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[54] **MULTI-STAGE GAS LIFT FLUID PUMP SYSTEM**

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[51] **Int. Cl.**.....**F04f 1/18,** B67d 5/54

[58] **Field of Search**.....412/108, 109, 110, 111, 172; 137/209, 210

[56] **References Cited**

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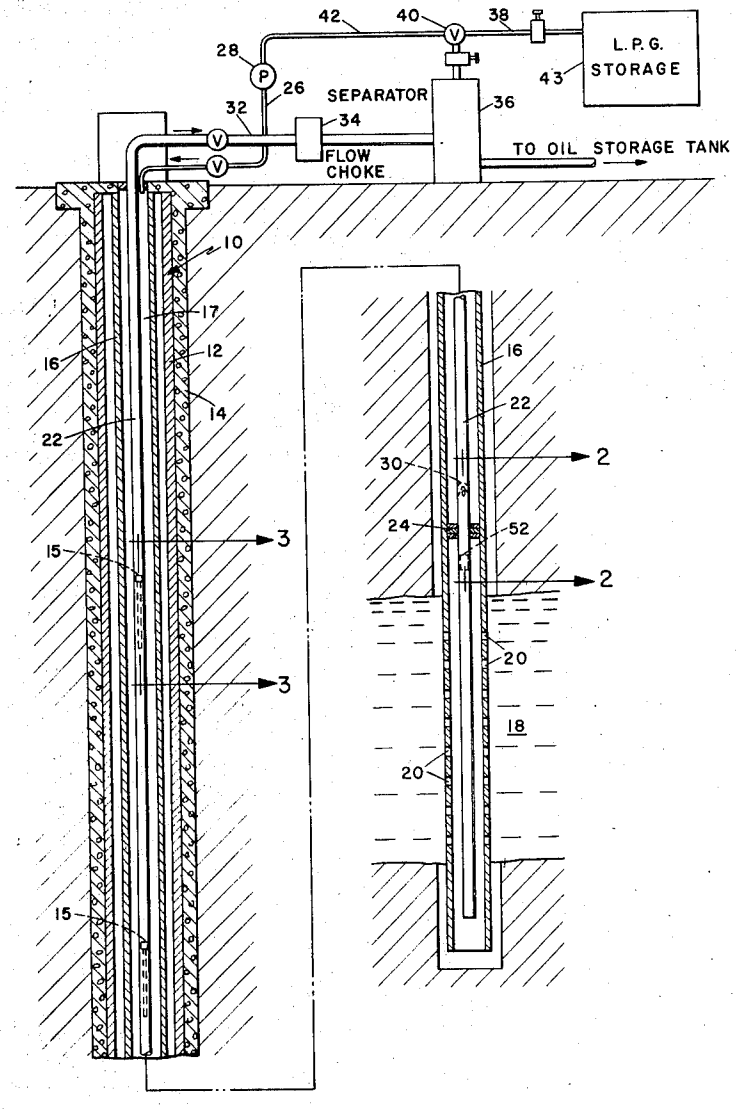
[57] **ABSTRACT**

A gas lift pump system utilizing high pressure gas from a pump delivered down a pipe string to a jet pump at the producing zone of a well to provide an initial lift for the fluid and to admix gas and fluid, and a series of supplemental lift devices at spaced intervals along the vertical extent of the well. The supplemental lift devices include a check valve which has the effect of reducing the total head of fluid which each section is called upon to lift and a gas chamber, in conjunction with a pipe mounted within the delivery tubing, to force the fluid into succeeding sections and further promote mixing. The fluid is raised stage by stage until it reaches the surface where the gas is removed and re-cycled.

