Advancements In Subsurface Hydraulic Pumping

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INTRODUCTION

Progress is an exciting adventure for any industry and more specifically for those directly affected by its benefits. In our free enterprise system the rewards of progress can be extremely gratifying to both the user and the supplier and consequently to the industry as a whole.

Advancements, during the last 30 years, made by the century old Petroleum Industry have been classed as phenomenal. These advancements have opened doors for far-reaching developments in nearly every other industry. The production branch of our industry and the manufacturers who supply its working tools can claim many important contributions during this period. One of these has been the introduction and development of the Subsurface Hydraulic Pumping System. Through the close cooperation of users and suppliers, this method of artificial lift has come "of age" and is today being applied to oil lifting problems which no other pumping system could so efficiently handle. The advancements which have fostered this development and those which may come in the future will be the subject of this paper.

Early advancements in subsurface hydraulic pumping came at a pace rather slow - after its initial commercial application in the early 1930's. The basic principles were sound, but problems of application and maintenance overshadowed the method's advantages. The first major breakthrough, which was to speed up all subsequent advancements, was made in the late 40's when Coberly's "free pump" system was successfully installed. This system eliminated the costly pulling job previously required to retrieve and run the submerged pumping unit and it removed the major road block which had hindered wide-spread field testing--an essential to any product development program.

With the way opened for accelerated testing, advancements came in rapid-fire order. Earlier equipment was improved upon; the number of installations increased steadily; the expanding market encouraged more manufacturers to assign research and development time to the system. One old-line rod pump manufacturer undertook an extensive program to translate his oil well pumping know-how to the problems of this new pumping method; and this increased manufacturing and sales activity sharpened competition which, in turn, supplied at least two basic ingredients for progress: (1) improved product design and (2) an expanding network of service facilities with qualified manpower.

Coincidental to these endeavors by the manufacturers, the users of artificial lifting equipment were completing wells at ever-increasing depths and were developing cost reducing completion techniques which strained the design and application limits of other pumping methods. Operators recognized that the hydraulic system overcame these limits and fitted ideally into their new application requirements.

Advancements, then, have been made not only in the design and application of subsurface hydraulic pumping equipment, but also in understanding on the part of the user of the economic and operational advantages which this system offers. The result of these advancements is a progressive movement toward expanding use of this method, a movement which continues to grow with each success story. And the progress which initiated this growing movement is the very thing which expands it further.

These comments give us some insight into the general advancements in subsurface hydraulic pumping. Now, to be considered are some of the specific improvements which have been made in individual components of the system, as well as application techniques which have been developed for specific requirements. As we progress, one will note that each has a definite effect upon equipment performance, capacity, flexibility, economy or safety.

ADVANCEMENTS IN SUBSURFACE EQUIPMENT

The principal development efforts of manufacturers of hydraulic pumping equipment have generally been concentrated on the subsurface components, and more especially on the submerged production unit itself. This unit is certainly the most critical component in the system since it performs the actual work assigned to the complete system. Advancements made on this unit and accessory subsurface equipment are, therefore, of primary importance in considering advancements in hydraulic pumping.

Hydraulic Production Unit Design

Competition among the manufacturers to build the "better mousetrap" has brought about many improvements in production unit design and material, both of which have contributed to higher levels of dependable and efficient performance from the units. Now are several basic unit design concepts including a double acting design, two single acting unbalanced units, and one single acting balanced design. A review of the relative merits of these design concepts is beyond the scope of this discussion; however, an inquiry to the manufacturer's representative will bring an enthusiastic dissertation on the design of his unit. But the availability of a variety of unit designs is significant because of the contributions that each has made in advancing general knowledge on the subject of hydraulic production unit design.

It would be impractical here to detail a long list of these advancements, but one example of improved design might be cited as an illustration. Through the years of rod pumping, fluid pound that has been caused by incomplete filling of the pumping chamber has taken an undetermined toll in the life of pumping equipment. In the hydraulic unit, this condition becomes an even more serious factor because of the excessive speeds which can be attained by the pump plunger before it hits solid fluid in the pump chamber. The suppliers of hydraulic units have taken various approaches to this problem, based on the characteristics of their unit design. For example, in the double acting unit, maximum piston velocity is limited by a governing effect built into the engine's hydraulic circuit, while one of the single acting pumps uses a selectively sized restriction in the hydraulic circuit which limits downstroke velocity, but which does not affect power consumption on the pumping stroke.

