Factors Affecting Choice of Rod Pumps

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There have been many papers, both technical and non-technical, written on this broad subject. This paper will be directed to those in attendance who are primarily responsible for the amount of crude oil that can be accumulated in the stock tanks. Improper operation of the surface pump is the major cause of failure in this assignment.

In the time allotted it will not be possible to present in detail all of the many factors that contribute to pumping problems. I have, therefore, selected the four most often encountered problems for presentation. These four problems are:

1. Gases
2. Sand
3. Corrosion
4. Scale (more commonly called Gyp)

The order in which these problems are listed does not necessarily indicate one more important than the other. Gas is generally associated with the first stages of pumping followed by sand if the formation structure is of that type. As the well is gradually depleted, corrosion seems to be closely associated with the increase in the volume of water produced. Scale formation is also closely associated with increased volume of water.

Before discussing each of these four factors separately, we will consider the selection of the proper size rod pump. We will attempt to choose the rod pump that will prove economical not for just the first cost but the one that will make its production for the longest time and require least amount of service and maintenance expense. Recently we helped to service a pump that had been running continuously for eleven years in the Wasson Field without having been pulled since its original installation. This was an inexpensive pump that cost about $100 when purchased. It was a pump made up of a precision honed cold drawn steel barrel and a one piece hardened alloy cast iron plunger with single stainless steel balls and seats. As a contrast to this pump another producer uses rod pumps that cost $450 each, in very corrosive H2S wells in the McElroy Field. These pumps average 800 days between major overhauls consisting of replacement of barrel and plunger. In other "outlaw" wells in the same field the $100.00 pump, that lasted so long in the Wassan Field, does well if it will pump 60 days. The destructive elements that made the expensive pump economical in the McElroy Field were not present in the Wasson Field. Our problem here is to study these factors when selecting a pump just as a driller often selects a diamond or carbide bit to drill chert and maybe a fishtail bit if he is drilling soft clay.

The optimum pump bore must be determined first. To decide this we must find out the amount of fluid that is to be pumped. Some operators think it is advisable to swab a well for several days to determine its daily capacity if it is a new well going on the pump. In addition to the amount of fluid to be lifted we must also consider, in selecting the correct pump bore, the depth, the rod and tubing stretch, the sucker rod stress and the probable efficiency of the pump. If the well is deep it is possible that a 1-1/4" pump will make more fluid than a 1-1/2" pump because the greater fluid load of the 1-1/2" pump causes more stretch in the rod string than the 1-1/4" pump. The plunger does not move at the beginning of the upstroke until all the stretch in the rods has been reached. Sucker rods stretch because each rod in the string supports the rods below it and all the fluid load. Thus the larger the pump bore the greater the stretch will be in the rods with the resulting decreased plunger travel.

At a pump setting depth of 7500', 2-1/2" unanchored tubing, 7/8" and 3/4" tapered rods, 16 - 54" strokes per minute and 1-1/4" bore pump will make more fluid than the 1-1/2" pump because the loss due to stretch is 47.2" with the 1-1/2" pump and only 34.2" with the 1-1/4" pump. The 1-1/4" pump also has the advantage in this case of lowering the stress on the top rod of each size by 4,000 PSI. The torque also is 44,000" lbs. less when the 1-1/4" pump is used than when using a 1-1/2" pump. This results in a better installation when the 1-1/4" pump is used for the rods, pump and unit.

In selecting the pump bore for a deep well the stress on the top rod or top rod of each size, if a tapered string is used, is often the limiting factor. Sucker rods have a lower margin of safety than steel used for most any other purpose because of the limits to their size. Most rod manufacturers suggest that the safe working load limits of a sucker rod should be half of the yield strength of the steel. For example, nickel moly steel sucker rods of the 4615 steel class have a yield of 70,000 PSI. If the fluid to be pumped is ideal, in that it is free from any corrosion, it may be safe to stress the rod to one half the yield or 35,000 PSI. However, if there is H2S gas, Carbon Dioxide gas, salt water, or electrolytic corrosion the safe working limit will be much lower than 35,000 PSI, the amount of decrease being dependent on the degree of the corrosion that is present.

With the optimum pump bore determined we will now discuss the factors affecting the rod pump.

