Non-Counterbalanced Hydraulic Pumping Units—A Progress Report

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INTRODUCTION

The history of hydraulics is a fascinating story dating back to about 1650, when Paschal discovered the fundamental laws of physics upon which all modern hydraulic equipment is based. About 1795, Joseph Bramah developed the first hydraulically operated press using water for power transmission.

Since then many changes have been made, so that today there is scarcely a product which does not utilize hydraulics at some phase in its production.

Why is this true? Many other means are available for power transmission. Hydraulic power is unique in the ease with which it may be controlled. The amount of force is almost unlimited and any practical stroke length is available.

Other basic advantages are:

1. Simplicity of design
2. Extreme flexibility of location with respect to actuated parts
3. Systems can be made completely automatic
4. Simplicity of speed control
5. Wide variety of speeds and forces
6. Reduction of wear on moving parts by:
   a. Controlled acceleration and deceleration
   b. Automatic protection against overload
   c. Absence of vibration
   d. Automatic lubrication
7. Efficient and economical to operate

Since these advantages of hydraulic systems in general fit so well the requirements for oil field pumping, it is not surprising to find hydraulics in use to actuate the sucker rod string.

Early applications of hydraulic units were for deep, high volume wells. A number of good units are available to do this job. More recent use has been made of hydraulics to produce shallow, medium and deep wells in the stripper class with simple noncounterbalanced hydraulic units. It is with these units that this paper will be concerned.

CONTRAST OF HYDRAULIC CYCLE WITH BEAM CYCLE

To better understand the hydraulic principle a contrast of hydraulic cycle with beam cycle is necessary.

The stroke cycle of the beam unit can best be described by an analysis of the mechanics of it. First, rotary motion is taken from a prime mover, transmitted through belts to a shaft which operates a gear which turns a crank which actuates a pitman. This causes the beam to be activated in reciprocating motion and actuates the rod string. In converting the rotary motion of the crank to the reciprocating motion of the beam, the vertical velocity in each direction accelerates from zero to maximum and decelerates to zero.

With the hydraulic unit, rotary motion of the pump moves oil through piping and valves to a cylinder which actuates the rod string. The upstroke and downstroke velocities are independent, but constant during each half cycle. Generally the upstroke is at a slow uniform rate and the downstroke at a faster uniform rate.

The basic design of the machine is very important.

The pumping circuit, as illustrated in Fig. 1, is very simple. The hydraulic pump draws oil from a reservoir and forces it into the bottom of a hydraulic cylinder, causing a piston coupled to the well polished rod to travel upward at a constant rate. When the piston nears the top of the stroke, it passes a port and sends pressure to a three way valve between the pump and cylinder. This valve changes position, causing the pump flow to bypass to the reservoir and bleeding the oil out of the cylinder at a controlled rate to allow the well rod load to return the piston to the bottom of the stroke. When the piston nears the bottom of the stroke, it passes another port and sends a reverse signal to the three way valve. This now returns to the first position and starts the next stroke.

Control valves are generally available to control the downstroke time and adjust the speed of the reversal.

Types of Mounts

There are several ways of attaching the cylinder to the well. The most common types are:

1. Production Tee Mount — This is the simplest mounting possible since the base of the unit is provided with male threads which screw into the pumping tee. Since alignment of the cylinder depends upon the tee, a quality tee is recommended. The tee should also be of adequate strength to support the well loads to be encountered. This type of mount is available with a cylinder mounted directly on the tee using a common polished rod. Another unit is available with the cylinder on a pedestal mounted on the tee with a separate polished rod for the well. Use of the latter prevents contamination of the hydraulic oil by entrance of well fluids into the cylinder; this takes place whenever the polished rod contacts the well fluid, then is introducted into the hydraulic circuit.