In the single acting balanced design, the manufacturer has overcome this problem by practically eliminating its cause: the unfilled pumping chamber. This elimination is accomplished by "flooding", with spent power oil at the end of each suction stroke, the unfilled portion of the pumping chamber. Except in extreme cases of poor pump filling--less than 50 per cent--the plunger immediately upon starting the discharge stroke, contacts solid fluid and the effects of serious fluid pound are thus avoided.

Additional advantages also accompany this design. The fluid in contact with the high pressure side of the plunger is always clean exhaust power oil which provides clean lubrication for the plunger and prevents abrasives in the produced fluid from entering the seal area between the plunger and barrel. The service life of these two parts is thus extended. This "flood valve" arrangement also prevents gas-lock and improves low efficiency caused by free gas in the pumping chamber. As the dead power oil enters the pumping chamber it absorbs a portion, if not all, of the free gas present. Furthermore, pump valve action at each stroke reversal is improved and over-all efficiency of the pump is increased.

Once the basic design concepts of the production unit were soundly established, development time could be devoted to metallurgical improvements to extend the service life of the component parts. Great strides have already been made in this direction. The selection of special materials, surface finishing, and heat treatment all combine to provide outstanding wear and corrosion resistance for adverse operating conditions. Again to illustrate, a couple of examples can be reviewed.

The pump barrel in any submerged pump is exposed to a combination of wear and impact loading which calls for an exacting range of physical characteristics in the barrel material. To combat wear, an extremely hard inside surface is required; to withstand severe and repetitive loading, a tough ductile material would be specified. But hard materials are normally brittle--they shatter on impact--and tough ductile materials are soft--they won't resist abrasion. In searching for the solution to this problem for rod pump barrels, one manufacturer perfected a heat treating process, unique in the industry, which forms a hard case on the inside of the barrel--in the 58 Rockwell C range--and at the same time produces a tough, ductile core of about 20 Rockwell C extending from the base of the hard case through to the outside of the tube. Rod pump barrels given this treatment have consistently turned in unexcelled performance. Too, this same heat treat process is applied to the pump barrels and engine cylinders used in this supplier's hydraulic production units with equal success.

Another design improvement, developed specifically for the hydraulic unit, is of particular interest in this discussion in relating advancements in hydraulics to those made in rod pump equipment. Valve cage design for ball and seat type valves used in submersible pumps presents a metallurgical problem similar to that just described for the barrel tube. Resistance to abrasive and impact wear in combination with load carrying capacity is a pre-requisite for the cage. But because of the fluid passages which must be provided together with the ball guide, controlled inside and outside heat treatment is difficult, if not impossible, to achieve. For years a compromise has been made in cage design to meet these peculiar requirements. However, in approaching this problem as it applied to the hydraulic unit, the designers developed an insert guided cage in which the elements requiring wear resistance were separated from the load carrying elements in such a way that optimum physical characteristics could be provided for each. This design has been so successful in the hydraulic unit that it has now been carried over to its designer's line of rod drawn pumps.

Production Unit Capacity

The range of capacities of hydraulic production units, both in displacement and lifting depth, has been expanded considerably through developments made in recent years. Many combinations of engine and pump bores are offered by the various suppliers to meet the requirements of widely different production rate and depth conditions. A tabulation of these combinations which fill the needs of the so-called general range of capacity requirements would be quite lengthy, and is therefore omitted. However, each supplier publishes data on his units, and this data can be obtained for further study.

Two suppliers have developed lines of high volume production units which are significant to this discussion because they have appreciably extended the range of application of hydraulic pumping. These units fall into two categories of high volume pumping requirements, that is medium depth production with normal power requirements and deeper production requiring maximum down hole horsepower. The capacities of these units are tabulated in Figure 1.

One supplier, taking advantage of his double acting design, offers a tandem pump end assembly consisting of one engine piston powering two pump plunger assemblies. The capacities of these units for various tubing sizes are tabulated under "Medium Depth" in Figure 1.

Nominal	Medium Depth			Maximum Depth		
Tubing Size	Displ. B/D	Max. Depth	Hyd. H.P. *	Displ. B/D	Max. Depth	Hyd. H.P. *
1-3/4"	-	-	-	260	10,000	18
2"	600	5000	20	500	10,000	35
2-1/2"	1000	5000	36	825	10,000	56
3"	1800	5000	62	1350	10,000	92
4"	3750	5000	130	-	-	-

* Based on 4000 P.S.I. operating pressure at maximum displacement.

