Advancements In Hydraulic Pumping

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INTRODUCTION

Much of the emphasis in the oil industry today is associated with deeper drilling, offshore development and continued activity in the formation of large secondary recovery projects. With each of these trends, when artificial lift is required, it will more than likely need to be capable of lifting greater volumes and in many instances from greater depths of lift. This means more downhole horsepower will be required. The manufacturers of hydraulic pumping equipment have been aware of this trend and each year spend considerable effort in the development of equipment which is capable of meeting the needs for increased inhole horsepower.

If the reader's area of responsibility is in one of these categories, it is hoped that he will gain some insight into the type hydraulic pumping equipment that will fill his lift needs. For others who may already have or are contemplating hydraulic pumping for a well which is not particularly in one of these categories but merely needs lift equipment, it is hoped that this presentation will present some ideas in the selection, installation or operating techniques which will materially assist in their operations. Hydraulics certainly merit consideration for the "plain vanilla" wells also because of the economic and operating advantages it has to offer. A previous paper presented at the Southwestern Petroleum Short Course showed that hydraulics were usually economically advantageous at rates in excess of 200 BPD from depths below 3000 ft.[1]

ADVANCEMENTS IN EQUIPMENT DEVELOPMENTS

Since the general subject of available hydraulic pumping equipment was discussed in considerable detail by Mr. G. R. Bond in 1962, this discussion will be limited to new developments from that time to the present.[2] Actually, advancements are of such a nature in terms of equipment capabilities, performance, flexibility and service that operators should reinvestigate this lift method and avail themselves of the economics it offers, particularly in secondary recovery projects.

Subsurface Equipment

The heart of the hydraulic pumping system is the subsurface production unit; the subsurface production unit develops the necessary horsepower within the confines of dimensional limitations of the tubing or casing string to provide the required energy to lift the well fluids to the surface. The hydraulic horsepower output of the subsurface production unit increased considerably during the period from 1958 to 1962 such that in 1962 the two full-line manufacturers of hydraulic pumping equipment were marketing 1:1 ratio free-type pumps with the following theoretical displacement ratings. The increases achieved during the previous years were made by increasing one or more of the following: plunger size, stroke length or pumping speed.

Tubing Size	Kobe Type B	Fluid Packed FEB
2"	556 BPD	517 BPD
2-1/2"	1122 BPD	843 BPD
3"	1925 BPD	1348 BPD

Since that time the originator of hydraulic pumping has chosen to achieve greater displacement rates by (1) powering two pump-plunger assemblies with a single engine piston—one engine and two plungers (2) installing two such pumps in tandem to produce a single zone—two engines and 4 plungers, and (3) installing two of the tandem units in parallel to produce a single zone—four engines and eight plungers (their recent advertisement stating their lift capacity has been "Doubled", "Redoubled" and "Doubled Again"). Certainly this arrangement can provide increased displacement rates but when two plungers are attached to one engine in a production unit to double the displacement rate, it reduces the depth of lift by 50 per cent. Actually, the horsepower output of the single engine, double pump has not been increased. However, for shallow to medium depth production, they offer maximum displacement capacities.

Some of the tandem units (two engines—four pumps) are being used for producing platform wells in Cook Inlet for initial producing rates of 4000 BPD in wells which have 9-5/8 in. casing. In a closed power-oil system as shown in Fig. 1, two 3-in. high-volume hydraulic pumps are used with two strings of 3-1/2 in. OD buttress tubing. The power oil is pumped down and back through these tubing strings and the casing annulus is used as the production string. Fig. 2 shows the open power-oil system in which the production is returned with the power oil

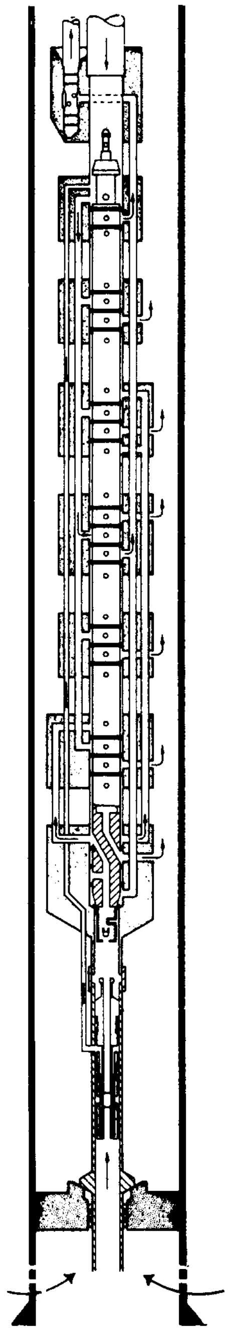

Fig. 1. In closed power oil system, crude oil is produced through the casing annulus.

