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[54] **WELL COMPLETION AND PUMPING SYSTEM**

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[52] **U.S. Cl.** **166/68,** 166/106, 166/314

[51] **Int. Cl.** **E21b 43/00**

[58] **Field of Search** 166/68, 106, 314, 89

[56] **References Cited**

UNITED STATES PATENTS

528,449	10/1894	Staley	166/68
1,849,374	3/1932	McEvoy, Jr. et al.	166/89
2,298,834	10/1942	Moore	166/106
2,905,099	9/1959	Turner	166/89
3,559,740	2/1971	Scraggs	166/106
3,736,983	7/1971	Beard et al.	166/68

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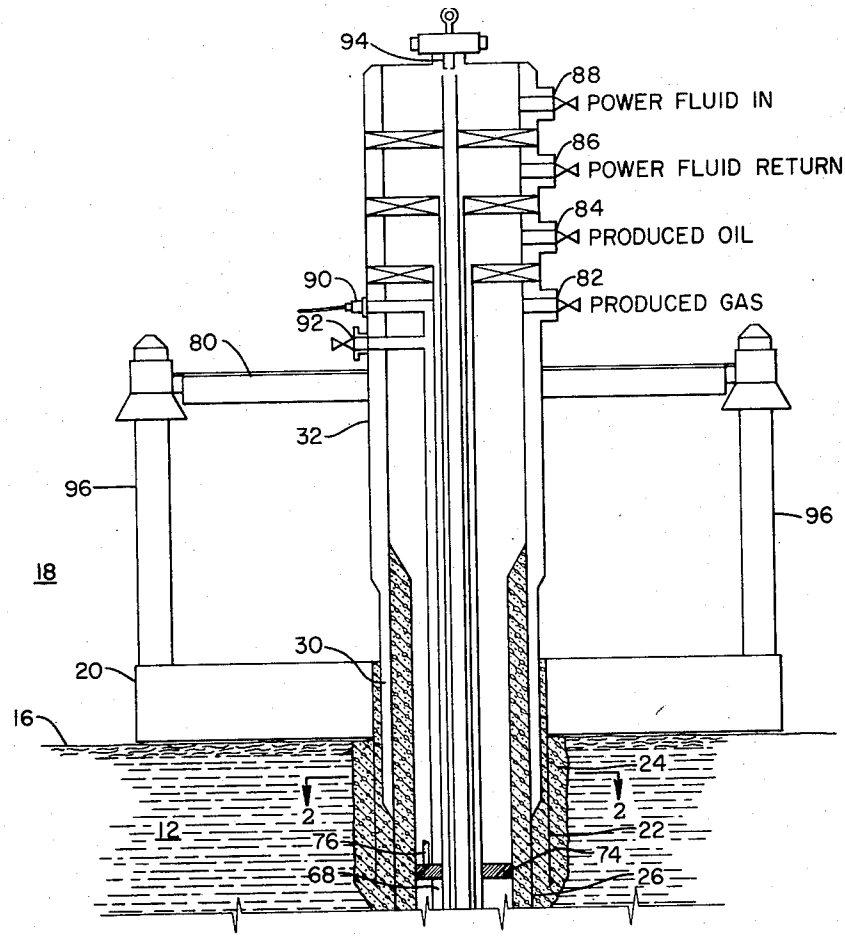
Attorney, Agent, or Firm—Richard C. Hartman; Dean Sandford

[57] **ABSTRACT**

A well completion and pumping system employing a free-type, hydraulic-drive, bottom-hole pump powered by a closed power fluid system, and providing separate means for producing gas and oil. The well is completed with three concentric fluid-carrying conduits installed within a production casing. The innermost circuit is used to supply power fluid to the pump, and the pump is placed in the well and recovered through this conduit. Power fluid exhaust from the pump engine is returned up the annulus between the center conduit and the next outer conduit, and the produced oil is pumped up the annulus between the second and third concentric conduits. The well annulus between the third conduit and the production casing is vented to recover gas, and hydraulic control piping and instrumentation cable is installed in this annulus on the exterior of the third conduit.

