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METHOD OF HEATING AND PRODUCING OIL WELLS

FIG. 1 is a cross-sectional view of a mechanical assembly. A central shaft (20) passes through a block (50). The shaft has a central section (54) with a shoulder (56) and a top section (58). The block (50) has a central hole (52) and two side holes (60, 62) containing springs. The top and bottom of the shaft are flared (20).

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This invention relates to a novel method for increasing the production of petroleum from wells subject to plugging by waxy, petroliferous deposits which form in the tubing string through which petroleum is produced. In a particular aspect, this invention relates to a method of assisting the production of petroleum from wells by gas-lift.

In certain oil reservoirs, crude oils are produced which contain large amounts of wax. Under virgin reservoir conditions, the wax is contained in solution in the reservoir fluid. When the oil is produced through a well under conditions of reduced pressure, wax deposits form in the tubing string by which the petroleum is conveyed from the producing horizon to the surface of the earth. The flow capacity of such wells is thereby reduced to a very low value. While periodic cleaning of the well tubing temporarily alleviates the situation, deposits continue to form in the tubing string and plugging again occurs. The problem is especially severe in low-pressure reservoirs wherein there may be insufficient pressure to raise the petroleum to the surface of the earth, even under ideal conditions of flow.

It has been proposed to heat wells subject to plugging by paraffin deposits by means of electric heaters, or by pumping a combustible mixture of gas and air down the well annulus to a burner, and returning the combustion products through the well annulus to the surface of the earth. It has further been proposed to increase the production from low-pressure reservoirs by pumping a pressurized gas, such as methane or air, down to the bottom of the well, and there introducing the gas, in proper amounts, into the oil column standing in the petroleum-producing tubing string, so that the gas exerts a lifting force on the petroleum. This technique is commonly referred to as gas-lift.

In some instances, where waxy oils are produced from a petroleum-containing stratum, it is found that a sub-adjacent or super-adjacent stratum exists which is permeable, but separated from the petroleum-producing stratum, by an impermeable layer of rock. In some instances, the permeable super-adjacent or sub-adjacent formation contains quantities of non-commercial combustible materials.

It is an object of this invention to provide a method for employing low-grade combustible materials produced from a formation adjacent to an oil-producing stratum as a source of fuel from which heat may be obtained to prevent the deposit of petroliferous materials in the petroleum production tubing string. Another object of this invention is to provide a method for heating the petroleum in an oil tubing-string by direct heat exchange with combustion products. Still another object of this invention is to provide a method by which combustion products may be employed to achieve gas-lift. Yet another object of this invention is to provide a method by which the pumping costs of heating a well bore by means of a fuel burner and of providing a gas-lift are reduced.

This invention is best described with reference to the drawings, of which:

FIGURE 1 shows, in section, a petroleum reservoir which is penetrated by a well,

FIGURE 2 is an enlarged sectional view of the element 42 of FIGURE 1, and

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FIGURE 3 is an enlarged sectional view of the element 50 of FIGURE 1.

Referring to FIGURE 1, the reservoir comprises a petroleum-producing stratum 10, an impermeable layer 12, and a permeable stratum 14 which contains non-commercial, 600-B.t.u.-per-cubic-foot natural gas. To be susceptible to treatment in accordance with this invention, the reservoir must have an impermeable layer with a thickness within the range of about 5 to 50 feet and a permeability which is less than one millidarcy, and preferably as low as 0.01 millidarcy. The porous, gas-containing stratum preferably has a thickness in the range of about 10 to 100 feet, and a permeability which is sufficient to provide a flow of gaseous fuel from the stratum into a well-bore. The well casing 16 is perforated at 18 to communicate with the petroleum-producing zone 10. Oil-producing string 20 extends through the well-bore to a point adjacent to perforations 18. A packer 22 is set at the impermeable layer 12 to isolate portions of the well-bore lying above and below the permeable layer, that is, to separate the gas-producing stratum from the oil-producing stratum. The casing is perforated at 26, adjacent to the gas-containing stratum 14. Packers 28 and 30 are preferably placed above and below the perforations 26, although the presence of such packers is not absolutely essential. A second tubing string 32 is also disposed within the well-bore. This tubing string terminates at burner 34, which is positioned adjacent to the impermeable layer 12. Thus the burner is positioned in an isolated well-bore zone 36 adjacent to the impermeable layer. A length of tubing 38 extends from the zone 36 through the well-bore zone between packers 28 and 30, and into the well-bore zone 40 above packer 28.