9 Claims, 3 Drawing Figures



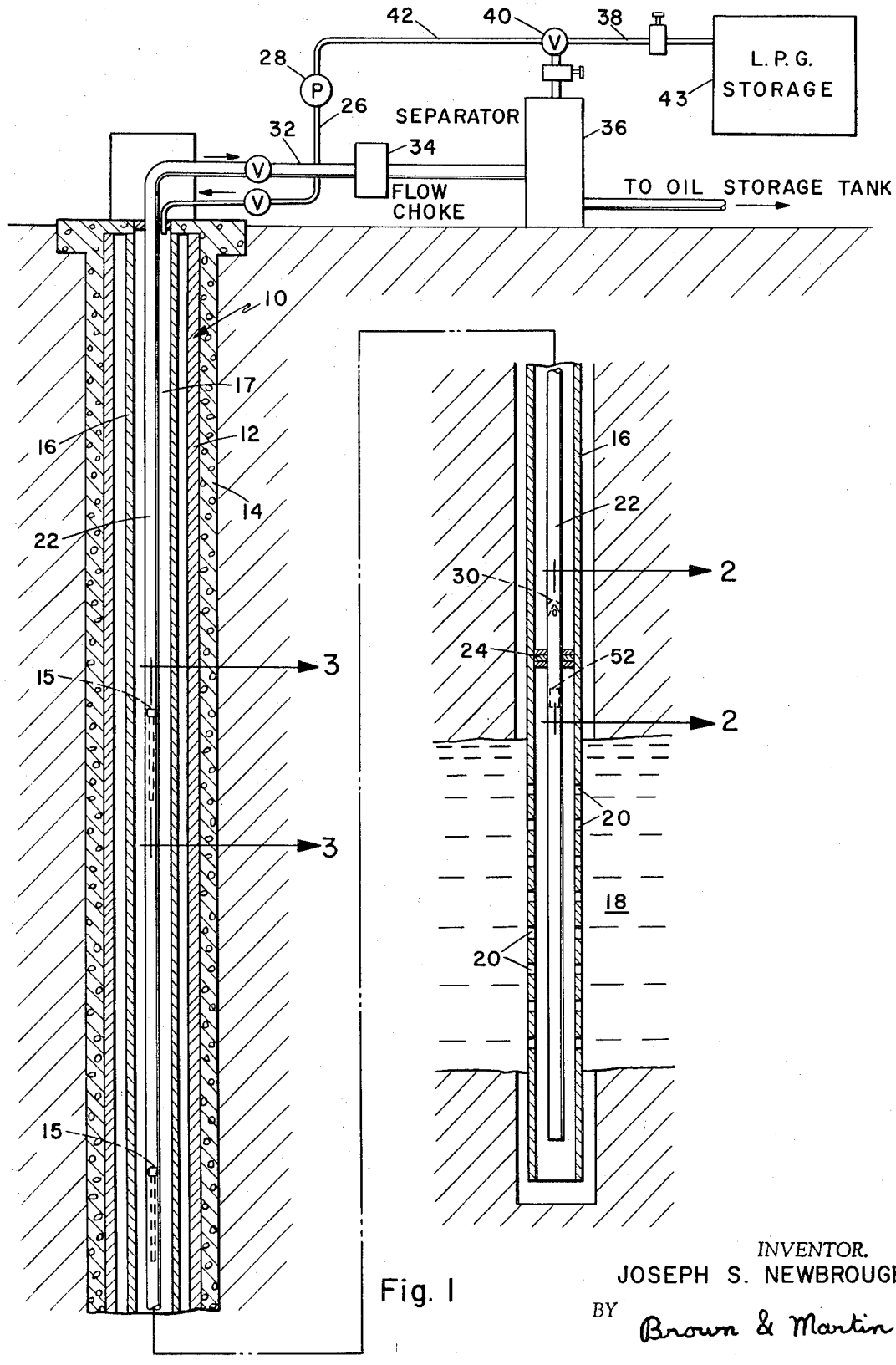


Fig. 1

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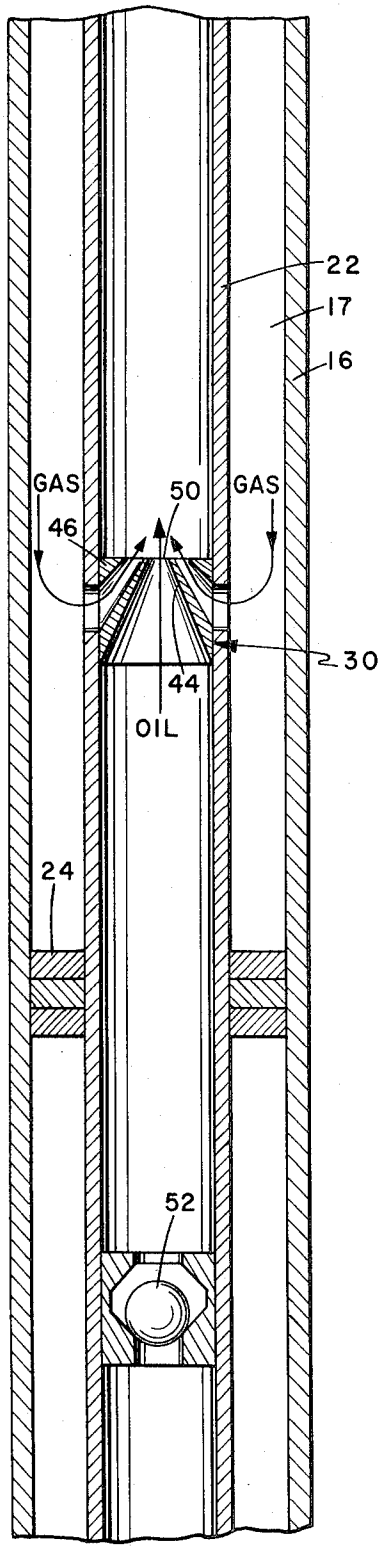

