THE DOWNSTROKE SUCKER ROD PUMP AND SPECIAL or UNUSUAL SUCKER ROD PUMPS EXPLAINED

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INTRODUCTION

Downhole sucker rod pumps are simple, linear, reciprocating hydraulic pressure pumps of oil well production, as well as water and condensate production from gas wells. This class of pump is relatively trouble-free and is resistant to fluid-borne particulates, corrosion, high pressure and varying oil/gas ratios, aided as needed by special metallurgies and/or special pump designs.

There are many sucker rod pump arrangements of standard parts which give us pumps for certain production characteristics, such as the top hold down pump for some particulate production problems that arise with bottom hold down pumps. Then there are certain sucker rod pump arrangements of standard parts which actually affect the loading characteristics of the sucker rod string and pumping unit. This paper will explain a few of these pumps.

Unless otherwise stated, this paper will consider only standard sucker rod pump parts, and their arrangement within a sucker rod pump.

THE DOWNSTROKE SUCKER ROD PUMP

History

I heard about the downstroke pump on my first day of employment in the artificial lift industry in 1986. At the time I understood nothing about sucker rod pumps, so I started learning. After a few months of building the prototype it was sent to the field for field testing. By this time I had decided that this pump would produce fluid and load the sucker rod string exactly as a standard sucker rod pump. My combination of inexperience and youthful overconfidence was soon proved wrong when the field salesman excitedly called to say that the pump inexplicitly pumped fluid on the downstroke. After our shock wore off I determined that I would understand why this pump was fundamentally different.

In Joseph Zaba's book, "Modern Oil Well Pumping", page 108, copyright 1962, he states that the hollow sucker rod pumping arrangement produces fluid on the downstroke, and that the loads are different, so the downstroke idea isn't very new.

Arrangement of Parts for a Standard Insert Style Sucker Rod Pump

There are only a few basic parts to a standard insert style sucker rod pump, the hold down seal assembly (seals the high pressure of the tubing from the low pressure of the formation), the barrel, plunger, traveling valve and standing valve. There are no holes in the barrel or other fluid passages to admit fluid into any area of the pump except through the standing valve. Please refer to Figure 1. The illustrated insert pump is a top hold down type that is popular in production with particulates when a bottom hold down type is in danger of being "sanded in" and possibly cannot be pulled with the rods.

Operation of a Standard Insert Style Sucker Rod Pump

a. On the upstroke, production fluid is forced into the volume between the standing valve and traveling valve by formation pressure. Thus, you have low pressure from the formation in this compression chamber below the plunger.

b. On the downstroke, this volume of fluid between the valves is compressed by the plunger to a pressure higher than the tubing pressure above the traveling valve, the traveling valve opens, and the plunger falls through the compression chamber fluid with high pressure on top of the plunger and below the plunger. As it falls, a volume of fluid equal to the area of the plunger times the stroke length at the pump is moved from below to above the plunger.

c. On the next upstroke, fluid comes into the compression chamber as described above in “a”, and fluid is lifted toward the surface at the same time. Actually, the entire fluid column is lifted, and given solid fluid, an approximate volume of fluid is pumped into the stock tank that is equal to the volume described in “b” above. The loading on the pumping unit prime mover is essentially half of the weight of this fluid column being lifted, because the other half of the load is in the pumping unit counterbalance, so that the electric motor has an almost equal electrical load on the upstroke and downstroke. Note that during this upstroke, there is high pressure on the top of the plunger and low pressure below. This unbalanced pressure is what creates that load on the sucker rod string and pumping unit on the upstroke of the pump. The sucker rod located just above the pump has the entire fluid load on the upstroke, plus other minor loads.

Arrangement of Pump Parts for a Downstroke Insert Style Sucker Rod pump

This description is generic of the family of downstroke pumps, and only describes my understanding of the theoretical principle behind a true downstroke sucker rod pump.

In Figure 2 you will see an insert pump, (a sucker rod pump installed inside the tubing and retrievable with the sucker rods.) This particular sucker rod insert pump is of the top hold down variety (bottom hold down pumps cannot be downstroke pumps.)

In order for a sucker rod pump to be a downstroke pump, it must allow the low pressure from the formation to have access to the top of the plunger, please see figure 2. Additionally, inside the pump, it must separate the high pressure inside the tubing from this low pressure of the formation above the plunger. Thus, a pressure packoff of some kind must be used above the plunger. Several current day sucker rod pump designs use a connecting plunger above the production plunger to provide a seal within a close-fitting packoff for various pumping reasons (not a downstroke pump), and the downstroke pump uses this same method. In Figure 2 you will see this packoff and the connecting plunger which attaches the sucker rod pump plunger to the sucker rod string.

