Hydraulic Pumping in Small Diameter Casing

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INTRODUCTION

The introduction and application of small diameter or slim hole completions have gained wide recognition and acceptance in some areas due to economics. Utilization of small diameter casing has stimulated the need for flexible artificial lift equipment. The need is magnified with the increasing depth of slim hole drilling. This paper will exemplify some of the methods, designs, and techniques used to produce these wells with the hydraulic pumping system.

ANALYSIS OF OPERATING CONDITIONS

For this presentation, we assume a general working knowledge of the subsurface hydraulic pumping principle. The pumps now in use are liquid powered, reciprocating, positive displacement units. The central plant, consisting of a power pump, power oil treating and storage connected to the bottom hole pump, completes the closed circuit of hydraulic pumping. For specific information, refer to "Design and Operation of the Double Acting, Reciprocating Hydraulic Production Unit", and "Selection and Analysis of Hydraulic Production Systems", printed in the proceedings of West Texas Oil Lifting Short Course, April 21-22, 1960 and April 20-21, 1961, respectively, by J. T. Lewis, and "Theory and Application of Hydraulic Oil Well Pumps" by C. J. Coberly, published in 1961.

Advantages of Hydraulic Pumps

There are several advantages inherent to hydraulic pumping, whether in a single or multiple completion. Some of these are:

1. All moving parts in the well are confined within the production unit; thereby eliminating casing wear.
2. A minimum of vibration, shock, and breathing is present, which is desirable in the use of packers.
3. Individual and complete control of the pump producing each zone is possible.
4. Increased lift depths are obtainable.
5. Volumes are increased greatly, compared to other mechanical methods.
6. Installation costs are minimized with several wells.
7. Remedial work on one zone does not affect production from the others.
8. Efficiency of power transmission assures a minimum of power cost.
9. Free pumps, where applicable, reduce well servicing cost.
10. Other factors, such as chemical injection, paraffin control, availability of bottom hole data, etc., are also desirable.

Required Data

All available information should be carefully considered before attempting to design the bottom hole equipment, whether multiple or single completions. Such information is as follows:

1. Number of zones present.
2. Type of completions:
   (a) Multiple casing strings in a single drilled hole:
      (1) Single Tubes (Size and Weight)
      (2) Parallel Tubes (Size and Weight)
   (b) Single Casing (Size and Weight)
3. Characteristics of each zone:
   (a) Producing formation
   (b) Production required
      (1) % Oil
      (2) % Water
   (c) Saturation pressure of oil
   (d) Gas - total fluid ratio, or GOR
   (e) Properties of fluid
      (1) Corrosive
      (2) Chlorides
      (3) Viscosity
   (f) Solids in fluid to be produced
      (1) Sand
      (2) Iron Sulfide
      (3) Iron Oxide
      (4) Etc.
   (g) Zone Depth
   (h) Static fluid level
   (i) P. I. of zone (Barrels per lb. pressure drop)
   (j) Paraffin

The above factors are important in the proper selection and design of equipment. Other factors to be considered are the future producing characteristics or changes that will affect design, i.e. volumes, fluid levels, etc. The costs of these changes, however, should be minimized with hydraulic pumping.

DETERMINING SIZE AND DESIGN

The first consideration is the selection of the bottom hole pump. The casing size, producing depth, and fluid characteristics will limit this, naturally. In general, the pump selected should be the one with the deepest setting allowed (low pump to engine ratio) to control operating pressure and still maintain production requirements. Figs. 1 and 2 show the wide range of displacements at various lift depths obtainable within the specified casing size.

Considering a broad range of small diameter casing (2-3/8 in to 4-1/2 in.), there are several designs of bottom hole hydraulic pump installations available. Fig. 3 is representative of these designs.