Fig. 2

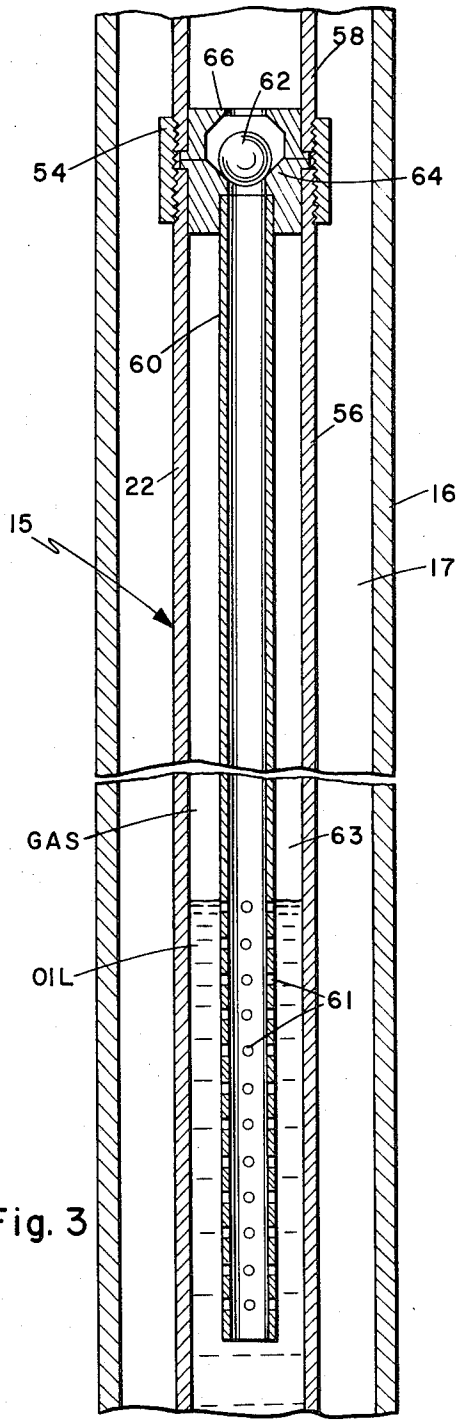

Fig. 3

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MULTI-STAGE GAS LIFT FLUID PUMP SYSTEM

