Selection & Application Of Bottom Hole Pumps

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TWO BASIC GROUPS OF PUMPS

The two basic groups of pumps covered in the A. P. I. Standard 11-A are tubing and insert pumps. From these, various combinations can be made for particular well conditions by rearranging existing equipment and substituting a few fittings.

A third group of pumps, which could be referred to as miscellaneous or special, use mostly standard fittings from the basic groups and are usually designed to overcome one particular difficult well condition.

Tubing Pump

A tubing pump has a larger bore for a given diameter of tubing than the insert pump and, consequently, produces a greater volume of fluid in any given size tubing. Since this greater volume of fluid results in heavier loads on sucker rods, there may be considerable rod stretch, reducing plunger travel and offsetting the advantage of the larger pump bore. For this reason, tubing pumps have depth limitations, especially in wells where bottom hole pressures are low.

The tubing pump barrel is suspended from the tubing string and retrievable only by pulling tubing. The plunger assembly and standing valve are run in and out on the sucker rods. A fixed standing valve can be used, which becomes a part of the tubing string and is used where an oversized valve is required and high fluid velocities tend to unseat the retrievable standing valve assembly.

The disadvantages in this arrangement are, the well has to be pulled wet and the standing valve assembly can only be recovered by pulling tubing. Tubing pumps are capable of handling small amounts of sand and a stroke through version of the pump is commonly used.

Insert Pumps

Insert type pumps are broken down into three categories which include top seating stationary, bottom seating stationary and traveling barrel bottom seating. They handle nearly the same viscosity oils; however, the traveling barrel bottom seating pump with its open cages may have more of an advantage in heavy viscous oil, especially when an oversize standing valve is used.

The top seating stationary pump has an advantage in sandy wells as oil is produced slightly above the hold down with little chance of sand packing around the pump. It is excellent for intermittent pumping and a sand checking device should be used to keep sand from settling on the plunger.

There is a depth limitation to this pump, especially when sectional liners are used, as the fluid column load is transmitted to the liner jacket and tends to separate the liners. As the standing valve is further submerged in the fluid to be pumped, the top seating stationary pump is ideally suited in some gassy conditions.

The top and bottom seating stationary pumps pivot from the hold downs and align themselves quite readily in crooked tubing.

The bottom seating stationary pump can be used at various depths, including deep hole applications. It is not recommended when sand is a problem unless a sealing arrangement is used at the top of the pump to prevent sand from packing around the barrel. This pump is also suitable for gassy conditions; however, a gas and oil separator should be used.

In the traveling barrel bottom seating pump, the barrel travels with the rods and the plunger is held stationary by a pull tube which connects it to the hold down. It is not likely to become "sanded in" since fluid surges in and out of the annulus between the pull tube and lower part of the barrel. Both standing and traveling valves are the open type; however, the standing valve is the smaller of the two.

It is a good first pump for a new well when the fluid level is high and can be used in reasonably deep wells. It can be used for intermittent pumping in moderate sand conditions as the traveling valve on top of the pump prevents sand from settling on top of the plunger.

OPTIMUM PUMP SELECTION

There are many things to be considered in determining the optimum pump. The pump bore will be of the smallest size to produce a given amount of fluid commensurate with stroke, speed, well conditions and associated equipment. The optimum selection will provide pump bore, stroke, speed and sucker rod string design, starting from the known given data to obtain the most efficient operation at the lowest possible cost. It will also provide a sucker rod string design with favorable maximum and minimum stresses and a desirable nonsynchronous pumping speed.

In a new installation, a complete design of equipment can be made starting with pump bore and rods to determine pumping unit size. As well conditions change and a different bore pump is desired, it will then be necessary to make a complete re-evaluation of the installation and make adjustments accordingly. Type of pump and length may be selected when bore size is determined, considering well conditions with thought given to standardization of pumps for a particular field. Final consideration is then given to materials, wearing surfaces and valving.

One can arrive at an optimum installation either by use of an optimum unit selection chart or by the more laborious method of trial and error. By trial and error, several calculations can be made using available well data, varying stroke, speed, bore and sucker rod string design. A slight adjustment in pumping speed may be required to obtain a nonsynchronous pumping speed. There are many data sheets on overtravel by depth, stroke and speed, and rod and tubing stretch data for various rod and tubing strings compiled for many depths and bore sizes.

With this information available, calculations by trial and error are not as cumbersome as it sounds. Well data for basing calculations should at least include estimated production and efficiency, gravity of oil, tubing size (anchored or unanchored) and depth of pump setting. Other data is of importance to determine materials, pump wearing surfaces, plunger fit, valving and type of pump.