Figure 1 High Volume Production Units

This arrangement provides two times the displacement capacity of this supplier's single pump end units, offering capacities of at least 50 per cent higher than do units in the general range class having a similar depth rating. Because no increased horsepower is provided in this tandem pump-single engine arrangement, these units are limited in relation to the depth from which fluid can be lifted within designed power oil pressure limits. However, for medium depth production, they offer maximum displacement capacities.

The manufacturer of the single acting balanced design unit has utilized the features unique to this design to provide a high volume unit in which both rated displacement and horsepower have been increased. These units provide capacities from 25 to 75 per cent higher than do general range units rated for 10,000 ft lifts. Their capacities are listed in Figure 1 under "Maximum Depth." This development has extended the range of application of the hydraulic free pump to high volume deep production.

We might point out that it is in this application range that the economics most heavily favor subsurface hydraulic pumping. For example, a rod drawn pumping installation having a designed displacement capacity of 825 B D in 2-1/2 in. tubing, lifting from 8000 ft, would require an API size 912 Pumping Unit, would stress the rod string well beyond recommended limits, and would consume nearly three times the power needed for hydraulic equipment of equivalent capacity. The cost of this size pumping unit alone exceeds the cost of the hydraulic equipment, including the production unit, subsurface accessories, surface controls, triplex power pump, and prime mover. Knowledge of operating expenses will quickly confirm the economies offered by the subsurface hydraulic free pump in high volume deep production.

Subsurface Accessories

Aside from the advancements which have been made in production unit design, outstanding progress has been made in developing the accessory subsurface equipment for special applications of hydraulic pumping. Because of the unusual equipment requirements peculiar to the free pump system, the greatest efforts have been directed to this area. The resulting advancements have contributed to both the flexibility and economy of this system.

Perhaps the most significant of these advancements was the development of equipment to permit independent landing of two or more parallel tubing strings in the hydraulic pumping installation. The parallel free pump installation frequently offers the most efficient hydraulic operation because of its capability to produce free gas up the casing annulus; however, prior to the development of independently landed parallel strings, this arrangement had the drawback of time-consuming simultaneous running of clamped strings. The independent landing technique had been applied extensively by packer manufacturers and by rod pump designers in their dual zone pumping installations, but had not been developed for hydraulic applications. The knowledge gained by one pump manufacturer in developing dual zone rod pump tools was translated to the problems of the parallel string hydraulic application to overcome the major drawback to this otherwise desirable hook-up. Figure 2 illustrates the subsurface arrangement of the parallel string landing spear as seated in the landing collar on the main tubing string. This independent landing development also opened the way for a whole variety of parallel string installations which have greatly broadened the range of application of hydraulics. Some of these will be reviewed later under advancements in application.

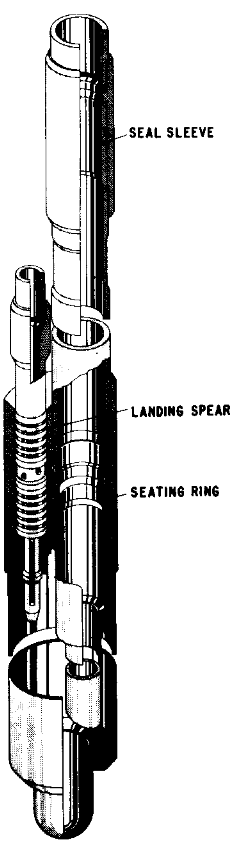

Figure 2 Independently Landed Parallel String Free Pump Cavity

ADVANCEMENTS IN SURFACE EQUIPMENT

As was pointed out previously, the principal development efforts of hydraulic equipment manufacturers have generally been directed to the subsurface components. Until recently, very limited design time had been devoted to improvements on the surface equipment required for the system, and for this reason, advancements in this area failed to keep pace with the developments on subsurface components. The control equipment available consisted largely of standard high pressure valves and fittings adapted to this special application. Available was only one triplex power pump which had been specifically designed for power oil service; others used were generally water flood pumps equipped to develop the high discharge pressures required. However, within the last few years, one hydraulic equipment supplier has initiated a major development program on surface equipment, and the program has already produced outstanding advancements in this area. These advancements have undoubtedly stirred new interest in surface equipment design, and this interest will induce still further progress. Our comments here will be limited to the equipment now being marketed.

