Deep Well Pumping Problems

By G. L. Porter
Humble Oil & Refining Co.
Midland, Texas

The problems of deep well pumping are many and varied. The troubles encountered not only vary from area to area, but from field to field in a given area, and even from well to well in a given field. The first problem of pumping a deep well is to design an installation that will produce either the desired amount of fluid, or the maximum amount of fluid, as the case might be. For a given size pump, the rod stress or hydraulic pressure increases with pump depth and the cost of lifting a barrel of fluid increases accordingly. We normally think of operating a sucker rod at a maximum stress of 30,000 pounds per square inch. The well is frequently equipped with 5 1/2-inch tubing and 1-inch rods. An 8200-foot string of 3/4-inch rods suspended in air will stress the top rod to 30,000 pounds per square inch. For the same stress, tapered strings of 7/8- and 3/4-inch, and 1, 7/8 and 3/4-inch can be about 10,000 and 11,000 feet in length, respectively. How is it then possible to pump wells deeper than 10,000 feet? The acceptable life of a rod depends not only on the maximum stress but also on the range of stress. We therefore permit an increase in the allowable stress, but reduce the stress range by using a smaller pump. Desired production is obtained by increasing the stroke length. Forgetting the design for the present, let us assume that we have a well equipped with a sucker rod pump and discuss some of the problems that may occur. The hydraulic long stroke pumping unit and the hydraulic pumping system will be discused later.

The problem of pumping a deep well with a sucker rod pump may be one of corrosion, formation of scale, paraffin, pump trouble, a crooked hole, insufficient production, or rod breaks. Rod failures occur in the body, the pin, and the coupling and for a different reason. Whatever the trouble, it must be corrected, and in such a way that the performance will be the best possible and the operating cost a minimum.

Several years ago the only method of combating corrosion in pumping wells was by the use of non-corrosive alloys. Sucker rods which are corrosion resisting are those which contain nickel and molybdenum, and sometimes chromium and copper. Monel resisted corrosion better than any other alloy but the cost prohibited its use except in cases of extreme corrosion. Monel sucker rods cost about 5 times as much as other rods. Some ten years ago, plastic coated rods and tubing were partially successful in combating corrosion. Today, the most economical method of alleviating corrosion is the use of inhibitors. Limited tests show that carbon maganese rods give better service in corrosive wells in which an inhibitor is used than nickel-molybdenum rods without the use of an inhibitor. Very little difference was noted in the service of carbon-manganese and nickel-molybdenum rods in inhibited wells. The cost of carbon-manganese rods is 13 to 20 cents per foot cheaper than the same sige of nickel molybdenum rod. The use of inhibitors will in many cases, permit the use of smaller rods, or a deeper pump setting with the same size rods, because the allowable stress can be increased.

Scale deposition can cause the pump to stick and create an expensive stripping job. The use of chemicals has been very beneficial in preventing the formation of scale.

There are several methods of removing paraffin. Electric heaters can be installed in the flow line, storage tanks, or in the tubing string. Soluble plugs or "rabbits" can be pumped through flow lines and in some cases down the tubing. Hollow sucker rods with a cross over check valve below the paraffin zone can be used for circulating hot oil through the rods and back through the tubing with the produced fluid. Solvents and inhibitors are very useful in certain areas. Portable steamers are used quite extensively. Mechanical scrapers attached to the sucker rods are used frequently but they may be a handicap to pumping a deep well because of the additional load imposed upon the rod string.

Pump troubles in a deep well are not too different from those in shallow wells. Some of the troubles encountered in pumping shallow wells are more severe than those encountered in pumping deep wells, but we do not recognize them as problems because the cost of a pump pulling job is relatively low. Servicing a deep well can cost as much as $1,000, so it becomes extremely important to correct the trouble and reduce the number of pulling jobs. The use of a dynamometer can be very helpful in solving pumping problems.

