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C. A. CARPENTER

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OIL WELL PROCESS

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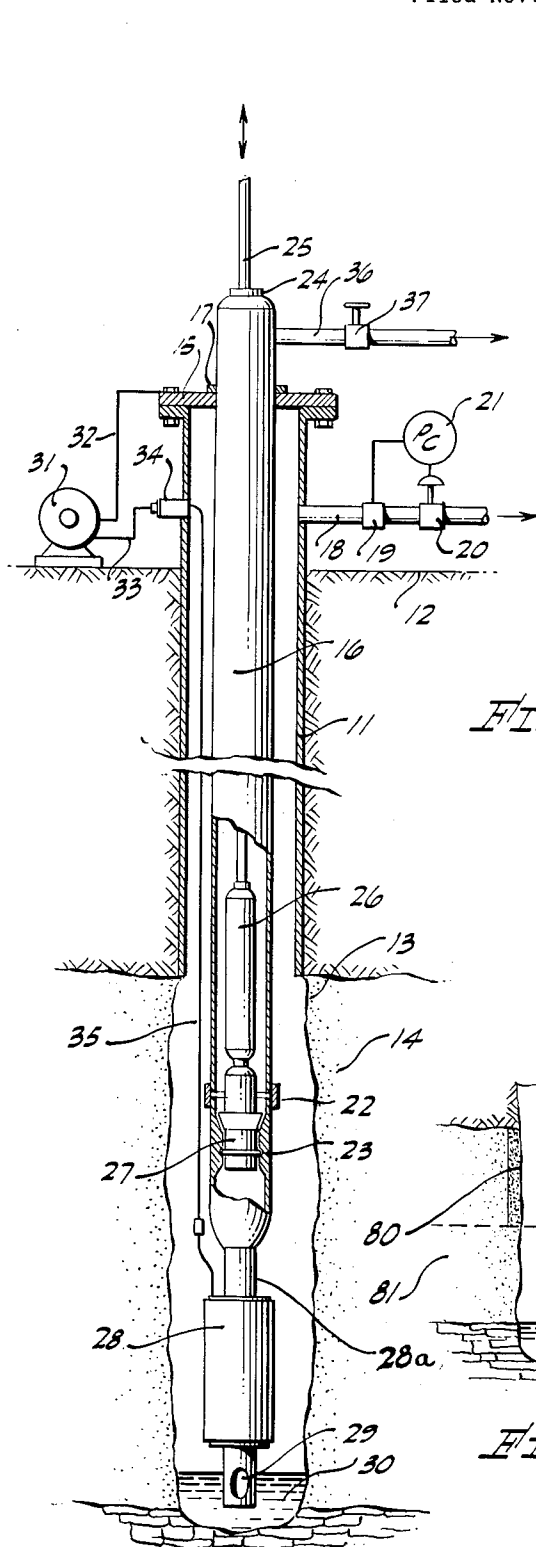


FIG. 1.

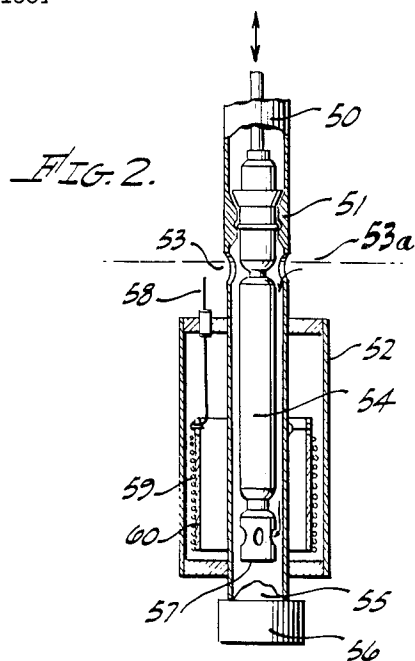


FIG. 2.

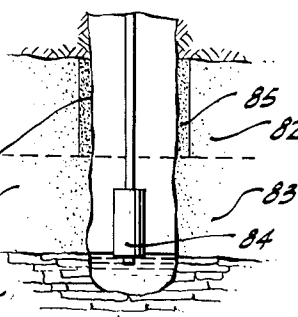


FIG. 4.