BACKGROUND OF THE INVENTION

It is common practice when providing for the raising of fluids, particularly petroleum, from wells, to utilize a pumping technique in the absence of natural flow or to supplement the natural flow to make more efficient utilization of and conserve the reservoir gas. A frequently used technique employs a reciprocating sucker-rod string, activating a mechanical pump located in the producing zone. These units require many man hours to install and are subject to high maintenance cost. In addition the long sucker rod string induces large friction losses and wear.

To overcome the disadvantages associated with the mechanical reciprocating method of lifting the fluids to be produced, various gas powered pumping techniques have been proposed. With the exception of relatively shallow wells, these techniques require the utilization of an extremely high pressure to force the fluids from the producing zone. The high pressures required may be beyond the capability of even the most expensive and complex pumping systems and the technique is limited by the ability of the pipe string to withstand the pressures induced. Numerous devices have been proposed to accomplish the lifting of the fluids in multiple stages so as to avoid excessive pressures for any one stage. These devices normally inject additional gas at multiple points between the producing zone and the surface to supplement the power of the initially utilized gas. As a consequence, these devices require a large volume of gas with the consequent inefficiencies in the pumping equipment and a large increase in the requirement for separating the gas and the oil if the gas is to be re-cycled.

Thus it would be advantageous if a low volume of relatively low pressure gas could be fully utilized to lift successive units of oil to the surface and then removed from the oil for re-use.

SUMMARY OF THE INVENTION

An exemplary embodiment of the multi-stage, gas lift, fluid pump system of the invention comprises a surface pump to produce high pressure gas for introduction into the annulus between the production string and the producing tubing. The gas is conveyed in the annulus to the producing zone where a side wall packer prevents further travel down the annulus. A jet pump is located above the packer in the producing tubing and produces a venturi effect where the oil is entrained in the gas and forced upwardly at high velocity producing a thorough admixture of gas and oil with sufficient pressure to raise the resultant mixture a considerable distance.

The first supplemental lift device is located spaced a vertical distance from the jet pump which approximately corresponds to the capability of that pump to raise the fluids in a single lift. The supplemental lift device comprises a pipe section suspended from a joint within the tubing. The pipe is approximately 10 feet in length with the last 2 feet thereof being provided with a plurality of openings for admitting the oil and gas mixture. A fluid gas interface is formed within each supplemental lift device at the upper end of this perforated area and a reservoir of gas is thus retained in the annulus between the supplemental lift device pipe and the production tubing. The pressure of gas in this chamber together with the gas pressure already admixed with the oil and that being released from the oil forces the oil through the perforations and effects a thorough mixing of the gas and oil which then progresses through the supplemental lift device pipe to its upper end where a check valve in the form of a ball and cooperating seat is located. When sufficient gas pressure is available the ball is forced off its seat and the mixture flows around the ball and into the succeeding section of producing tubing. The ball prevents reverse flow of the fluids and separates the producing tubing into a series of steps, each step having a supplemental lift device associated with it. In normal operation, the oil is lifted in intermittent steps, each section of oil being lifted to the succeeding section as sufficient pressure becomes available and when the succeeding section is relatively empty of the previously lifted column of oil. The lifting process is assisted by the additional gas volume which is created as the fluids are raised from the relatively high pressure conditions in the producing zone towards atmospheric pressure at the surface. The reduction of pressure results in the release of dissolved gases from the fluid and this additional volume thoroughly mixed by each succeeding supplemental lift device aids in the overall lifting effect.

The action continues through successive stages until the gas-oil mixture is raised to the surface, where it is directed to a conventional pressure type separator which removes the gas from the mixture for re-cycling.

It is therefore an object of this invention to provide a new and improved multi-stage gas lift fluid pump system.