Several articles have been published on the selection and application of sucker rod pumps. Briefly, the pump for a deep well should have a metal plunger and should, if possible, be the rod type in order to keep the pulling cost at a minimum. If sand is not present, a pump with a bottom hold-down should be used. Since the seal between the pump and tubing is at the bottom of the pump, both the outside of the barrel and the inside of the barrel above the plunger is subjected to the same pressure and there is no tendency for the barrel to expand. The section of the barrel below the plunger is exposed only to the comparatively low bottom hole pressure of the well and a differential pressure is created across that portion of the barrel. This tends to reduce the clearance between the plunger and barrel and increase the efficiency of the pump.

If sand is present in a pumping well, there is less chance of a pump becoming stuck when the type with a top hold-down is used because the sand cannot settle in the space between the pump and tubing. The pump setting is limited because of the differential pressure across the barrel which may expand or even break the barrel. A pump with a bottom hold-down and a top seal can be used in a deep well making sand. The top seal permits the passage of fluid which eliminates the undersirable pressure across the barrel and traps the sand, thus preventing it from settling between the pump and tubing. Sand can, however, settle on top of the plunger when the pump is stopped.

The traveling barrel type of pump can be used in sandy wells and at all depths. The movement of the barrel tends to keep the sand washed out of the space between the pump and tubing and the traveling valve acts as a check to keep the sand from settling on top of the plunger.

If a scaling problem occurs, a pump with extension nipples on each end should be used, and the plunger so spaced that it passes through the barrel on each stroke.

A pump for a gaseous well should have the highest possible compression ratio. This can be done by selecting the proper type of pump and by using the smallest bore pump and the longest stroke length that will obtain the desired displacement. The use of a tubing anchor will increase the compression ratio because the effective plunger travel is increased. The anchor should have the maximum passage area for the gas to go through. The pump should also permit very close valve spacing and be of the stationary barrel type so the maximum size standing valve can be installed. It is good practice to use a gas anchor assuming, of course, that there is no packer in the well and that the casing pressure is held to a minimum. The type most used is one in which the perforated nipple is just below the pump seating shoe, a mud anchor below the nipple, and a gas anchor pipe that extends from the pump to a point several feet below the perforations.

A special type pump that will break a gas lock has recently become available. The pump has three valves and two chambers so arranged that compression occurs on both the up-stroke and down-stroke. The valve arrangement assures that whatever fluid is in the pump will be displaced.

If a particular type of trouble develops, a careful analysis must be made. When the solution is not readily apparent, then one must experiment.

For example, trouble with stainless steel pump valves in a particular field caused 50 percent of the pulling jobs. The operator began exhaustive tests of pump balls and seats made of various metals. The study resulted in doubling the life of pump valves and in this case reduced the pulling jobs 25 percent.

The troubles caused by crooked holes are additional rod stress, wear of the tubing and casing, and rod coupling wear. The rod stress can be reduced by the use of a rod weight compensator which will be discussed in more detail later. There is no way to eliminate the wear on the inside of the tubing or rod couplings but the wear can be distributed evenly by rotating both the rods and the tubing. Wear on the casing and the outside of the tubing can be prevented by anchoring the tubing.

If the problem is to increase production, the first thing to do is to be absolutely sure that the well is capable of more production. A large percentage of rod and pump jobs result from attempting to pump more fluid than a well will produce. A recent check in one area indicated that 80 percent of the pumps pulled were from wells making less than 40 barrels of fluid per day. It was also found that quite often the pumps were being pulled prematurely.

The easiest way to increase production is to increase the length of the stroke and/or the strokes per minute. Let us assume, though, that we are already operating the equipment at its maximum stroke length and that the maximum rod stress is the most practical value for the existing conditions. Pump displacement still may be increased in several ways. The permissible rod load may be increased by using a better grade of rod, by using high tensile rods, by using a rod weight compensator, and in a corrosive well, by using an inhibitor. Increasing the allowable rod load will permit a faster pumping speed and/or a larger pump. Anchoring the tubing will increase the effective plunger travel by eliminating the tubing stretch and thus increase pump displacement.