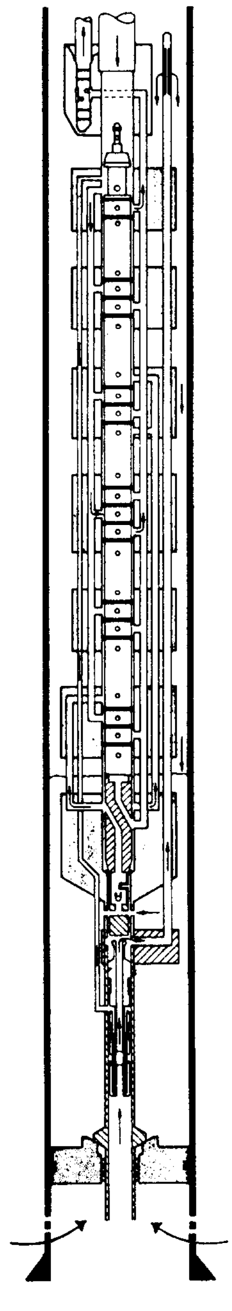

Fig. 2. In the open hydraulic system, crude and power oil mixture return in tubing.

through the return tubing string. On both installations, the pumps are unseated and surfaced by pumping down the power-oil return string.

Cook Inlet regulations require the use of a downhole safety valve on flowing wells and this requirement is uniquely answered where hydraulic pumps are used to increase production from flowing wells. A packer is installed below the bottom-hole assembly and a pressure-operated safety valve is installed between the packer and bottom-hole assembly. The surface operating pressure required to operate the pump is used to open the safety valve. When the surface pressure is bled off, the valve automatically closes.

The other major full-line manufacturer of hydraulic pumping equipment was of the opinion that increased displacement met only half of the requirement and thus set out to develop a hydraulic production unit which was actually able to provide an increased amount of horsepower such that it could not only lift larger fluid volumes but could do so from greater depths of lift. This brought forth a completely new unit, the Volumaster Hydraulic Production Unit, designed to provide a higher reliability, a longer wear life and a greater tolerance to severe operating conditions. The Volumaster, being completely new, has many features worthy of mention but there are two in particular which should be given attention. The engine valve is stationary and is mounted above the engine cylinder, permitting the use of a larger engine valve which has unprecedented fluid passage characteristics. The pump end of the Volumaster has been designed to combine the best features of a subsurface sucker rod pump and a subsurface hydraulic pump into one unit. Use of the ratio compound principle in the pump end eliminates gas lock, increases pump efficiency and eliminates fluid pound on the downstroke of the pump.

In order to obtain the increased displacement rates offered by the single engine Volumaster unit from greater depths of lift, the Tandem Engine Volumaster was developed. This unit has all the features of the single engine unit but employs an additional engine piston and cylinder to provide the additional horsepower needed to lift from greater depths without exceeding 4000 psi maximum recommended pressure rating. Schematics of single and tandem engine Volumaster Units are shown in Fig. 3. The single engine unit is shown on the right with the tandem engine unit shown on the left.