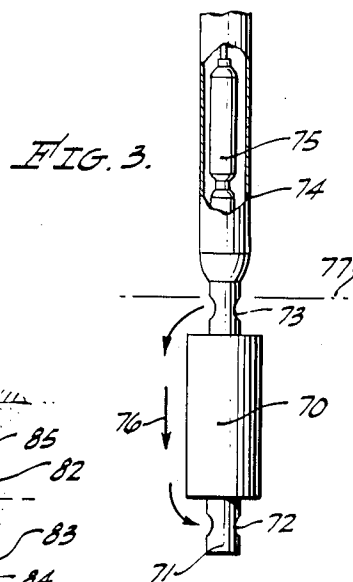


FIG. 3.

INVENTOR
CLAYTON A. CARPENTER,
BY
Raymond H. Fleck
AGENT.

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OIL WELL PROCESS

Clayton A. Carpenter, Los Angeles County, Calif., assignor to Union Oil Company of California, Los Angeles, Calif., a corporation of California

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4 Claims. (Cl. 166—39)

This invention relates to a method for heating oil wells, whereby the rate of oil flow and the net yield of oil can be increased. More particularly, this invention relates to a method for positioning a heater within a well to obtain maximum advantage of the heating effect. The method for positioning the heater within the well may be employed in conjunction with the simultaneous and continuous heating and producing of the well. Alternatively, the method of heater positioning may also be employed under conditions wherein a positive back pressure is maintained within the well to conserve the heat content of the system and prolong the advantages of either intermittent or continuous heating.

Many methods have been employed in the prior art for heating oil wells, e. g., by electrical means, by injecting into the well heat transfer agents such as steam, hot oil, etc., and by burning natural gas in the well bore. In general, such methods have met with little or no commercial success, partly due to the relatively large amounts of energy which are required and the correspondingly high costs.

A new method for heating wells has been discovered whereby the heater is positioned in the lowermost part of the well, and is preferably employed in wells wherein the upper portion has not been previously heated. The invention is particularly well suited for the recovery of highly paraffinic wax bearing crudes which are of premium refining quality.

It has been found that the mere heating of an oil well is generally not satisfactory for raising and maintaining a high yield of oil in the absence of other operational and process controls. When a well producing a relatively small quantity of oil per day is subjected to merely transitory heating, the yield of oil increases momentarily. However, after discontinuance of the heating, the production rapidly declines to its original low rate. One method for circumventing the decline comprises producing the well during continuous heating wherein relatively mild conditions of heating are employed in order to avoid coking of the oil and other deleterious effects. In such case, the well is produced during substantially continuous heating. An economically small amount of electrical energy is consumed and the well production is maintained at a favorably high rate.

It has also been found that if the well heating is carried out while producing the well under a substantial back pressure, the high production rate can be successfully maintained by employing merely intermittent heating. However, when a stimulated well is substantially completely depressured, its production rate rapidly declines to the initial unstimulated rate. In such case, the high stimulated production rate can not be restored simply by repressuring. On the contrary, the well must again be heated, and preferably while maintaining a suitable back pressure. However, the favorable effect of heating and producing while maintaining a positive back pressure can be obtained with intermittent or continuous heating, whichever is desired.

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It has now been found that the response to electrical heating is in great measure governed by the precise position of the heater with respect to the oil bearing formation undergoing heating. Certain oil bearing formations and particularly those which are more than about 15 feet thick have been found to respond poorly to indiscriminate heating. It has now been found that the use of relatively small electric heaters, the length of which is, for example, about 25 per cent of the formation thickness, are extremely effective in stimulating a formation when such heaters are positioned in the well bore near the bottom of the particular formation. This method of heater positioning increases the response of all wells, whether such wells are produced during continuous heating or are produced during the maintenance of a suitable back pressure with either intermittent or continuous heating.

It is therefore an object of this invention to heat oil-bearing formations surrounding a well bore by positioning electric heaters so that only the lower 50 per cent of the formation, or portions thereof, is heated while the upper 50 per cent of such formation is substantially unheated.

It is another object of this invention to heat an oil-bearing formation under such conditions that a positive back pressure is maintained on the well, which back pressure is sufficient to prevent deposition of paraffinic or paraffin-like deposits in the immediate vicinity of the bore hole but which is insufficient to prevent oil flow into the bore hole, and wherein only the lowermost 50 per cent of such formation, or portion thereof, is subjected to heating.

