United States Patent [19]

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[11] **3,773,437**

[45] **Nov. 20, 1973**

[54] **JET PUMP SUPERCHARGING OF OIL FIELD PLUNGER PUMP**

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[22] Filed: **May 17, 1972**

[21] Appl. No.: **254,276**

[52] **U.S. Cl.** **417/87**, 417/554

[51] **Int. Cl.** **F04b 23/04**, F04b 21/04

[58] **Field of Search** 417/87, 554, 173, 417/172, 79

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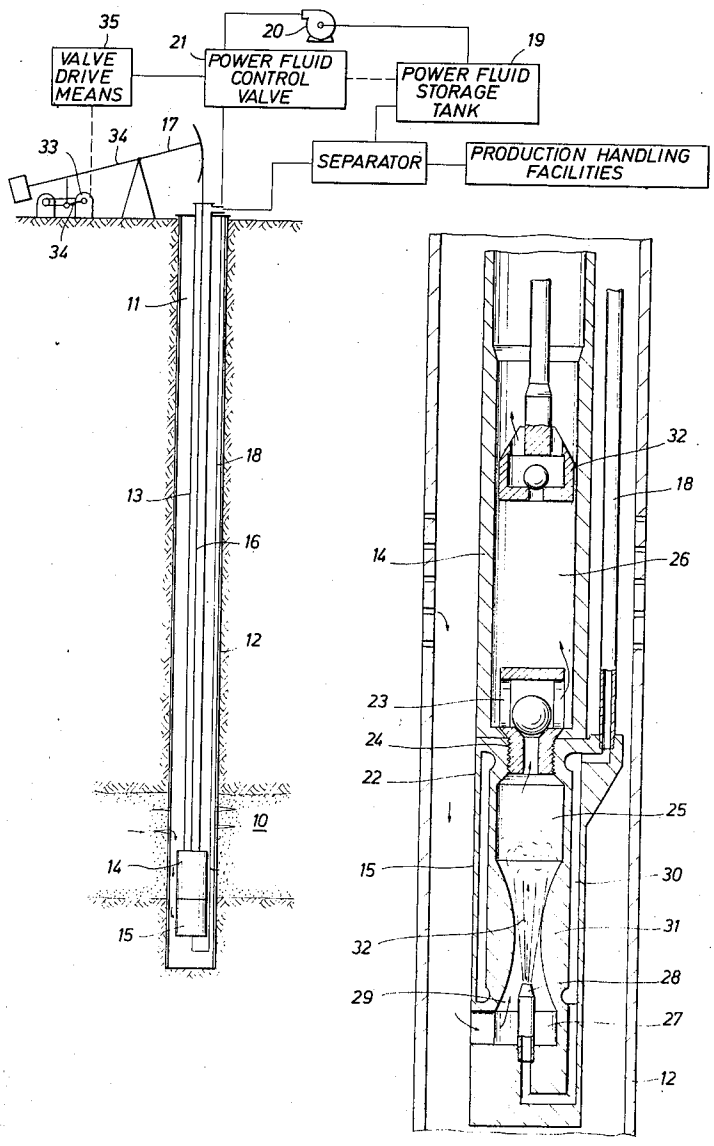
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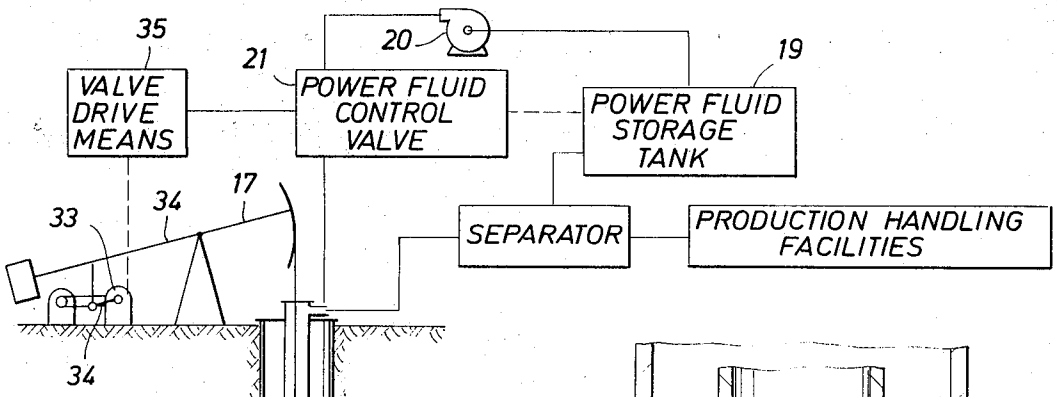
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[57] **ABSTRACT**