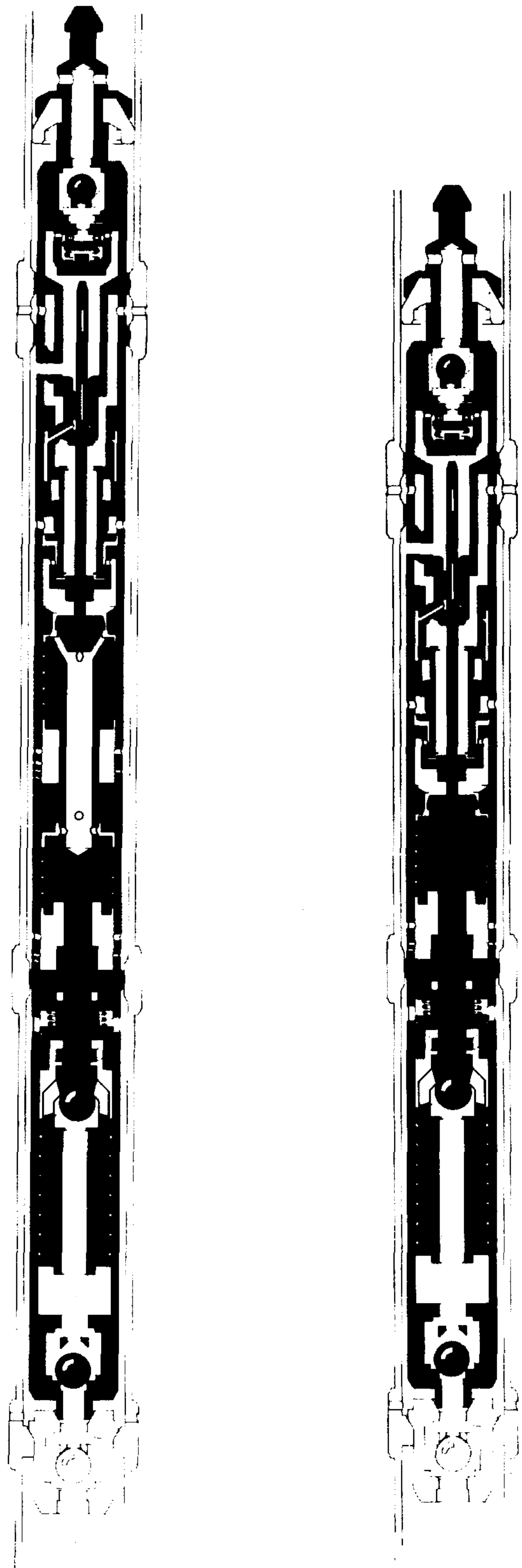

FIGURE 3

Volumaster Hydraulic Production Unit

Since the Volumaster is an all new unit and designed to be run exclusively as a free pump, it requires an all new bottom-hole assembly. Preferably, the Volumaster Unit should be run in its specially designed floating seal bottom-hole assembly which eliminates the tendency of the assembly to bow and cause the production unit to run in a bind. The compressive load of the tubing string is supported on the large diameter jacket of the floating seal bottom-hole assembly while the elements supporting and sealing the unit are guided in a slip fit as shown in Fig. 4. This floating seal bottom-hole assembly also directs exhausted power oil down the outside of the production unit barrel to help eliminate scale buildup which could cause the pump to stick in the cavity.

The latest addition to the Volumaster line of hydraulic production units is the VHT High Volumaster. This unit has the same engine as a tandem engine Volumaster but additional displacement ability has been provided by the addition of a second producing chamber in the pump end of the production unit to increase its displacement rating. The maximum displacement ratings for the various Volumaster Units are as follows:

	2" Tbg	2-1/2" Tbg	3" Tbg
Single Engine Volumaster			
Displacement, BPD	674	1,120	1,613
Depth of Lift, Ft	7,500	7,500	8,000
Hydraulic Horsepower	34.7	57.7	85.7
Tandem Engine Volumaster			
Displacement, BPD	674	1,120	1,613
Depth of Lift, Ft	12,500	13,500	13,300
Hydraulic Horsepower	56.6	104.3	159.0
VHT High Volumaster			
Displacement, BPD		1,780	
Depth of Lift, Ft		8,500	
Hydraulic Horsepower		103.4	

The VHT High Volumaster unit is becoming a very popular replacement for casing pumps because of its combination high displacement rate from the greater depths of lift and the fact that it runs as a free pump in casing as small as 5-1/2 in.

As a further extension of the tandem engine, double-pump principle of the VHT High Volumaster, a three-engine, two-pump combination production unit has been developed for produc-