It is another object of this invention to heat an oil-bearing formation while simultaneously producing oil therefrom, wherein only the lowermost 50 per cent of such formation, or portions thereof, is subjected to appreciable heating.

It is another object of this invention to stimulate oil-bearing formations and thereby increase the net yield of oil and the rate of oil flow therefrom by subjecting the lowermost 50 per cent of such formation, or portions thereof, to such heating while maintaining the upper 50 per cent under substantially the same conditions as prevail in the absence of any heating whatsoever.

It is another object of this invention to heat the lowermost 50 per cent of an oil-bearing formation surrounding a well bore, or portions thereof, by suitable positioning of a heater in the proximity thereof and wherein the heat transfer between said heater and said oil-bearing formation takes place principally by radiation through an intervening gaseous phase.

It is another object of this invention to remove selectively the paraffinic deposits from the lower portion of an oil-bearing formation such that the fluid flow into the bore hole thereafter contains a lower gas-oil ratio and the formation pressure and reservoir energy are thereby conserved.

Other objects and advantages of this invention will become apparent to those skilled in the art as the description thereof proceeds.

Briefly, this invention relates to a method for heating the lowermost 50 per cent, and preferably only the lowermost 30 per cent of an oil-bearing formation, or portions thereof, in the vicinity of a well bore in order to remove paraffin-like deposits from that portion or portions of the oil-bearing formation, and subsequently or concurrently producing oil therefrom. Under these conditions, the paraffin-like deposits remain in the upper portion of such formation and impede gas flow therethrough while the paraffin-free lower portion readily admits oil flow. Under this method of operation, it is generally preferable to control the pressure of the gas phase undergoing separa-

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tion from the liquid phase in the bore hole at a suitably high value to minimize gas expansion in the well bore and in that part of the oil-bearing formation immediately surrounding the well bore and particularly the lower portion thereof. This minimizes further deposition of paraffin-like deposits which would plug, clog or impede oil flow therethrough. That portion of the invention which is directed to pressure control during and subsequent to the heating is based on the discovery that increased oil flow from the well may be maintained once the lower portion of the well bore has been freed of paraffin-like deposits if the pressure is properly controlled. A rapid decline in the well production occurs when no back pressure is maintained following discontinuance of the heating.

The back pressure on the gas phase in the annular space of the well bore is preferably controlled so as to permit oil flow and yet prevent appreciable gas expansion. In addition, it is highly desirable to control the pressure during any heating of the well. Once production has been stimulated by an initial heating under these conditions, the increased production rate is maintainable for a considerable period of time following the cessation of heating. In this manner, wells may be maintained at a high production level for as long as three to six months after a single heating period of a few days or weeks to remove accumulated deposits. The accumulation of further deposits is controlled or even prevented by suitable regulation of the back pressure. Where a slow accumulation tends to build up over a period of time, intermittent heating is preferably employed to remove periodically the accumulated deposits and to restore the well to a high level of production.

During the heating operation, it is preferable to employ relatively small amounts of electrical power such as those of the order of only 0.02 to 1.0 kilowatt per foot of formation being heated. Where such heating is applied to a previously unheated oil well, the production rate is increased several fold in the case of marginal wells. Often marginal wells initially producing only 5 to 15 B./D. can be made to yield as much as 40 to 100 B./D. However, only slight permanent improvement in the production is obtained unless the heating is continuous, or unless a back pressure is maintained on the well annulus to minimize gas expansion cooling. With most wells which are amenable to heating, the formation pressure is generally less than 500 p. s. i. and in these cases the back pressure is maintained between the range of about 5 to 50 p. s. i. and preferably in the range of about 15 to 40 p. s. i. Such pressures are predicated upon conditions in the formation, and in all events must be less than the formation pressure in order to induce oil flow into the bore hole. In the application of the invention to relatively high pressure formations such as those above 500 p. s. i., the back pressure is increased correspondingly and generally varies between about 50 and 200 p. s. i.