Method and apparatus for improving volumetric efficiency of a positive displacement type well pump by supercharging the pump suction with a jet pump to prevent vapor lock.

6 Claims, 2 Drawing Figures




35
VALVE DRIVE MEANS
21
POWER FLUID CONTROL VALVE
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19
POWER FLUID STORAGE TANK
SEPARATOR
PRODUCTION HANDLING FACILITIES
17
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34
34

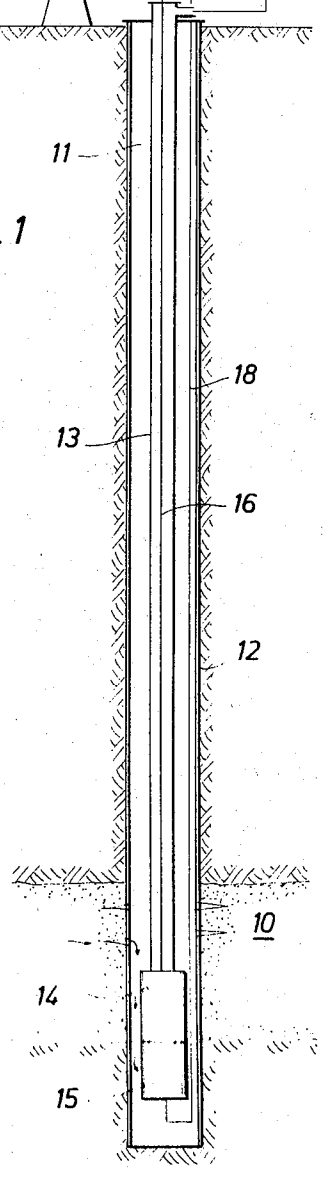

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FIG. 1

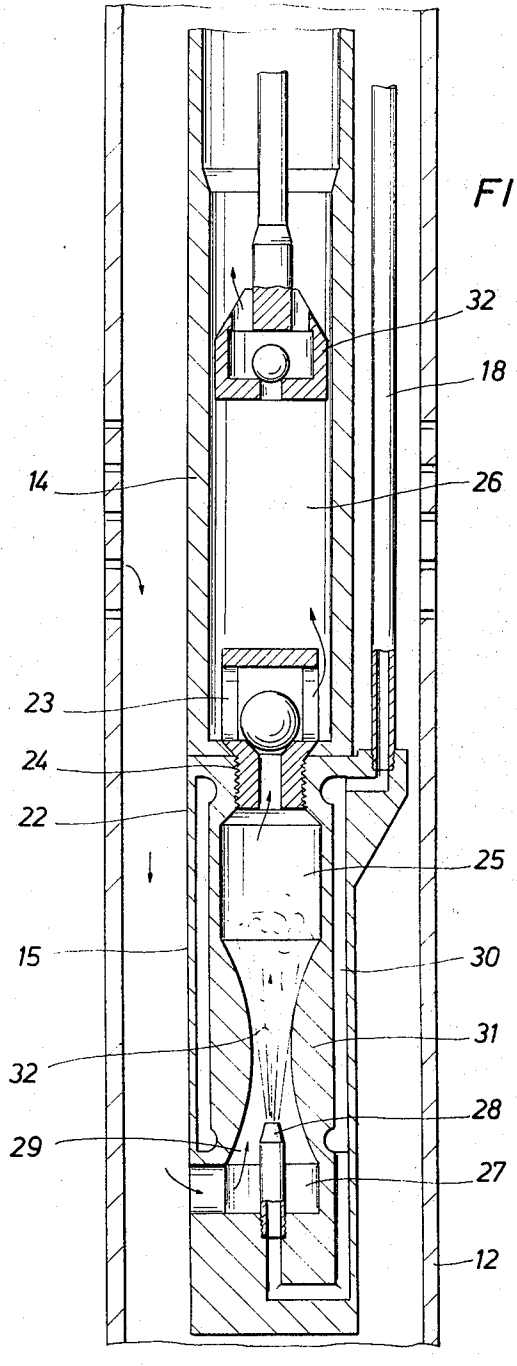

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FIG. 2

JET PUMP SUPERCHARGING OF OIL FIELD PLUNGER PUMP

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of subsurface well pumps, and more particularly, to an improved subsurface well pump of the positive displacement type such as sucker rod or hydraulic powered well pumps.

2. Description of the Prior Art

When recovering liquids such as oil or water from subsurface earth formations, it is often necessary to lift the liquid from a well with a subsurface pump. The subsurface pump most commonly used in oil field practice is a positive displacement type pump such as a sucker rod pump or a hydraulic powered pump.

In its simplest form this type pump comprises a working barrel suspended on a string of well tubing and a plunger which is moved up and down inside the barrel by a drive means. In the sucker rod pump, the drive means comprises series of screwed steel rods attached at the surface to a pumping unit or other means for imparting a reciprocating movement to the rods. In the hydraulic pump the drive means is a hydraulic engine powered by liquid pumped into the well from the surface.

Intake and exhaust valves control the flow of fluid into and out of the working barrel in sequence with the motion of the plunger. For example, in the conventional sucker rod pump, a stationary ball and seal valve, the standing valve, is positioned at the bottom of the working barrel. A second ball and seat valve, the traveling valve, is located in the plunger. As the sucker rods pull the plunger upwardly through the working barrel, the traveling valve closes, pressure is reduced in the working barrel below the plunger and, in response to this reduced pressure, fluid flows through the standing valve into the working barrel.

