FLEXIBILITY AND PERFORMANCE OF SUBSURFACE HYDRAULIC PUMPING

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INTRODUCTION

Over the last 50 years hydraulic lift has proven its worth to operators worldwide in varying lift conditions, both on and offshore. Since the development of hydraulic lift in the 1930's, the products and technology have rendered hydraulics a viable means of artificial lift in today's oilfield. Through understanding and foresight, the operators can optimize the production and minimize the operating expense through equipment flexibility and performance. By utilizing the flexibility of a hydraulic lift system, both the surface and subsurface equipment can adjust to changing well conditions through the life of the well without major equipment change-outs. Optimizing equipment performance through efficiency, treatment, and monitoring, the operator is able to keep a handle on lifting costs.

The following will cover the flexibility and performance on a casing-free single well hydraulic lift system. Many of the topics covered also apply to other types of single zone completion installations such as parallel-free, gas vent, etc.

SURFACE DRIVE ARRANGEMENTS

After the calculations have been run and surface horsepower requirements established, a decision must be made on how the speed for the power fluid pump will be controlled (assuming an electric motor is used as prime mover). There are currently a number of viable control configurations available, with the most popular being:

Direct Drive through a Gear Reducer
Transmission Drive
Conventional Belt Drive
Variable Speed Controller (Frequency Drive)

Each of these drives has advantages and disadvantages, either economic or convenience. By selecting the proper drive configuration, the down-hole flexibility is greatly enhanced, with the ability to control the amount of power fluid sent down-hole. In selecting the drive to be used, consideration needs to be given to the frequency of its use. For example, if a jet pump is to be operated on a well with a strong water drive and resizing is unlikely, the best option would be direct drive through a gear reducer since mechanical efficiency would remain high and maintenance is low. The flexibility supplied by the other drives would be wasted.

The objective of controlling the speed of the power fluid pump is to minimize the amount of fluid by-passed. By-passed power fluid is by-passed horsepower, thus increasing the electrical cost and decreasing the efficiency of the system (Fig. 1). Earlier hydraulic units were almost entirely dependent upon the changing of either sheaves or plungers for power fluid flexibility. This created an unattractive and often uncompleted task. With some of the more recent developments in speed control, the operator simply has to flip a lever or turn a rheostat to change to desired speeds (Fig. 2).

JET PUMP

The jet pump's flexibility begins at the design stage where the operator can select from a wide range of throat and nozzle combinations, providing varying degrees of lift which best fit the production requirements. Horsepower requirements may vary from 30 to 275 and up, depending on the lifting conditions and throat and nozzle selected. Caution must be exercised not to oversize the surface equipment just to capture the initial production volumes, but to size according to the depletion and/or the lift of the well. Once the throat and nozzle requirements are established, the surface horsepower can be sized. The initial throat and nozzle selected will maximize the surface horsepower available and/or maximize draw-down based on the well's I.P.R.

To ensure optimum performance for the jet pump, periodic pressure recorders can be run in the jet pump housing, monitoring the well's draw-down. By acquiring this pressure data, evaluations can be made through performance calculations. If conditions allow, the throat and nozzle can be resized to adjust to the changing well pressures. As nozzles are down-sized, the surface triplex can be slowed by the speed controllers mentioned earlier, and a reduction in horsepower is experienced. If in the life of the well a water flood is planned and production volumes need to be increased, the combinations can again be resized, eliminating the need for expensive equipment change-out (Fig. 3).

Because of the jet pump's design, the well conditions it operates in differ dramatically from high volume, high G.O.R. wells to salty and abrasive production. Although the jet pump is not without flaws in some of these applications, its performance can be enhanced through power fluid selection and treatment. With the flexibility to operate on either water or oil conditions such as high paraffin and high pour point crudes, problems and expenses can be minimized. The velocities initiated by the nozzle create excellent mixing for down-hole chemical treatment with the power fluid. Although the power fluid does not come in contact with the production end of the pump or well perforations, the chemical will assist in treatment of the cross-overs and tubulars. Operators have successfully experimented by running continuous coil tubing from the surface to below the packer, and injecting fresh water or chemical to treat down-hole problems.

