HYDRAULIC PUMPING SYSTEMS

Artificial Lift for Varied Lifting Requirements

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ABSTRACT

The hydraulic method of artificial lift has traditionally offered creative solutions to operators faced with a wide array of producing problems. A long history of equipment and application development has brought today's hydraulic pumping systems to a status of unique adaptability to varied application requirements with reliable operating performance.

This update on the capabilities of the hydraulic system will review system hardware and describe installation and operating characteristics which account for the versatility of this lift method.

Examples of application flexibility are discussed, including installations for horizontal completions, hydraulic lift powered from the water flood injection plant, wireline set hydraulic pumps in existing wells and well testing.

INTRODUCTION

Applications for artificial lift systems cover the whole gamut of requirements for delivering energy downhole to lift well production into the surface facilities. In areas of stabilized production, the lift system of choice has typically been well established as the most suitable method for effectively producing the wells. As fields mature, changing downhole or surface operating conditions may require adjustment or complete revision of the lift system to maintain effective and efficient performance. New well completion techniques, such as horizontal completions, may call for change in the lift method commonly used. And, in addition to the long term production requirements for non-flowing wells, artificial lift equipment may also be required for short term activities, such as unloading the flowing well, evaluating production through testing in newly completed or workover wells, or for temporarily maintaining production during equipment changeover.

The Hydraulic Pumping System has developed a long history of successfully providing creative solutions in dealing with difficult long term producing applications, and as well, solutions for a variety of short term lifting requirements. The following discussion briefly reviews this system, identifies pertinent benefits, and describes some of the noteworthy lifting solutions.

HYDRAULIC PUMPING SYSTEM

General Description

The Hydraulic Pumping System uses fluid under pressure to transfer energy to the downhole pump. The power fluid used may be produced oil or water, or other suitable available liquid. Surface equipment for the system prepares the available fluid for use as power fluid, and delivers to the downhole pump at the required volume and pressure to produce the well. The most typical downhole installation for long term production by this system is completed having a single tubing string landed on a casing packer, with a special pump landing nipple or Bottom Hole Assembly (BHA) located just above the packer (Ref. Fig. I). A seal profile is located in the top of the BHA, a retrievable standing valve at the bottom, and discharge ports above the standing valve. A free type hydraulic pump is circulated into the tubing with the power fluid and is landed into the BHA to establish the appropriate seals between the pump and BHA. Continued circulation increases power fluid pressure and initiates operation of the pump. Produced fluid is drawn into the pump intake through the retrievable standing valve. Produced fluid plus exhausted power fluid is discharged from the BHA and is pumped to the surface through the tubing/casing annulus. Retrieval of the free pump for inspection or servicing is accomplished by reversing the flow direction of power fluid which closes the retrievable standing valve and circulates the pump up the tubing to the surface.

Many variations of the required downflow and upflow tubular conductors for the hydraulic circuit are possible to meet most completion and producing requirements. Optional installation arrangements can also be made for the downhole pump to fit various well completion schemes. Examples of these will be described.

Downhole Equipment

Two types of downhole hydraulic pumps are available which meet a wide range of producing requirements:

Piston Pump (Ref. Fig. II)

The hydraulic piston pump is a reciprocating, positive displacement pump design consisting of a hydraulic powered engine piston connected through a packed-off "polished rod" to a pump piston, with each piston stroking within a hardened cylinder, and with appropriate engine and pump valving. In operation, the displacement rate can be controlled from about 20% to 100% of rated displacement simply by adjusting the power fluid rate at a surface control valve to set the stroking speed of the pump. Hydraulic piston pumps provide a wide range of volume and lifting depth capacities, are capable of operating at very low pump intake pressure, and provide high displacement efficiency when handling low GLR production through the pump. These pumps operate at reduced displacement efficiency when handling high rates of free gas, and have limited capacity for excessive sand production through the pump.