As the plunger moves downwardly after completing the upstroke, pressure within the working barrel increases. This closes the standing valve. Further downward movement of the plunger increases the pressure within the working barrel to a pressure greater than that in the tubing above the plunger. In response to this pressure the traveling valve opens to allow fluid to flow through the plunger. On the next upstroke this fluid will be lifted into the tubing by the plunger and more fluid will be drawn into the working barrel. Conventional hydraulic powered pumps operate on the same principle; however many of these are of the double acting type which displace fluid into the tubing on both the up and down strokes. In such pumps the valve arrangement is more complex, but still comprises intake and exhaust valves for each stroke.

In positive displacement pumps, if free gas is present in the working barrel during the displacement stroke, e.g. the upstroke in a single acting, sucker-rod pump, pressure falls gradually as the plunger moves upwardly since volume vacated by the plunger is immediately occupied by expanding gas. This reduces the volume of liquid drawn into the working barrel. Similarly, on the intake stroke, e.g. when the sucker rod pump plunger is moving downwardly, there may be considerable loss in effective downward stroke before the traveling valve opens since pressure in the working barrel builds up gradually as the gas is compressed. This loss of effective stroke can greatly diminish the efficiency of a positive displacement pump. In some cases the pump merely repetitively compresses and expands gas within the working barrel. In such cases it is "gas locked" and pumps no fluid at all.

Therefore, it is common practice when producing a well with a high ratio of gas to oil in the produced fluids to employ a gas anchor for separating gaseous fluids from liquids to be pumped before the fluids are drawn into the working barrel. Such a system usually directs the gaseous produced fluids up the casing tubing annulus while pumping liquids up the tubing with a sucker rod pump.