Operation of a Downstroke Insert Style Sucker Rod Pump

a. On the upstroke, production fluid is forced into the volume between the valves by formation pressure, just like with a standard insert style sucker rod pump. Thus, you have low pressure from the formation in the compression chamber below the plunger. And, that is all that happens on the upstroke. There is no fluid load on the upstroke as described in “c” above for a standard insert style sucker rod pump. The reason for no fluid load is that the pressure is balanced above and below the plunger during the upstroke. In figure 2 you will see low pressure labels above and below the plunger on the upstroke. If there is no hydraulic pressure differential across the plunger on the upstroke, then there is no fluid column lifted, and no work done by the plunger on the upstroke.

b. On the downstroke, the volume of fluid between the valves is compressed by the plunger to a pressure higher than the tubing pressure above the traveling valve, the traveling valve opens, and the plunger moves through the compression chamber fluid with low pressure above the plunger and high pressure below the plunger. This is the key to lifting the fluid on the downstroke, an unbalanced pressure differential with high pressure below and low pressure above the plunger. This is just the opposite of a standard sucker rod pump. Thus, the fluid column is lifted toward the surface on the downstroke instead of the upstroke.

Discussion of the "Benefits" of the Downstroke Pump

On first thought, this seems like a great idea! It appears that we can use part of the weight of the sucker rod string to produce fluid to the surface, and eliminate some of the counterbalance weight on the pumping unit. And, in some ways this is true. However, most pumping wells have 3/4" rods on the bottom of the string, and operators don't like to put rods into compression, because it can lead to early fatigue failures. So, should we add sinker bars in the amount of the fluid load so that the bottom rods are not in compression on the downstroke during lifting of the fluid? Yes, and here is how the loads work out:

Downstroke Insert Pump:

Polished Rod Load, **Going Up**:	Counterbalance:
Weight of sucker rods +	Weight of sucker rods +
Weight of sinker bars (fluid load weight equivalent)	1/2 weight of fluid load
Polished Rod Load, **Going Down**:	Counterbalance
Weight of sucker rods only*	Weight of sucker rods +
	1/2 weight of fluid load

*(Sinker bar weight is used for lifting fluid on the downstroke, and is not a load felt by the polished rod going downward.)

The loads above look just like the loads on a standard insert sucker rod pump:

Standard Insert Pump:

Polished Rod Load, **Going Up**:	Counterbalance:
Weight of sucker rods to the pump +	Weight of sucker rods +
Fluid load weight	1/2 weight of fluid load
Polished Rod Load, **Going Down**:	Counterbalance
Weight of sucker rods to the pump	Weight of sucker rods +
	1/2 weight of fluid load

Because the polished rod and counterbalance loads are the same for a downstroke pump and a standard pump, when using sinker bars, our initial supposition that maybe some of the sucker rod load could be used to lift the fluid is false. Also, there is not a change in the counterbalance weight. And, there is not a difference in stress at the top rod in the sucker rod string for a downstroke pump, because on the upstroke the sinker bar weight is only equivalent to the fluid load that a standard pump sees on the upstroke.

I am sure that the dynamics of the up and down motions of the rod string are changed in some way with the downstroke pump, due to the sinker bars replacing the fluid load, and there are experts in this field who can shed light on this part.

There does not seem to be an advantage to a downstroke pump, and there is probably a disadvantage due to putting the sinker bar part of the rod string in compression on each downstroke of the pump.

THE INCREASED DISPLACEMENT SUCKER ROD PUMP

History

The term in common use for a pump with two plungers and two compression chambers, with subsequent increased displacement is a “double displacement pump” which is a phrase trademarked by a current pump company. Therefore, this paper will refer to this class of sucker rod pumps as “increased displacement pumps” in respect of the trademark.

These pumps have been available from several manufacturers for many years in several configurations; Traveling Barrel, Stationary Barrel (bottom hold down and top hold down), Tubing Pump, and possibly other configurations.

Arrangement of Pump Parts for an Insert Style Increased Displacement Sucker Rod pump

In Figure 3 you will notice that this insert pump has two plungers, two barrels, and a connecting plunger between the two barrels that maintains a seal as it goes through the packoff during stroking. The pump in Figure 3 is a bottom hold down pump. You can see from the labels of pressure that both plungers lift fluid on the upstroke, resulting in an increase in pump displacement over a single plunger standard pump, and resulting in an increase in loading linearly proportional to the increase in pump displacement. Typically an increased displacement pump will lift around 1.7 times more fluid than a standard pump of the same diameter, and increase the loading by that much also. These increases vary depending on the size of pump chosen as well as the size of the connecting plunger. Note that the pressures (high or low) above and below the two plungers are the same as for a standard sucker rod pump.

