Specialized Pumps — The Double Volume And The Two-Stage

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In this day of specialism it is only natural the oil well pump manufacturers should follow this normal trend by supplying pumps which are designed for specific application. Heretofore, the oil producer has been obliged to utilize available pump assemblies in an effort to combat unfavorable well conditions. In doing so the volumetric efficiency of the pumping system has been considerably lessened. Our discussion concerns two such pumps which are designed for specific applications, the Double Volume and the Two-Stage.

The Double Volume Pump

The Double Volume Pump is applicable to wells which produce large water volumes where restrictions are imposed on the pump selection by the tubing size. Increased gross fluid volumes are obtained at the same cycle rate or current gross production may be maintained at an appreciably reduced cycle rate. These producing advantages are obtained without tubing replacement and, in many cases, installation can be made by simply replacing an existing insert pump assembly without a tubing job. The following chart will graphically illustrate the obtainable advantages of the Double Volume Pump:

Pump Size	1-1/2" x 1-1/16"	2" x 1-1/4"	2-1/2" x 1-3/4"
Equivalent Pump Diameter for Production Calculation	1.837"	2.536"	3.072"
Displacement Increase Over Tubing Pump	10% over 1-3/4 bore	27% over 2-1/4" bore	25% over 2-3/4" bore

The Double Volume Pump is constructed as two pumps in tandem although its operation simulates two pumps in parallel. As these units reciprocate, two displacement areas simultaneously fill from the formation and transfer into the tubing string. On the upstroke the upper and lower areas are expanded and fluid is drawn into the chambers thus formed. Fluid enters the lower chamber as in a conventional stationary rod pump and continues through the Sealing Plunger and out the holes in the Pull Tube, filling the annular upper chamber as well. When the cycle is reversed, the upper and lower areas are telescoped, thus reducing their volume and forcing the fluid, trapped by the closed Standing Valve, through the Pull Tube and out the Traveling Valve.

An important factor in increasing production is the ability of the pump to completely fill during the up-stroke. Velocities of flow are reduced by permitting the larger of the two displacing chambers to fill directly from the Standing Valve. A lesser quantity of fluid is then required to pass through the restricted Seal Plunger and Pull Tube to fill the upper displacing chamber. The resultant condition accomplishes a more effective filling of the pump.

The Double Volume Pump offers certain mechanical advantages. On the down-stroke, fluid is compressed, opening the Traveling Valve and transferring fluid into the production tubing. While the greater portion of the effect of compressing the fluid is provided by hydraulic force, a slight amount of column stress is imposed upon the Sealing Plunger. The resultant bending forces are fully accommodated by the restraining effect of the Sealing Barrel, together with the advantageous location of the large Plungers.

The principal disadvantage encountered in using pumps of this type is the disconcerting tendency of the pumps to unseat. This unseating tendency is created due to the fact that the area of the lower plunger is greater than the area of the Sealing Barrel to the extent that the upward force exceeds the downward force. This unseating tendency from unbalanced areas may be calculated as follows:

	Pump Sizes		
	2"	2-1/2"	3"
lbs./1,000'	64 lbs.	468 lbs.	639 lbs.

There is a further tendency to unseat the pump during the upstroke occasioned by the hydrostatic head in the casing. Pressure drop through the suction side of the pump and friction of the sealing affect this force.

Calculation can be made toward reasonable estimations in determining what pressure drop could be withstood by a mechanical lock hold-down before unseating occurs. This pressure drop has been theoretically established at 205 PSI. Therefore, the worst condition contributing towards an upward thrust would occur when formation pressure is 205 PSI with little or no resistance in the areas contained in the upper and lower maximum pump chambers. Such a condition would result in the following upward forces:

2" Pump	513 lbs.
2-1/2" Pump	815 lbs.
3" Pump	1220 lbs.

The total unseating force would then be the sum of the force occasioned by hydrostatic presure in the tubing and the force occasioned by pressure drop and friction.

In order to counteract the unseating forces, a series of tests have been conducted to determine the holding tendency of over-size seating cups. The following figures indicate the force necessary to move seating cups after they have been seated:

	Plus 60 Cups		
	2"	2-1/2"	3"
1 Cup	640 lbs.	520 lbs.	1050 lbs.
2 Cups	1300 lbs.	1100 lbs.	1900 lbs.
3 Cups	1720 lbs.	1500 lbs.	2700 lbs.