Another feature of this invention resides in maintaining the well sufficiently pumped out during the heating so that all or a part of the heat transfer from the heater to the surrounding well bore wall in the oil-bearing formation takes place through an intervening gaseous phase rather than through a liquid phase. Under these conditions, there is less coking of the oil. The deposition of coke on the heater is considerably less when the heat transfer surface is exposed to a gaseous phase rather than when it is exposed to a liquid oil phase. Furthermore, since the flow of heat to the formation is generally counter-current to the oil flow, a more efficient transfer of heat to the formation results when the level of the oil pool is maintained both below the heater and below the oil sand being heated.

In the accompanying drawing which forms a part of the specification:

Figure 1 shows a view of an oil well partly in section, wherein an electric heater is employed for heating the lowermost portion of the oil well while pumping may be

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carried on during either continuous or intermittent heating, wherein the well may be controlled to produce a substantial back pressure or none at all, and wherein the heat is transferred from the heater substantially through a gaseous phase through the above oil pool.

Figure 2 shows an alternative modification of a heater and pump assembly, wherein the heat may be transferred to the oil-bearing sand through the intervening oil pool by convection and/or conduction. This method is adopted to prevent gas-locking of the pump in high gas-oil ratio wells.

Figure 3 shows a modification of the invention, wherein the heat is transferred through the oil pool by convection and/or conduction, and wherein the contents of the oil pool are circulated by the thermal pumping which results from the temperature differential set up between the fluid passageway of the heater and the external oil pool.

Figure 4 shows a cross-sectional view of an oil-bearing formation undergoing electric heating in its lower portion wherein the initial paraffin deposits in the upper portion of such formation have not been removed by heating.

Referring now more particularly to Figure 1, well casing 11 extends downwardly from the earth surface 12 within bore hole 13 to the vicinity of upper boundary of oil-bearing sand 14. Well casing 11 is capped with a tubing head 15. Tubing 16 is suspended through packing ring 17 and tubing head 15 downwardly with casing 11.

Casing 11 above the earth's surface 12 is fitted with gas discharge line 18. Gas discharge line 18 is fitted with pressure tap 19 and motor valve 20 which is controlled by pressure controller 21. Motor valve 20 is regulated by pressure controller 21 to maintain a positive and controlled back pressure in line 18 at all times. Alternatively, gas discharge line 18 may be fitted with any suitable "pop-off" valve to maintain a suitable back pressure in line 18. Such valves are generally of the spring loaded variety which are set to open when a given pressure is exceeded. This type of valve may be substituted for pressure tap 19, motor valve 20 and pressure controller 21.

Tubing 16 at its lower end is attached to pump lock shoe 23 by means of joint 22. Above earth surface 12, tubing 16 is fitted with stuffing box 24 through which sucker rod 25 is permitted to reciprocate. Sucker rod 25 in turn operates pump 26 which is secured within tubing 16 by the engagement of pump lock 27 within pump lock shoe 23. The sucker rod 28a below the pump lock shoe carries heater 28.

The extension of the sucker rod 28a below heater 28 contains port 29 for the intake of oil from oil pool 30. The location of port 29 controls the level of oil pool 30 below heater 28 such that heat is transferred from heater 28 to oil-bearing formation 14 through an intervening gas phase, as in the preferred modification of the invention.

At earth surface 12 electric generator 31 supplies electrical current to lines 32 and 33, respectively. Line 32 is grounded to tubing at 15 whence electrical current is carried through tubing 16 and sucker rod 28a to the frame of heater 28 which is thus maintained at ground potential. Line 33 passes through insulator 34 to the interior of casing 11 whence it passes to and connects with cable 35 which in turn connects with heater 28 providing a complete electrical circuit.

The oil flow is removed from tubing 16 above the earth surface through line 36 by suitable manipulation of valve 37.

The positioning of heater 28 and its vertical height are such that in this particular case only the lower portion of the particular oil-bearing formation 14 is subjected to electric heating. As shown in Figure 1, the heating is confined to the lowermost portions of the formation and preferably the entire output of heater 28 is radially directed toward portions or all of only the lower 50 per cent, preferably on the lower 30 per cent, of oil-bearing formation 14.

In the operation of the invention, heater 28 is run in

on tubing 16 and the tubing and the pump and rods are locked into position by means of pump lock shoe 23. Electric current is supplied to heater 28 with or without simultaneous operation of pump 26. In the preferred modification, motor valve 20 is positioned by pressure controller 21 to maintain a suitable back pressure, such as is described hereinafter.