The lower plunger in Figure 3 lifts a full plunger area of fluid like a standard pump, but the upper plunger’s production volume is reduced by the area of the connecting plunger. This is the reason that the production of an increased displacement pump cannot be the sum of two standard plunger size production volumes.

The pump in Figure 4 is an increased displacement pump in a top hold down insert pump configuration. By inspecting the figure you will notice that the pressure labels for the lower plunger are the same as the pressure labels for the downstroke pump in the above discussion. But, the pressure labels for the upper plunger are the same as for a standard insert style sucker rod pump. The top hold down variety of an increased displacement pump thus lifts fluid from the upper, smaller chamber on the upstroke, and it lifts fluid from the lower, full sized chamber on the downstroke. This same logic applies to an increased displacement style tubing pump, because its pressure arrangement with the formation and tubing is the same as for a top hold down pump, i.e. formation (low) pressure on the outside of the barrel.

SUMMARY

Sucker rod pumps continue to be the most popular form of artificial lift in the oil production industry, and there are many configurations for different pumping situations. It has been said that there are over 700 variations of the standard sucker rod pump.

This paper is intended to put forth reasoning and explanations that explain the operation of a downstroke sucker rod pump as well as the well-known, and proven increased displacement sucker rod pump. It is the author’s belief that there is no merit to the use of a downstroke sucker rod pump, however there may be arrangements of parts or other considerations unknown to him. Innovations in sucker rod pumps, their parts, metallurgies and parts arrangements abound each year for specific pumping conditions, and are encouraged by this industry.