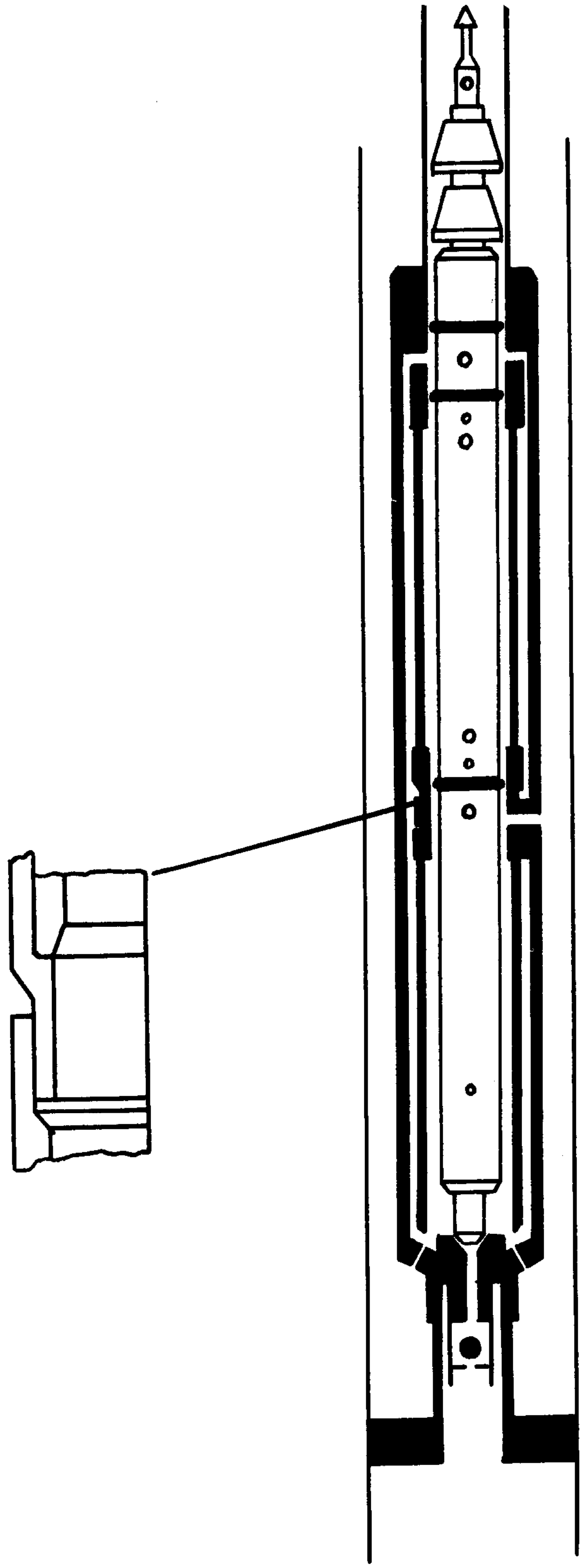

FIGURE 4

Volumaster Floating Seal Bottom-hole Assembly ing very deep wells. These are currently being run in three-string closed power-oil systems. The design of this unit is a fairly wide departure from normal hydraulic design practice since it employs a six-inch stroke and a 360 stroke per minute maximum cycle rate. Performance has been good and producing rates in excess of 1200 BPD have been measured with the pump producing from 11,000 feet. Sonic fluid level measurements showed 1000 feet of fluid over the pump when this test was made. This model is still in a probational status pending a thorough evaluation of field performance and possible design refinements, so it is not being offered as a standard model at this time. However, the short-stroke, high-cycle rate design with multiple engines and pumps in tandem, does offer a compact method of increasing the horsepower and consequently the volume that can be lifted from increased depths. Whether or not this is the ultimate form the hydraulic unit of the future will take, it is an interesting approach and one that has shown considerable early promise. It will be worth watching to see what develops.

A paper presented at the 1968 Southwestern Petroleum Short Course cited production increases made possible by venting formation gas where wells were being produced below a packer.[3] In order to evaluate the possibility of achieving the same results from high displacement wells, several prototype installations of the 2-1/2 in. VHT High Volumaster have been made in 5-1/2 in., 20 lb/ft casing with the use of a 1-in. gas vent string. Results to date have been very encouraging with this new subsurface arrangement. If it continues to give satisfactory performance, production of the finished product should be available by mid 1970.

Surface Equipment

Developing subsurface production units which have increased producing capabilities also requires larger volumes of power fluid to be directed to these units in order to provide the additional energy required. Higher flow rates to subsurface production units, therefore, have dictated the need for surface control equipment which will pass the required fluid volumes without excessive fluid friction losses. Such equipment—wellhead control assemblies and power control manifolds—are now available in "high flow" versions which are capable of flow rates as high as 2400 BPD.

Since the last general discussion of hydraulics at the Southwestern Petroleum Short Course, a 250 input horsepower horizontal quintuplex pump has been developed for hydraulic pumping application. See Fig. 5. This larger power oil pump has the same quality design and safety features of the four smaller sizes all of which have proved themselves in hydraulic pumping systems. Two recent major field expansions for multiple well systems have been made in which several of these larger power pumps were used to provide the required power oil volumes. Soon to be off the drawing board are plans for power pumps in the 375 and 625 horsepower sizes.

Power Pump Installation Procedures

The following recommendations will help assure efficient fluid flow conditions through the power oil pump, minimize fluid impulses, minimize material fatigue failures and provide the maximum in trouble-free, safe and economical operation.