Jet Pump (Ref. Fig. III)

The hydraulic jet pump is a dynamic pump design which requires no moving parts to develop the pumping action. This is accomplished by fluid momentum transfer through an ejector nozzle, throat and diffuser assembly by (1) converting high pressure power fluid at the nozzle to a high velocity, low pressure jet stream as it enters the throat, where it (2) increases the velocity of the produced fluid drawn into the pump as the mixture moves through the throat, and (3) by slowing the velocity of the mixture passing through the diffuser, increases discharge pressure to a value sufficient to lift the fluid to the surface. The pumping rate of the jet pump can be adjusted from zero to full capacity by adjustment of power fluid rate and pressure at surface controls. Operating benefits of the jet pump include moderate to very high producing rates, with deep lifting capacity, plus the ability to handle well fluids which are sandy, corrosive, high temperature or which contain high volumes of free gas. Overall operating efficiency is lower than the piston pump, and the jet pump requires sufficient pump intake pressure to effectively charge the pump suction.

Surface Equipment

The surface power fluid system is designed to deliver the selected power fluid to the downhole pump at the required rate and pressure. This system can be provided in a compact skid mounted unit, installed at the well site, to remove suspended solids from the produced oil or water and deliver as high pressure power fluid to one or more wells. This unit includes: a pressure vessel for separation of the liquid and gas returns from the well; a charged cyclone fluid cleaning system for removal of entrained solids from the power fluid; and a high pressure plunger pump to deliver power fluid to the well at the required rate and pressure. As the power fluid is drawn-off from the pressure vessel, the fluid volume remaining in the vessel represents gross well production (oil, water and gas) and is discharged directly into the flowline.

Alternate surface power fluid systems may utilize a power oil tank for preparation of power oil by gravity separation, water drawn from a treater to be cleaned through a cyclone system for use as power fluid, or power water from a water flood injection system if available injection pressure meets the hydraulic operating pressure requirement. During short term testing, such as drill stem tests with hydraulic jet pumps from an offshore platform, treated sea water, pressured by the rig pumps, is typically used as power fluid.

HYDRAULIC SYSTEM VERSATILITY

Hydraulic power, used as the means for transfer of energy to the downhole pump, permits adapting the hydraulic lift system to a wide variety of the typical and atypical artificial lift operating and application requirements. A few of the system characteristics will serve to illustrate this versatility.

Downhole Pump Installation

The fluid conducting tubulars are the only connection required from the surface to the downhole pump. And most commonly, the pump is run or retrieved by circulation into or out of one of these tubular conduits with the power fluid system. No pulling equipment is required, and minimum turn-around time is involved. In other installation arrangements, the pump may be conveyed on a rigid or coiled tubing string, or handled in the well by wireline tools. In any case, no mechanical friction or wear is developed in well tubulars during operation of the hydraulic pump. These installation characteristics are of particular benefit in highly deviated wells, and may permit installing hydraulic lift in other existing well completions without pulling tubing.

Depth and Production Rate Range

Wells deeper than 10,000 feet can be difficult to produce by the most common sucker rod, gas lift or electric submersible artificial lift methods. The application depth for hydraulic systems is generally limited only by the tubulars and horsepower available. Production in the 250 BPD range has been lifted from below 15,000 feet by hydraulic piston pumps for many years. Jet pumps can be operated at these depths with high producing rates, provided the well tubulars are of adequate size to carry the fluid volumes involved without excessive pressure loss. The minimum application depth for hydraulic systems from an economic standpoint falls in the 3,000 to 4,000 foot range. Operating benefits of this system often justify its selection for more shallow applications.

Production Rate Control

Surface power fluid flow controls permit easy adjustment of the pumping rate of the downhole pump. Rate adjustments within the operating range of the installed pump are accomplished with no mechanical change. Increasing or decreasing the power fluid rate at the adjustable constant flow control valve changes the stroking rate and displacement of the piston pump. Jet Pump displacement responds to adjustment of either power fluid rate or pressure at the surface controls. If greater capacity change is required, the pump can be retrieved and replaced by a suitably sized pump with minimum downtime. If a jet pump is being used, the jet nozzle and throat can generally by changed at the well site to match pump capacity to the current conditions.