In a new installation, the important data of experience will not be available, i. e., the performance of the previous pump, more exacting information on sand, corrosion and so forth. As data is compiled after each pulling, one can better determine future pump requirements to lessen the frequency of pulling due to pump or other failures.

Better or different materials may be required to prolong pulling, if pulling is the result of corrosion or mechanical pump failure. By the same token, less expensive materials may be used if pulling is for other reasons or the appearance of the pump indicates the more expensive equipment is not required.

Calculations for production and optimum pump size selection are usually based on fluid level at the pump. In a new installation the fluid level can be quite high due to high bottom hole pressures. More barrel length than usual is required as the net plunger stroke will be longer with less rod stretch. Length of barrel required in this instance is more difficult to determine. Usually a longer barrel than required is used to insure against the possibility of bumping on both ends of the stroke. Barrel wearing surface can be observed in pump repairing and barrel length shortened as bottom hole pressures decrease. With further depletion, pump bores, stroke, speed and rods can be adjusted for further economy.

Application

Since all parts of a bottom hole pump are machined to exacting dimensions, efficient operation and long extended runs are dependent upon the alignment of many parts and much care must be taken in operation, maintenance, handling and transportation of pumps. In the smaller bore pumps which usually run in the deepest holes, cross sectional areas, especially around some threads, are small and are subjected to high stresses.

Under normal operations the barrel below the plunger is full at the top of the up stroke, resulting in a relatively smooth operation as it makes the down stroke. If the barrel is not completely full at the beginning of the down stroke because of the well being "pumped off" or inadequate oil-gas separation, the plunger "pounds fluid." This action is not only detrimental to the pump as the fluid shock is further transmitted to the tubing, rods and surface equipment, causing additional damage.

Performance records on length of run, efficiency, types of pumps, materials and wearing surfaces give good reference data to determine future pump requirements. As each pump is pulled, examination of parts will provide information as to what corrective measures should be made. Sometimes these corrective measures cannot be initiated until the pump is pulled the following time as a stand-by pump may be run in before the other is disassembled for repair.

Grooved plungers give some apparent relief in stroke-through pumps where sand is a problem. Sand picked up by the grooves can be unloaded while stroking out the end of the barrel. Plunger scores from abrasives sometimes are stopped at the first or second groove.

Sand cannot be relieved from the grooves in a full barrel pump and grooving is not too effective. Since sand is continually carried in the grooves it is possible to have more wear on both plunger and barrel. There is also some doubt that plunger grooves are beneficial when used as a carrier for lubricants; however, when using a hard surfaced plunger, such as chrome plating and a soft barrel, it is believed galling tendencies are lessened.

FLUID SLIPPAGE PAST PLUNGERS

The factors affecting the estimation of the amount of slippage past a plunger are oil viscosity, length of plunger, plunger fit in barrel, differential pressure of fluid column above plunger and bottom hole pressure and plunger diameter.

Viscosity being one of the determining factors in plunger selection, it is important the desired fit is used for a particular viscosity oil. A plunger with a relatively loose fit may operate efficiently in high viscous oil, whereas the same plunger fit may fail to deliver oil to the surface in a well producing oil of low viscosity.

Fluid slippage past the plunger heats the fluid and decreases the viscosity, causing an increased amount of slippage. Slippage loss results directly in power loss, because the same amount of power is used to lift a plunger with a large amount of fluid slipping past during the upstroke as is required with only a small amount of slippage. A large amount of slippage agitates the fluid, causing water and oil to emulsify and gas to separate from the oil.

Plunger length has relatively little effect in correcting slippage. In one example, using a minus four fit to correct slippage to approximately the equivalent rate of a minus three fit, the plunger would have to be more than twice as long. Slippage varies by the cube of the fit. As clearances increase above a three fit, slippage rates occur at an increasingly rapid rate.

From this, it is reasonable to assume that with adequately controlled clearances shorter plungers and shorter barrels could be used. Following the old idea of selecting plunger length, when it was felt one foot of plunger was required for each 1000 feet of depth, could result in an expensive and long pump in deep wells, since for a given length of stroke, each additional foot of plunger requires an additional foot of barrel.

Tolerances

Consideration should be given to the tolerances on barrels and plungers when estimating slippage. Combining the maximum barrel tolerance with the minimum plunger tolerance, the sum is approximately .002 in. Then, using a minus three fit plunger, the total diametral clearance would be nearly .005 in.

Tolerances on barrels and plungers are not conceded to be liberal. The tolerance on plunger outside diameters is plus 0 in., minus .0005 in., whereas sectional liner tolerance on inside diameters is minus .0002 in., plus .0012 in. Full barrel tolerances for metal plungers are generally held within a plus .002 in. Plungers and barrels are rigidly controlled as far as micro finish and straightness.