Following the initial heating period, the well production will be increased markedly and such production can be maintained at the increased level by continuing the application of heat during the pumping and/or by maintaining the back pressure within suitable limits. When a positive back pressure is maintained, the heating may be conducted intermittently or continuously, as desired.

In the preferred modification of the invention, heat is transmitted to the oil-bearing formation through the medium of an intervening gas phase, as shown in Figure 1. In certain cases, the heat may be transmitted through the medium of the intervening oil of the oil pool. Such heat transfer is sometimes desirable, such as in the case where sand conditions prohibit pumping off the bottom and/or high gas-oil ratios lead to "gas-locking" of the pump. Under these conditions, the use of the oil pool as a heat transfer medium serves to direct the heat toward the very lowest portion of the bore hole providing the bottom of the heater is placed at or below the bottom of the formation.

Referring now more particularly to Figure 2, tubing 50 is fitted with pump lock shoe 51 located somewhat above heater 52, and intake port 53 is disposed therebetween. Pump 54 is disposed generally within tubing 50 and skooter bill 55. Skooter bill 55 supports heater 52. Skooter bill 55 is plugged at its lower end by plug 56 which causes the entire oil production to flow into port 53 and downwardly through the annular space between pump 54 and skooter bill 55 and thence into the pump intake 57 which is located in the general proximity of the bottom of heater 52. The location of port 53 does not permit the liquid level to fall below a line indicated generally by dotted line 53a. In this modification, the heat is transferred through the intervening oil pool.

In the particular modification shown in Figure 2, the tubing 50 and skooter bill 55 are electrically grounded as in the case of Figure 1, and the high potential is supplied through cable 58. The heating coils 59 are wound non-inductively on insulated tubular shell 60 disposed within the interior of the heater in any desired manner.

The particular modification of the invention described in Figure 2 may be advantageously employed in the production of crude oil having a high tendency to gas lock the pump since any liberated gas tends to rise to port 53 and be discharged therethrough.

In another modification of the invention wherein the heat transfer takes place across an intervening liquid phase, the heater may be operated to effect thermal pumping by means of the liquid convection currents as indicated by fluid flow directional arrows in Figure 3.

Referring more particularly to Figure 3, heater 70 is supported on skooter bill 71 and forms a unitary structure therewith. Two series of ports are located in skooter bill 71, namely 72 and 73. Tubing 74 enclosing pump 75 is located somewhat above skooter bill 72.

In the operation of this modification of the invention, the oil within skooter bill 71 is heated by heater 70, thereby lowering its density, effecting an upward circulation and causing additional oil to be drawn through port 72. The heated oil is discharged in part from port 73, causing a circulation exterior to heater 70, as indicated generally by directional arrow 76. The intake of the pump, because of the location of port 73, causes the liquid level to fall only to the level of port 73, thereby maintaining a liquid level at an elevation indicated generally by dotted line 77.

This modification has the advantage of causing an internal circulation of the heated oil through the pool whence heat is transmitted to the surrounding oil-bearing formation from the circulating oil pool.

The precise mechanism by which improved stimulation can be obtained by positioning of the heater according to this invention is not fully understood. Figure 4 illustrates one possible theory of operation. It is to be understood, however, that the advantages and mode of operation of this invention are not dependent on any particular theory of mechanism and the invention is not necessarily limited thereto.

Referring now more particularly to Figure 4, bore hole 80 passes through oil-bearing sand indicated generally by reference numeral 81. Miscellaneous other formations lie above and below oil-bearing sand 81. Oil-bearing sand 81 is roughly divided into an upper portion, indicated by reference numeral 82, and a lower portion, indicated generally by reference numeral 83. Heater 84 is positioned in the lowermost portion of bore hole 80 such that the heat output therefrom flows to and thereby heats that portion of the lower oil-bearing sand 83 which circumscribes bore hole 80. That portion of the upper oil-bearing sand 82 which circumscribes bore hole 80 is not subjected to heating and therefore tends to remain plugged by the accumulated paraffin deposits resulting from prior operation of the well.