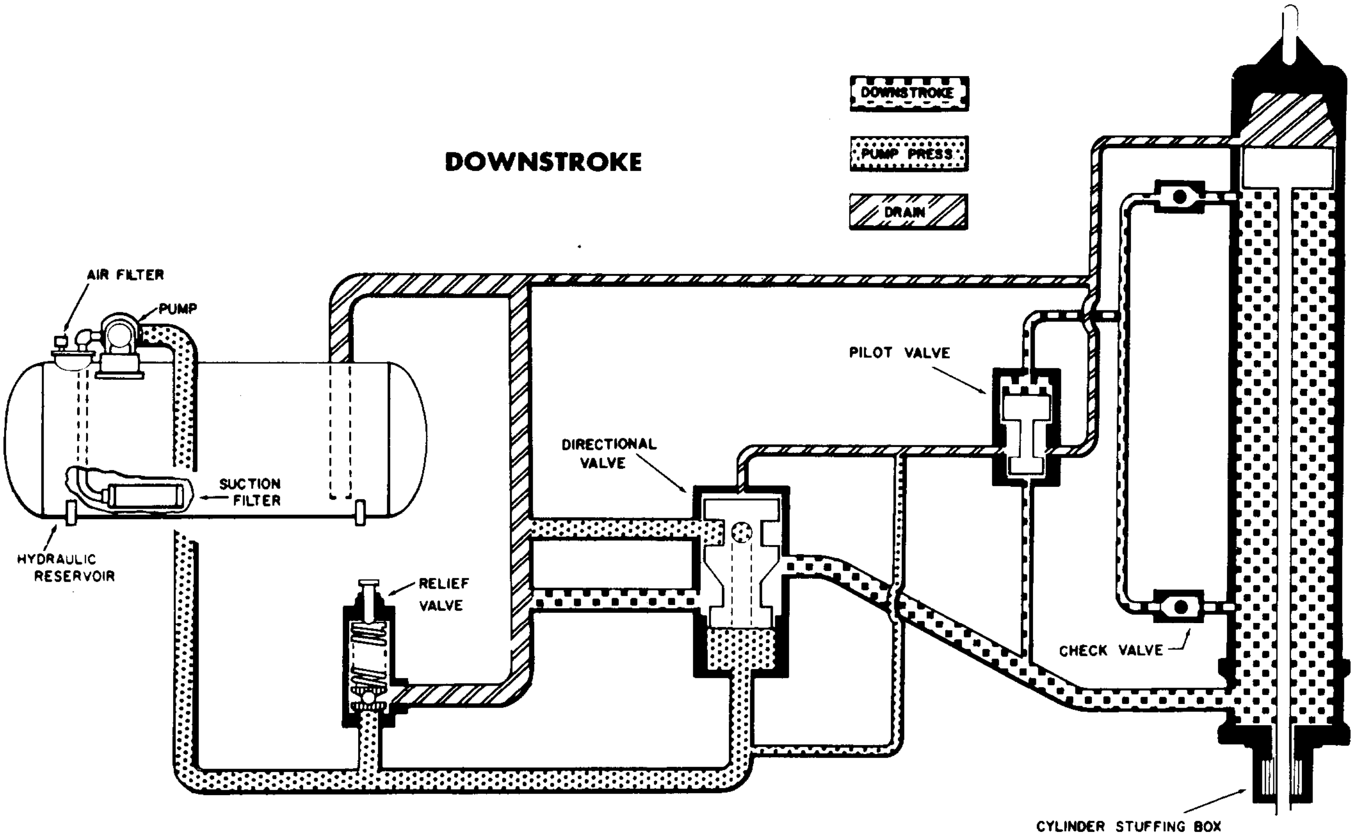
2. Flange Mount — This type of mount is generally used on heavier wells where well loads are carried on the surface pipe or casing flange. In screw type heads, an adapting flange is used. Generally, a pedestal mount is used which provides a separate polished rod for the cylinder and well.

3. Skid Base — In this type installation a foundation is generally required, but the well may be serviced simply bv skidding the unit back from the well.

Piping must be of adequate size to handle the desired volume without approaching turbulent flow. It is also required to safely handle the pressures encountered with a safety factor. Extra heavy pipe is suitable.

Tubing for best design should be 1010 fully annealed steel. Seamless copper tubing is sometimes used, but the trend is toward steel.