Another method for improving sucker rod pump efficiency when pumping high gas content fluids is to use a two-stage pumping system in which fluid passes from the working barrel past the traveling valve into a second chamber through which flow is regulated at the bottom by the traveling valve and at the top by a valve, such as a ring valve, connected to the sucker rod string. The ring valve keeps the fluid column in the tubing off the traveling valve on the downstroke to reduce the pressure differential required to open the valve. On the upstroke the fluid load above the ring valve keeps this valve closed until the fluid between it and the traveling valve is compressed to a pressure equaling the head of the fluid column. This ensures that some fluid will be forced through the pump into the tubing.

Prior art devices such as gas anchor systems and two-stage pumps still suffer reduced efficiency when pumping fluid containing significant proportions of components which are at or near their bubble point temperature at pressures prevailing in the wellbore. When pumping these fluids, lowered efficiency is experienced because the components which are near their bubble point temperature tend to vaporize as they move into the pump working barrel because of the reduced pressure in this barrel. The vapor occupies a disproportionate amount of space in the working barrel thereby keeping produced liquids out of the barrel. Consequently, the volume of liquid pumped on each stroke is reduced. In some cases, when using conventional one-stage pumps, complete gas lock may be experienced. Two-stage pumps tend to prevent complete loss of efficiency but still suffer substantial losses.

This loss of efficiency is often particularly acute when producing wells in steam stimulation oil recovery projects where the produced fluid contains a substantial amount of steam condensate almost a vapor temperature and pressure which flashes to steam upon a relatively small reduction in pressure. It is known that steam flood production well pumping efficiency can be improved by maintaining a sufficient fluid head in the wellbore above the pump to prevent fluid pressure from falling below the vapor pressure of the condensate as fluids are drawn into the pump suction. However this method has the disadvantage of increasing fluid pressure in the well bore adjacent the producing formation and thereby reducing the productive capacity of the well.

One answer to the problem of reduced productivity capacity has been to dig a rat hole below the producing formation. The pump is extended and a fluid head is maintained on the pump but not on the producing formation. This has the disadvantage of increasing drilling expense.

SUMMARY OF THE INVENTION

It has now been discovered that the volumetric efficiency of a downhole positive displacement pump producing fluid substantially at vapor pressure at well bore conditions of temperature and pressure can be improved by supercharging the pump suction with a jet pump powered by a power fluid flowed down the well and into the jet pump from the earth surface. The power fluid should preferably be at a lower temperature and higher pressure than the wellbore temperature and pressure as it enters the jet pump.

A downhole pump for pumping fluid out of a well according to the invention comprises a sucker rod pump including a working barrel having a suction end in which a standing valve is positioned. A plunger carrying a traveling valve is slideably positioned in the working barrel. A jet pump comprising a housing defining a hollow elongate chamber is connected in fluid communication with the suction end of the plunger pump. A nozzle head is connected to the housing and positioned to direct a stream of high pressure liquid into the hollow chamber through an opening of selected diameter in the housing spaced from the pump suction. The nozzle head has an internal diameter less than the selected diameter of the housing opening so that in operation an annular space exists between the fluid jet emitted from nozzle head and the walls of the housing opening. Means are provided for connecting the nozzle head with a source of high pressure liquid. When the apparatus is in operating position in a well, a stream of high pressure liquid passes from the nozzle head into the hollow chamber drawing well fluids into the chamber by suction. The sucker rod pump draws fluid from the hollow chamber and thereby pumps both high pressure liquid and well fluids from the well.

Advantageously, the means for connecting the nozzle head with a source of high pressure fluid comprises an outer, annular fluid passageway surrounding the hollow chamber. The annular passageway is connected in fluid communication with the nozzle head and with the source of high pressure fluid so that as this fluid flows from the earth surface into the well it passes first through the fluid passageway around the hollow chamber in counter current, heat exchange relationship with fluid discharged into the chamber from the nozzle head. Thus the power fluid cools the supercharged chamber from which the rod pump draws produced fluid. This further diminishes the tendency of this fluid to vaporize in the pump suction.