VOLUMES BY CASING SIZE

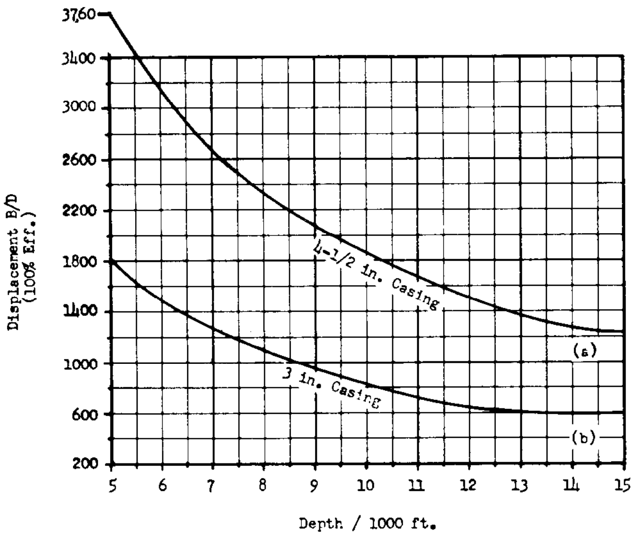

Fig. 1

VOLUMES BY CASING SIZE

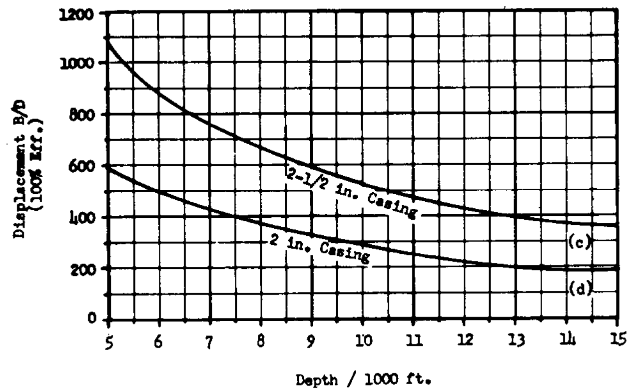

Fig. 2

SUBSURFACE SLIM-HOLE DESIGNS

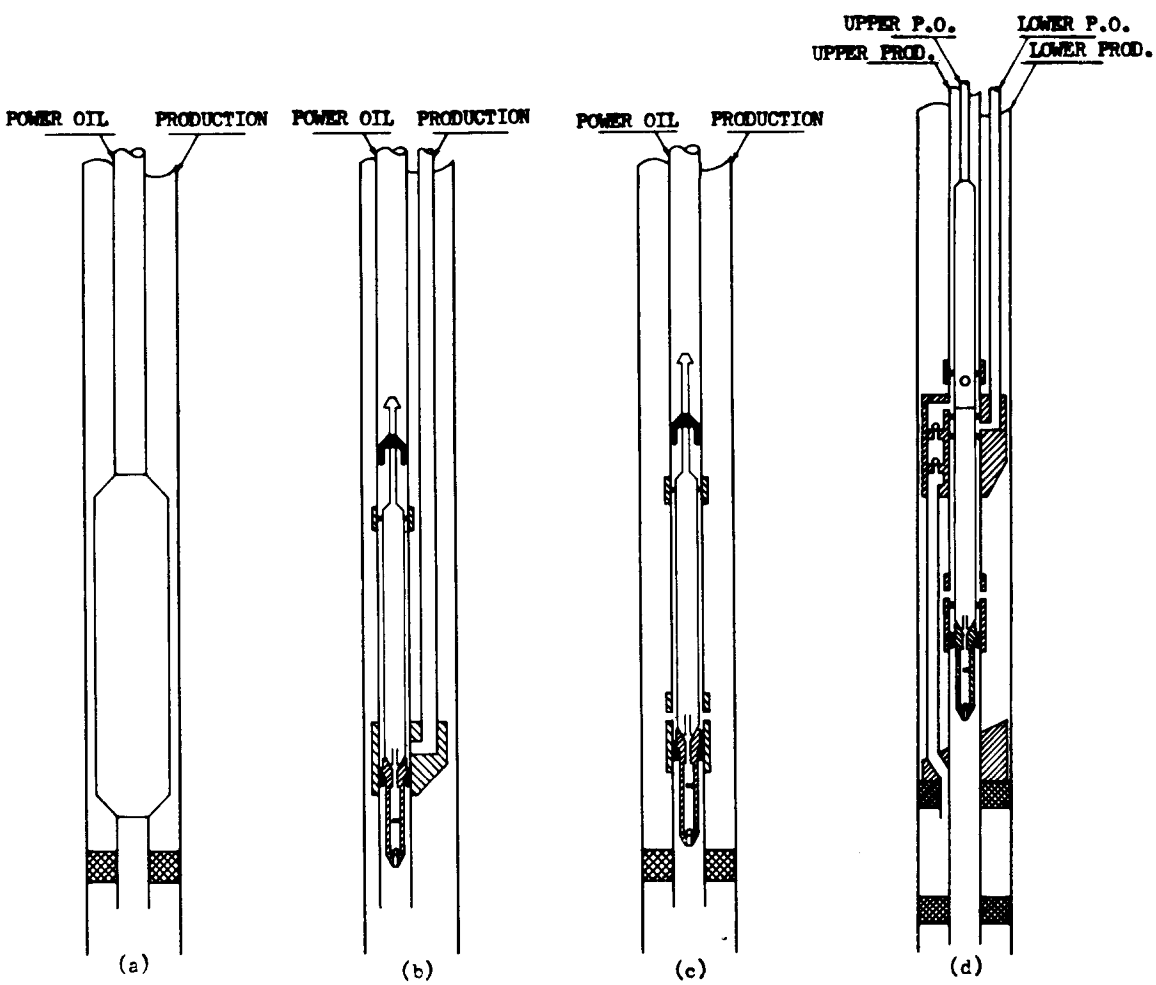

Fig. 3

Fixed Casing, (Fig. 3a)