It is another object of this invention to provide a new and improved gas lift pump system which utilizes a flow of gas injected at a single point within a well string.

It is another object of this invention to provide a new and improved gas lift pump system with provision for re-cycling of the gas used to lift the produced fluid.

It is another object of this invention to provide a new and improved gas lift pump system which maintains the produced fluid in thorough mixture with the lifting gas.

It is another object of the invention to provide a new and improved gas lift pump system which reduces the cost of producing fluids from wells.

It is another object of the invention to provide a new and improved gas lift pump system which requires relatively little maintenance.

It is another object of the invention to provide a new and improved gas lift pump system which incorporates a series of check valves to reduce the total head lifted by any one stage.

Other objects and many attendant advantages of this invention will become more apparent upon a reading of the following detailed description and an examination of the drawings wherein like reference numerals designated like parts throughout.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view, partially in section of the complete apparatus.

FIG. 2 is an enlarged sectional view taken on line 2—2 of FIG. 1.

FIG. 3 is an enlarged sectional view taken on line 3—3 of FIG. 1.

Referring now to the figures, there is illustrated a multi-stage gas lift fluid pump system. The entire system is illustrated in FIG. 1 and includes a well pipe installation 10 including a surface pipe 12 surrounded by a cement casing 14. The production string 16 is carried within the surface pipe 12 for a portion of the total depth of the well and the remainder of the well is in direct contact with the strata through which the production string passes. Where the production string extends into the producing zone 18 a plurality of oil entry perforations 20 are provided. A producing tubing 22 is shown located within the production string and extending downwardly at least as far as the producing zone.

The annulus 17 between the producing tubing 22 and the production string 16 is shown to be open for the passage of gas throughout its length except that the downward travel of gas is limited by a side wall packer 24 shown located just above the producing zone. At the casing head, the annulus is sealed and is penetrated by a gas delivery pipe 26 which is capable of supplying gas under pressure from pump 28 to the gas entry nozzle or jet pump 30 through the annulus 17. The oil and gas lifted from the well are delivered through pipe 32 and flow choke 34 to a separator 36. The gas segregated by the separator is conveyed by a pipe 38 to a storage facility (not shown). The segregated gas is directed through a pipe 40 to a gas storage facility 43 or is returned to the gas pump for re-use through pipe 42. The jet pump 30 is shown to comprise two generally conical upwardly curving sections 44 and 46 which converge toward their upward end to form a nozzle like termination. Gas passing through these nozzles exits the upper end of the nozzle at high velocity and creates a low pressure area in accordance with the well known Bernoulli effect, drawing the oil through the orifice 50. The side wall packer 24 is effective to seal the gas from travelling further down the well and forcing the entire gas supply to pass through the jet pump. A check valve 52 is provided to prevent backwards flow of the oil under the influence of gas pressure.

FIG. 3 illustrates the details of the supplemental lift device 15 which is conveniently supported from the joint coupling 54 between successive sections 56 and 58 of the producing tubing 22. The device includes a pipe 60 having an outside diameter considerably smaller than the inside diameter of the producing tubing. A ball check valve 62 is illustrated and includes a seat portion 64 and retainer 66.

The pipe 60 is approximately ten feet in length with the last two feet thereof provided with a plurality of openings 61. The gas-oil interface is maintained at approximately the level of uppermost openings 61. The annulus 63 between the supplemental lift device pipe and the production string provides a chamber for the gas which has separated from the oil.