Plungers have been run with a minus one fit and less. Closely fit plungers are sometimes used in sand conditions and fit selection is usually dependent upon sand grain size and the viscosity of oil.

Closely fit plungers can have disastrous effects as far as sticking and galling. Plunger and barrel wearing surfaces should be highly polished to minimize galling effect and materials with a low coefficient of friction should be used. A plunger is usually made from a different material than the barrel, resulting in a differential rate of expansion with heat.

Thus, with high bottom hole temperatures, the plunger fit could be reduced when run in the well. Some wells that produce a great deal of water for the first few hours have little lubrication and plungers have tendencies to gall with tight fits. This can sometimes be corrected with lubricative coatings on plungers and barrels. These are usually effective until the time lubrication is taken over by the oil.

It is important that all precautions be taken against sticking and galling when running close clearances. Even if the pump continues to operate without the necessary precautions, there may be considerable stock removal from abrasion and galling the first few hours, defeating the advantage of a close fit.

CORROSION AND METALS

The greatest contributions to down hole applications in the past few years probably has been in inhibitors and metallurgy. Inhibitors have prolonged the life of bottom hole equipment and various metals and wearing surfaces have been developed to lower the frequency of well pulling in corrosive and problem wells. In many cases both the use of inhibitors and intelligent selection of metals have had to be used to achieve the objective. In other instances, inhibitors have provided conditions where less expensive metals could be used.

Although the use of a completely equipped stainless pump or corrosion resistant materials involves considerable initial expense, it is usually offset by the first pulling job that has been eliminated. The use of nickel moly alloys, sufficiently high enough in nickel, will give satisfactory results in many medium corrosive conditions.

Occasionally when water flooding is introduced, corrosion becomes a larger problem. As the water content increases, corrosion is likely to increase. Gross production increases and larger pump bores are required, yet the amount of oil recovered may decline. With increased velocities, overall effectiveness of inhibition is less and in areas where friction occurs, it is difficult to retain a protective coating. The cost of inhibiting such installations may be unusually high and the combination of moderate inhibition and selection of corrosion resistant materials could be an economical approach.

Carbon steel fittings can be used almost exclusively in mild pumping conditions. They can be used to some extent in deeper holes with mild corrosive environments. Selection depends upon amount and type of corrosion, cross sectional area of fitting and its function in the pump.

Parts that are required to pull the pump should be made of a strong and durable metal, especially in deep holes, to insure retrieving the pump without a fishing job. Some fittings have heavy cross sectional areas and the mass of the metal usually offsets the requirements for stronger and corrosion resistant metals.

The use of carbide balls and seats contributes much to long valve life and prevents many pulling jobs in the tough wells. Another combination that gives good results with lower operating costs is the carbide seat and stainless ball.

DESIGN

Outside diameters of pump parts are controlled by the inside diameter of the tubing and hold down in which it runs, or a determined inside diameter within the pump, depending upon where the part is used. Hole sizes in pump parts are generally limited by threads and the amount of fluid that passes through the pump. Cross sectional areas are usually made as large as possible within these limitations, to produce a part with maximum strength by cross sectional area.

Other refinements are necessary to reduce stress concentrations, prolong the life of the part and prevent premature failure. Some of these refinements include filets, contours, finishes, selection of metals and heat treatment. Most valve cages have as many as four highly stressed areas and a failure in one area results in a completely inoperative pump.

Filets are used on pin and box thread reliefs, wrench flats, milled slots and in abrupt changes of contours or cross sections, to alleviate stress concentrations and eliminate stress raisers.

The contouring of parts at entries and exits of smaller diameters provides for less turbulence of fluid. Interrupted flow resulting from right angular obstructions, steep tapers and recesses, causes excessive turbulence and accelerates corrosion and erosion. All obstructions cannot be relieved since some, such as clutches and prongs, which are used for rotation, serve as a function in the pump.

A rough finish is vulnerable to corrosion attack and provides a notch effect in critical sections. Nearly the same effect is produced in exposed threads. Some protection against corrosion is obtained by covering these threads with pilots and counterbores. Inside facing of mating fittings with thin sections is highly recommended in parts that are subjected to hoop tension.

One of the most important items related to design is the selection of metals. Selection and heat treatment are primarily dependent upon the function of the part and the environment in which it will be used. Adequately controlled heat treating procedures and specifications are necessary in obtaining the desired qualities.

In the A. P. I. Standard 11-A all threads, as well as many pitch lengths and diameters, are established for the standard pumps. Manufacturers have the option of determining design and incorporating it with these standards to provide complete interchangeability of parts.

With the exception of the special type pumps that are required for difficult wells, it is of importance that a program of standardization be followed in selecting pumps. The use of standard barrel lengths, flat type cages and seats, as well as other standard fittings, results in a direct and indirect savings to the buyer.