Flexible hose used should be adequate to handle the



FLOW DIAGRAM

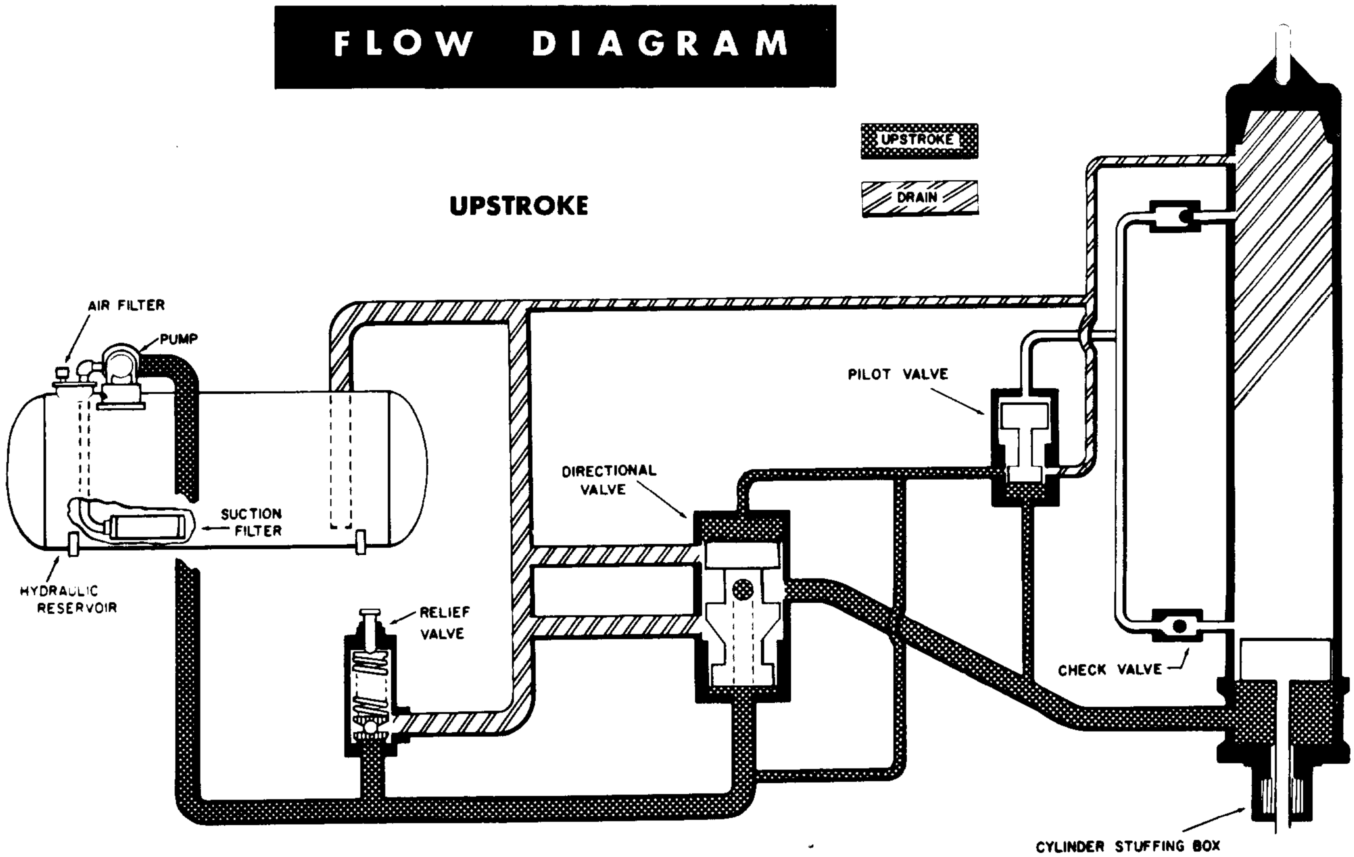


Fig. 1

pressures and volumes encountered.

Size ranges of hydraulic pumping units are now almost unlimited. Stroke lengths are available from 2 feet to 12 feet.

Hydraulic Units Have Limitations

Hydraulic units have some limitations which must be recognized. Economics continues to be the most important factor in the selection of equipment. A profit must be made in order to remain in business. The economics of an hydraulic unit are based upon three considerations.

1. Initial cost must be competitive, but quite often a saving is possible with an hydraulic unit. The nearer the unit can be tailored to actual requirements, the better the economics will be.