1. Suction Line (For operations without a charging pump).
   a. Use individual suction lines to each surface power pump whenever possible.
   b. Select adequate line size to reduce fluid velocity, minimize the effect of paraffin buildup and prevent suction cavitation. Line should be one size larger than pump suction flange.
   c. Try to streamline flow by using the straight line approach and full opening valves and fittings.
   d. Paint lines a light reflecting color to minimize gas breakout in suction line during hot weather.
2. Discharge Line
   a. Again, streamline flow with the straight line approach. Avoid unnecessary valves and fittings.
   b. Tie down discharge line as soon as possible after leaving the pump and at numerous points leading to the power control manifold.
   c. Use welded line connections for high-pressure operation using proper welding techniques and matched metallurgy.

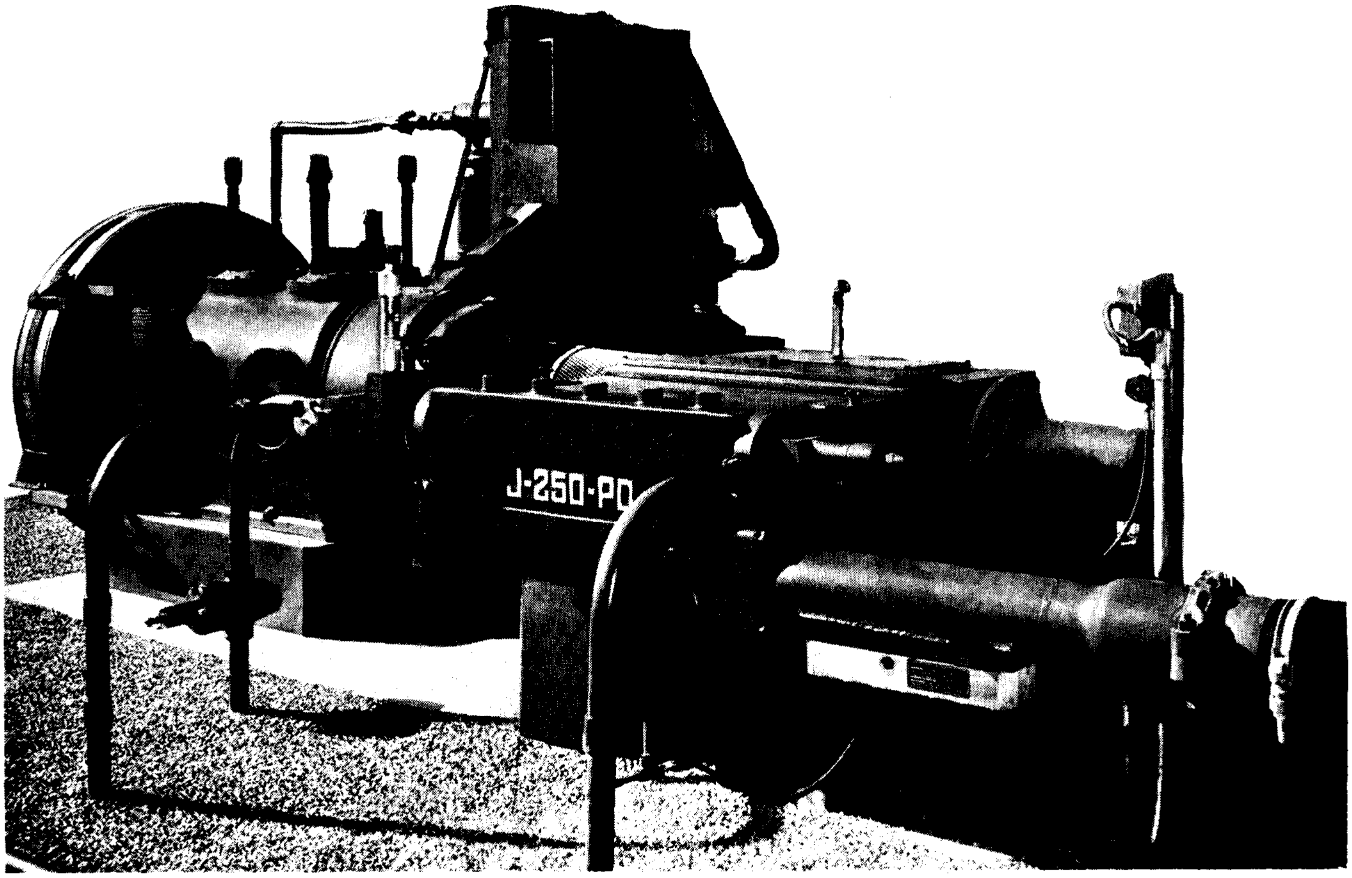

FIGURE 5

Oilmaster J-250-PO Quintuplex Power Oil Pump

3. General
   a. Spread out power pumps and manifold wherever possible to minimize fluid impulses and potential loss should fire occur.
   b. Use sump tank with gas blow-down buried away from the power pump to collect and salvage surplus plunger leakage and keep ground around pumps free of oil.
   c. Use valves, fittings and tubular material of adequate pressure rating for equipment and personnel safety.