In a preferred embodiment of the invention a power fluid control means is coupled to the means for delivering power fluid. This control means functions to minimize the amount of power fluid which must be pumped up the well in order to increase the efficiency of the apparatus of this invention in producing well fluids. This is preferably achieved by stopping fluid flow through the power nozzle during the downstroke of a single acting plunger pump as by opening and closing a control valve at the earth surface in timed relationship with the motion of the rod string. In practice it may be preferable to regulate the power fluid so that flow is begun near the end of the downstroke so that the jet pump is fully operative at the beginning of the upstroke when the standing valve opens.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic drawing partly in block form of apparatus suitable for the practice of this invention.

FIG. 2 is a sectional view of a preferred embodiment of the sucker rod pump and jet pump supercharger of this invention positioned in a well.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to FIG. 1 we see a subsurface earth formation **10** traversed by a well **11** which is suitably equipped for the practice of this invention. A casing **12** has been extended into the well and cemented in place. A string of tubing **13** is extended into the well from the earth surface and carries at the lower end thereof a conventional sucker rod pump **14** coupled at its lower end to a jet pump supercharger **15.** A string of rods **16** connects the rod pump **14** to a reciprocating drive means, such as beam type pumping unit **17,** at the earth's surface.

A third conduit such as a string of small diameter tubing **18** for carrying power fluid to the jet pump **15** extends into the well from the earth surface. This power fluid conduit **18** is coupled to a source of power fluid such as storage tank **19.** In some cases sufficient pressure for operating the jet pump **15** will be obtained from the fluid head of power fluid in tubing **18.** In these cases power fluids may be allowed to flow directly from storage tank **19** to jet pump **15** under the force of this fluid head. In other cases it will be necessary to boost the pressure of the power fluid with means such as pump **20** before the fluid reaches jet pump **15.**

FIG. 2 shows a preferred embodiment of the jet pump supercharger **15** of this invention. The jet pump **15** comprises a housing **22** connected to the rod pump **14** below standing valve **23** by suitable means such as threaded connection **24.** The housing **22** encloses a hollow chamber **25** which is in fluid communication with the working barrel **26** of the rod pump **14** via the standing valve **23.** An opening **27** spaced from the end of the housing **22** adjacent the rod pump **14,** and preferably near the bottom of the housing **22,** provides communication between the chamber **25** and the interior of the casing **12.** The portion of the housing **22** adjacent the opening **27** and nearer the rod pump **14** than the opening **27** may define a narrowed throat **31** which expands in the direction of the rod pump **14** to the full diameter of the chamber **25.**

A nozzle head **28** is positioned to direct a jet of power fluid **32** into the chamber **25** through throat **31** downstream of the opening **27.** The nozzle head **28** is of internal diameter less than the minimum internal diameter of the throat **31** so that in operation there is an annular space **29** between the fluid jet **32** and the interior wall of at least a portion of the throat **31.**

Nozzle head **28** is connected in fluid communication with power fluid tubing **18** by apprepriate connecting means. Preferably this connecting means comprises an annular flow passageway **30** within the housing **22** external of the chamber **25.** Fluid flowing down the tubing **18** to the nozzle head **28** passes through the housing **22** in heat exchange relationship with fluids in the chamber **25** before reaching the nozzle head **28.**

In operation, fluid comprising a high proportion of liquids near their bubble point, for example produced fluid from a steam drive thermal recovery process containing oil and a high proportion of steam condensate,

flows from formation **10** into the well **11** through perforations in casing **12.** To pump this liquid to the surface, power fluid is flowed from power fluid storage **19** down tubing **18,** through annular passage **30** in housing **22** and then through jet nozzle **28** into fluid chamber **25.** The power fluid may be water or any other liquid compatible with liquids produced from the formation **10.** For best results, the power fluid is at a temperature at least 25° F lower than that of the produced liquids.