The conventional casing or fixed casing pump has been very successful in artificially lifting inside small diameter casing. This design is both common and economical. It is not a miniaturized version of the standard; so larger volumes are obtainable from deeper depths within the smallest diameter casing. Since the use of streamlined tubing is widely accepted, the fixed pump may be run to most any depth without undue concern of friction losses in the subsurface system. It must be remembered, however, in using this design in the smaller casings without venting provisions, all produced gas must be handled through the pump. Positive paraffin control and chemical injection are desirable features of this installation. With the use of special equipment or additional tubing in the larger casing (4-1/2 in.), gas may be vented successfully.

Parallel Free (Fig. 3b)

The parallel free pump is normally limited to the casing size, which allows the running of 2 parallel strings. This may be accomplished by clamping the 2 strings together, or if clearances permit, by running the first string with a stab-in bowl (for the second string) above the bottom hole assembly, and running the second string independently; the latter being more desirable because of simplicity in running.

There are several desirable features of this design, among which are:

1. Gas separation in the well
2. Positive paraffin control
3. Chemical injection for inhibiting all surfaces in the well
4. Accessibility of well data by use of a topmounted pressure bomb
5. Retrievability of the pump by lease labor only. (This is particularly desirable in inaccessible locations).
6. Ability to handle solids in produced fluids

The parallel free pump system has also been utilized where 2 strings of tubing have been cemented in the hole together with a bottom hole assembly run in place. The sealing surfaces in this assembly are all retrievable and may be changed, if necessary.

Casing Free Pump (Fig. 3c)

The casing free pump has many of the same desirable features as the parallel free pump. The low initial cost is inherent due to the single tubing string and packer arrangement. However, this standard design does not provide for gas separation in the well. In the larger casing sizes, gas venting may be incorporated by running a small independent vent string, and still utilize the casing free pump without high friction losses. This same system can also be used to inject chemical below the packer for applications not concerned with gas venting.

Fixed Tandem Dual (Fig. 3d)

This dual design is one of many which has been successfully adapted to run inside of 4-1/2 in. casing. The determining factor in designing a dual such as this, is the size of casing and tubing available to permit parallel, independently run strings. In one case, inside 4-1/2 in., 11.6 lb. casing, the bottom hole assembly was run on a string of 2.38 in. O.D. Hydril FJ tubing. A second string of 3/4 in. CS Hydril was independently run and stabbed into the bowl above the bottom hole assembly. The tandem pumps were run on 3/4 in. upset tubing. The two packers used were Baker's Model D on lower, Model DA wire line set on upper, with the flow tube run in conjunction with the bottom hole assembly. The standing valves, although not shown in the schematic, are both wire line retrievable.

This type installation insures complete and positive control over each zone, yet does not reduce the producing capacities from standard single applications.

Surface Facilities

The power station (Fig. 4) is typical of the central plants for hydraulic pumping systems. They can be installed at any convenient location with power transmission lines laid to the wells a considerable distance away. The control manifold may be located either at the central plant or, as in Fig. 5, at the well head. In this particular case, to cut costs, a 2 in. line was laid to a triple slim hole completion (Fig. 6) to supply power for all 3 pumps. This is practical as long as constant flow valves are utilized in the manifold.