I. Gases

In selecting pumping equipment for oil wells, it should be remembered that in most cases some component parts of the fluid being pumped are above or near their boiling points at pressure and temperature conditions existing within the pump. This means that with a slight drop in pressure on the well fluid, a large volume of dissolved gases and vapors may be set free in addition to any free gas in the well formation. For this reason, it is very difficult to pump some wells down and many wells will apparently pump off with several hundred feet of fluid standing in the hole. This is due to the fact that the condensable vapors and gases occupy the entire displacement volume of the pump. The pressure below the plunger cannot be raised sufficiently to overcome the tubing pressure above the traveling valve. This pressure must be raised before the traveling valve can open and deliver oil to the tubing. This is known as "Gas-Lock." To minimize gas-locking as much as possible, the following precautions are offered:

Precautions For All Pumps

(a) Position the pump so that the traveling valve and standing valve come as close to each other as possible at the lowest position of the pump stroke without making contact.

(b) Use as long a stroke as possible with the equipment available.

(c) Flow velocities and turbulence at the pump inlet should be kept at a minimum. This is accomplished by using the largest standing valve possible and a suitable gas anchor with the largest possible flow passages.

(d) Use the largest standing valve possible so that there will be a minimum pressure drop across the face of the valve.

(e) Where the gas is at the top of the oil, considerable gas is eliminated from the pump by placing it below the gas section of the zone.

Precautions For Rod Pumps

(a) The compression ratio should be made as high as possible. This is accomplished by using a closed cage type valve below the plunger in a stationary barrel pump, or a valve above the plunger with a traveling barrel type pump.

(b) The casing pressure should be kept to a minimum.

Precautions For Tubing Pumps

(a) The choice of regular or oversize standing valves may be dictated by strength requirements of the valve cage for use in deep wells inasmuch as the cage may be subjected to the sucker rod load when spacing the pump or in the case of a rod failure.

Gas Anchor

In general, where gas anchors are used, the pressure drop through the gas anchor is greater than that through the standing valve because of the greater length of the gas anchor flow passage. In many cases the inside diameter of the gas anchor is less than that of the standing valve. It is important to make this connection as large as possible for handling extremely gassy or volatile fluids.

II. Sand

Some sandy wells have high maintenance costs because of pump failures. The most difficult well to pump is the stripper well that has a sand pay and a very small volume of fluid. Such wells are at Orla, the South Ward Field, and at Fort Stockton. Bottom hole pumps can handle some sand without excessive wear if there is enough fluid available to keep the sand moving through the pump. A pump made out of the hardest and most wear resistant materials in both barrel and plunger will soon wear out if the fluid velocity through the pump is not great enough to keep the sand in the fluid moving through the pump. When the well is pumped down, greater amounts of sand will heave in the well bore and the movement of the fluid through the tubing will be so reduced that the sand will settle out on the pump. Then the plunger may only be churning up and down in the sand. The pump will rapidly wear and the sand will jam in the resulting greater clearance of the barrel and plunger. This may make it necessary to clean out the well. The following practices may overcome some of the difficulties in pumping sandy wells of low fluid volumes:

a. Use the smallest pump bore possible.

b. Slow the pumping speed down and use a long stroke. The small pump and slow speed operation will retain a higher fluid level and help prevent loose sand sloughing in from the formation.

c. In heavy sand wells intermittent pumping may not be successful because too much sand may settle out of the fluid, in the "down" period, on top of the pump. Generally intermittent pumping is better than pumping off and pounding fluid.

In wells having sand formation or wells that have been given sand frac jobs the pump should be designed as follows:

a. Use double valves. There has been. considerable discussion concerning the desirability of two balls and seats in series and it has been argued that the load cannot distribute itself between the two valves, and only one will form a tight seal on any particular stroke. This line of reasoning has led to the conclusion that two valves in series cannot be of any particular advantage. However, experience has shown that two valves in series will give much longer service than a single valve if the valve life is determined by wear, or fluid cutting, rather than by corrosive action. This result appears entirely logical where sand or other solid material is lifted with the oil. In such cases failure is likely to occur as a result of fluid cutting when a solid particle is caught between the ball and seat and prevent perfect seating. A pressure differential of 2,000 psi will produce a jet of fluid having a velocity of over 500 ft. per second, and such a fluid velocity can easily damage the lapped valve seating surface on balls and seats in a short time; especially if the fluid jet carries solid material in suspension.