Central Power Control

One of the basic advantages offered by the hydraulic pumping system is found in the convenience and economics of centrally controlled operation of several wells. Individual control of each well in the system is provided in a central manifold consisting of the necessary valving to control the flow-rate and distribution of power oil to each well. Metering equipment is also generally included in the manifold to permit measuring the power oil flow to each well. Manifolds for this purpose have for years been constructed by welding high pressure screwed body valves into an assembly suitable to perform these functions. Although functionally acceptable, manifolds of this construction require design compromises which affect operating ease, flexibility and--most importantly--safety. It was the safety requirements established for this manifold which had predominant influence on the design of the recently developed central power control illustrated in Figure 3. The designer's fundamental objective was to provide maximum protection against hazardous leakage of high pressure power oil. In addition, simplified operation of the control and improved installation flexibility were called for. This manifold meets all these three requirements through the use of specially designed multiple valve housings and a "building block" type of assembly which incorporates face type, O ring

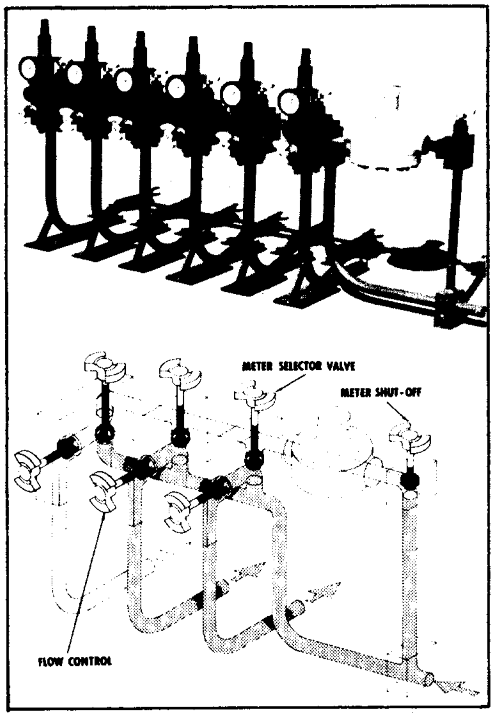

Figure 3   Single Meter Central Power Control

sealed, flanged connections throughout. The combination of positive seal, flanged connections in a compact, low profile assembly are a major contribution to the safety aspect of this equipment, while the clean-cut design of flow passages and valve placement, as illustrated in the schematic flow diagram in Figure 3, greatly facilitates operation of the control. And the "building block" construction gives the assembly a high degree of flexibility and assures easy installation. Manifolds of this design are available for both selective and continuous power oil measurement and can be equipped with either uncalibrated adjustable flow controls or calibrated, pressure compensated constant flow controls. Accessories such as soluble plug injectors and by-pass controls are offered as optional equipment for initial installation or later modification to the manifold.

An important development which has accompanied the introduction of this newly designed manifold offers further economies for the hydraulic system. This development is related to the method of power oil measurement which is used. Common are two alternates: (1) continuous measurement, providing a meter for each well in the system and (2) selective measurement, requiring only one meter which is used to meter selectively the flow to each well in the system. The latter method obviously reduces initial cost of the manifold, but was previously objectionable because of the rather complicated switching required to put each well "on the meter." As the flow diagram in Figure 3 illustrates, switching a well to the meter in this new manifold requires adjustment of only the double seated meter selector valve; and where continuous measurement of power oil flow to each well is not required, the economies of the single meter manifold can now be realized without the operating inconvenience previously associated with this arrangement.

Free Pump Well Controls

In any free pump installation, in which the high pressure power oil system is also used to circulate the production unit to the surface, controls at the well are required to direct power oil and production through the proper downhole circuits during the operating and pump-out cycles. A latching device is also needed to catch the production unit when it is circulated to the surface; and a safety relief is desirable to protect the production string or casing from excessive pressure during pump-out. While all these requirements can be fabricated into the wellhead assembly, greatest economy and convenience is achieved by using a specially designed Wellhead Control. In developing the new control illustrated in Figure 4, the designers again placed great emphasis on maximum safety, both in the installation