Under the conditions of operation generally outlined herein, the liquid content of oil-bearing sand 81 tends to migrate and gravitate into the lower portion 83 of the sand while the gas content simultaneously tends to migrate to the upper portion 82 of the sand. Gas from upper sand 82 is prevented from freely flowing into the bore hole by paraffin deposits 85. The liquid flow from lower sand 83 flows freely into the bore hole under the protection from paraffin plugging afforded by the continuous or intermittent operation of heater 84.

According to this theory of operation illustrated by Figure 4, it is apparent that the gas-oil ratio of the well production may be favorably decreased in a paraffinic crude oil field by the selective removal of the paraffin plug from the lower portion of the particular oil bearing formation involved. Such results are obtained in practice. This results in the favorable conservation of the reservoir energy and permits a greater recovery of oil and a higher production rate than can be obtained either with or without the operation of indiscriminately positioned heaters.

The following examples will illustrate practice of the invention:

Example I

An oil well in the Cut Bank, Montana, area was producing about 12 B./D. of a 38° API gravity highly paraffinic crude oil. The production rate was determined under conditions of substantially no back gas pressure. When the well was in production without heating, the temperature of the oil pool was 70° F. and the formation temperature at a point removed from the well was determined to be about 82° F. The thickness of the formation was about 44 feet with the lowermost 10 feet considered to be oil-saturated. The heater was about 25 feet long and was positioned with its lower end about 1 foot above the bottom of the oil-bearing sand. A substantially uniform rate of heating was obtained from the continuous consumption of about 7 kilowatts of electrical power. The production rate rose rapidly to about 45 B./D. and remained at that point for about 30 days during the continued heating. After the 30-day heating period, the heating was discontinued and the production was continued with no back gas pressure being maintained. The following daily production figures show the rate of decline after cessation of heating.

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Lapsed time, days:	Production, B./D.
1 -----	44
2 -----	44
3 -----	38
4 -----	34
5 -----	31
6 -----	30
7 -----	29
8 -----	24

Paraffin deposition on the well tubing, rods, etc. necessitated a shutdown of the well 8 days after discontinuance of the heating. It is apparent from the foregoing data, however, that where no back pressure is maintained on the well and heating is discontinued, the well production declines rapidly. No permanent advantage of the heating is realized under these conditions.

Example II

Another oil well in the Cut Bank, Montana, area producing about 3.7 B./D. of 39° API gravity highly paraffinic crude, was selected for a second heating experiment. The thickness of the oil-bearing sand was around 6 feet. After a short initial period the well steadily produced about 27 to 30 B./D. of crude oil during a continuous heating consuming about 7.5 kilowatts of electrical power and with no back pressure being maintained on the annular space of the well casing. After about 2 months of continuous heating without a back pressure on the annular space, a back pressure was established therein by controlling the gas flow therefrom so as to create and maintain such pressure. On successive days the back pressure was raised from 0 to 18, 24, 28, 34 and 44 p. s. i. Under these conditions the oil production remained substantially constant at about 27 to 30 B./D. When the back pressure was raised to 50 p. s. i. and above, a decline of oil production was noted which is possibly attributable to gas locking of the pump. The well was then operated under a positive back pressure in the range of 8 to 30 p. s. i. for 3 months after which heating was discontinued. Just prior to the end of the 3-month period the production was about 33 B./D. The back pressure was maintained after cessation of heating, and about 10 days thereafter was adjusted to 30 p. s. i. and maintained at this figure for an additional 3 months. No further heating was employed during the latter 3-month period. As a result of the maintenance of the back pressure, the well production did not decline upon cessation of heating but remained constant at about 36 B./D. during the final 3-month period. When the back pressure diminished to zero, the well production declined in amount and manner corresponding to that found for the well described in Example I, for which numerical data are presented.

The formation pressure in Examples I and II was about 350 p. s. i.

The foregoing two examples serve to illustrate the fact that the heating of a well in a highly paraffinic field increases the flow of oil into the well when such heating is controlled within suitable limits and serves to increase and maintain the oil flow at a high steady rate. Where a suitable back pressure is not maintained in the annular space, the improvement resulting from the heating is rapidly dissipated once the heating is discontinued, often in as little as one week. However, if the heating period is followed by a production period wherein the pressure is controlled so as to minimize gas expansion in the formation, the advantages of the heating are retained and the resulting high level of production may be sustained for as long as 3 months or more.