Figure 6 is a schematic drawing showing these recommendations for piping at the central battery.

One-Well Unitized Hydraulic Pumping System

A one-well unitized hydraulic pumping system is being evaluated at the present time on a major company lease in southwest Texas. Several "firsts" have been incorporated into this concept.

1. All equipment is skid-mounted and located at the wellhead.
2. Produced water is being used as the power fluid.
3. A centrifugal separator is serving to clean the power fluid.

Referring to Fig. 7, the flow pattern is as follows beginning at the triplex pump. Water as the power fluid is directed down the tubing string in this casing-free installation. Exhausted power water and produced well fluids (water, oil and gas) are brought to the surface through the casing annulus. From the wellhead this mixture goes to a separator-accumulator tank under about 100 psi. This tank has two main outlets, one at the bottom which feeds water to the centrifugal separator for cleaning to then feed the

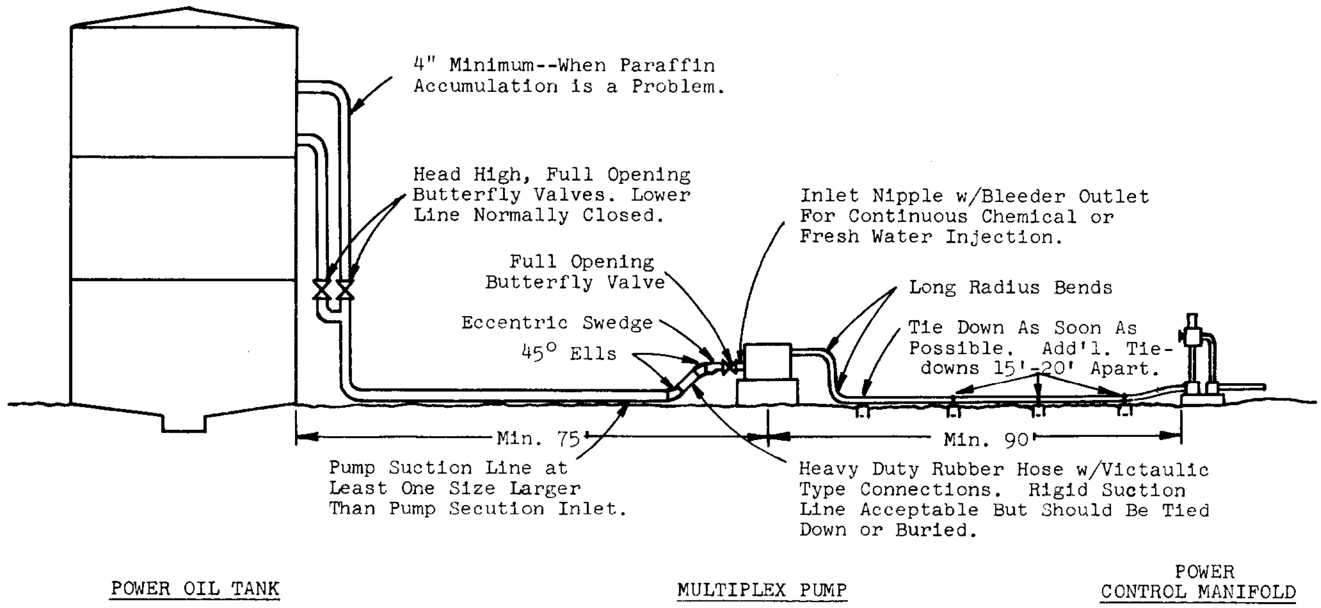

FIGURE 6

Central Battery Piping Recommendations

triplex suction and reused to lift the well and the other which dumps gas, oil and excess water to the flow line to be processed in the same fashion as if the well were on any other kind of artificial lift. The underflow from the cyclone separator is also fed into the flow line to be processed with normal treating facilities.

Through the years, hydraulic pumping has been thought of as a producing method applicable to deep or difficult wells only. Earlier in this paper, hydraulics were cited as economically advantageous for producing rates in excess of 200 BPD from depths below 3000 ft. The simplicity of this unitized power package and the elimination of additional treating facilities or tankage should make it economically applicable for the shallow to medium depth wells which are producing only moderate to small amounts of fluid.