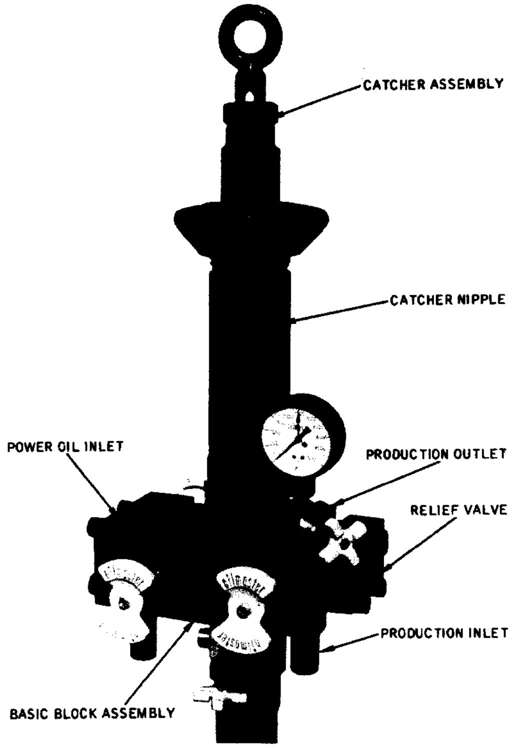

Figure 4   Free Pump Wellhead Control

and operation of the control. And by using the "building block" design concept, they have provided considerable flexibility in the selection of optional accessories to meet the needs of varied operating practices.

This Wellhead Control contributes several advancements to the free pump installation, but perhaps the most significant are those which permit unattended pump-out operations. With the control valves set to circulate the unit to the surface, the control provides automatically reset pressure relief protection, securely latches the surfaced unit, and then safely by-passes the circulating fluid. With these operating features, the pumper is free to return, at his convenience, to the well to remove the surfaced unit. Other design improvements which contribute to the safety of the retrieving operation include an externally released catcher assembly to give complete control of the overshot type slips which latch the unit, and an automatic bleed for any gas pressure which may build up behind the pump-out swab cups on the surfaced free pump.

Another recent development in surface controls for the free pump is a Remote Well Control in which, to provide greater flexibility in installation, the control valves are physically separated from the wellhead assembly. This arrangement is essential on parallel string dual zone installations having close spacing between the two tubing strings. All the safety features described above are also available in these remote controls.

Triplex Power Pump

In the hydraulic pumping system, the triplex power pump can be pictured as the prime mover, or primary power source, for the system. It converts the mechanical power into hydraulic power used to operate the submerged production units. Advancements in triplex design, then, which improve dependability, convenience and economy, are important to the entire system. The service requirements placed on a power oil triplex are probably even more demanding, from the standpoint of uninterrupted operation, than are those placed on water flood pumps. The power end of the unit must be of a rugged design which will stand up under heavily loaded continuous operation. The fluid end construction must provide the same dependability, and must also be arranged to permit easy routine maintenance as well as quick change-out of plunger size as required by the hydraulic operations. And, a full range of plunger sizes must be offered to closely match displacement volume and discharge pressure, within the power rating of the pump, to the requirements of the hydraulic system. These requisites indicate the limitations which arise in simply applying water flood pumps to power oil service.

One leading triplex manufacturer has overcome these limitations, but at the same time has retained a high degree of flexibility; he developed power oil pump packages which are built around the power ends of their standard line triplex pumps. Specially designed fluid ends provide a range of displacement-pressure combinations closely keyed to hydraulic system requirements; and quick change plunger connections facilitate maintenance and plunger size changes. Auxiliary equipment which is desirable for power oil installations is integrally mounted with the triplex. And for minimum field installation expense, the whole package is assembled on a heavy steel skid. Figure 5 illustrates one of these triplex packages which are offered in a wide range of input horsepower capacities to assure economical matching of installed triplex horsepower to varied system requirements. The development of these triplex packages, tailored for power oil service, is an excellent illustrating of the progress being made in improving the over-all hydraulic pumping system.

Power Oil Cleaning Equipment

A discussion of advancements in hydraulic pumping would be incomplete without mention of power oil cleaning equipment and its use. The most noteworthy progress with this part of the system has undoubtedly been made by the operator of hydraulics. That investment in adequate cleaning facilities will pay off many times over in savings on production unit repair and related downtime is now generally accepted, and this major step will, in itself, promote further progress in development of improved cleaning equipment. This is the old law which states that progress is directly proportional to demand.