Example III

Another well in the Cut Bank, Montana, area was drilled into an oil-bearing sand which was approximately 44 feet thick. Prior to any application of heating, the well had consistently produced approximately 11 B./D.

for an extended period of time. The heating of this well was carried out successively in three different types of operation. In case 1, a 25-foot heater was installed with the bottom of the heater approximately 1 foot above the bottom of the oil sand. The pump intake was such as to drain about 2 feet below the bottom of the oil sand. In case 2, after plugging back about 1 foot of the well bore below the oil sand, a 10-foot heater was installed with the bottom of the heater about 2.5 feet above the bottom of the sand in such a manner that the pump intake was about 2 feet above the bottom of the sand. In case 3, a 10-foot heater was installed with the bottom of the heater about 12.5 feet above the bottom of the sand with the pump intake located about 12 feet above the bottom of the sand. In all three cases the pump intake port was below the heater such as is illustrated in Figure 1.

The oil production in case 3, wherein the heat was transferred to the formation through the oil pool was about 25 B./D. whereas in cases 1 and 2, wherein the heat was transferred to the formation through a gas phase, the production was about 35 B./D.

Example IV

Another well in the Cut Bank, Montana, area was drilled into an oil-bearing sand estimated to be approximately 35 feet thick. In case 1 of this example, a 10-foot heater was placed about 5 feet above the bottom of the sand and the pump intake was located above the heater as illustrated in Figure 2. In case 2 of this example, the same heater was lowered so that the bottom was about 1 or 2 feet above the bottom of the sand.

In this particular well there was little or no oil production increase resulting from stimulation by the method of heating employed in case 1 but the gas production increased from 40 MCF/day to 60 MCF/day. When the heater was lowered as in case 2, the production increased from about 15 to 30 B./D. in a relatively short time, i. e., about 3 days. A back pressure of about 20 p. s. i. was maintained on the well in both cases.

Example V

Another well in the Cut Bank, Montana, area traversed an oil-bearing sand with a thickness of about 40 feet. In case 1 of this example, a 10 foot heater was installed with the bottom about 10 feet above the bottom of the sand such that the pump intake was located below the heater, as shown in Figure 1. In case 2, the heater was raised 2 feet. In case 3, the heater was lowered 10 feet below the case 2 position (8 feet below the case 1 position). The well without stimulation had produced only about 12 B./D., and this production was increased very slightly (less than 1-2 B./D.) by operation, according to case 1. The production level was unaffected by the change from case 1 to case 2. By operating according to case 3, the production increased from 12 B./D. to 20 B./D. A back pressure of about 30 p. s. i. was maintained throughout the entire testing.

The foregoing three examples serve to illustrate the fact that the positioning of the heater within the well is an extremely important factor in determining the extent of the production improvement obtained by heating. Faulty positioning of the heater results in only very marginal improvements which are economically unattractive. On the other hand, proper positioning of the heater according to the method of this invention increases the daily well production up to 100 per cent or more over the unstimulated production rate. Furthermore, the employment of the methods of this invention increases the oil flow substantially relative to the gas flow.

In the present invention, only a limited amount of heat is applied to the oil-bearing formation. It has been found that heaters operating at a power level of between about 0.02 to 1.0 kilowatt per foot of formation undergoing heating are most efficient for wax-bearing wells. The

preferred power requirement depends somewhat on the oil and gas production rates of the wells and the original formation temperature.

It is believed that the previous attempts to employ electric heating of oil producing formations have generally met with failure for the reason that it was thought that a barrier of wax was built up over a considerable period of time and that if it were removed the well would thereafter continue to produce at a high rate for a considerable period of time. Accordingly, the prior art was wholly occupied with drastic heating during relatively short periods of time, after which periods of heating the pumping equipment was reinstalled and the well put on production. In accordance with the present invention, it has been found that continuous heating in the lower portion of the oil-bearing sand gives a sustained high daily production rate from a given well. It has also been found that when the heating period is followed by production in a pressure controlled system so as to minimize gas expansion in the well bore and the neighboring portion of the formation, the high production rate may be maintained for considerable periods of time. In accordance with the present invention, it has also been found that the positioning of the heater in great measure governs the magnitude of the improvement obtained as a result of the heating. Thus, it is preferable to heat only the lower 50 per cent, preferably only about the lower 30 per cent, of the oil-bearing formation while maintaining any paraffin deposits in the upper 50-70 per cent of the formation substantially intact and/or subsequently producing the well such that paraffin will even tend to accumulate in the upper 50-70 per cent of the oil-bearing sand as by minimizing any extraneous heating thereof.