Produced Fluid Characteristics

Downhole hydraulic pumps like clean, sweet crude as well as any other lift system. But they also do survive in a wide range of difficult to produce crude. The power fluid circuit to the downhole pump provides an convenient carrier for conducting chemicals downhole to be mixed with produced fluid at the pump. Various inhibitors are routinely injected into the power fluid stream to piston or jet pumps for downhole protection. The simple configuration of the hydraulic jet pump permits full use of corrosion resistant materials for application in highly corrosive well fluids. Heavy crude, under 10 API, are pumped with both piston and jet pumps. The power fluid selected for heavy crude pumping may serve as a diluent to be introduced at the pump to reduce viscosity of the return stream. The jet pump is most adaptable in dealing with difficult crude due to the simplicity of the pumping chamber. As noted, high gas rates, heavy sand content, and highly corrosive fluids can all be tolerated by the jet pump.

APPLICATION FLEXIBILITY

The discussion of hydraulic system versatility has highlighted some of the characteristics of this lift method which extend its application into special producing requirements. The following examples are but a few of the possibilities.

Horizontal Well Completions (Ref. Fig. IV and Fig. V)

Downhole hydraulic pumps are a natural fit to the horizontal completion. For over half a century hydraulic pumps have successfully produced crooked or purposely deviated wells. The rule of thumb developed from this extensive experience says that if the tubing will go into the well, the hydraulic pump will run in the tubing. This has been confirmed in hundreds of deviated wells having build rates of 5 to 10 degrees per 100 ft. below the kick-off point, and completed at 70 to 80 degrees off vertical. With increasing use of horizontal well completions, analysis of permissible deviation severity for hydraulic pumps indicates at least 14°/100 ft. for piston pumps and 20°/100 ft. for jet pumps as conservative application points for a 2-1/2" pump in 2-7/8" tubing. Among several jet pump installations in 10,000 inch medium radius horizontal wells, one well survey showed a dogleg severity of 22°/100'. None of the free type jet pumps used in this well has failed to run-in or be retrieved trouble free. Piston pumps and jet pumps are operated in horizontal completions below the kick-off point in a variety of installation arrangements and landed at the bottom of the tangent or on into the horizontal lateral.

Water Flood Injection For Hydraulic Power

Hydraulic power is developed by the combination of the hydraulic fluid volume and pressure. For example, 1500 BPD of power water at 3000 PSI drivers about 75 hydraulic horsepower

(HHP). Or, 3000 BPD power water at 1500 PSI delivers the same 75 HHP. The downhole pumps, both piston and jet, can be configured within design limitations to reduce the required power fluid pressure by increasing the power fluid volume used. By designing the power fluid system requirement to be within the injection pressure of the water flood plant, this power source may be suitable for operation of the artificial lifting system in the flood field.

Hydraulic piston pumps are now being powered from the water injection plant in a large California producing field. The specially developed piston pump operates at half the normal pressure by taking power fluid (water) at double the normal rate. This has reduced total operating costs by eliminating the separate power fluid pumping system. Flood water used as power fluid is recovered into the water injection plant supply. Jet pumps are also being sized to fit the requirements of this power source, making hydraulic pumping systems potentially the most economic lift system for water flooded production.

Wireline Set Hydraulic Pumps

Installation of hydraulic pumping for increased production from existing wells may be feasible if the installation can be made within the current completion without pulling tubing. Several options may be possible by landing the pump in the well tubing by wireline tools.

Tubing Packer Installation (Ref. Fig. VI and Fig. VII). In gas lifted wells, if available gas is no longer adequate to lift the well, a hydraulic pump may be landed into the gas lift mandrel on a straddle packer installation. The lower tubing packer is landed on a tubing stop below the GLM. A hydraulic jet pump is set between the upper and lower packers. With dummy valves in all other mandrels in the string, power fluid is directed down the tubing to the jet pump. Produced fluid is drawn into the pump through the lower tubing packer mandrel, and the produced fluid plus exhausted power fluid is discharged through the GLM and returned up the tubing/casing annulus. A similar hydraulic pump installation may be possible in any well having the tubing landed in a casing packer by perforating the tubing at the pump setting depth to open tubing-to-casing ports for the straddle pack-off installation.