ADVANCEMENTS IN APPLICATION

Throughout this discussion, there have been illustrated advancements in equipment design which, among other benefits, have extended the range of application of hydraulic pumping. Advancements in application are the obvious ultimate goal of all developments which have been described to this point. Now, on the assumption that the "proof's in the puddin", look should be had at the end results of these and other developments.

Conventional Installations

The conventional hydraulic installation, in which the production unit is run-in on macaroni tubing, offers many advantages over other pumping methods and lacks only the pump-out retrieving feature of the free pump hydraulic installation. The many unit design improvements which have contributed to highly dependable operation of the production unit serve to minimize the less desirable aspects of this arrangement. In many cases, a combination of minimum casing size and tough pumping conditions restricts the efficient operation of a free pump, but poses no serious problems for the conventional installation. For instance, in slim hole or tubingless completions, a relatively large capacity hydraulic unit can be run conventionally on a concentric macaroni string and as a casing pump if gas production is low, or as an insert pump if an annulus for gas venting is required.

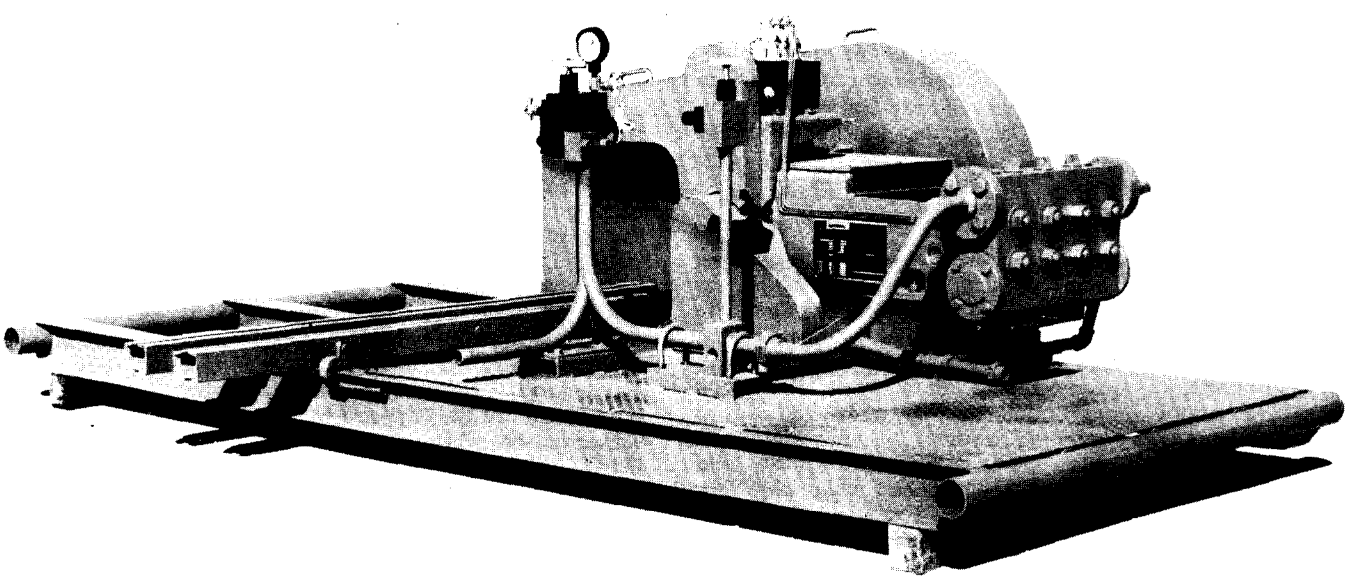

Figure 5 Power Oil Triplex Pump Package

Adaptations of this type of installation to meet unusual conditions further enhance its use. An example of this is the reverse-flow conventional installation illustrated in Figure 6. In this arrangement, a specially jacketed

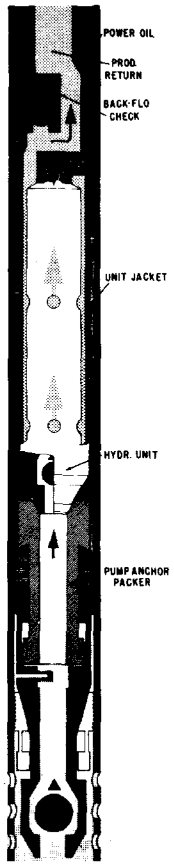

Figure 6 Reverse Flow Conventional Installation

production unit is run as a casing pump in 2-7/8 in. O D casing. To eliminate the hazards often attributed to a casing pump installation, the normal circulation is reversed; power oil is pumped down the annulus; and production and exhaust power oil are brought up the macaroni tubing. In this way the casing is protected from corrosive attack or deposition of solids from the produced fluid, and is exposed only to the clean power oil. Injection of inhibitors in the power oil can give positive protection to the casing string, and paraffin build-up in the macaroni string can be controlled by periodically circulating soluble plugs down this tubing.