Rods break in three places: the body, the pin and the coupling. Breaks in the body of a rod are nearly always caused by fatigue. Occasionally a failure will occur because of material defects or poor workmanship. Rod breaks resulting from fatigue depend upon the maximum stress, the stress range, the number of reversals, and the medium in which the rods are used. Things to check are whether the correct size and type of rod is being used, whether the pump size, pumping speed, or stroke length can be reduced, whether the pumping speed is synchronous, whether or not an inhibitor is being used.

Rod coupling breaks are relatively few, and they can nearly always be attributed to hammering or wear because of a crooked hole.

Pin breaks seldom occur in a properly made-up joint. The threads should be clean and a thread lubricant should be used. The rod in the derrick should hang straight to avoid cross threading or galling of the threads. The joint must be properly shouldered and with a torque sufficient to stress the pin above the maximum load to be applied. If the pin shoulder does not remain in contact with the coupling face, the pin is subjected to stress reversals which causes the metal to fatigue and the pin breaks. Usually, no difficulty is experienced in making up 5/8 and 3/4-inch rods with the ordinary impact wrenches, however, the required torque of 500 to 800 foot-pounds for 7/8 and 1-inch rods, respectively, is hard to obtain. This is proven by the fact that pin breaks occur much more frequently in the larger rods. Power rod wrenches are therefore recommended for the use with rods larger than 3/4-inch. Rods should be hung whenever possible. The threads will be kept cleaner, and, if they can be pulled in doubles or triples there will be less joints to make and break and less chance of trouble. Rod elevators should be in good condition and they should rest on a level survace. The weight of a long string of rods can easily kink a rod at the base of an uneven elevator.

Long stroke hydraulic pumping units properly adjusted and correctly counterbalanced will give excellent performance on wells that do not pump off or on wells where trouble with gas is not encountered. If a well pumps off, or if the pump gas locks, operation may become erratic. The unit should be regularly checked for counterbalance, oil level in the balance tank, level of make-up oil in the sump tank, oil leaks in the hydraulic system, particularly at the main pump and at the polished rod packing gland. The filters should be changed occasionally—the length of time between changes will very according to the operating conditions. Some fluid should be drained from the bottom of the sump tank as often as necessary to prevent an accumulation of water. If the oil in the hydraulic system becomes contaminated, it becomes necessary to drain the system and refill with new fluid. The mechanical seals on the main pump, and the scavenger pump itself, cause the majority of the mechanical failures.

Reference has been made to the use of tubing anchors and the rod weight compensator. It is felt that these items should be discussed in more detail.

Tubing anchors can do only one thing—eliminate tubing stretch. What is to be gained by this? Unanchored tubing moves up and down as the fluid load is alternately transferred to the rods and tubing, and the effective plunger travel is reduced by the distance that the tubing moves. Anchoring the tubing increases the effective plunger travel by the amount of tubing stretch. The increase in plunger travel can be used to increase the production or reduce the pumping time. A reduction of pumping time will rsult in less wear on the pumping equipment and lower power cost if an electric motor is being used. Calculations show that production can be increased about 10 percent by anchoring the tubing. Production from one well, equipped with a 2-1/4-inch pump set at 3850 feet and operated at a speed of twenty 74-inch strokes per minute, was increased from 500 to 700 barrels per day, or about 40 percent.

There are three types of tubing anchors, tenison, compression and hydraulic. The tension type has slips with teeth either straight or pointed up, and it is istalled by first releasing the slips and then raising the tubing to obtain the desired tension which should be in excess of the fluid load. The advantage of the tension type is that it can be installed at the end of the tubing and the entire string placed in tension, thus assuring that the tubing is straight as possible. The disadvantage of the tension type is that the slips must retract before the anchor can be pulled. Some anchors have a shear mechanism designed to release the slips if the normal operation fails to release them. The anchor should not be set too close to bottom if the tubing must be lowered to release the slips. If there is any "fill-up" it may not be possible to lower the tubing enough to release the anchor.