An important feature of the new process resides in the fact that very small amounts of thermal energy are supplied to the oil-bearing sand so as to effect improvement without substantial coking of the oil. When the heater is suitably positioned within the oil-bearing sand, an increased production rate can be maintained either by (1) continuing the application of heating during the subsequent production of the well, or (2) maintaining a suitable back pressure on the gas phase in such well which is sufficient to minimize gas expansion in the formation and is insufficient to prevent oil flow therefrom.

In the practice of this invention, alternating current is generally preferred to direct current for convenience of handling and availability. Electrolytic corrosion is generally greater when direct current is employed. The voltages employed in the case of alternating current are generally between about 10 to 1000 volts and preferably between about 30 to 600 volts. Voltages between about 5 to 600 volts, preferably between about 20 to 300 volts, are employed in the case of direct current.

It is very important in the practice of this invention that local overheating of the oil be avoided. Overheating is especially apt to occur where the oil comes in contact with the heating surface or element. Local overheating is preferably avoided by maintaining the well continuously pumped out so the heater transmits heat through an intervening gaseous phase, as shown in Figure 1.

With regard to the amount of heat required to remove deposits and sustain a high rate of flow from a given oil-bearing sand during pressure controlled production, it has been found that usually a heater operating at a power rate between about 0.02 and 1.0 kilowatt of energy per foot of formation to be heated is suitable. Preferably the power rate should be between about 0.1 and 0.5 kilowatt per foot. During the heating period the gaseous phase above the oil pool and adjacent to the heater should be heated at least to about 25° F. above the formation temperature, and the oil in the well bore should be heated

at least about 10° F. above the formation temperature. In general, the gaseous phase next to the heater should be heated to between about 100° F. and 200° F. and preferably to between about 130° F. and 180° F. Where the oil is heated to higher temperatures, considerable deleterious gas separation coke and gum deposition occurs. At appreciably lower temperatures, no increase in the production rate is obtained.

The foregoing disclosure of this invention is not to be considered as limiting since many variations may be made by those skilled in the art without departing from the spirit and scope of the following claims.

I claim:

1. The method of producing oil from an oil well which comprises ascertaining the thickness of the oil-bearing formation; positioning an electric heater in the well bore at a depth below that of the mid-point of said formation, whereby only about the lowermost 50% of said formation is subjected to substantial heating and the uppermost 50% of said formation remains at substantially the normal formation temperature; supplying electrical energy to said heater; and pumping oil from the well at such rate that the level of the oil pool at the bottom of the well is below a substantial portion of the heater, whereby a substantial portion of the heat which is transferred from the heater to the oil-bearing formation is transferred through the intervening gaseous phase occupying the space above said oil pool.

2. The method of claim 1 wherein the heater is positioned at such depth that only about the lowermost 30% of the oil-bearing formation is subjected to substantial heating and about the uppermost 70% of the formation remains at substantially the normal formation temperature.

3. The method of claim 1 wherein the well annulus is maintained under a back pressure between about 5 and about 200 p. s. i.

4. The method of producing oil from an oil well which comprises ascertaining the thickness of the oil-bearing formation; positioning an electric heater in the well bore at a depth below that of the mid-point of said formation, whereby only about the lowermost 50% of said formation is subjected to substantial heating and the uppermost 50% of said heating remains at substantially the normal formation temperature; supplying electrical energy to said heater until the gaseous phase above the oil pool at the bottom of the well is heated to a temperature at least about 25° F. above the normal formation temperature; discontinuing said supply of electrical energy; and pumping oil from the well at such rate that the level of the oil pool at the bottom of the well is below a substantial portion of the heater, whereby a substantial portion of the heat which is transferred from the heater to the oil-bearing formation is transferred through the intervening gaseous phase occupying the space above said oil pool, while maintaining a back pressure within the well annulus of between about 5 and about 200 p. s. i.

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