Free Pump Installations

The hydraulic free pump obviously offers outstanding advantages over all other pumping methods. It, of course, is not free of all limitations, but advancements in application techniques are steadily reducing these limits. For instance, the development, as described earlier, of equipment for independently landed parallel strings made a major contribution to this end. The initial application of this equipment improved the installation of the highly efficient parallel free hydraulic system. But the limits of this system are reached when high flow rates through the relatively small diameter parallel string cause excessive friction losses which in turn raise operating pressures above acceptable levels. The casing free installation overcomes this limit, because return fluid is brought up the casing annulus with minimum pressure loss. However, with the combination of low bottom hole pressure and relatively high GOR, the efficiency of a casing pump may become so low that its fluid displacement capacity fails to meet the pumping requirement. Figure 7 illustrates an arrangement of subsurface equipment which now provides a solution to this limit. This solution is a casing free gas vent installation, which retains the maximum displacement capacities and minimum fluid friction loss characteristics of the casing pump, but which provides improved efficiency in gassy production by releasing free produced gas through an independently landed gas vent string.

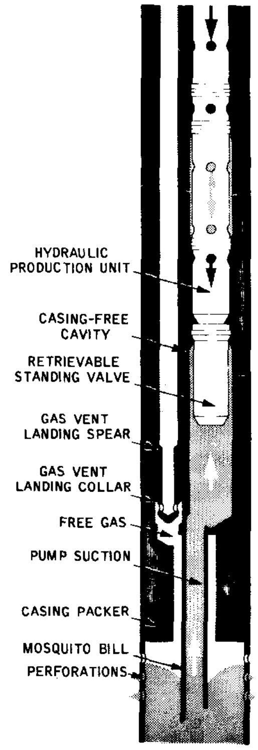

Figure 7 Gas Vent Casing Free Installation

Dual Zone Installations

The economics of the dual zone completion are now universally acknowledged. Completion techniques and related equipment continue to be improved and this improvement results in an increasing number of dually completed wells and a bigger demand for artificial lifting equipment for this application. The hydraulic pumping system has been found to be particularly well suited to dual zone production because of its high degree of flexibility in the arrangement of equipment, both on the surface and in the well bore, and because of the ready achievement of independent control of the two pumps. And with only a slight modification to the flowing well Christmas tree to accommodate suspension of the macaroni tubing, hydraulic production units can be run conventionally in a parallel string dual zone well. Furthermore, all other surface equipment can be placed free of any limits imposed by the closely spaced parallel strings; and where gas venting is required for both zones, two insert conventional units can be used, with a third parallel string run as a gas vent for the lower zone.

The advantages of the free-pump system are equally adaptable to dual zone production, within the limits posed by adequate internal casing clearance to accommodate the multiple tubing strings required. Two alternate arrangements of dual zone free pumps illustrate the flexibility of this system even with the restrictions of

5-1/2 in. casing. A tandem dual zone installation is illustrated in Figure 8, which uses one string of 2-3/8 in. O D and two strings of 1.315 in. O D tubing in 5-1/2 in casing. Two hydraulic production units are physically connected into a tandem assembly to facilitate running and retrieving, but they are entirely separated in their hydraulic circuits. This arrangement provides completely independent operation and control of the two units and is a highly desirable feature for dual zone pumping equipment. The tandem assembly can be surfaced for inspection and repair simply by reversing power oil flow; and each unit in the tandem assembly

