipple 101. Heater 107 is then energized in the manner similar to that described above. After the consolidation operation has been performed the apparatus is removed from the borehole after releasing hanger and packer assembly 104 from engagement with casing 96 and removing plug 101A. It is removed in a conventional manner by pulling tubing 95. Surface equipment for pulling tubing 95 and generating the electricity for the heater 107 have not been shown as suitable means are well known to those skilled in the art.

The following example describes a test conducted to carry out the process of the present invention. It will further illustrate the nature and value of the process. In one test a heater having a 3-inch diameter and approximately 10 feet long was placed inside a borehole lined with 4-inch casing. The borehole had a 16-inch diameter and was about 16 feet deep. The annular space between the casing and the borehole wall was filled with Bachaquero pipeline sand, i.e. sand separated from the oil in which it was produced. The casing had perforations in its lower portion opposite the Bachaquero sand. Seventeen degree A.P.I. gravity Bachaquero crude oil was then placed in the borehole to a height above where the heater was positioned within the lower portion of the casing. The heater was energized for a period of approximately 25 hours with its maximum temperature being thermostatically controlled at approximately 1570° F. The temperature of the casing was approximately 1450° F. The borehole above the heater was closed. At the end of this time of 25 hours and after a cooling period of about 18 hours, the heater and the casing were withdrawn from the borehole. The casing around the heater was surrounded by a hard permeable shell about 2-inches thick the approximate length of the heater. This hard consolidated shell was given a permeability test and was found to have a permeability of 5,320 millidarcys. Additional tests showed that the compressive strength of the shell was 431 p.s.i. The thickness of the consolidated shell can be increased by increasing the length of the time heat is applied.

Various tests have been set up for determining the stability of the consolidation. One sample of sand consolidated in accordance with the process disclosed herein was exposed to napoleum, carbon tetrachloride and chloroethene in a Soxhlet extraction apparatus. After approximately 680 hours the sample appeared to have lost only approximately 0.36% of its original weight. Another sample consolidated in accordance with this invention was exposed to both concentrated sodium hydroxide and hydrochloric acid for a period of 35 days and lost none of its original weight. Another sample of consolidated Bachaquero sand was flow tested by Bayol, a light, paraffinic mineral oil having a viscosity of about 25 centipoises, at 300° F. After 720 hours it appeared to have lost a total of approximately 0.8% of its original weight. A compression test made on the last mentioned sample after the 720 hours showed it to have a compressive strength of 1,377 p.s.i. All of the samples mentioned above in which stability tests were run remained well consolidated. It is believed that the principal reason for the loss of weight

of some of the samples is due to the sand grains that are inadvertently broken off when the cores are handled.

While there are above disclosed but a limited number of embodiments of the structure and process of the invention herein presented, it is possible to produce still other embodiments without departing from the inventive concept herein disclosed. For example, if sufficient residual hydrocarbons are not present in the formation, such as in gas formations for example, residual hydrocarbons may be added. It is desired therefore that only such limitations be imposed on the appending claims as there are stated therein or required by the prior art.

What is claimed is:

1. A method of completing and producing a well that penetrates an unconsolidated oil bearing subterranean formation which comprises positioning a heater assembly in the well bore opposite the formation to be consolidated; isolating that part of the well bore opposite the formation to be consolidated from the remainder of the well bore; heating the fluid in the isolated part of the well bore sufficiently so that heat will be transferred into the formation raising the temperature of the portion of the formation immediately surrounding the well bore to a range of about 700° F. to about 1500° F. so as to consolidate such portion of the formation; removing the heater from the well bore; and establishing fluid communication between the formation and the surface so that fluid may be produced from said formation.

2. The method as defined in claim 1 in which the temperature of the formation is raised to about 900° F. to about 1300° F.

3. A method as defined in claim 1 in which the temperature of a formation is raised to a range from about 1000° F. to about 1200° F.

4. A method as defined in claim 1 in which a catalyst of the metal ion type is added to the fluid in the well bore prior to its heating.

5. A process as defined in claim 1 in which residual hydrocarbons have been added to the fluid in the well bore prior to the heating thereof.

6. A method of completing and producing a well from an unconsolidated subterranean formation having volatile and residual hydrocarbons and through which casing has been set, said casing having perforations opposite the subterranean formation, which comprises: positioning a heater in the well bore opposite the formation to be consolidated; sealing the well bore above the heater from fluid communication with the formation with said seal being immediately above said heater; heating the formation immediately surrounding the well bore opposite said heater to a range of about 700° F. to about 1500° F. so as to form a consolidated shell about said casing; and thereafter establishing fluid communication between the formation and the surface so that fluid may be produced through said consolidated shell through the well bore to the surface.

7. A method as defined in claim 6 in which the tem-

perature of the formation is raised to a range from about 900° F. to about 1300° F.

8. A method as defined in claim 6 in which the temperature of the formation is raised to a range from about 1000° F. to about 1200° F.

9. A process as defined in claim 1 which includes initiating production of the well after the formation has cooled to at least 700° F.

10. A method as defined in claim 6 including the producing of fluid from the formation in which the producing is begun after the temperature of the heater is allowed to cool below about 300° F.

11. A method of completing and producing a well from an unconsolidated subterranean formation having volatile and residual hydrocarbons and through which casing has been set, said casing having perforations opposite the subterranean formation which comprises: positioning a heater in the well bore opposite the formation to be consolidated; sealing that part of the well bore above the heater from fluid communication with the formation, said seal being immediately above said heater; heating the formation immediately surrounding the well bore opposite said heater to a range of about 700° F. to about 1500° F.; injecting water into the well bore about the heater; and thereafter establishing fluid communication between the formation and the surface.

12. A method of completing and producing a well that penetrates an unconsolidated oil bearing subterranean formation which comprises: positioning a heater assembly in the well bore opposite the formation to be consolidated; isolating that portion of the well bore opposite the formation to be consolidated from the remainder of the well bore; heating the fluid in the well bore sufficiently so that the heat will be transferred into the formation raising the temperature of the portion of the formation immediately surrounding the well bore to a range of about 700° F. to about 1500° F. so as to consolidate a portion of the formation adjacent the heater assembly; injecting a fluid which is non-miscible with the oil into the isolated portion of the well bore; and removing the heater from the well bore.

13. A method as defined in claim 12 in which the injected fluid non-miscible with the oil is water.

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