5 Claims, 3 Drawing Figures



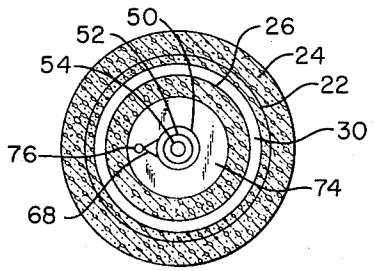

50
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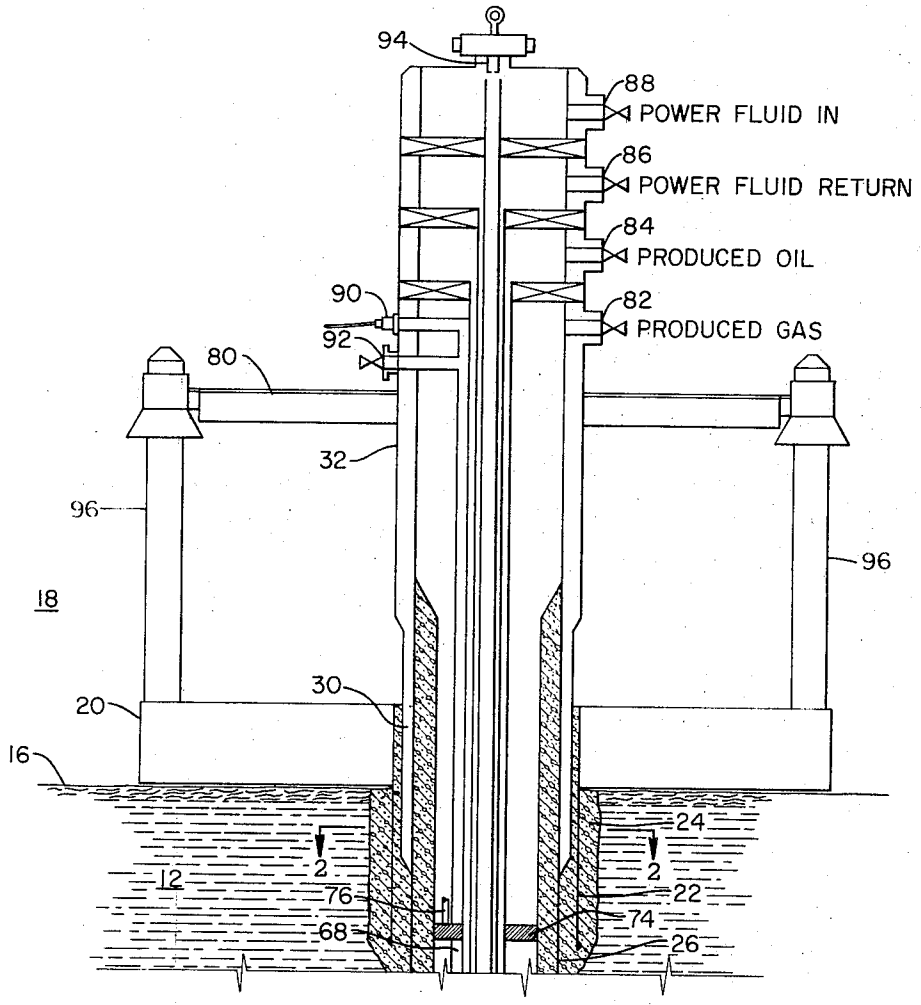
FIG 2


94
88
POWER FLUID IN
86
POWER FLUID RETURN
84
PRODUCED OIL
82
PRODUCED GAS
90
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80
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FIG 1a