FIGURE 1
STANDARD
PUMP

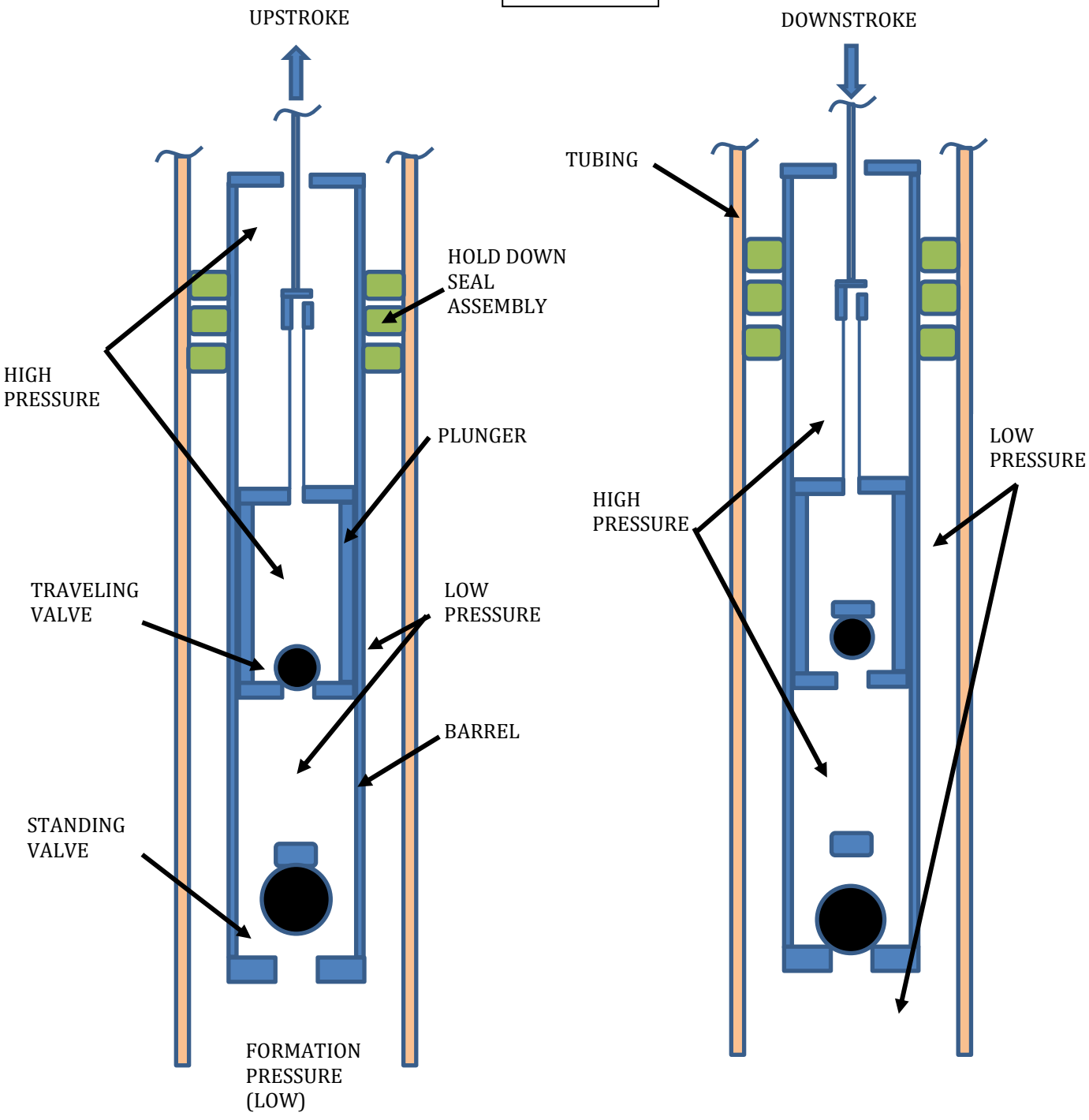

FIGURE 2
DOWNSTROKE
PUMP

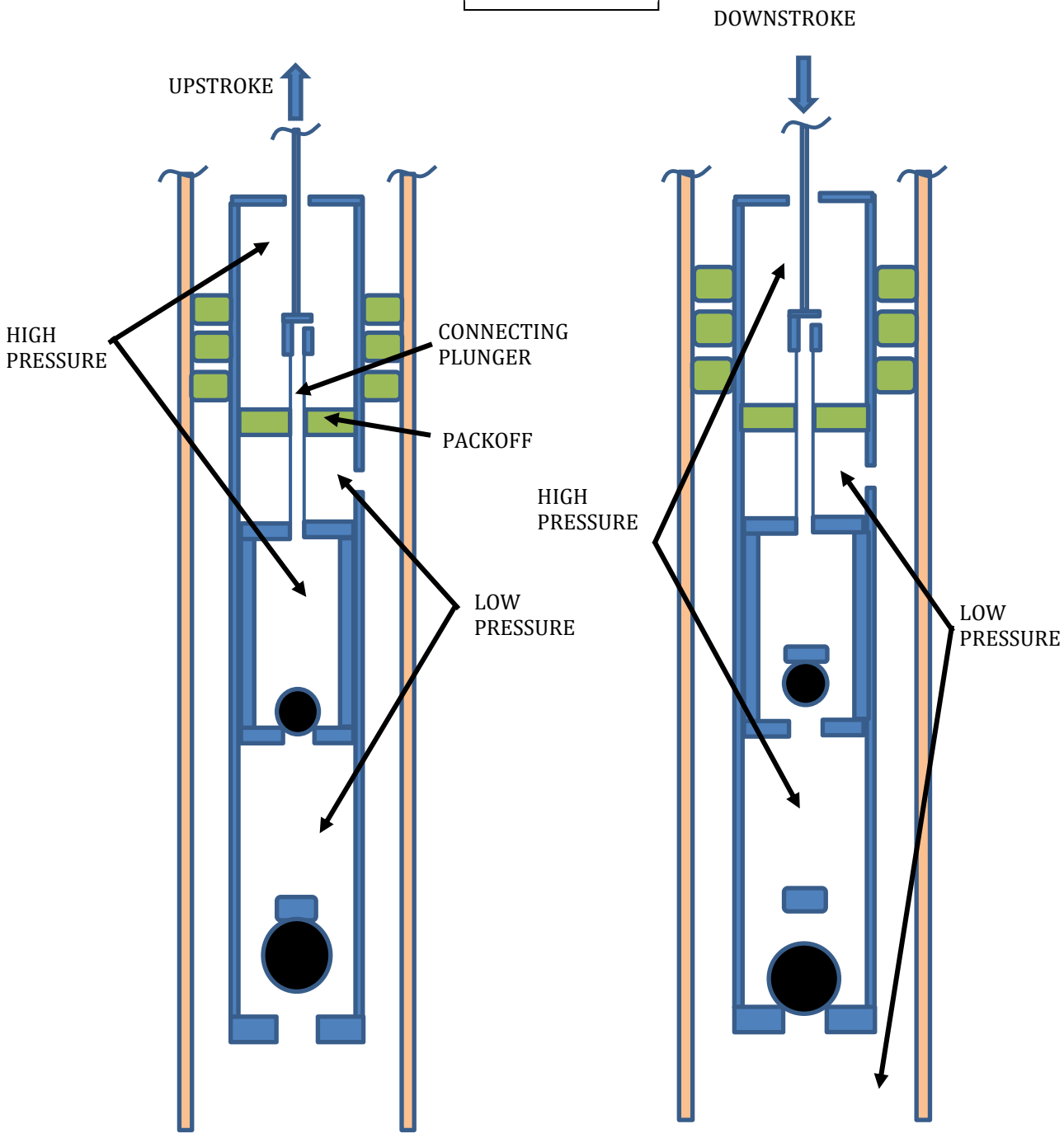

FIGURE 3