Field Service and Training

Manufacturers of hydraulic pumping equipment have recognized that for this lift system to merit enthusiastic consideration by oil operators, field service would need to be available and their operating people would need training in its operation. Field service is now readily available in nearly all areas of operation and training programs are being given with regularity to instruct users about the capabilities and proper operation of hydraulic pumping equipment.

POWER OIL

The power fluid is the life blood of a hydraulic pumping system since it transmits energy to the various parts of the system and should be given due consideration in this paper.

Power Oil Quality

The condition of the power oil is a pretty good measure of the operating success of the system. Several years ago "bad power oil" was the standard term used as the cause for a substandard or inoperative hydraulic pumping system. Certainly such was not always the case but a clean power oil system is a prerequisite for the successful operation of hydraulics and a reasonable amount of attention to its quality will pay big dividends in reduced operating costs and downtime.

Two practices which are presently materially assisting in determining the cause of poor performance with a hydraulic pumping system are the establishment of field service and repair shops and the development of laboratory and

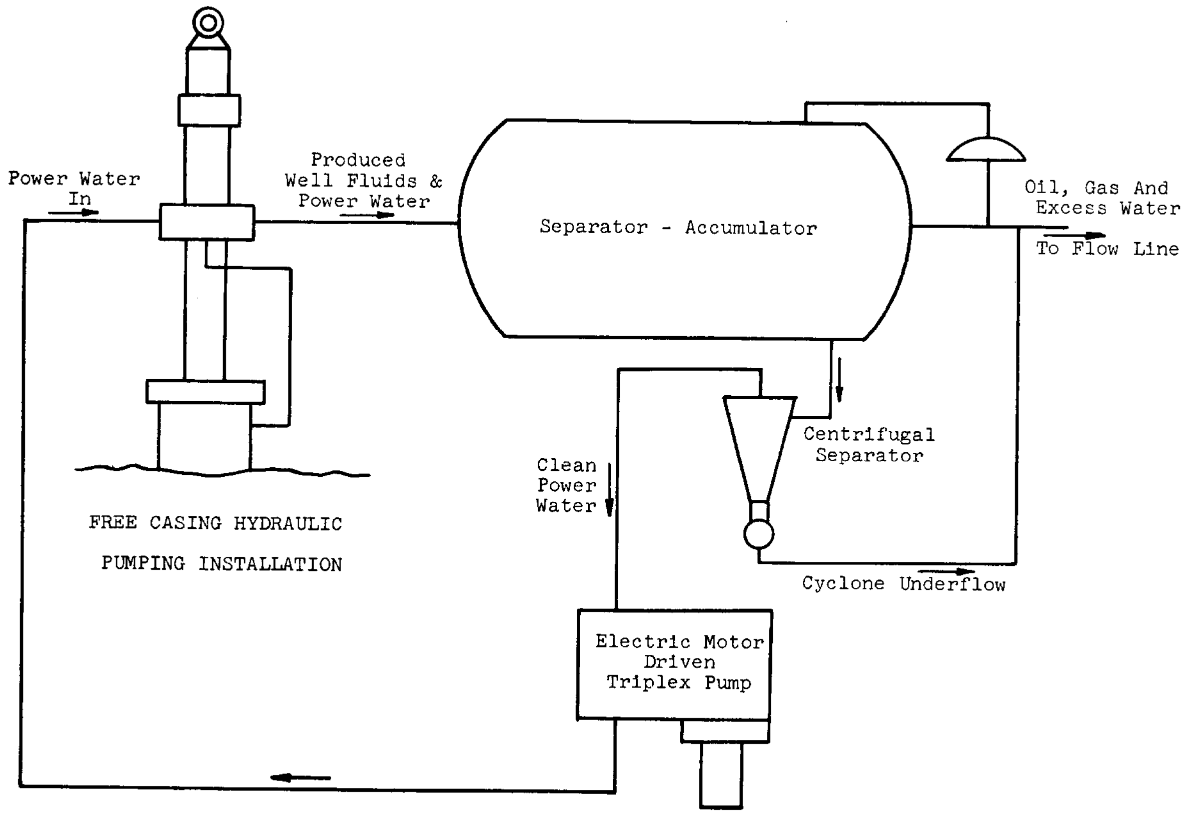

FIGURE 7

One Well, Self Contained Hydraulic Pumping Installation

field study programs for analyzing power oil and the treating system. Field service and repair shops strategically located in hydraulic pumping areas places knowledgeable men where they can diagnose field operations and inspect the subsurface production unit during repair. With this firsthand knowledge, they are better able to make quick and meaningful recommendations for improving the service life of the equipment.