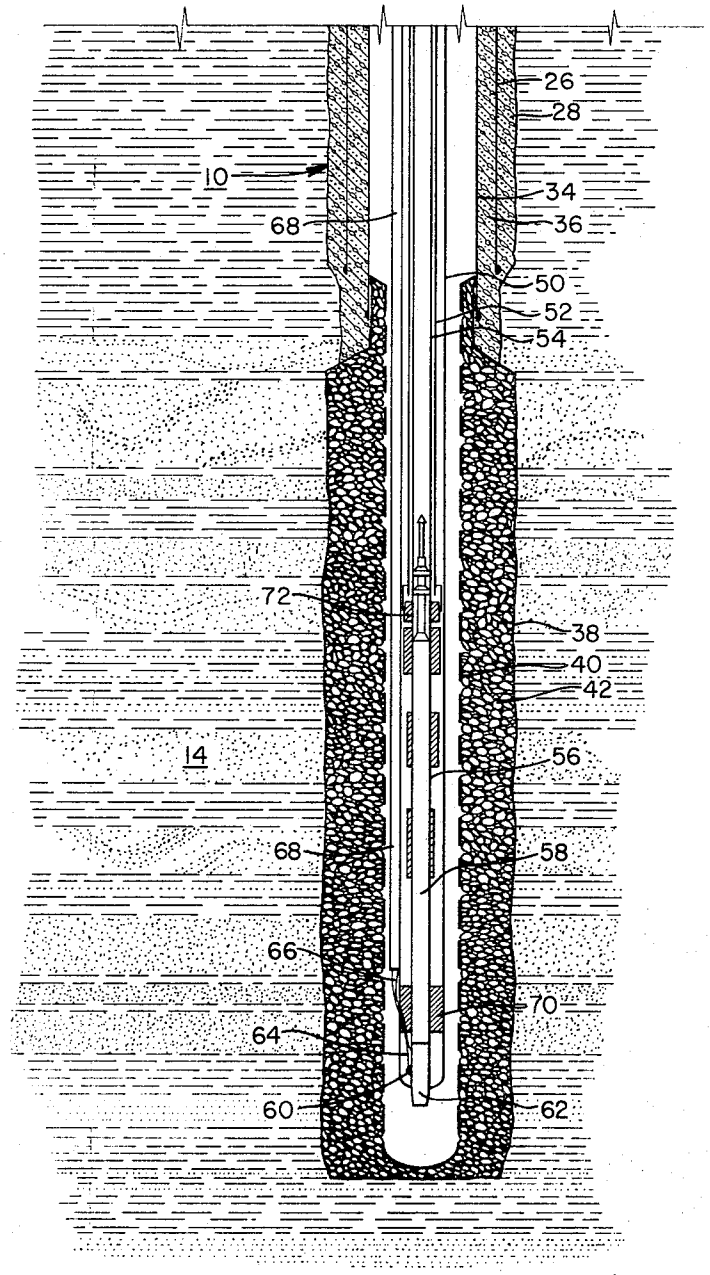

FIG Ib

WELL COMPLETION AND PUMPING SYSTEM

This invention relates to wells for recovering petroleum and the like, and particularly to wells employing hydraulic-drive, bottom-hole pumps.

Petroleum accumulations are commonly encountered that either initially or at some stage during their productive lives require pumping to lift the produced oil to the surface. Various types of bottom-hole pumping equipment have been developed for this service, such as the reciprocating pump driven by a pump rod extending to the surface and moved in a reciprocating manner by a walking beam; electric motor driven bottom-hole pumps where both the pump and the motor are placed in the well; and hydraulic-drive, bottom-hole pumps, usually of the reciprocating type, which are powered by a power fluid pumped down the well to the hydraulically driven pump engine. The rod-driven pumps are often not economical in deep wells and cannot be used in subsea wells completed on a marine floor. The electric-drive and hydraulically driven down-hole pumps are preferred in these applications. Also, bottom-hole pumps must be periodically removed from the well for inspection and maintenance. The so-called free-type of hydraulically driven bottom-hole pumps have the advantage that they pass through the tubing string and can be placed in the well and recovered therefrom without pulling the production tubing, thus eliminating the expense of moving a derrick rig onto the well site to pull the pump. This is particularly advantageous in wells completed on a marine floor because of the high cost of derrick vessels required for subsea workovers. Free-type, hydraulic-drive, bottom-hole pumps are placed in the well by inserting the pump in the center tubing string and pumping fluid into the tubing to force the pump down the well. These pumps are recovered by reversing the flow of fluid in the central tubing string and forcing the pump up the tubing to the surface.