The operation of the system will be considered with respect to its use in a non-flowing well. In such a well the residual pressure in the reservoir will cause the oil to be forced upwards in the production string to a level somewhat above the producing zone. For example, in the instant device, the level might be considerably above the area of the jet pump. Thus the initial operation with respect to commencing pumping would be to apply gas pressure from the gas storage facility 43 through the use of pump 28 so as to force the oil down the production string. The side wall packer is effective to force the oil through the jet pump and into the producing tubing. The increased pressure forces check valve 52 against its seat so as to prevent the flow of oil into the producing zone and the oil therefore flows upwardly through the producing tubing until all the oil is exhausted and only gas is flowing through the jet pump. The gas flow results in a low pressure zone which forces the oil through the orifice 50. The reduced pressure eventually communicates with the check valve 52 and additional oil is drawn in by the action of the jet pump. From this point forward, during the operation of the system, the check valve 52 will be held away from its seat. Under the action of the jet pump the oil is thoroughly admixed with gas and is forced upwards a considerable distance into the vicinity of the supplemental lift device. At this point the lifting power of the gas is beginning to dissipate because of the separation of the gas and oil into distinct phases and because the limited gas pressure is not capable of lifting the oil against excessive heads. The annulus between the supplemental lift device and the producing tubing fills with the separated gas which forms a reservoir down to the level of the first perforations of the supplemental lift device pipe. As the devices achieve stabilization the quantity of gas entering the system will all be passing through the perforations and by this action will thoroughly mix again with the oil, producing an additional lifting effect and raising the oil past the check valve into the next section of producing tubing.

The action of the subsequent supplemental lift device is similar, with each device remixing the oil and gas to obtain maximum lifting effect from the originally induced gas as well as the gas produced from the oil by the result of the reduction in overall pressure. The flow between the supplemental lift devices, for example, between the first lift device and that next above it is intermittent, that is, the flow from the first device into the next following device takes place only when the fluid in the upper string has been lifted past the following device's check valve, and no head holds the check valve against its seat. When these conditions prevail, the oil, under the influence of the lifting gas, can lift the check valve from its seat and flow into the following section of producing tubing without the necessity of lifting a large column of oil. Thus the oil is lifted in stages until it reaches the casing head from which it flows through pipe 32 and flow choke 34 to the separator 36. The separator may be any one of several well known types which are effective to segregate the two components of the mixture reaching the surface, e.g., gas and oil. Any gas lost in the process is replaced from the LPG storage facility which maintains the volume of gas circulating in the system at a constant value.

Having described my invention, I now claim:

1. In a gas lift pump including a source of gas under pressure communicating with a pump means at the lower end of tube extending into the proximity of a quantity of fluid to be pumped, that improvement comprising:

a plurality of supplemental lift means for utilizing a flow of gas through said tubing to lift said fluid,

and said supplemental lift means comprising a length of pipe mounted within said tubing and having a

portion adjacent its lower end perforated to admit fluid and gas.

2. The improved pump system of claim 1 wherein,

said length of pipe includes a check valve mounted at its upper end.

3. That improved pump system as claimed in claim 1 wherein,

said gas enters said tubing and only at the portion of said tubing in proximity to said quantity of said fluid.

4. That improved gas lift system as claimed in claim 1 wherein,

said pump means comprises a jet pump,

said tubing is suspended within a production string of pipe in a well,

and said source of gas being located at the upper end of the producing string and communicating with said jet pump through the annulus formed between said production string and said tubing.

5. The improved gas lift pump system as claimed in claim 1 wherein,

said supplemental lift means further comprises,

check valve means for preventing substantial flow of fluid from said tubing means above said check valve into said length of pipe.

6. The improved gas lift pump system as claimed in claim 5 wherein,

said check valve comprises a ball check valve mounted in proximity to the point of suspension of said length of pipe.

7. The improved gas lift pump system as claimed in claim 1 further including,

a side wall packer means mounted between said production string and said tubing for forcing the gas from said source of gas to flow into said jet pump.

8. The improved gas lift pump system as claimed in claim 11 further including,

supplemental check valve means for preventing the backward flow of fluid during the initial actuation of the system,

and said supplemental check valve means being located in said tubing below said jet pump means.

9. The improved gas lift pump system as claimed in claim 1 further including,

separator means for separating the gas from said fluid after said fluid is raised to the top of the tubing,

and pump means for recirculating the separated gas for pumping additional fluid.

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