INCREASED DISPLACEMENT PUMP
BOTTOM HOLD DOWN

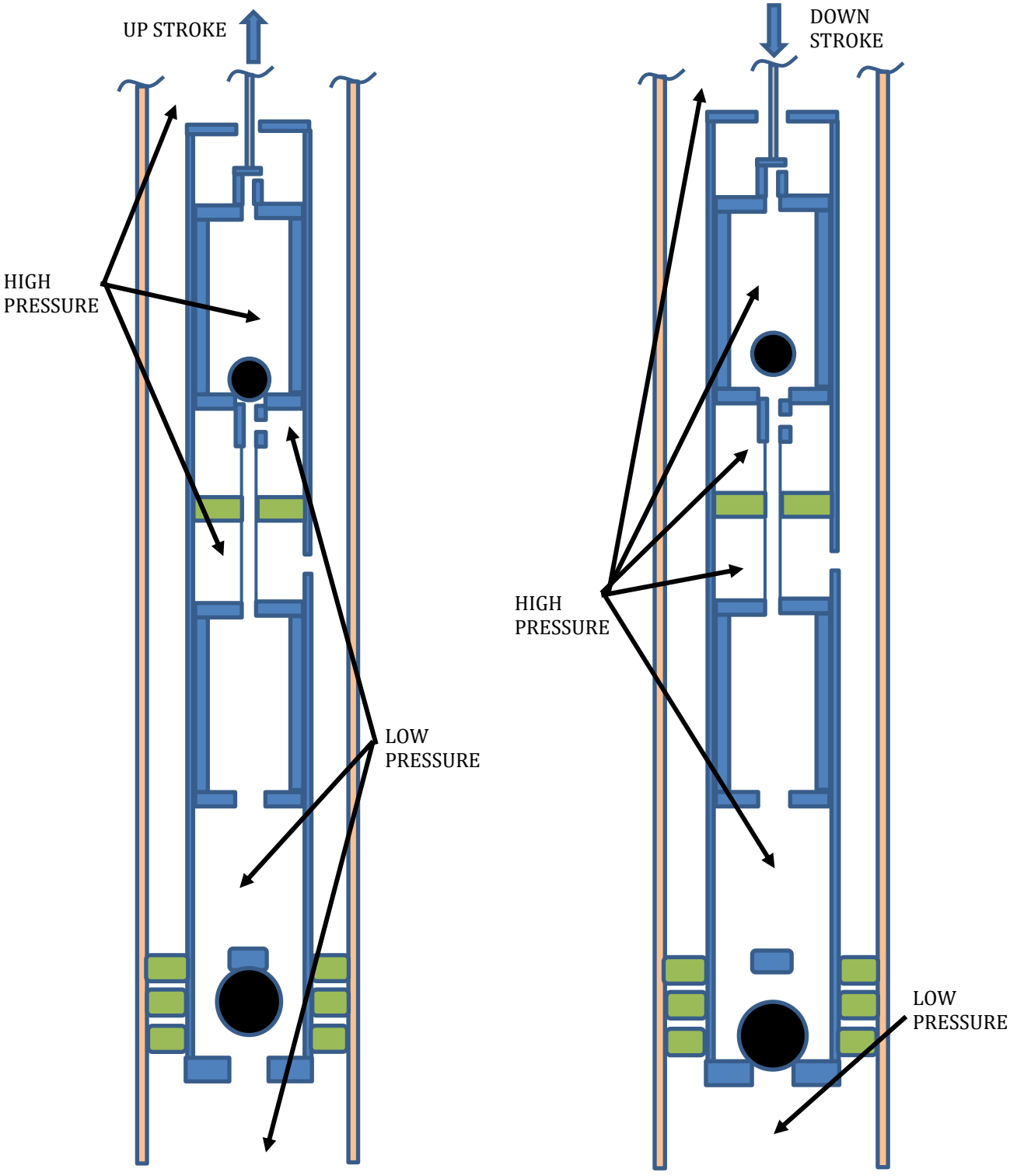

FIGURE 4
INCREASED DISPLACEMENT PUMP
TOP HOLD DOWN
OR **TUBING** PUMP