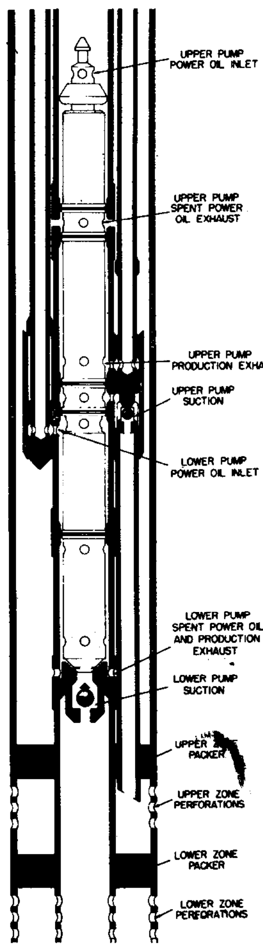

Figure 8 Tandem Dual Zone Installation

can provide rated displacement capacities up to 400 BPD for depths to the 10,000 ft range. At the 1961 Short Course complete installation details of this system were described by Bob G. Murphy of Cities Service Petroleum Company, in his paper entitled, "Installation and Operation of Free Type Tandem Dual Zone Hydraulic Pumps."

In a parallel dual zone installation, illustrated in Figure 9, hydraulic production units are run in separate parallel tubing strings. This arrangement makes it possible to retrieve separately each unit and also to provide independent operation and control of the pump for each zone. In 5-1/2 in. casing, two strings of 2-1/16 in. O D and one string of 1.315 in. O D tubing will accommodate this system. Free pump production units to operate in 2-1/16 in. O D tubing have a rated displacement of 268 BPD for 10,000 ft maximum depth or 192 BPD for greater depths.

These present a few of the variations which have

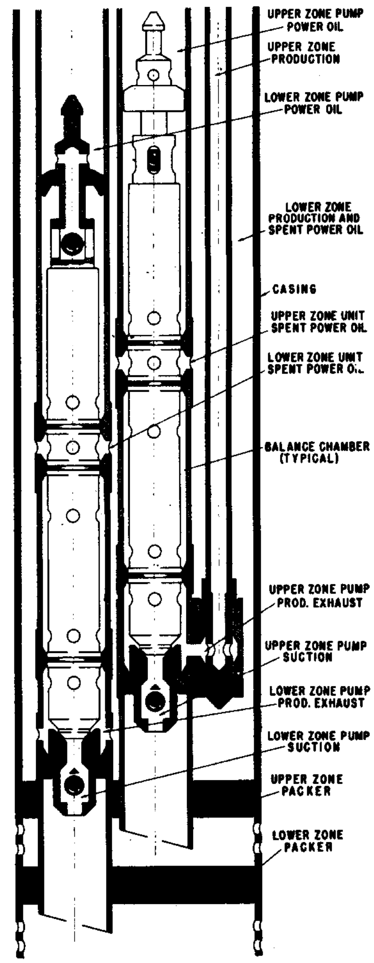

Figure 9 Parallel Dual Zone Installation

contributed to advancements in the application of hydraulic pumping systems. Many others are available or can be made with only slight modifications to existing equipment. For example, combinations of conventional and free pump hydraulic units have been adapted for triple zone wells. It appears that advancements in application will be limited only by the ingenuity of the operators and suppliers in adapting equipment to the requirements.

SUMMARY

This has been a review of the advancements in hydraulic pumping which have developed this system to its present state of relative maturity. We have stated that the progress which has developed the art to this point is the very thing which will expand it further. Future advancements will be determined by the imagination of the users and suppliers who will benefit by further progress--the same imaginative efforts which have fostered the advancements we have covered.

Consideration of possible future advancements opens our thoughts to extremely interesting possibilities. A remotely controlled, completely automated hydraulic pumping system, for instance, is not beyond reason. Although such a system has not as yet been fully developed, the hydraulic equipment now being built would form a very sound basis for its development. Consider the safety features which are built into the hydraulic system for unattended operation. Malfunction of any element in the system is offset by a fail-safe device which protects the equipment against serious damage. Too, equipment for monitoring the operating status and performance of the system at a remote control point is now available; and remote operation of the production units--both speed adjustment and start-stop control--can be easily accomplished with devices now in use. This type of remote adjustment becomes practical since the hydraulic system provides a self-compensating operation under varying well conditions or operating speeds. In a free pump system, the automation could be carried to the extent of automatic surfacing of the production unit when its output reaches an unacceptable performance level. The unit would be safely latched in the wellhead until the pumper or service crew arrived on location to run a replacement.

The advancements which have been made in subsurface hydraulic pumping since its introduction typify the aggressive approach being taken by suppliers and users of this equipment. We are confident that future progress will be equally as rewarding to our industry as past advancements have been.