Free-type, hydraulic-drive, bottom-hole pumps can be powered by an "open" or a "closed" power fluid system. In the open system, power fluid, usually a treated portion of the produced crude oil, is supplied to the pump engine from the surface under sufficient pressure and at sufficient volume to drive the pump at the required rate. The power fluid exhausted from the engine is mixed with the oil being lifted to the surface. Thus, the power fluid is used in a once through operation. On the other hand, in the closed system, the power fluid, which is usually a specially treated water, is returned to the surface through a separate tubing string and recirculated. The closed system is less costly to operate and is generally preferred where the well can be adapted to provide the additional power fluid exhaust conduit.

In the open-type power fluid system, it is conventional practice to install two parallel conduits side-by-side in the well. The pump is installed in one conduit and power fluid supplied to the well through this conduit, and the second conduit conducts the mixture of produced oil and exhausted power fluid to the surface. The well annulus can be vented to avoid producing gas through the pump. Alternatively, the pump can be installed in a single tubing string and the mixture of produced oil and exhausted power fluid conducted to the surface through the well annulus. However, this configuration has the disadvantage that all produced gas must pass through the pump.

The closed-type power fluid system requires three separate conduits, i.e., a power fluid supply conduit, a power fluid exhaust conduit, and a produced oil conduit. One conventional configuration for installing a free-type, hydraulic-drive, bottom-hole pump in a closed power fluid system utilizes three parallel tubing strings for the separate power fluid supply, power fluid exhaust and produced oil. This configuration has the advantage that gas can be separately produced from the annulus. Alternatively, two parallel strings can be installed in the well and the well annulus utilized to conduct the produced oil to the surface, however, gas must be produced through the pump.

The installation of parallel tubing strings in a well is undesirable in that a larger diameter well may be required to contain the strings in a side-by-side configuration, and it is more difficult to obtain fluid-tight closure of the blowout preventers around the side-by-side strings, particularly where three or more strings are employed. This is particularly a problem in subsea completions where a higher degree of integrity must be provided. Also, it is difficult to land parallel strings from a drilling vessel. Thus, need exists for a practical and safe technique for completing a well equipped with a free-type, hydraulic-drive, bottom-hole pump powered by a closed power fluid system.

Accordingly, a principal object of this invention is to provide a well completion system for installing a free-type, hydraulic-drive, bottom-hole pump powered by a closed power fluid system which provides means for separately producing gas and oil.

Another object of the invention is to provide a well completion and pumping system for a subsea well completed on a marine floor.

Still another object of the invention is to adapt a well having separate oil and gas production means to accommodate a free-type, hydraulic-drive, bottom-hole pump powered by a closed power-fluid system.

A further object of this invention is to provide a well completion system employing a free-type, hydraulic-drive, bottom-hole pump powered by a closed power fluid system and which has means for separately producing gas and oil and down-hole means to shut in the well which are operable from a remote surface location.

Other objects and advantages of the invention will be apparent from the following description and accompanying drawings, wherein like numerals refer to like parts throughout, and in which:

FIGS. 1*a* and *b* are vertical views partially in cross-section schematically illustrating the well completion and pumping system of this invention in a subsea well located on a marine floor; and

FIG. 2 is an enlarged horizontal cross-sectional view taken along the line 2—2 of FIG. 1*a*.

Briefly, this invention contemplates a well employing a free-type, hydraulic-drive, bottom-hole pump powered by a closed power fluid system and providing means for separately producing gas and oil. The well is completed with three concentric fluid carrying conduits installed within a production casing. The innermost conduit is used to conduct power fluid to the pump, and the pump is placed in the well and recovered through this conduit. Power fluid exhaust from the pump engine is returned up the annulus between the

center conduit and the next outer conduit. Produced oil is pumped up the annulus between the second and third concentric conduits. The well annulus between the third conduit and the production casing is vented to recover gas, and hydraulic control piping and instrumentation is installed in this annulus on the exterior of the third conduit.