Sliding Sleeve Installation (Ref. Fig. VIII). In many international and offshore producing areas, wells are completed with a sliding sleeve (sliding side door) installed above a casing packer. This practice provides access to tubing/annulus communication by shifting the sleeve. A variety of hydraulic applications have been made in these completions by running a jet pump by wireline, with packing mandrels on the jet pump landed in the upper an lower seal bores in the sliding sleeve. This installation is used for long term production, or for short term operations. One short term application has proven beneficial in offshore wells being produced by ESP pumps installed below the casing packer. If the rig is not immediately available for pulling the ESP, the sliding sleeve is shifted open, and a jet pump is wireline set into the sliding sleeve to continue production while awaiting rig availability. Other short term applications are related to well testing as described below.

Well Testing

Well testing for the purpose of evaluating the well's inflow performance is an important short term application for artificial lift systems. The broad application range and installation flexibility of the hydraulic lift system has made it an attractive means for informative testing. Step rate production tests with downhole pressure recorders in place permit accurate data gathering within controlled producing parameters.

Offshore, hydraulic jet pumps are extensively used for conducting drill stem tests on newly completed wells. The pump is wireline set in the sliding sleeve, and water is circulated by the rig pumps to operate the jet (Ref. VIII). The jet pump installation is fully compatible with the standard DST tool string. The power water is injected in a "reverse circulation" path, down the casing annulus with returns up the drill string. This circulation path isolates hydrocarbons from the casing, and also provides controllable pressure to actuate the casing pressure responsive DST tools. Throughout the test procedure, surface pressure and volume recordings of the power fluid may be used to estimate the dynamic bottom hole pressure at the pump. This DST system has been used from both fixed platforms and semi-submersibles in worldwide offshore locations.

Reliable well tests are being conducted in onshore wells using a trailer mounted power fluid system to power the downhole hydraulic piston or jet pump (Ref. Fig. IX). The pump may be run as a tubing conveyed or free pump installation, and the trailer mounted power fluid unit can be connected at the well for start-up of the test within a few hours. Produced liquid is used as power fluid. Typically, the gas fueled engine mounted on the trailer with the triplex pump, vessel and control equipment circulates power fluid to the downhole pump.

CONCLUSIONS

The hydraulic lift system has achieved a high degree reliability and flexibility in meeting a wide range of conventional and unique artificial lift requirements.

Refinement of the jet pump and its operation has expanded the application of hydraulic lift systems.

Hydraulics present an effective lift system for long term and short term artificial lift.