Considerable time has been spent during the last four years to establish minimum quality requirements for power oil and a systematic field analysis program to determine the effectiveness of the power oil treating system.

The beginning of this effort involved taking the information obtained from a rather simplified power oil analysis, Table 1, and correlating it with known performance data on the subsurface hydraulic production units being used in the systems. Based on the results of about 50 such correlations, the following limits have been tentatively established:

Maximum Total Solids	20 PPM
Maximum Particle Size	15 Microns
Maximum Permissible Salt	12#/1000 bbl

It should be emphasized that these acceptable limits have been established on the results of a given test procedure. The next step should be the establishment of a standard testing procedure, the results of which could be used to formulate uniform limits for power oil quality.

Also, more extensive analysis services are now available which not only determine the quality of the power oil but also the effectiveness of the lease treating facilities. As depicted on Fig. 8, millipore samples are taken before and after each vessel in the flow pattern. This makes

TABLE 1

POWER OIL ANALYSIS

Consists of the following:

API Gravity at 60° F
B S & W Breakdown, Solids & Water by Per cent
Paraffin Content by Per Cent
Salt Content in Pounds Per 1000 Bbl Oil
Iron Sulfide in Parts Per Million
Total Solids in Parts Per Million
Microscopic Study Identifying Major Solids by Micron Sizes.

it possible to determine which components are functioning as they should and pinpoints the source and cause of poor quality power oil.

Power Oil Treatment

The standard "rule of thumb" for selecting a power-oil tank size has been to select one which would provide 24 hours of settling time, i.e., tank capacity equal to the daily circulating rate of the hydraulic pumping system. For several reasons, this is not always possible or practical and in recent years several major operators have installed centrifugal separators in their hydraulic pumping systems to supplement the power oil tank in its cleaning operation.

In one such installation, the operator was circulating about 4000 bbl of power oil per day through two 750-bbl power oil tanks which were connected in series and was experiencing triplex failures and excessive engine valve wear in the bottom-hole pump due to a carryover of solids. Installation of a centrifugal separator consisting of six 3-in. cones between the two 750-bbl tanks reduced the solids content of salt and sand from 98 down to 14 PPM. Ninety-five per cent of the material was larger than 20 microns. Subsurface pump repairs were immediately reduced about 60 per cent and there was a significant reduction in triplex maintenance. Actually, the operator had determined in this application that 24 hours of settling time would have provided quality power oil. However, it was much quicker and much more economical to install the centrifugal separator than it would have been to install the additional tankage to provide increased settling time, Not only do centrifugal separators provide a monetary saving but they also require less space and substantially reduce the volume of power oil in the hydraulic pumping system.

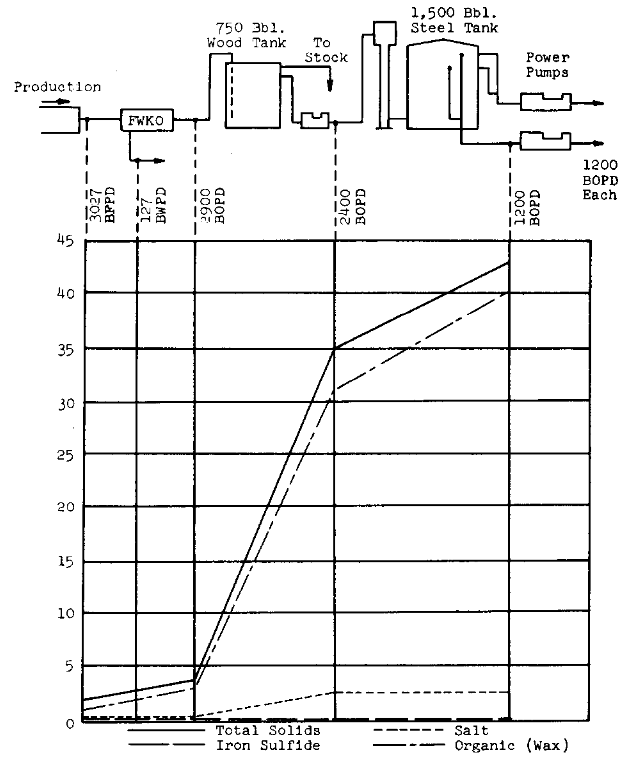

FIGURE 8

Power Oil Lease Treating Facilities

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