Referring now to the drawings, well **10** is drilled through overburden **12** and a plurality of underlying permeable oil-bearing strata **14** lying beneath a marine floor **16** which is submerged below a body of water **18.** The well can be drilled from a jackup drilling vessel, a floating vessel, a semi-submersible vessel, or a platform, in conventional manner. Guide base **20** is installed on the marine floor at the commencement of the drilling operation and consists of a hexagonal channel iron structure having a central circular aperture through which the well is drilled. A first bore hole is drilled to a shallow depth below marine floor **16.** Conductor **22** having a gimbled landing mandrel at its upper end is the outer most of the concentric well casings and is secured in the bore hole by outer cement sheath **24.** A smaller diameter casing **26** is placed concentrically within conductor **22** so as to extend into a smaller diameter section of the bore hole drilled through conductor **20.** Casing **26** is cemented in place by outer cement sheath **28** which extends from the bottom of casing **26** to marine floor **16.** The upper section **30** of casing **26** can be a double wall pile section to provide additional structural strength, and is fitted with subsea casing head **32** which extends above marine floor **16.**

Production casing **34** is installed concentrically within casing **26** and extends below the bottom of casing **26** into a yet smaller diameter bore hole drilled through casing **26.** Production casing **34** is surrounded by outer cement sheath **36** extending from the lower end of the casing to casing head **32.** The bore hole is drilled through oil-bearing strata **14** and underreamed to increase the diameter of the hole in section **38.** Slotted liner **40** is suspended from production casing **34** and extends through section **38** of the bore hole. A body of gravel **42** surrounds liner **40.** Alternatively, the production casing can be extended through oil-bearing strata **14** and perforated to provide fluid communication from the oil-bearing strata into the well. Also, an open hole completion can be employed, if desired. It is to be recognized that considerable latitude and flexibility is available in the choice of the number of casing strings employed and the design of the various casing strings to meet the particular circumstances and conditions encountered, and that the design of an appropriate casing schedule is within the skill of the prior art and does not form a part of the present invention.

In the well completion and pumping system of this invention, concentric casing strings **50** and **52** and tubing string **54** are concentrically suspended in the well from casing head **32.** Pump shoe assembly **56** is mounted at the lower end of tubing string **54** and consists of a tubular member adapted to receive pump **58.** Casing **52** and tubing string **54** terminate above the lower end of casing **50,** and casing **50** extends downwardly around pump shoe assembly **56.** The annulus between casing **50** and pump shoe assembly **56** is fluid-tightly closed at its lower end by packing element **70,** and the annulus between casing **52** and tubing **54** is fluid-tightly closed by packing element **72.** Pump **58** is a free-type, hydraulic-drive, bottom-hole pump comprised of a hydraulic engine and one or more longitudinally arranged piston pumps reciprocally operated by the hydraulic engine. Suitable hydraulic-drive oil well pumping systems are manufactured by Kobe, Inc. of Huntington Park, Calif.

Pressure sensor **60** and a safety valve **62,** such as a hydraulically operated ball valve, can be optionally mounted below pump shoe **56** to provide a remote reading of the bottom-hole pressure and to permit flow from the well into the pump and upwardly through the production annulus to be shut off from a remote surface location. Pressure sensor **60** is connected to a suitable display unit at the surface by electrical conductor **64,** and hydraulic fluid to operate shutoff valve **62** is supplied through conduit **66,** both of which are housed within protective channel **68** secured to the exterior of casing **50.** Means, not shown, are provided for monitoring the bottom hole pressure at a remote location, and for shutting in the well either automatically in the event of an unsafe condition or manually from a remote location.

Casing **50** is supported from hanger-packer **74** which has built-in connections to pass electrical conductor **64** and hydraulic conduit **66.** Hanger-packer **74** is also provided with hydraulically operated vent valve **76** to pass gas from the lower portion of the well annulus to the upper portion thereof. Vent valve **76** can be remotely operated from the surface.

Casing head **32** is equipped with a diver platform **80** to provide diver access to the working portion of the casing head, casing port **82** provides fluid communication with the well annulus between casing **50** and production casing **34,** casing port **84** provides fluid communication with the annulus between casing **52** and casing **50,** casing port **86** provides fluid communication with the annulus between tubing **54** and casing **52,** and casing port **88** provides fluid communication with tubing **54.** Electrical conductor **64** is passed into casing head **32** through fitting **90,** and hydraulic fluid to operate the down hole safety valves is passed into the casing head through casing port **92.** Casing head **32** is also provided with a pump catcher **94** to engage a mandrel on the pump when the pump is pumped up the tubing string, and with guides **96** through which guide lines can be passed to the surface for use during workovers and like operations.