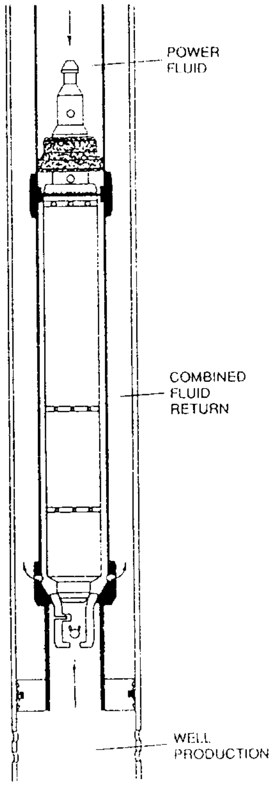

Figure 1 - Typical installation

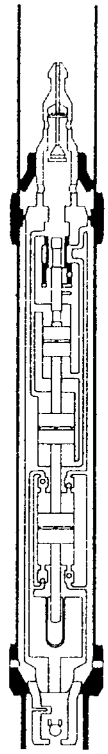

Figure 2 - Piston pump

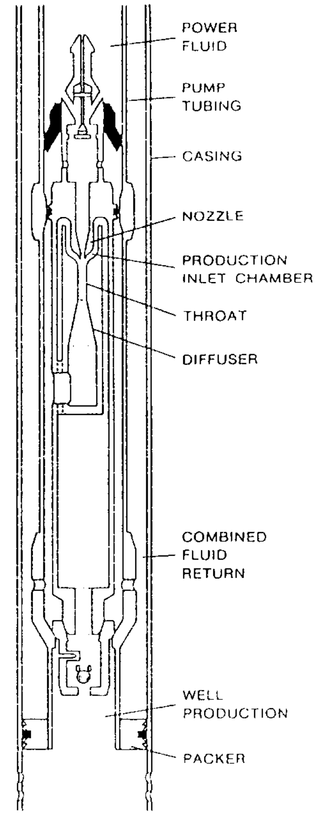

Figure 3 - Jet pump

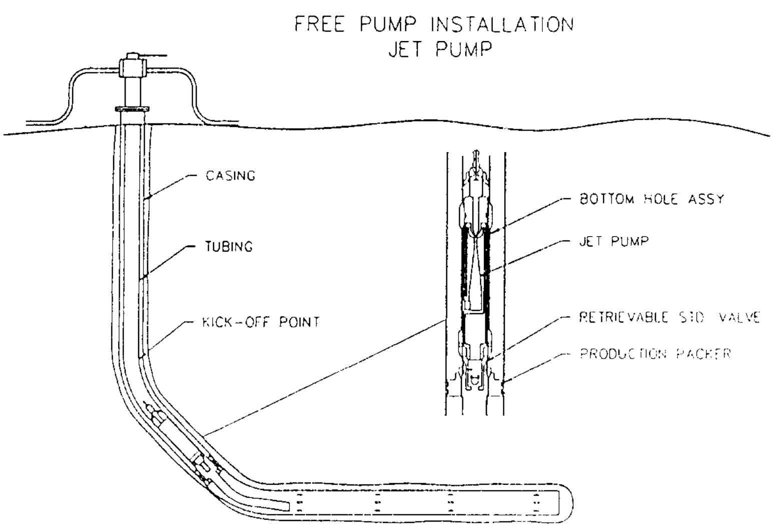

Figure 4 - Horizontal installation – free pump

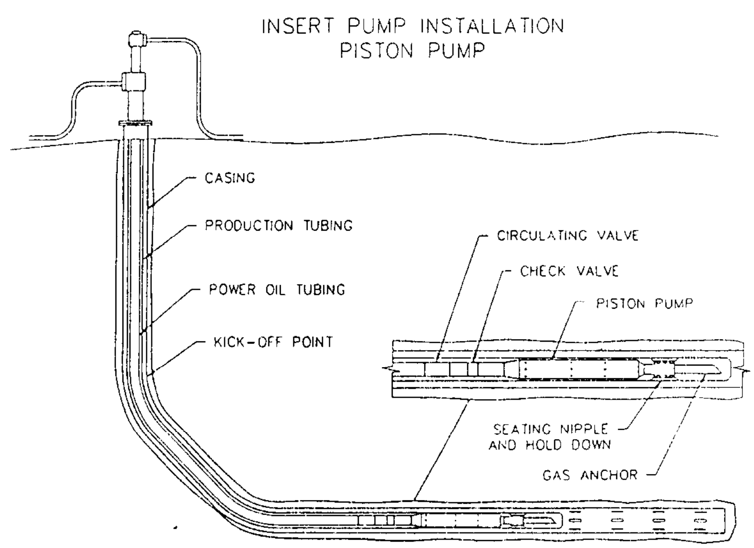

Figure 5 - Horizontal installation – insert pump