The power fluid is forced through the nozzle head **28** at a sufficient flow rate and with a sufficient pressure drop across the nozzle head to create a fluid jet **32** which, as it passes into the throat **31** of the chamber **25,** develops a suction that causes produced liquid in the well to be drawn through passage **27** into the throat **31.** This produced liquid is entrained with the power fluid and carried into the chamber **25.** In this way the jet of power fluid maintains pressure in the chamber **25** higher than that in the well bore **11** while still drawing produced fluid into the chamber **25.** Because of the increased pressure in chamber **25,** fluid can be drawn through the standing valve **23** into the working barrel **26** of the pump **14** on the upstroke of that pump at a pressure not significantly less than, and in some cases as high as or greater than, that in the well bore depending upon the pressure increase required to condense any vapors which may be present due to the pressure drop due to draw down as the produced fluid enters the well bore. Therefore the tendency for steam condensate to vaporize in the working barrel **26** is significantly reduced. Also any vapor drawn into the working barrel from the well bore is condensed. The particular power fluid flow rate required will, of course, vary with the depth of well **11,** the capacity of rod pump **14,** temperature of the fluids produced, etc. Those skilled in the art will have no difficulty selecting a proper flow rate for a particular set of well conditions.

Of course, because the working fluid must be pumped from the well along with produced fluids, the work load on the pump **14** is increased. Thus, produced liquid volume (e.g. oil and steam condensate) pumped from the well by the apparatus of this invention is greater than that pumped by the conventional sucker rod pump **14** alone only if the efficiency of the sucker rod pump **14** is improved by a sufficient amount to handle this increased fluid volume and more. That is, if the efficiency of the pump **14** when operating alone is 50 percent and if the addition of the jet pump **15** increases this efficiency to 100 percent, then the amount of produced liquid lifted from the well by the pump **14** will be increased only as long as power fluid for the jet pump **15** represents less than one half of the total fluid passing through the pump **14.** Therefore, if it is desired to operate jet pump **15** continuously, in many cases it is advantageous to use a double acting type pump (not shown) which displaces fluid into tubing **13** on both the upstroke and downstroke instead of single acting sucker rod pump **14.**

If a single acting pump such as sucker rod pump **14** is used, then in order to reduce the amount of power fluid which must be pumped from the well **11,** power fluid control means, such as valve means **21,** for regulating the flow of power fluid may be advantageously coupled to the power fluid supply system e.g. to conduit **18.** The power fluid control means preferably comprises means for directing fluid flow through the jet pump **15** during approximately one half of the cycle of the rods **16** and for stopping the flow of power fluid through the jet pump **15** during the other half of the cycle of the rods **16.** For example, if a pump **20** is used to increase the pressure of the power fluid, it may be desirable to direct power fluid to a surge tank such as storage tank **19** during the one half of the rod pump cycle. In this case the valve means **21** may include a two-way valve.

Power fluid control valve means **21** is coupled to the sucker rod pumping apparatus by means, such as valve drive means **35,** for controlling the operation of valve **21** in timed relationship with the stroke of the rods **16.** The drive means **35** may be, for example, mechanical, such as reciprocating connecting rod (not shown) eccentically connected to a rotating member, such as the crank **34,** of the pumping unit **17** and to the valve **21,** or electrical, such as a solenoid activated means for opening and closing the valve **21** electrically coupled to a switch means driven by the reciprocating motion of pumping unit **17.** The drive means can be connected directly to the gear box **33** of the pumping unit **17,** to the walking beam **34** of that unit or to any other suitable portion of the sucker rod pumping apparatus including the rod string **16** and the pump **14.**