The life of a ball and seat will depend largely on the number of times it is subjected to the action of such fluid jets, and this can be decreased greatly by the use of double valves, inasmuch as a jet cannot occur until both balls are held off their seats during the same stroke. For example, if conditions are such that a single ball and seat is prevented from seating properly one out of each 100 strokes, on the average, the chances of both of two valves in series failing to seat properly will be reduced to one in ten thousand strokes. Furthermore, when this occurs the pressure drop will be distributed between the two leaking valves and the cutting action will be less severe than with a single valve.

The extra first cost of double valves is so small in comparison with the average pump pulling job that the use of double valves should be well justified by the saving resulting from fewer pulling jobs. Also, fewer balls and seats should be required over a long period of operation because of the much greater life to be expected under average conditions.

The only apparent objection to double valves is the possibility of affecting pump efficiency by the slight added pressure drop at the pump inlet, when pumping highly volatile and gassy fluids, especially when it is necessary to pump the well down to a low fluid level to produce its allowable. Any influence on production can be determined by making alternate runs with single, and double, standing valves. In the case of traveling valves, the use of double valves of standard size cannot adversely affect production rates. The contents of the pump barrel must be raised to the tubing pressure of several hundred, or several thousand, psi before the traveling valve will open, in any case, and the extra pound or two required to overcome the resistance of an additional valve is of no significance.

We have seen many frac wells that just wouldn't pump at all with single valves.

b. Usually pumps having extremely hard surface barrels and plungers are most economical for sand wells in spite of these type pumps being higher priced than common cold drawn precision honed steel barrel type of pumps that are unhardened. Such premium priced pumps have better resistance to sand abrasion and will outlast the cheaper pump many times. After a sand frac job on a well, some operators will run a precision hard surface premium priced pump or a three tube pump and only leave this pump in the hole until the well is fairly well cleaned up. Then after they believe the excess sand is already pumped out and the well is settled back to a stable rate of production, they will then run back the lower priced pump. The pump business is very competitive and to those of you who are operators we would like to say that all pump manufacturers are always studying new designs and better metals to handle abrasives in well fluids. Improvements in pumps have been numerous in the past and competition in the industry, which is keener than ever, will bring even better metals and designs in pumps in the future. When pumping problems are encountered, take advantage of the services of your pump manufacturer's representative. He studies these problems night and day and can help you and you can surely help him.

c. Generally plain plungers are better than grooved plungers for sandy wells. The sand tends to lodge in the grooves.

d. On the proper clearance between barrel and plunger in sandy wells, there are two schools of thought. There are those who like a fit to be as much as .008". They use longer plungers and they think that sand particles will slip past the plunger rather than sticking or galling it. They may be right for pumping wells of heavy viscosity oils.

Others prefer using pumps with close tolerances. If a pump can be assembled with only .001" clearance and it strokes free and easy with a 10 weight lubricating oil, it is better suited to the fluids in this country. The clearance should be kept to a minimum because sand cannot wedge in such a small clearance causing the pump to jam and stick. These close clearance pumps have been very successful in sand frac wells at Crane, South and North Cowden and in Andrews County. Wherever sticking has occurred it has been after the pump has been in service so long that wear has increased the clearance.

e. A traveling barrel type of pump is excellent for sandy wells except those with such high volumes of heavy sand that it might settle on top of the seating cups. Then the traveling barrel can pound on the settled sand shortening the stroke. Stationary barrel pumps are also suitable for pumping sand wells. Top hold down stationary pumps are not as apt to become sanded up in the tubing as bottom hold down stationary pumps. Sand from the tubing may settle between the pump tube and tubing of a bottom hold down stationary. This sand may pack so tight that the pump cannot be pulled and then it must be stripped out. This cannot happen with a top hold down which makes it preferred in most sandy wells.

III. Corrosion

Hydrogen Sulphide gas is the principal destroyer of subsurface pumps in the West Texas area. There are a few wells having carbon dioxide gas and some with both H2S and carbon dioxide. Inhibitors that are periodically injected in the casing annulus are providing protection against corrosion to the casing, tubing, rod string, flow lines, tanks and pipe lines. But the bottom hole pump does not get as much benefit from the inhibitor. The close tolerance of barrel and plunger prevents the protective film coating of the inhibitor from adhering to the working surfaces. Also the valve rod works through the neck of the guide or on a traveling barrel pump; the pull tube works through a pull nut. This rubbing action prevents the protective film from forming. In San Andres pay wells at Goldsmith, Crane, South Cowden, McCamey, and Penwell, bottom hole pump parts such as cages, bushings and adapters that have no contact with other parts are severely pitted. We used to have a theory that moving fluid was not as corrosive as still fluid. We had this idea because we had seen so many pull tubes that were badly pitted on the bottom end near the hold down and the upper sections of these pull tubes were in fairly good condition where the pump had been stroking. Recently we had to discard this theory when we checked a bottom hold down stationary barrel pump that made a run in a San Andres well at

Goldsmith. Everything on the outside of the pump. std. valve cage, barrel and upper fittings just looked perfect until we disassembled the pump and looked inside where the moving fluid passed. Inside all parts that contacted the moving fluid were badly pitted. There must be a reason for corrosion being more severe on the pump than any other equipment in the hole.