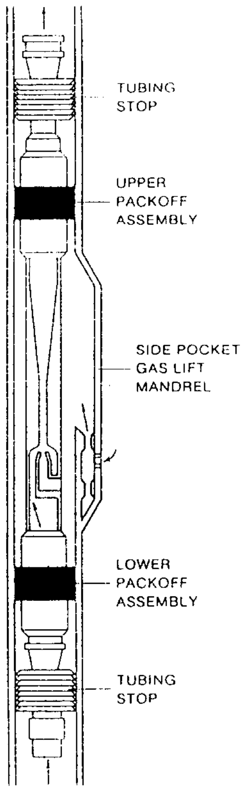

Figure 6 - Tubing packer installation – gas lift mandrel

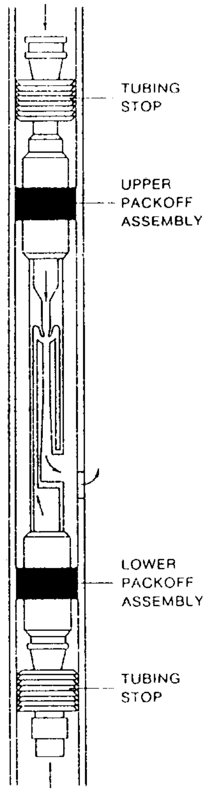

Figure 7 - Tubing packer installation – perforated tubing

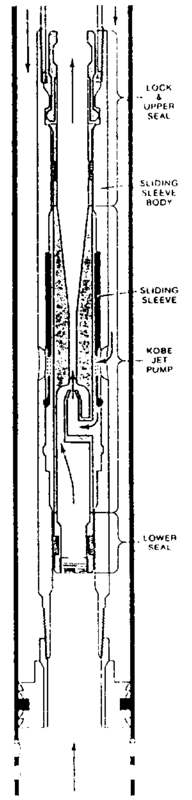

Figure 8 - Reverse circulation

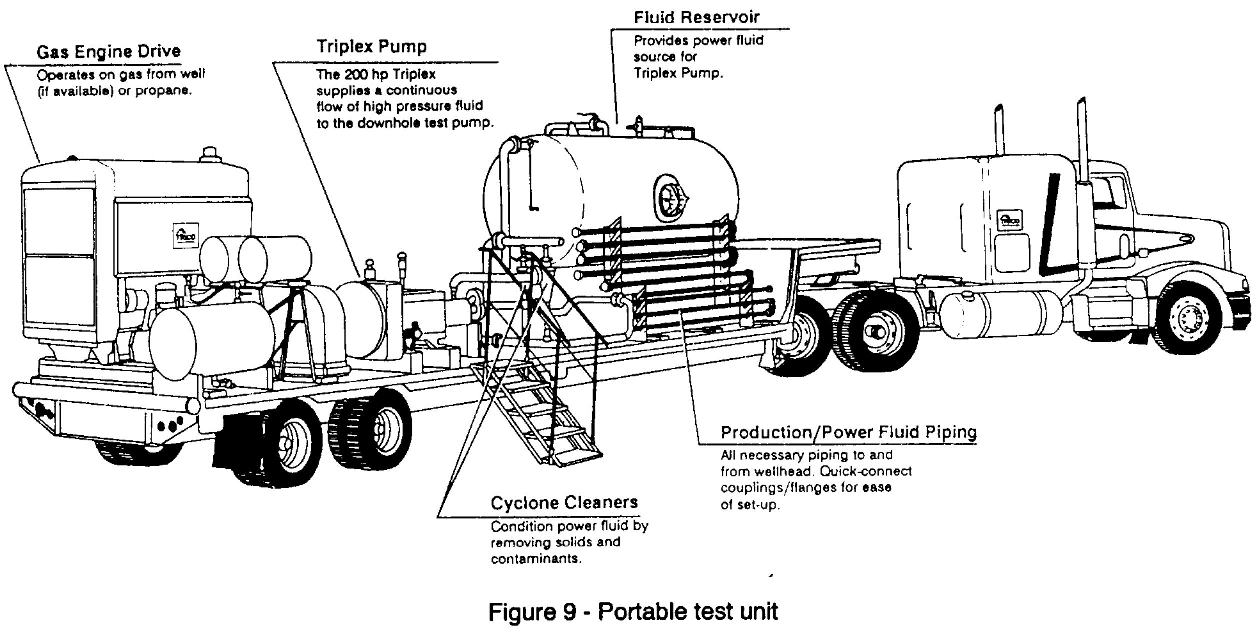

Figure 9 - Portable test unit