In the tubing string 32, in the zone between packers 28 and 30, is gas-air manifold 42. Referring to FIGURE 2, this manifold is seen to comprise a collar 44 and a plurality of gas-induction tubes, such as tubes 46 and 48. In the combustion zone 36, where burner 34 is located, a lifting-gas induction manifold 50 is provided in the petroleum-producing string 20. A second lifting-gas induction manifold 50 is placed in the petroleum string 20 in well-bore zone 40 above packer 28. Referring to FIGURE 3, the lifting-gas induction manifold is seen to comprise a collar 52 having a central bore 54 of lesser diameter than the interior of the tubing which comprises the tubing string. Communicating with bore 54 are gas inlets, such as inlets 56 and 58. These inlets are controlled by means of check-valve assemblies 60 and 62, respectively. The check valves are of the conventional type, and act to close the conduits 56 and 58 in the event the inlet pressure drops below the predetermined closing pressure of the valves.

In operation, while petroleum is produced from stratum 10, gas is collected in the zone between packers 28 and 30. Air, or other oxygen-containing gas, is pumped down the tubing string 32 to gas-air mixing manifold 42, where the gas and air mix to form a combustible mixture, which flows to burner 34, where combustion occurs. The combustion products are released in the well-bore zone 36, adjacent to impermeable layer 12, and a portion of these combustion products flows upward through tubing 38 into the well-bore annulus above packer 28, the remainder of the combustion products entering the petroleum tubing-string 20, at lifting-gas induction manifold 50, to provide gas-lift and to bring the combustion products into direct heat exchange with the petroleum. Additional lifting-gas induction manifolds 50, as many as desired, may be placed at various intervals in tubing string 20 to provide for the introduction of additional quantities of combustion products to the tubing string, to compensate for the loss of volume of the combustion products which occurs as the combustion products cool by heat exchange

with the petroleum in the tubing string. The hot combustion products serve to warm the petroleum, preventing the formation of waxy deposits and melting deposits already formed.

It will be evident that where the gas produced from stratum 14 is of no commercial value, and is available in ample quantities such that it need not be conserved, it will not be necessary to provide packers 28 and 30 as shown. The combustion products may merely be allowed to mix with produced gas and pass up the well-bore in heat-exchange relationship with the petroleum tubing-string, portions of the combustion products and natural gas entering the petroleum string at the lifting-gas induction manifolds 50 to provide gas-lift. Further, in some cases it will be desired to limit the quantity of air pumped down the well-bore to a value below that sufficient to provide enough combustion products for the gas-lift. It is desirable to keep the quantity of air as low as possible, both to reduce pumping costs and to keep temperatures in the well annulus at an acceptable level, whereby petroliferous deposits are melted, but deleteriously high temperatures are not encountered. In such cases, it will be desirable to introduce a portion of the unburned natural gas produced from the stratum 14 into the petroleum tubing-string 20, to provide additional gas-lift. This can be accomplished simply by disposing a manifold 50 in the tubing string 20 between packers 28 and 30, or by perforating packer 28, so that the produced unburned gas can flow upward to the manifold 50 disposed above packer 28. Where the combustion products are available in quantities in excess of that required for gas-lift, the excess combustion products may be vented up the well-bore to the atmosphere. The proper pressure can be maintained in the well annulus by venting through a check valve, not shown, located at the top of the well casing.