In FIG. **1,** power fluid control valve means **21** is shown positioned above the earth surface. However in practice it may be advantageous to place this valve means any place in the tubing **18** or other conduit which connects the jet pump nozzle **28** with the source of power fluid **19.** In particular it may be advantageous to place at least one element of the control valve means in the well near or in the jet pump **15,** for example, in the housing **22** immediately upstream of the nozzle **28.** Where a pump **20** is used to increase the pressure of the power fluid, the control valve means may comprise a back pressure valve positioned in the well **11** adjacent the jet pump **15.** The back pressure valve can be of the type which is normally closed but which opens to allow power fluid to flow to nozzle **28** when the pressure upstream of the valve exceeds a selected threshold pressure. This threshold pressure can be selected such that the back pressure valve opens when pressurized fluid from pump **20** is directed down tubing **18** as by a two-way valve at the earth surface.

While this description of the invention has been given primarily with reference to the combination of jet pump **15** with a single acting sucker rod pump **14,** it should be understood that the invention is applicable to any positive displacement type subsurface well pump including hydraulic engine powered pumps and double acting sucker rod pumps.

I claim:

1. In an apparatus for pumping liquids from a well of the type comprising a positive displacement pump including a working barrel having a suction end and a discharge end and including a plunger slidably positioned for reciprocating motion within the working barrel, in operation the positive displacement pump drawing liquid into the working barrel through the suction end on an intake stroke of the plunger in which the plunger is moved axially within the working barrel in a first direction, the improvement which comprises:

a jet pump connected to the suction end of the working barrel for supercharging the positive displacement pump to boost fluid pressure in the working barrel on the intake stroke of the plunger; the jet pump being positioned to draw liquid from the well

and to discharge this liquid into the suction end of the working barrel; and

means for stopping and starting flow of power fluid to the jet pump in timed relationship with the reciprocating motion of the pump plunger.

2. The apparatus of claim **1** including conduit means for connecting the jet pump in fluid communication with a source of power fluid.

3. The apparatus of claim **1** wherein the jet pump comprises:

a housing having a hollow chamber therein which chamber is connected in fluid communication with the suction end of the working barrel; and

a nozzle head connected to the housing and positioned to direct a stream of power fluid into the hollow chamber.

4. The apparatus of claim **3** wherein the housing is provided with an annular passageway surrounding the hollow chamber, the annular passageway being connected in fluid communication with the conduit means and with the nozzle head intermediate said conduit means and nozzle head, whereby in operation power fluid passing from the conduit means to the nozzle head passes through the annular passage before reaching the nozzle head.

5. Apparatus for pumping produced fluid out of a well comprising:

a sucker rod pump positioned in the well adjacent a producing formation; the sucker rod pump comprising a working barrel with a suction end;

a string of steel rods for driving the sucker rod pump connected to the sucker rod pump and extending from the sucker rod pump to the earth surface;

means for imparting reciprocating movement to the string of rods to drive the sucker rod pump;

a housing defining a hollow chamber connected to the working barrel suction end, the housing having therein an opening spaced from the working barrel suction end for admitting produced well fluid into the hollow chamber, the housing also defining a narrowed throat of selected minimum diameter in the hollow chamber adjacent the housing opening;

a nozzle head operatively connected to the housing and positioned to direct a stream of high pressure power liquid into the hollow chamber through the narrowed throat, the nozzle head having an internal diameter less than the minimum diameter of the throat;

a power liquid control valve positioned in the conduit means; and

control valve drive means for opening and closing the control valve connected to the control valve and to the means for imparting reciprocating movement to the string of rods;

wherein, in operation, a stream of high pressure liquid is passed through the nozzle head into the hollow chamber drawing produced well fluid into the hollow chamber through the housing opening by suction and wherein the sucker rod pump draws fluid from the follow chamber and pumps this fluid from the well.

6. The apparatus of claim **5** wherein the conduit means for connecting the nozzle head with a source of power liquid comprises an annular passageway within the housing surrounding the hollow chamber.

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