Pump **58** is installed in the well by removing the pump catcher on top of casing head **32** and inserting the pump into tubing **54.** Power fluid is then pumped into tubing **54** through casing port **88,** and pump **58** is forced downwardly through tubing **54** until it seats in pump shoe **56.** In operation, power fluid, which can be treated water or oil, is pumped down tubing **54** at sufficient pressure and volume to drive pump **58** at the required speed. Power fluid exhausted from the engine of pump **58** is returned upwardly through the annulus between tubing **54** and casing **52,** and discharged through casing port **86.** The power fluid returned from the well is recovered in a closed power fluid system, not shown, and recirculated to the well. Produced oil discharged from pump **58** passes upwardly through the annulus between casing **50** and casing **52** and is discharged through casing port **84.** The well annulus between production casing **34** and casing **50** is vented through vent valve **76** in hanger-packer **74** and gas produced through casing port **82.** Thus, well **10,** employing a

free-type, hydraulic-drive, bottom-hole pump powered by a closed power fluid system provides means for separately producing gas and oil from subterranean oil-bearing strata.

The pump is removed from well **10** by pumping power fluid down the annulus between casing **50** and casing **52** to unseat pump **58** from pump shoe **56** and force the pump up tubing **54.** On reaching casing head **32,** a mandrel on pump **58** latches into pump catcher **94.** Power fluid circulation can then be shutdown and the well closed in by hydraulically closing safety valve **62** and gas vent valve **76.** The pump catcher on top of casing head **32** can then be opened and the pump removed from tubing **54.** These operations can be performed by a diver working on the marine floor, or from an atmospheric capsule lowered over the well head, thus eliminating the necessity of moving a derrick vessel on to the site to pull and set the pump.

In a specific example of the well completion and pumping system of this invention, a well is drilled and completed on a marine floor at a depth of approximately 200 feet of water. A 26-inch diameter bore hole is drilled to a depth of about 110 feet below the mud line. Conductor **22** is a 100-foot length of a 20-inch diameter, 104.13 pound/foot, ½-inch wall structural conductor having Vetco couplings and provided with a 20-inch gimbled landing mandrel. A 17½-inch diameter bore hole is drilled through conductor **22** to a depth of about 300 feet below the mud line. Casing **26** is a length of 13⅜-inch diameter, 54.5 pound/foot, K–55 seal-lock casing, the top joint of which is a 16-inch diameter × 13⅜-inch diameter pile joint. Casing head **32** is a 13⅜-inch diameter subsea casing head. A 12¼-inch diameter bore hole is drilled through casing **26** to the top of the productive interval. Production casing **34** is a 10¾-inch diameter, 40.5 pound/foot, K–55 casing. A 9⅞-inch diameter bore hole is then drilled through productive zone **14** and underreamed to a diameter of 17 inches. Slotted liner **40** is a 600-foot length of 8⅝-inch diameter, 32 pound/foot, K–55 casing slotted with 24 rows of 2-inch long slots on 6-inch centers cut to 60 mesh. Casing **50** is a 6⅝-inch diameter, 24 pound/foot, K–55 casing; casing **52** is a 4½-inch diameter, 10.5 pound/foot, modified special clearance buttress casing; and tubing **54** is 2⅞-inch diameter, 6.5 pound/foot, K–55 tubing. Pump **58** is a 2½-inch diameter, free-type, hydraulic-drive, bottom hole pump mounted in a pump shoe adapted to receive three concentric conduits.

Although the well completion and pumping system of this invention has been described in conjunction with a subsea well located on a marine floor, the completion and pumping system of this invention can be also readily utilized in on-shore wells and wells completed from marine platforms, as well as with wells completed below the surface of a body of water.

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 scope of the claims.