RECIPROCATING PUMP

A reciprocating pump is the optimum subsurface pump because of its operating efficiencies and lower horsepower requirements. The key to operating flexibility and performance for a recip. is speed control on the surface triplex. Power fluid volumes and pressures can vary dramatically from recip. to recip. because of the different engine bores and speeds. For initial design recips, just like jets, are designed to maximize the surface horsepower or maximize draw-down based on the well's I.P.R. Unlike the jet, however, the recip. gives the operator greater flexibility by being able to control the SPM on the positive displacement recip.

In order to obtain peak performance from the reciprocating pump, it is recommended that the pump be operated at its optimum running speed. These speeds differ from well to well, and can be found by running the SPM up incrementally while monitoring the pump end efficiency. Once the efficiency begins to fall off, the pump SPM should be backed off to the last incremental change. There is no reason that the recips. cannot operate above the optimum running speed, but the longevity of the pump is jeopardized.

The reciprocating pump acquires its flexibility through a number of avenues -- stroke length, speed, and engine and pump bore sizes. Depending upon the series or design of pump run, the speed and bore sizes are the easiest to modify, since it often requires changing the bottom-hole assembly to dramatically alter the stroke length. By switching bore sizes, the operator can control production and power fluid displacement as well as operating pressure. This enables him to adjust to lowering efficiencies and changing well conditions (Fig. 3).

Unlike the jet pump, a recip. is easier to predict bottom hole pressures at the pump. The procedure used is called the "last stroke pressure method". A discussion of this field technique was presented in article 5394 entitled, "Determining Bottom-Hole Pumping Conditions in Hydraulically Pumped Wells", which was co-authored by L. O. Buehner and T. W. Niebrugge and appeared in JPT Forum, Journal of Petroleum Technology, July, 1976. By utilizing this method, the operator is able to monitor changing bottom-hole well conditions on a regular basis with no expense.

The reciprocating pump can operate on either power oil or water, but more caution must be practiced when water is used since the engine end of the pump relies on some lubrication from the power fluid. Because of this, some form of lubricity should be added. The performance of the engine on the recip. is entirely reliant on clean power fluid because of the tolerances needed to function. If the use of clean power fluid is not adhered to, engine end failures can be common occurrences.

In the majority of installations, a recip. and jet can incorporate the same bottom-hole assembly, and if sufficient horsepower is available, both can operate in the same well with only slight modifications to the surface equipment. With this in mind, it is often standard practice to run a jet pump initially to clean up the hole after completions or work over. This also gives the operator the flexibility to change to a jet down the road if well conditions require.

SUMMARY

Many companies view hydraulic lift as a last ditch effort to produce a problem well, and consider the system expensive and unforgiving. By looking at the total picture, the flexibility and performance supplied by hydraulic lift is often viewed in a different light by those same companies. Economics in today's oilfield is playing a bigger role than ever before, and flexibility and performance is the name of the game.

REFERENCE

L. O. Buehner and T. W. Niebrugge, "Determining Bottom-Hole Pumping Conditions in Hydraulically Pumped Wells", JPT Forum, SPE 5394, Journal of Petroleum Technology, July, 1976.

$$\text{H.P. loss due to by-passed power fluid} = \frac{\text{Quantity of fluid by-passed} \times \text{PSI} \times 0.000017}{\text{Conversion factor, hydraulic to input H.P.}}$$

$$= \frac{200 \text{ BPD} \times 3000 \text{ PSI} \times 0.000017}{.90}$$

$$= 11.3 \text{ H.P.}$$

$$\text{Energy cost for by-passed power fluid} = \frac{\text{H.P. loss} \times \text{conversion to KW} \times \text{Hrs./Mo.} \times \text{KWH Cost}}{\text{Motor Efficiency}}$$