Perhaps, if we could reduce the bottom hole temperature, we could retard pump corrosion. A rise of 20 defrees F, approximately doubles the chemical action of corroding acids. In pumping a well with a pressure of 2000 PSI any gas collected in pump barrel must be compressed to this pressure before any fluid can be delivered to the tubing. If oil and methane or H2S gas are being pumped from a well having a bottom hole temperature of 150 deg. with an intake pressure of 20 pounds per square inch, the temperature of the gas when compressed to 2000 PSI can rise to a value above 1300 deg. Still higher temperatures can result from higher fluid pressures, lower intake pressures, higher bottom-hole temperature, or any combination of these factors. This explanation of high temperature causing an accelerated corrosive action is logical because burnt plungers are often found in pumps.

To reduce the temperature caused by the compression of gas, we could do the following:

a. Space the well so that the traveling valve just almost strikes the standing valve on the bottom of the down stroke. This reduces the volume of collected free gas between the valves, and the compression is accomplished quicker to overcome the pressure differential of above and below the traveling valve.

b. Use double traveling valves. The upper ball and seat will be protected from the high temperature by the fluid between the two valves. The standing valve is immersed in fluid and will not be adversely affected by the high temperature.

c. Use large pump inlets to reduce restrictions at pump entrance.

It is usually the case that corrosive wells are also very abrasive. The abrasives may partly be from the pay zone but we believe that iron sulphides caused by the corrosion on the tubing and rods also contribute to wear on the barrel and plunger of a corrosive well. In our selection of a pump we need not only materials that are very resistant to corrosion but we also need a barrel and a plunger that have extreme hardness and resistance to abrasion such as we recommended for sandy wells. We need a close clearance here for corrosion also. The cause of pump failures in corrosive wells is easily at least 50 percent due to excessive wear. The ideal metal for barrel and plunger would be one that is extremely hard and wear resistant and not subject to corrosion. High nickel moly steels are very successful. The nitriding of the bore of high nickel moly steel tubes has accomplished two things to improve the pump barrel. The nitriding produces a shallow penetration of hardness in the bore and it improves the corrosion resistance to such an extent that the barrel is often not even discolored after running in a corrosive well.

IV. Scale—"Gyp"

There doesn't appear to be much written on the mechanics of scale or "gyp" forming in the rod pump, tubing and sucker rods. Scale generally forms after the well is producing large volumes of water. The scale deposits in majority of cases contain carbonates. These chemical compounds are either in solution at the static formation pressure or are disolved out of the formation by the movement of the water to the well bore. When the supersaturated solution reaches the pump the pressure is released and the saturated salts solidify on any nonwearing surface. We have seen tubing that was almost completely closed with this scale or "gyp" deposit. There are many chemicals on the market that can be used in the same manner as corrosion inhibitors to prevent such deposits. These deposits create a serious problem in the rod pump. The deposit forms on the part of the barrel that does not contact the plunger on the pumping stroke. When a slight change of the plunger stroke occurs, the scale may wedge the plunger so tightly that a stripping job is necessary. This of course is expensive.

In such wells the following corrective measures should be employed:

a. Use a stroke through pump. Such a pump is designed so that the plunger can stroke out the bottom and top of the barrel. The length of barrel or liners should be of such length to permit the plunger to stroke through.

b. Use all metal plungers.

c. Secure a sample of the well fluid and have it chemically tested. From such tests the proper chemical can be introduced into the casing annulus to keep the carbonate or other salts in solution.

The Metallurgists of the many manufacturers are always seeking new metals that will have better resistance to the four factors found in the wells of West Texas. Much progress has been made and again we suggest to those of you who are operators, these factors vary from one field to the next and a pump man's experience can help you in the selection of a pump that has been found to withstand any one of them in the field where your wells are.