As a specific example of the method of this invention, a well penetrating a gas-producing stratum, an impermeable layer, and a petroleum-producing stratum is equipped as shown in FIGURE 1. Gas pressure at the well is 200 p.s.i. One hundred standard cubic feet of air per hour, at a pressure of 225 p.s.i., are pumped down tubing-string 32 and mixed with a stoichiometric quantity of gas. The combustible mixture is burned in burner 34. One-quarter of the volume of the combustion products is introduced into petroleum tubing-string 20 at lifting-gas induction manifold 50 in zone 36. The remainder of the combustion product passes upward through tube 38. At the induction manifold in zone 40, a quantity of combustion product amounting to one-eighth of the total is introduced into the petroleum tubing-string. The remainder of the combustion products passes upward through the well-bore in indirect heat-exchange relationship with the external surface of the petroleum tubing-string.

As another specific example of the method of this invention, a well penetrating a gas-producing stratum, an impermeable layer, and a petroleum-producing stratum is equipped as shown in FIGURE 1. Gas pressure in the gas-bearing formation (6,000 feet subsurface) is 1,000 p.s.i. Crude petroleum produced at a rate of 200 barrels per day enters the tubing string at 6,500 feet subsurface at a temperature of 140° F. Bottom-hole pressure in the tubing string is 1,150 p.s.i. Experience has shown that it is necessary to heat the crude petroleum to a tem-

perature of 200° F. for it to reach the surface without having paraffin deposit on the internal surfaces of the tubing string. To burn sufficient gas to increase the temperature of the crude petroleum from 140° F. to 200° F., it is necessary to inject 800 to 1,000 s.c.f. of air per hour at a pressure of 1,200 p.s.i. The combustible mixture is burned in burner 34. The combustion products, plus additional unburned gas making a total of about 2,000 s.c.f. per hour, are introduced into petroleum tubing string 20 at lifting-gas induction manifold 50 in zone 36. Approximately 6,000 s.c.f. of hydrocarbon gas per hour passes upward through tube 38. At the induction manifold in zone 40, approximately 2,000 s.c.f. of gas per hour is introduced into the petroleum tubing-string. The remaining gas passes upward through the well-bore to be introduced into the tubing string through additional gas-induction manifolds.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In the recovery of petroleum through a well-bore penetrating a subterranean reservoir including an oil-producing stratum, a combustible gas-producing stratum vertically spaced therefrom, and a substantially impermeable layer lying between said strata, wherein viscous deposits of petroliferous material form in and plug a petroleum tubing-string in said well-bore, the improvement comprising isolating zones of said well-bore adjacent to said oil-producing stratum and said gas-producing stratum from each other, collecting gas produced from said gas-producing stratum in said well-bore, pumping air down said well-bore at a pressure approximating that of said gas to at least the depth at which said petroliferous deposits form in said tubing-string, burning said gas in the presence of said air, and exhausting the combustion products upward through said well-bore in heat-exchange relationship with petroleum in said tubing-string.

2. The method in accordance with claim 1 including the step of introducing combustion products of said gas and air into said petroleum tubing-string.

3. The method in accordance with claim 2 in which said burning occurs in a zone of said well-bore adjacent to said impermeable stratum.

4. The method in accordance with claim 2 in which combustion products are introduced into the petroleum tubing-string at a plurality of vertically spaced points along said tubing-string.

5. The method in accordance with claim 4 in which unburned gas produced from said gas-producing stratum is also introduced into said petroleum tubing-string.

6. The method in accordance with claim 3 including the step of isolating, by means of packers, a well-bore zone adjacent to said oil-producing stratum, a well-bore zone adjacent to said impermeable layer, and a well-bore zone adjacent to said gas-producing stratum, and introducing a portion of the combustion products of gas and air into said petroleum tubing-string at a point within said well-bore zone adjacent to said gas-impermeable layer.

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