The compression type of tubing anchor has slips with the teeth pointed down and it is installed by releasing the slips and then lowering the tubing. The advantage of this type anchor is that there is less chance of getting it stuck; particularly, if it is the kind that requires only an upward pull to release the slips. It may be possible to pull the anchor even though the slips do not fully retract. The anchor should be installed with enough tubing below it to offset the fluid load, plus the force required to unseat the pump, plus an allowance for friction, otherwise the anchor will move up the hole and tend to put the tubing in compression. Care must be taken in setting the anchor to prevent the tubing from being in compression when it is landed. It is possible to "corkscrew" the tubing and impose undue loading on the rods.

There are two types of hydraulic tubing anchors: those with pistons that push against the casing, and those with pistons that push against slips which are moved outward to contact the casing. The force is provided by the weight of the fluid in the tubing which varies in wells with high gas-oil ratios or wells that flow after being agitated. The force may vary enough to permit the anchor to move. Movement causes wear and the type without slips can become locked. Setting the anchor up the hole will partially offset its tendency to move.

A more complete discussion on the use of tubing anchors was published in the February 1955 issue of "Drill Bit."

The rod weight compensator is a hydraulic tool that counterbalances the weight of the lower part of the rod string, thus reducing the stress in the rods above it. The lifting force is applied to the rods by the compensator piston. The tool is so constructed that the weight of the fluid in the tubing above the compensator is applied to the bottom of the piston while the top of the piston is exposed only to the casing-tubing annulus which is assumed to contain only low pressure gas. The difference in pressure across the piston causes a lifting force, that, it is claimed, will reduce the dead weight of the rods 33 percent.

A hydraulic pumping system consists of a surface pump that takes oil from a tank, pumps it through surface lines and tubing to a subsurface pump that is of the single cylinder, single or double acting, piston type. There are three types of installations. First, the casing type where the pump is run in a well with a string of tubing, usually 2 or 2-1/2-inch and landed on a packer. The installation can be either the free type where the pump can be retrieved hydraulically, or the conventional type where the tubing must be pulled to remove the pump. Second, the insert type, in which the pump is run inside of the well tubing on a macaroni string of tubing, usually 3/4 or 1-inch. Third, the free type parallel system in which a string of macaroni tubing is clamped to, and supported by, the regular tubing. For deep well pumping, the hydraulic pumping system is better adapted to isolated or water locations or to the pumping of crooked holes.

The casing type installation will pump more fluid than other types but should be used only in wells in which gas separation does not occur until after the fluid has passed thru the pump. If there is any free gas present, pump operation becomes erratic. The setting depth is limited only by the pressure rating of the pumping equipment. The insert type can be used in any well and can be set deeper than the parallel free type with the same safety factor. The disadvantage is that the inner string of tubing has to be pulled to recover the pump. The parallel free type installation is somewhat limited to setting depth because the main tubing also has to support the parallel string. This difficulty can be overcome partially by anchoring the tubing. The advantage is that the pump can be landed and retrieved hydraulically.

The most important part of a hydraulic pumping installation is the treating system. For successful operation the power oil must be free of water and foreign material. Better operation will be obtained if the produced fluid is also free of foreign matter. All mill scale, rust and foreign matter must be removed from the power oil line and tubing prior to the installation of a pump or early pump failure will occur. Paraffin accumulation appears to be accelerated if the water percentage is high. The light ends, particularly the butane and propane which are natural paraffin solvents, are lost during the continuing recirculation of the power oil. Paraffin removal, however, is done very easily with the proper equipment. Treating capacity has to be increased, because the power oil has to be passed through the treating system, but the treating problem is no more difficult. Testing a well is sometime difficult because of the inaccuracy of fluid meters or the inconvenience of shutting in all wells except the one under test.