Having now described the invention, we claim:

1. In a well for producing petroleum from a petroliferous subterranean formation underlying a non-petroliferous overburden wherein a bore hole extends from the surface through the overburden and into the petroliferous formation and including a casing head at the surface and a production casing in said bore hole extending from the casing head at least substantially through said non-petroliferous overburden, the improvement which comprises:

a first conduit suspended concentrically within said production casing and extending from said casing head into said petroliferous formation;

a second conduit suspended concentrically within said first conduit and extending from said casing head into said petroliferous formation;

a third conduit suspended concentrically within said second conduit and extending from the casing head into said petroliferous formation;

a free-type, hydraulic-drive, bottom-hole pump inserted into said third conduit;

means for seating said pump at the bottom of said third conduit to provide fluid communication from said third conduit to the power fluid inlet in the hydraulic engine of said pump, to provide fluid communication from the power fluid exhaust of said engine to the annulus between said second and third conduits, to provide fluid communication from the well bore below said pump to the inlet of said pump, and to provide fluid communication from the discharge of said pump to the annulus between said first and second conduits;

power fluid inlet means in said casing head to provide fluid communication from a power fluid source to said third conduit;

power fluid outlet means in said casing head to provide fluid communication from the annulus between said second and third conduits to a power fluid exhaust;

produced oil outlet means in said casing head to provide fluid communication from the annulus between said first and second conduits to a produced oil outlet; and

a vent means in said casing head to provide a fluid conduit from the annulus between said first conduit and said production casing to a produced gas outlet.

2. The device defined in claim **1** including a hanger-packer mounted in said well in the annulus between said production casing and said first conduit above said petroliferous formation to support said first conduit and to prevent fluid flow upwardly through said annulus, said hanger-packer including a vent having a valve operable from a remote location and including means to operate said valve from said remote location.

3. The device defined in claim **1** including a pressure sensor located adjacent to the bottom of said first conduit and including means to transmit a signal from said pressure sensor to a remote location at the surface.

4. The device defined in claim **1** including a remote-operated valve adjacent to the bottom of said first conduit to prevent the flow of fluids into said pump and upwardly through the annulus between said first and second conduits, and including means to operate said valve from a remote location at the surface.

5. In a well for producing petroleum from a petroliferous subterranean formation underlying a non-petroliferous overburden wherein a bore hole extends from the surface through the overburden and into the petroliferous formation and including a casing head at the surface, a production casing in said bore hole extending from the casing head at least substantially through said non-petroliferous overburden, and a fo-

raminous tubular member extending from the bottom of said production casing to the bottom of said bore hole, the improvement which comprises:

a first casing suspended concentrically within said production casing and extending from said casing head into said petroliferous formation;

a second casing suspended concentrically within said first casing and extending from said casing head to a point a short distance above the lower end of said first casing;

a tubing string suspended concentrically within said second casing and extending from said casing head to the bottom of said second casing;

a free-type, hydraulic-drive, bottom-hole pump inserted into said tubing string;

means at the bottom of said tubing string for seating said pump and to provide fluid communication from said tubing string to the power fluid inlet in the hydraulic engine of said pump, to provide fluid communication from the power fluid exhaust of said engine to the annulus between said tubing string and said second casing, to provide fluid communication from the well below said pump to the inlet of said pump, and to provide fluid communication from the discharge of said pump to the annulus between said first and second casing, said pump being housed within said first casing;

a pressure sensor located adjacent to the bottom of said first casing and including means to transmit an electrical signal indicative of the bottom-hole pressure to a remote location at the surface;

a hydraulically operated safety valve located adjacent to the bottom of said first casing to prevent the flow of fluids into said first casing on closure, and including means to operate said valve from a remote location at the surface;

a hanger-packer mounted in the annulus said production casing and said first casing above said petroliferous formation to support said first casing and to prevent fluid flow upwardly through said annulus, said hanger-packer including a vent having a hydraulically operated valve and including means to operate said valve from a remote location at the surface;

power fluid inlet means in said casing head to provide fluid communication from a power fluid source to said tubing string;

power fluid outlet means in said casing head to provide fluid communication from the annulus between said tubing string and said second casing to a power fluid exhaust conduit;

produced oil outlet means in said casing head to provide fluid communication from the annulus between said first casing and said second casing to a produced oil outlet conduit; and

gas vent means in said casing head to provide a fluid conduit from the annulus between said production casing and said first casing to a produced gas outlet conduit.

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