2. Horsepower requirements are usually somewhat greater than for a counterbalanced unit. If the units are used on the proper applications, this can be minimized.

3. Maintenance costs for the surface unit is likely to be somewhat more for an hydraulic unit, but with proper preventive maintenance procedures this is a very small item. A survey made to classify the various causes of operating difficulties in hydraulic systems indicates that:

10% are due to improper diagnosis of trouble or lack of know-how in making repairs

10% are due to mechanical failures such as bearing failures, seal failures, etc.

5% are due to operation of units beyond recommended limits of speed, pressure, or volume

5% are due to miscellaneous unclassified causes

70% are due to improper condition of the hydraulic oil

This would indicate it is very easy to eliminate the cause of 70% of the trouble simply by selecting the proper oil and maintaining it properly.

Overall maintenance cost including pulling rods and tubing can be materially reduced by the use of an hydraulic unit.

The advantages of an hydraulic unit are many:

1. Reduced rod stress and longer rod life due to steady polished rod velocities, steady loads, and fewer reversals result from the long low stroke. These benefits are not only due to fewer reversals, as compared with short stroke pumping, but also to the difference in vibratory motions.

2. Decreased wear of the bottom hole pump and tubing is due to fewer work cycles with the longer strokes.

3. Gas locking tendencies are minimized by the higher compression ratio obtainable with the longer stroke.

4. It is possible to eliminate the overpumped condition or "fluid pound" by closely tailoring the pumping rate to the producing capacity of the well by slower pumping rates.

5. Constant flow from the formation into the well bore is approached more closely as the plunger upstroke occupies more of the stroke cycle time. This reduces the causes of sanded up pumps and stripping jobs.

6. Where low gravity and viscous fluids are produced the downstroke can be made in whatever time required with the upstroke occupying a fixed amount of time. The lower reversal is smooth and at the bottom of the stroke. On beam units it is quite common for the polished rod clamp to ride up off the carrier bar on the downstroke. The reversal takes place and the clamp and carrier bar meet with a bang. Frequent rod troubles result. This can be eliminated by use of an hydraulic unit.

WELLS PRODUCED ECONOMICALLY

Many wells of medium depth are being produced very economically with the hydraulic unit. A good example is a 7600 foot well with 2 inch tubing, 3/4 inch and 5/8 inch tapered rod string engineered for 54 B/D. It is powered with a multicylinder engine. The total installation cost only a little more than half that for a conventional unit.

Many slim hole completions are being produced by hydraulic units. Most of these utilize line pipe or 1 inch tubing in place of the sucker rod string. Principle advantages are lower cost, longer pump life, and less stress on the tubing due to long, slow strokes.

Another very interesting application for hydraulic units is on gas wells. Many wells still produce large volumes of gas, but lowering pressures have allowed the encroachment of water to the extent that production has been lost. Siphon strings have been partially effective, but due to exposure to atmospheric pressure, additional water is admitted to the reservoir as the water is siphoned off. In one case this has been stopped by lifting the water. Bottom hole pressures were allowed to build up enough to exclude additional water for the present.

A double example of profitable stripper applications is two 4300 foot wells. These were equipped with 6 foot hydraulic units with 5 H. P. electric motors approximately five years ago. The units have been trouble free and are giving good service today.

One of the latest specialized applications for these units is the dual completion unit. This unit was designed at the request of operators who were having problems with conventional units on dual completions where two strings of tubing and rods were used.

Two power pumps, two cylinders, and two separate circuits were used. All equipment was mounted on a single base which supported a quadriped stand upon which the lower cylinder was bolted. The upper cylinder utilized the regular pedestal, which was bolted to this same base with the polished rod of the upper cylinder offset to clear the lower cylinder.

Since the pumping rate for each zone is based on the pump speed, and two pumps with two prime movers are used, the most desirable pumping rate for each zone may be used. Crossover valves allow the operator to use the output from both pumps to power one circuit. This allows a maximum pumping rate for well testing.

Stroke lengths available are 4 foot, 6 foot and 10 foot in any combination. Triple completions may be produced in this manner.

Each of us has many examples of places where proper application of hydraulic units have saved money initially and continued to make money for the operator over long periods of time.