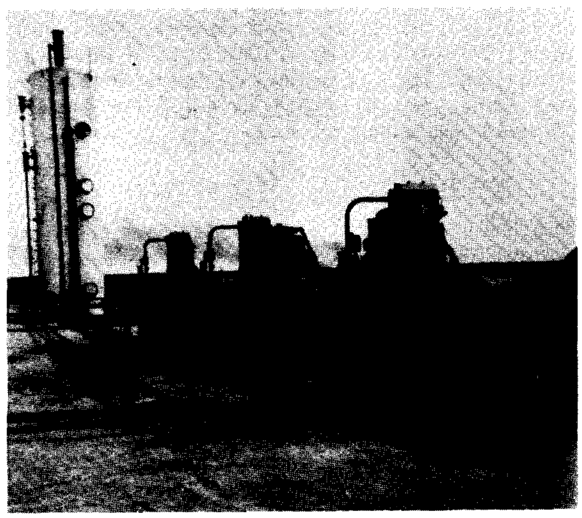

Fig. 4

Fig. 5

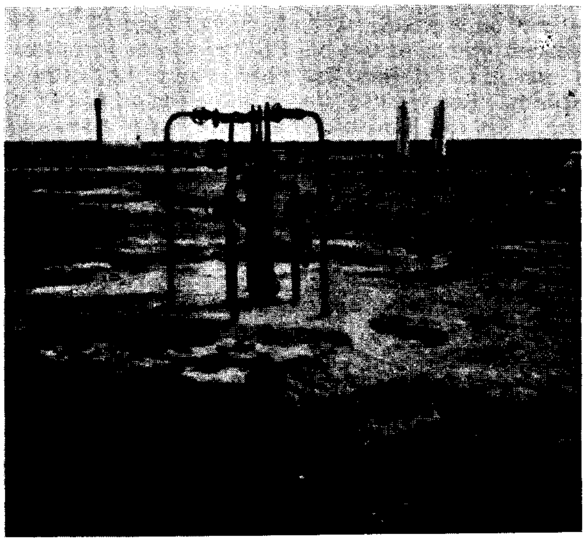

Fig. 6

OPERATIONAL PROBLEMS AND SOLUTIONS

In many oil fields, there are various operational problems with which we must contend. Many of these problems can be minimized with correct design of the hydraulic pumping equipment. We have previously discussed some designs which have inherent advantages for various operating problems.

Gas Production

Efficiencies of the positive displacement pump are of prime importance in design and operations; the submergence pressure will determine this. Produced gas may be either free gas or gas in solution, or both. The effect of submergence pressure is to increase the amount of gas in solution, thereby reducing the volume occupied by free gas. When oil contains gas in solution, the specific volume is increased. This volume, as compared to tank oil, may be considerably less due to shrinkage, indicating an apparent volumetric efficiency far below the actual efficiency of the pump. Several charts have been made establishing this relationship of pressures, volumes, and temperatures. Refer to: "Theory and Applications of Hydraulic Oil Well Pumps", by C. J. Coberly, published in 1961.

A comparison of the apparent volumetric efficiency to actual efficiency indicates the necessity of separating the free gas from the liquid before it enters the pump. A frothing condition may be more troublesome to handle.

The clearance of a positive displacement pump may be great enough that the pump load has sufficient free gas to "gas lock" the pump. The pump merely compresses the gas and never reaches a pressure sufficient to discharge, or low enough pressure to intake additional fluid. The inherent design and operational features of a hydraulically-operated positive displacement pump make it impossible to gas lock. A positive stroke length permits a design to minimize the clearance volume, thus producing a high compression ratio. The deliberate lubricating leakages, built in the pump, are continually loading the clearance volumes and displacing the gas.

To obtain separation of free gas and fluid, gas anchors have been utilized to various degrees of success.

Corrosion

Corrosion effects are reduced considerably in the hydraulic pumping system. Corrosion fatigue in the tubing, due to cyclic loading, is practically eliminated because all moving parts are confined within the pump. Since the hydraulic pump is relatively small, costly materials may be used. The extensive use of nickel, chromium, cobalt, and their alloys are effective in reducing corrosion.

Chemical inhibitors have been successful, and may be applied in the power oil to protect the bottom hole equipment. To protect the casing and outside of the tubing, the inhibitor is batched down the casing.

Paraffin

Several features of the hydraulic system make it adaptable to the control of paraffin deposits. The high pressure power oil system allows heat circulation, running of plugs, or operation of mechanical scraping devices. There are several ways to control paraffin deposits in tubing and surface lines. This deposit may be inside the tubing, or tubing annulus of insert pumps. In circular tubes, scrapers have been made which drop from the well head to a point below the paraffin. This closes the fluid passage of the scraper so that it is pumped to the surface with the wax ahead of it.

Annulus scrapers may be applied to the inner tube. In some cases, passing couplings, or lifting the tubing a distance equal to coupling spacing, has been successful. Hydraulic lifts on the well head, using the power oil to operate the lift periodically, are available.

Soluble plugs are another method of controlling paraffin. A cylindrical plug, with proper solubility, will pass through elbows and tees easily. These are used in surface lines as well as tubing, and will be either dissolved or sufficiently softened to pass through the pump without any trouble. Special valves are available for injecting these plugs.

Hot oil is also used by batch and continuous flow. Line heaters installed on the power oil lines have been used successfully to maintain tubing as well as surface lines in deep wells. Hot oil may be batched down the casing if applied before the build up of paraffin is excessive. Reverse flow check valves are used for this purpose, and are placed just below the paraffin to conserve the heat and reduce friction.

Tubing coatings are also used and have been very successful in some cases.

Wax solvents and inhibitors are used with varying degrees of success. Batch continuous treatments are used, but the cost of treatment is usually high with effective solvents. Some inhibitors change the character of the deposits so that it is more easily removed by other treatments.

CONCLUSION

Slim hole drilling has created a need for flexible artificial lift techniques, designs, and equipment. Hydraulic pumping with advanced theories, increased technology, and practical economics is the solution to many of these problems.