To further resist the aforementioned unseating tendency, a combined Cup and Friction Ring Hold-Down has been developed. In effect a tapered cone of brass is pressed into seating nipple. After the initial installation, at which time a cold flow is encountered, there remains an interference fit into the seating nipple. The resultant holding force then remains constant during subsequent entries and releases. Brass is used because of its more constant coefficient of friction and its lower modulus of elasticity.

The recommended depth settings for the Double Volume Pumps are 5,000 feet for the 2" (1-1/2"), 4,000 feet for the 2-1/2" (2"), and 3,000 feet for the 3" (2-1/2"), although depth settings may be less due to rod stress. The pump must have good submergence and will perform as predicted but with a corresponding increase in rod loads and polished rod horsepower. The pump is not recommended for gaseous or corrosive wells, or for sandy and viscous crudes. To a great extent, the components of the Double Volume Pump are standard API items with the entire pump being of a metal-to-metal construction. Thus a variety of wearing surfaces are placed at the option of the user with repair parts easily accessible.

The Two-Stage Pump

The second of the two special application pumps which we shall discuss is the Two-Stage Pump. If current pumps are operating inefficiently due to high gas-oil ratio or gas locking, or if the pump is set below a packer and must handle all of the gas produced, the Two-Stage Pump could be a solution to the problem.

The operation of the Two-Stage Pump can be most aptly described by comparing the pump's action with that of a two stage compressor. These compressors consists of a large primary cylinder and an appreciably smaller secondary cylinder. Operation of these cylinders is opposed; i.e., when the primary cylinder is compressing, the secondary cylinder is expending.

The primary cylinder of the compressor moves air through the valve system to the secondary stage. If back pressure out of the secondary stage is low, the compressed air can move on through and out into the receiver. However, if back pressure is greater than the compression of the primary stage, the secondary stage becomes pressurized in its expanded state.

On the other side, or compressing stage, of the cycle the supercharged secondary stage would become further pressurized as the volume of same is reduced, thereby insuring movement of air out of the discharge valve and into the receiver. At the same time the primary stage is being expanded and receives a fresh charge of air to be compressed.

In the evaluation of the advantage of such a system, the compression ratio is not the sum of the two stages but, rather, the multiple of same. When this theory is applied the large plunger and the secondary stage is confined by the annulus above the large plunger.

On the downstroke of the pump, the primary stage is compressed to be moved, said surplus is forced up through the upper traveling valve into the production tubing. If, however, the primary stage has only partially filled, the secondary stage receives this partial volume and stores the energy thus imparted. Thereafter, on the upstroke, the secondary stage is further compressed and fluid and gas moves through the upper traveling valve into the production tubing.

As an example: If a well were being pumped with a 40" plunger stroke and the pump was closely spaced, a compression ratio of 20/1 would be obtained with a conventional pump. If the pump becomes gas locked, the fluid level in the casing would have to raise to 1/20th of the total depth of pump setting before the gas lock could be broken. In the Two-Stage Pump the ratio of 20/1 would still be maintained in the primary stage, but this stage would be compounded by the compression ratio in the second stage (assume 3/1) for a total compression ratio of 60/1. Such compounding means, automatically, that, in the event of gas lock, the fluid level would have to raise to only 1/60th the total depth of the pump setting to permit the breaking of the locked system.

If, during the downstroke, solid fluid is being displaced, fluid in excess of capacity of the secondary stage simply bypasses the annulus and continues up through the traveling valve. Some deviation from normal rod loads may be noted when the pump is not fully filling, especially in that an appreciable reduction of fluid pound will be apparent. Otherwise, peak and downstroke loads due to hydraulic action will be similar to those encountered with a standard pump of the larger plunger size.

Normally, pumps are assembled with sufficient spacing allowance since only one side of the pumping cycle is producing. In the Two-Stage Pump both sides of the cycle affect the ultimate compression ratio; hence, it is to the operator's advantage to compute rod stretch and overtravel closely in order to determine the pump length best suited to the application.

In the Two-Stage Pump assembly all but two parts are standard fittings, thus permitting the option of selecting pump components of material and surface treatment which best counteracts the particular corrosion and/or abrasion problem.