$$= \frac{11.3 \times .746 \times 720 \times .06}{0.9}$$

$$= \$405.00 \text{ per month}$$

Figure 1—Conversion of by-passed fluid to KWH cost per month based on .06/KWH

Plunger Size and Maximum Pressure Rating	Transmission Gear and Triplex Speed			
	1st Gear 248 RPM	2nd Gear 284 RPM	3rd Gear 324 RPM	4th Gear 372 RPM
	BPD / GPM	BPD / GPM	BPD / GPM	BPD / GPM
1-1/2" 5000 psi	976 BPD 29 GPM	1117 BPD 33 GPM	1275 BPD 37 GPM	1463 BPD 43 GPM
1-5/8" 4725 psi	1145 BPD 33 GPM	1311 BPD 38 GPM	1496 BPD 44 GPM	1718 BPD 50 GPM
1-3/4" 4075 psi	1328 BPD 39 GPM	1521 BPD 44 GPM	1735 BPD 51 GPM	1992 BPD 58 GPM

Figure 2—Flexibility selection for J-165-H with a 4-speed transmission

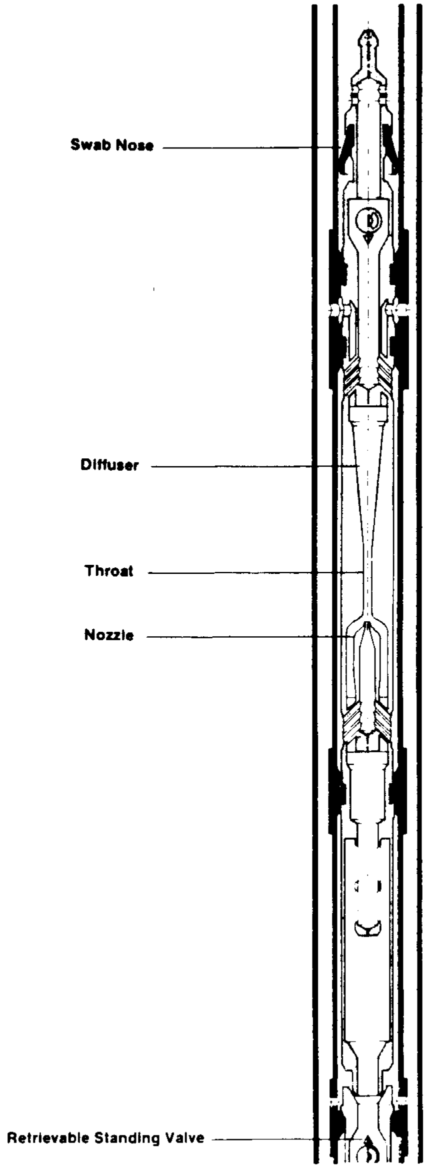

Figure 3—Jet pump cut-away

Operating Specifications

MODEL	NOM. PUMP O.D.	BORE DIA. (inches) Engine	BORE DIA. (inches) Pump	PRESS. RATIO P/E	DISPLACEMENT Bpd @ Rated Speed Engine	DISPLACEMENT Bpd @ Rated Speed Pump	RATED SPEED (SPM)	STROKE LGTH. (inches)
2" NOMINAL TUBING								
F201311	1⅞"	1.30	1.10	.71	286	204	68	22
F201313		1.30	1.30	1.00	286	286	68	22
F201611		1.60	1.10	.47	435	204	68	22
F201613		1.60	1.30	.66	435	286	68	22
FEB201613		1.60	1.30	.66	517	340	55	32
FEB201616		1.60	1.60	1.00	517	517	55	32
2½" NOMINAL TUBING								
F251611	2 5/16"	1.60	1.10	.47	455	214	65	24
F251613		1.60	1.30	.66	455	299	65	24
F251616		1.60	1.60	1.00	455	455	65	24
FE251613		1.60	1.30	.66	530	350	53	34
FE251616		1.60	1.60	1.00	530	530	53	34
FE252011		2.00	1.10	.30	843	259	51	36
FE252013		2.00	1.30	.42	843	355	51	36
FE252016		2.00	1.60	.64	843	540	51	36

Figure 4—2" and 2½" reciprocating pump specifications